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Assessment of Water Quality Index of River Salandi at Hadagada Dam and Its Down Stream upto Akhandalmani, Bhadrak, Odisha, India

Pratap Kumar Panda[1,*], Rahas Bihari Panda[2], Prasant Kumar Dash[3]

[1]Department of Chemistry, A.B College, Basudevpur, Bhadrak, Odisha, India
[2]Department of Chemistry, VSSUT, Burla, Odisha, India
[3]Department of Chemistry, Bhadrak Autonomous College, Bhadrak, Odisha, India
*Corresponding author: pandapratap100@gmail.com

Abstract The river Salandi, originated from well-known bio-sphere of Similipal forest and joints with the river Baitarani near Akhandalmani, the Tinitar Ghat after passing through Hadagada dam, Agarpada and Bhadrak town. During the course of journey, it receives forest run off, untreated and semi treated mining wastes, agricultural wastes, industrial wastes of Ferro Alloys Corporation (FACOR) and urban wastes. In the present study, physico-chemical & bacteriological parameters of water were analyzed by collecting water samples from nine different stations in summer (April and May), rainy (August), post rainy (October) and in winter (December) during the year 2015 by applying standard procedures. The mean values of twelve important parameters were calculated for the entire year and were computed to water quality index (WQI) of river Salandi by using the weighted arithmetic index method. The water quality index (WQI) reveals that the quality of water is different at different monitoring stations i.e. quality is good at Hadagada dam, Satabhauni and Dhusuri, poor at Akhandalmani & very poor at Bidyadharapur, very poor and unfit for drinking purpose at Agarpada, Randia (FACOR) and Baudpur and belongs to class 'C' river water at Rajghat.

Keywords: *standard procedures, WQI, weighted arithmetic index method, standard limit*

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1. Introduction

The fresh water is one among the fundamental, indispensable and essential natural resources as good quality of water is required for both micro and macro organism to maintain and promote day-to-day biochemical activities. The human body contains 70% of water by weight. It is a matter of surprise that water covers 71% of the total surface of the earth and only 3% of water is fresh. Out of this 3% of water 2.5% is stored in Antarctica in the form of ice [2]. Now- a- days, the proliferation of water pollution is being taken place due to rapid industrialization, urbanization and other anthropogenic activities which pose a challenge on the survival and propagation of future generation including both human, animal and plant kingdom [27,29]. In the present study, we have taken the river Salandi, originated from well-known biosphere of Similipal forest of Mayurbhanj district in Odisha & joins with the river Baitarani at Tinitar before its confluence in Bay of Bengal at Dhamara. A dam was built across the river Salandi at Hadagada in Anandapur sub-division of Keonjhar district for irrigation of large area.

After Hadagada, the river receives mining discharges from the Nuasahi Chromites mining belt while passing through it as because there are three chromite mines, namely, Boula Open Caste and underground mines, Bangur Chromite mines and Nuasahi Chromite mines [1,28]. It is only the Bangur Chromite mines that release one lakh tons chromites ores per year& 7 lakh tons over burdens are excavated, which is responsible for the pollution of river Salandi by total chromium & hexavalent chromium in the form of mining discharges and surface run off [1,27,28,29]. There after the river passes through Bidhyadharpur barrage and Agarpada town & travels through 40 KM agricultural field and passes through FACOR industries at Randia and finally Bhadrak municipality where it receives industrial effluents, agricultural runoff and urban wastes. The aforesaid factors are responsible for the pollution of the river Salandi.

This paper deals with analysis of water samples collected from nine different stations during summer (April & May), rainy (August), post rainy (October) & winter season (December) for study of physico-chemical & bacteriological parameters by using standard procedures [24] in the year 2015. Finally, mean values of twelve important parameters have been computed for calculation of water quality index by using Weighted Arithmetic Index method [26] to depict the water quality of the river Salandi for the greater interest of the society.

2. Materials & Methods

2.1. Sampling Stations

The sampling stations were selected on the basis of gravity of expected concentrations of pollutants to meet the purpose. Water samples were collected from nine different stations in summer (April & May), rainy (August), post rainy (October) & in winter season (December) in the year 2015, described in Table 1 & different sampling stations of the river Salandi have been located in Map 1.

Table 1. Location of different Sampling Stations

Sl No.	Name of Stations	Brief Description on Sampling Stations
01	Hadagada Dam	It is 40 KM from Bhadrak town and is a hilly & mining area where the river receives mining, agricultural and forest effluents from Similipal Biosphere.
02	Bidyadharpur	It is nearly 30 KM from Bhadrak town and a barrage is on the river Salandi where it receives mining and agricultural effluents.
03	Agarpada	It is 20 KM from Bhadrak town where the river receives agricultural wastes & urban wastes primarily.
04	Randia(FACOR)	At the bank of river Salandi, the village Randia, Ferro Alloys Corporation Industry is established where industrial effluents and agricultural effluents enter into the river.
05	Baudpur	It is 02KM from Bhadrak town where the river receives agricultural effluents.
06	Rajghat	It is situated at the heart of Bhadrak Municipality and nearest to the District head quarter hospital where mainly urban wastes and medical wastes enter into the river.
07	Satabhauni	It is around 15 KM away from Bhadrak town where the river receives mainly agricultural runoff as it is covered with plenty of agricultural lands
08	Dhusuri	It is around 30 KM from Bhadrak town where the river receives mainly agricultural wastes
09	Akhandalmani(Tintar)	It is more than 40 KM from Bhadrak town and is a confluence place of river Salandi & River Baitarani and thereafter the river runs towards Bay of Bengal where the river receives back flow of sea water due to tide and agricultural wastes

Map 1. Location of sampling stations across river Salandi

2.2. Analysis of Physico-Chemical Parameters

Further the water samples which are collected in well cleaned plastic bottles by adding about to 2 ml conc. HNO_3 in each bottle (to avoid the precipitation of metals) have been analyzed to study the physico-chemical & bacteriological parameters according to the method APHA, prescribed in 1995 [24]. TDS was measured by gravimetric method & total hardness was measured by complexometric method by using EDTA solution with eriochrome black-T as indicator and calcium content was determined by EDTA with murexide as indicator. Sulphate was measured by turbidimetry method & iron was measured by using phenanthroline as indicator with the help of spectrophotometer at 510 nm. Total chromium & nitrate were measured by spectrophotometer at 540 nm & 275 nm respectively [1].

2.3. Fluoride, Chloride & Bacteria

The fluoride was determined by using SPAND reagent & acid zirconium chloride by spectrophotometer at 570 nm [22,23]. Chloride & bacteria were determined by titration method & H2S kit method respectively [1]. The analysis results of the months April, May, August, October & December have been reported in Table 2, Table 3, Table 4, Table 5 & Table 6 respectively. Finally mean values of twelve important parameters of nine monitoring stations have been placed in Table 7 for computation of water quality index.

Table 2. WATER ANALYSIS REPORT OF RIVER SALANDI IN APRIL 2015
Unit - except pH all concentrations are expressed in mg/L

Place	pH	Turbi-dity	TDS	TH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	Total Cr	F^-	Cr^{6+}	DO	BOD
Hadagada	6.7	6	89	30	25	3.7	10	4.2	2.8	20	0.4	0.05	0.98	<0.01	7	2.5
Bidyadharpur	6.9	5	96	50	45	4.6	8	4.3	2.9	15	0.27	0.2	1.2	0.03	6.7	5
Agarapada	7.2	4	73	60	55	4.9	8	4.1	2.9	30	0.38	0.15	1.2	0.07	6.8	3.5
Randia	7.1	4	76	60	55	4.7	12	5.2	3.1	20	0.3	0.17	0.96	0.08	6.7	3.8
Baudpur	7.2	4	73	50	46	3.8	10	5.1	3.1	20	0.3	0.2	0.95	0.05	6.8	2.8
Rajghat	7.1	5	95	30	25	3.6	12	4.9	2.9	30	0.35	0.15	1	0.01	6.6	5.8
Satabhauni	6.8	6	95	70	65	4.3	8	4.2	2.8	20	0.3	0.11	1.1	<0.01	6.8	4.6
Dhusuri	6.9	5	92	60	55	4.4	8	4.8	2.6	20	0.3	0.08	0.96	<0.01	6	4.2
Akhandalmani	7.3	5	500	450	430	18	8	4.2	2.1	1745	0.43	0.05	0.45	<0.01	7	4.2
Bacteria	Positive in all stations															
Standard value of Drinking Water IS-10500	6.5-8.5			300	75	45	150	45	5	250	0.3	0.5	0.6	0.05	6.0	3.0

Table 3. WATER ANALYSIS REPORT OF RIVER SALANDI IN MAY 2015
Unit - except pH all concentrations are expressed in mg/L

Place	pH	Turbi-dity	TDS	TH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	Total Cr	F^-	Cr^{6+}	DO	BOD
Hadagada	7	6	96	80	75	4.5	8	4.1	2.6	25	0.43	0.05	0.93	0.01	7.2	2.6
Bidyadharpur	6.8	5	95	30	25	4.2	7	4.2	2.5	25	0.20	0.04	1.06	0.06	6.8	5.0
Agarapada	7	5	86	20	15	4.1	6	4.1	2.4	20	0.39	0.13	0.52	0.07	6.6	3.4
Randia	7	4	84	60	55	4.2	6	4.5	2.1	25	0.28	0.16	0.85	0.08	6.4	3.7
Baudpur	6.8	4	82	50	45	4.1	6	4.3	2.1	20	0.25	0.20	0.56	0.04	6.8	2.8
Rajghat	6.5	4	85	60	50	4.5	8	4.1	3.1	15	0.33	0.14	1.1	0.02	6.2	5.7
Satabhauni	6.9	5	85	70	60	4.6	7	4.1	2.9	15	0.21	0.12	1.2	0.01	6.4	4.7
Dhusuri	7	5	82	70	60	4.3	7	4.2	2.7	20	0.25	0.06	0.95	0.01	6.6	4.2
Akhandalmani	6.9	5	600	470	450	15	12	5.4	4.2	1750	0.47	0.06	0.42	0.02	6.9	2.0
Bacteria	positive in all stations															
Standard value of Drinking Water IS-10500	6.5-8.5			300	75	45	150	45	5.0	250	0.3	0.5	0.6	0.05	6.0	3.0

Table 4. WATER ANALYSIS REPORT OF RIVER SALANDI IN AUGUST 2015
Unit - except pH all concentrations are expressed in mg/L

Place	pH	Turbi-dity	TDS	TH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	Total Cr	F^-	Cr^{6+}	DO	BOD
Hadagada	7.1	11	105	130	110	8.6	15	5.6	4.1	15	0.36	0.04	0.76	<0.01	7.2	5.0
Bidyadharpur	7.0	10	100	110	100	8.4	13	5.2	3.9	20	0.59	0.30	0.93	0.06	7.0	5.1
Agarapada	6.8	9	98	105	96	6.3	12	5.1	3.4	20	0.34	0.18	0.91	0.05	7.0	5.2
Randia	7.0	10	100	108	98	5.6	12	5.4	3.3	15	0.34	0.17	0.92	0.8	6.4	5.1
Baudpur	7.2	9	96	105	96	5.2	14	5.1	3.5	20	0.32	0.25	0.90	0.6	7.0	5.0
Rajghat	7.0	10	95	100	95	4.5	12	5.2	3.4	20	0.30	0.15	1.1	0.1	6.8	5.3
Satabhauni	7.1	10	98	110	98	4.8	12	5.4	3.8	20	0.30	0.05	0.90	<0.01	7.0	5.0
Dhusuri	7.0	9	100	120	108	5.4	12	5.3	3.5	20	0.30	0.08	0.92	<0.01	7.0	4.9
Akhandalmani	7.2	10	800	480	460	18	15	5.6	4.2	1760	0.45	0.05	0.95	<0.01	7.0	4.4
Bacteria	positive in all stations															
Standard value of Drinking Water IS-10500	6.5-8.5			300	75	45	150	45	5.0	250	0.3	0.5	0.6	0.05	6.0	3.0

Table 5. WATER ANALYSIS REPORT OF RIVER SALANDI IN OCTOBER, 2015
Unit - except pH all concentrations are expressed in mg/L

Place	pH	Turbi-dity	TDS	TH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	Total Cr	F^-	Cr^{6+}	DO	BOD
Hadagada	7.1	10	108	140	115	8.8	20	5.8	4.8	20	0.3	0.06	0.75	0.01	7.0	5.2
Bidyadharpur	7.3	10	104	155	120	8.4	18	5.4	4.6	25	0.58	0.34	0.91	0.04	7.1	5.3
Agarapada	7.2	9	102	115	100	6.5	15	5.2	4.4	25	0.35	0.20	0.91	0.05	6.8	5.3
Randia	7.1	10	103	110	100	5.8	15	5.6	4.3	18	0.35	0.20	0.92	0.08	6.8	5.5
Boudpur	7.1	8	102	106	98	5.3	16	5.3	4.3	25	0.32	0.22	0.90	0.06	6.8	5.3
Rajghat	7.2	10	100	110	98	4.8	15	5.4	4.2	25	0.30	0.18	1.0	0.03	6.4	5.3
Satabhauni	7.1	10	100	120	100	5.3	16	5.6	4.4	25	0.30	0.05	0.89	0.01	6.7	5.3
Dhusuri	7.1	9	100	126	110	5.6	17	5.6	4.5	25	0.30	0.07	0.91	<0.01	6.7	5.2
Akhandalmani	7.3	11	820	500	470	20	18	5.8	5.4	1760	0.50	0.06	0.94	<0.01	7.1	4.8
Bacteria	Positive in all stations															
Standard value of Drinking Water IS-10500	6.5-8.5			300	75	45	150	45	5	250	0.3	0.5	0.6	0.05	6.0	3.0

Table 6. WATER ANALYSIS REPORT OF RIVER SALANDI IN DECEMBER,2015
Unit - except pH all concentrations are expressed in mg/L

Place	pH	Turbi-dity	TDS	TH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	Total Cr	F^-	Cr^{6+}	DO	BOD
Hadagada	6.9	07	100	56	40	6.2	12	4.8	3.8	25	0.59	0.04	0.25	<0.01	7.2	5.0
Bidyadharpur	7.2	06	98	60	45	6.1	10	4.6	3.6	20	0.76	0.32	0.25	0.02	7.0	5.1
Agarapada	7.2	05	92	64	48	5.6	10	4.5	3.4	15	0.52	0.18	0.28	0.02	6.8	5.1
Randia	7.4	05	96	66	48	5.8	12	4.6	3.2	20	0.48	0.20	0.15	0.08	6.7	5.2
Boudpur	7.2	05	94	65	45	5.5	10	4.5	3.2	20	0.44	0.18	0.15	0.06	7.0	5.1
Rajghat	7.0	06	92	70	56	5.0	12	4.4	3.6	20	0.44	0.18	0.15	0.02	6.5	5.3
Satabhauni	7.1	06	89	75	58	5.5	10	4.5	3.2	20	0.43	0.02	0.10	0.01	6.7	5.2
Dhusuri	7.2	05	90	80	62	5.5	10	4.5	3.5	20	0.43	0.02	0.10	<0.01	6.7	5.2
Akhandalmani	7.3	08	680	315	275	15	15	5.1	4.7	75	4.9	0.05	0.05	<0.01	7.1	4.8
Bacteria	Positive in all stations															
Standard value of Drinking Water IS-10500	6.5-8.5			300	75	45	150	45	5	250	0.3	0.5	0.6	0.05	6.0	3.0

Table 7. MEAN Values for twelve important parameters, 2015

Name of Parameters	Hadagada	Bidyadharpur	Agarapada	Randia	Baudpur	Rajghat	Satabhauni	Dhusuri	Akhandalmani
P^H	6.96	7.04	7.08	7.12	7.10	6.96	7.0	7.04	7.2
TDS	99.6	98.6	90.2	91.8	89.4	93.4	93.4	92.8	680
TH	87.2	81	72.8	80.8	75.2	74	89	91.2	443
SO_4^{2-}	13	11.2	10.2	11.4	11.2	11.8	10.6	10.8	13.6
NO_3^-	4.9	4.74	4.6	5.06	4.86	4.8	4.76	4.88	5.22
PO_4^{3-}	3.62	3.5	3.3	3.2	3.24	3.44	3.42	3.36	4.12
Cl^-	21	21	22	19.6	21	22	20	21	1418
Fe	0.416	0.48	0.396	0.35	0.326	0.344	0.308	0.316	1.35
F^-	0.734	0.87	0.764	0.76	0.692	0.87	0.838	0.772	0.562
Cr^{6+}	0.0094	0.042	0.052	0.08	0.054	0.018	0.0096	0.0092	0.0112
DO	7.12	6.92	6.8	6.6	6.88	6.5	6.72	6.6	7.02
BOD	4.06	5.1	4.5	4.66	4.2	5.48	4.96	4.74	4.04

Table 8. water quality index of sampling station hadagada, 2015

Sl. No	Parameters	Observed Values (Mean)	Standard Values (Si)	Unit Weight (Wi)	Quality rating (Qi)	WiQi	Remarks
1	**P^H**	6.96	8.5	0.117	-2.666	-0.311	$WQI = \frac{\sum WiQi}{\sum Wi} = \frac{1116.1529}{25.8526} = 43.1737(Good)$
2	**TDS**	99.6	500	0.002	19.92	0.039	
3	**TH**	87.2	300	0.003	29.066	0.087	
4	**SO_4^{2-}**	13	150	0.006	8.666	0.051	
5	**NO_3^-**	4.9	45	0.022	10.888	0.239	
6	**PO_4^{3-}**	3.62	5	0.2	72.4	14.48	
7	**Cl^-**	21	250	0.004	8.4	0.0336	
8	**Fe**	0.416	0.3	3.333	138.666	462.173	
9	**F^-**	0.734	0.6	1.666	122.333	203.806	
10	**Cr^{6+}**	0.0094	0.05	20	18.8	376	
11	**DO**	7.12	6	0.1666	86.9767	14.4903	
12	**BOD**	4.06	3	0.333	135.333	45.065	

$\sum \mathbf{Wi} = 25.8526$ $\qquad$ $\sum \mathbf{WiQi} = 1116.1529$

2.4. Water Quality Index

Water quality index is a modern method that depicts the whole water quality of any water body through a single number, developed by considering the combined effect of important physico-chemical parameters. In the present study, weighted Arithmetic Index method[26] has been used preferably to calculate Water Quality Index of the river Salandi due to following reasons:

i) It classifies the water quality of any water body according to degree of purity by using most commonly measurable parameters and it is widely used by the different scientists, workers and organisations [5,38,39,40,41,42].

ii) It reflects overall effects of different parameters for better assessments and managements of water quality of any water body under study.

iii) Less number of parameters are required in comparison to other methods.

iv) It reflects the suitability of both surface and ground water sources for human consumption [43].

This method includes following steps which is explained briefly.

1) Quality rating scale of each parameter is calculated [34] by using following formula quality rating scale

$$(Qi) = \left[(Vo - Vi)/Vs - Vi\right]100$$

Where Vo= observed value or mean of the observed values of any parameter.

Vi= ideal value of that particular parameter

Vi= 0 for all parameters except p^H & DO

Vi for p^H= 7 & Vi for DO= 14.6 mg/l.

Vs= Standard permissible value of particular parameter, determined by WHO.

2) Calculation of relative unit weight (Wi)- The relative unit weight of any parameter (Wi) α 1/Si or Wi= K/Si

Where Si= standard permissible value of particular parameter

K= proportionality constant.

For the sake of simplicity K is taken as 1.

3) Finally water quality index= $\frac{\sum WiQI}{\sum WI}$

The overall quality of any water body is assessed by using following WQI level given below:-

WQI Level	Water Quality	Grading
0 -25	excellent	A
25 - 50	good	B
51 - 75	Poor	C
76 - 100	Very Poor	D
>100	Unfit for Drinking Purpose	E

In other words

i. 0<WQI < 100 fit for human use

ii. 0> WQI>100 unfit for human use [15].

Water Quality Index (WQI) of monitoring station Hadagada has been given in Table 8 as for example & WQI for other eight monitoring stations have been calculated in a similar way & presented in Table 9 for study and to derive conclusion.

Table 9. Water Quality of river Salandi for nine monitoring Stations

Sl No.	Name of Stations	WQI	Water Quality
1	Hadagada	43.1737	Good
2	Bidyadharpur	98.3067	Very Poor
3	Agarpada	108.7467	Very Poor & unfit for Drinking purposes
4	Randia	147.0829	Very Poor & unfit for Drinking purposes
5	Baudpur	108.0049	Very Poor & unfit for Drinking purposes
6	Rajghat	55.4871	Class 'C ' River water
7	Satabhauni	44.3559	Good
8	Dhusuri	39.2897	Good
9	Akhandalamani(Tintar)	83.8872	Very Poor & unfit for Drinking purposes

3. Result & Discussion

WQI

The water quality index of present water body under study has been assessed by taking twelve important parameters into consideration & has been presented in Table 9. The value calculated are 43.1737, 98.3067, 108.7467, 147.0829,108.0049,55.4871,44.3559,39.2897 & 83.88718 for monitoring stations Hadagada, Bidyadharpur, Agarpada, Randia, Baudpur, Rajghat, Satabhauni, Dhusuri & Akhandalmani respectively. It indicates that different stations have different WQI values & hence different water quality [5,19,26,30,37]. Further WQI calculated for different monitoring stations has been supported by the interpretation of following physico- chemical parameters along with graphs given & it highlights that no station comes under class A quality. Besides, the monitoring stations at Hadagada, Satabhauni & Dhusuri come under class B, Rajghat comes under class C, Bidyadharpur, Baudpur & Akhandalmani are very poor and unfit for drinking purposes.

p^H

The p^H of water sample of nine monitoring stations was measured form the month of April to December in 2015. It was observed that although there is slight variation, but it is within the prescribed standard limit IS-10500 [25] (6.5 – 8.5). Further higher p^H is observed from the month of April to December except May in the monitoring stations from Hadagada to Dhusuri. The comparatively low p^H in the month of May can be attributed due to low flow of water which raises the concentrations of acidic pollutant [1,3]. The higher p^H may be due to photosynthesis by aquatic plants as in the process of photosynthesis the aquatic plants [3,17,18] consume dissolved carbon dioxide and hence increases p^H. Besides, high water content of the river dilutes the pollutants [36]. But at the monitoring station Akhandalmani the pH changes from 6.9 (in May) to 7.3 (in other months). The lower p^H in the month of May can be due to unseasonal rainfall runoff in the coastal region as because Akhandalmani is nearer to Bay of

Bengal.The mean value of pH from the month of April to December, 2015 for nine different stations is given in Figure 1. From the mean value, it is evident that pH is lowest in Hadagada (6.96) and increases gradually up to Baudpur and then decreases and reaches minimum at Rajghat (6.9) and again increases to maximum at Akhandalmani (7.2). The lowest pH at Hadagada is due to receiving of forest runoff, mining runoff and lowest pH at Rajghat may be due to the receiving of medical wastes as district head quarter hospital and private hospitals are closer to it.

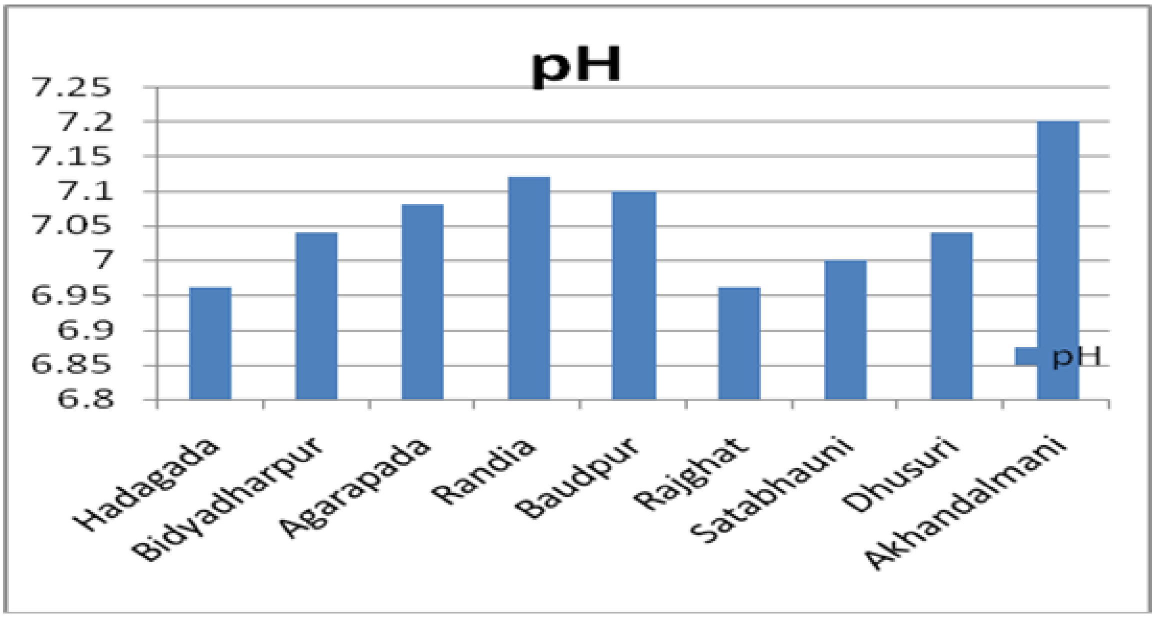

Figure 1. P^H for nine different sampling stations, 2015

TDS & Turbidity

The variation of TDS & turbidity is nearly equal. But from the month of August to October, both TDS & Turbidity are higher due to high rain fall run off, forest run off, mining run off, agriculture run off along with entering of domestic wastes to the river water in large scale [19,20]. The higher TDS value in the monitoring station at Akhandalmani from the month of April to October is due to the back flow of sea water [35] as because the station is nearer to sea shore. The mean TDS value from April to December, 2015 for nine different stations is given in Figure 2.

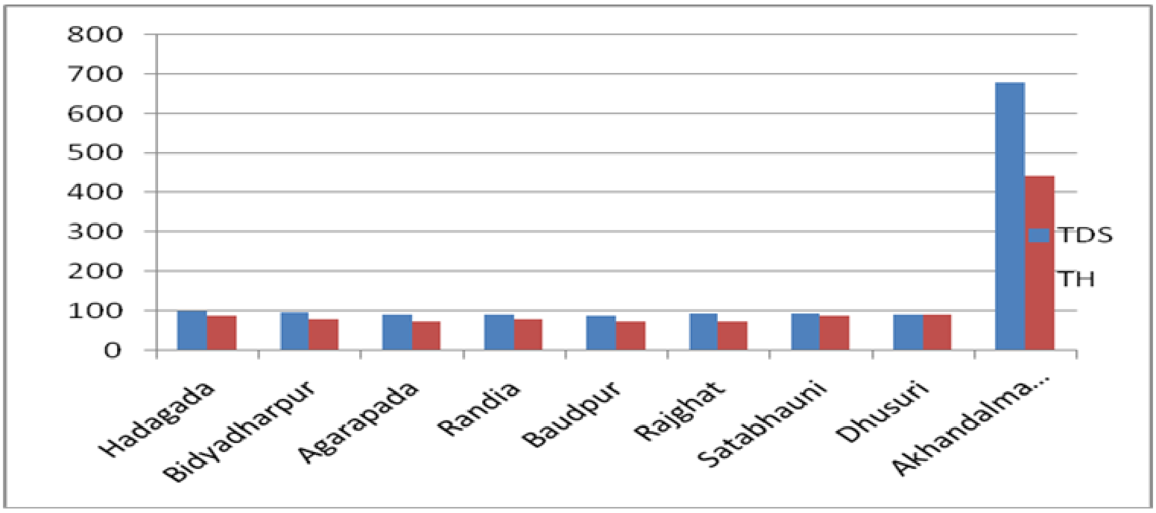

Figure 2. TH & TDS for nine different sampling stations, 2015

TH, Ca, Mg, NO_3, SO_4, PO_4 & Cl

All the values for above parameters except TH, Ca & PO_4 are within the prescribed limit for drinking water IS-10500, in rainy (August) and post rainy (October) though there is variation in quantity. But the monitoring station at Akhandalmani, the results are high in all times of monitoring as back flow of sea water takes place from the sea (Bay of Bengal). But it is worth mentioning that the results are higher in rainy (August) & post rainy (October) than summer & winter. Further it is marked that mean values of TH increase from Hadagada (87.2) to Dhusuri (92.2) in an irregular way & between the months of April & May, TH is higher in May than April due to low flow of water that raises the concentrations. The higher values of all parameters in rainy & post rainy than summer and winter is due to entering of mining effluents, Industrial effluents, urban waste and agricultural effluents along with forest run off and anthropogenic activities such as septic tank effluents, animal feeds and use of bleaching reagents by launderers. The agricultural effluents contribute significantly as pesticides and certain fertilizers such as Calcium Ammonium Nitrate (CAN), basic calcium nitrate, calcium superphosphate used by the farmers for cultivation purpose release sulphates, nitrates, calcium, phosphates and heavy metals to surface water bodies [6,14,21,31,36]. In ideal condition plants use only 50% of nitrogenous fertilizers applied, 2-20% lost due to evaporation 15-25% reacts with organic compound of soil & remaining 2-10% interfere with surface & ground water [21]. The mean value of TH from April to December, 2015 for nine different stations is given in Figure 2 & mean values of SO_4 and NO_3 for the above nine stations are given in Figure 3.

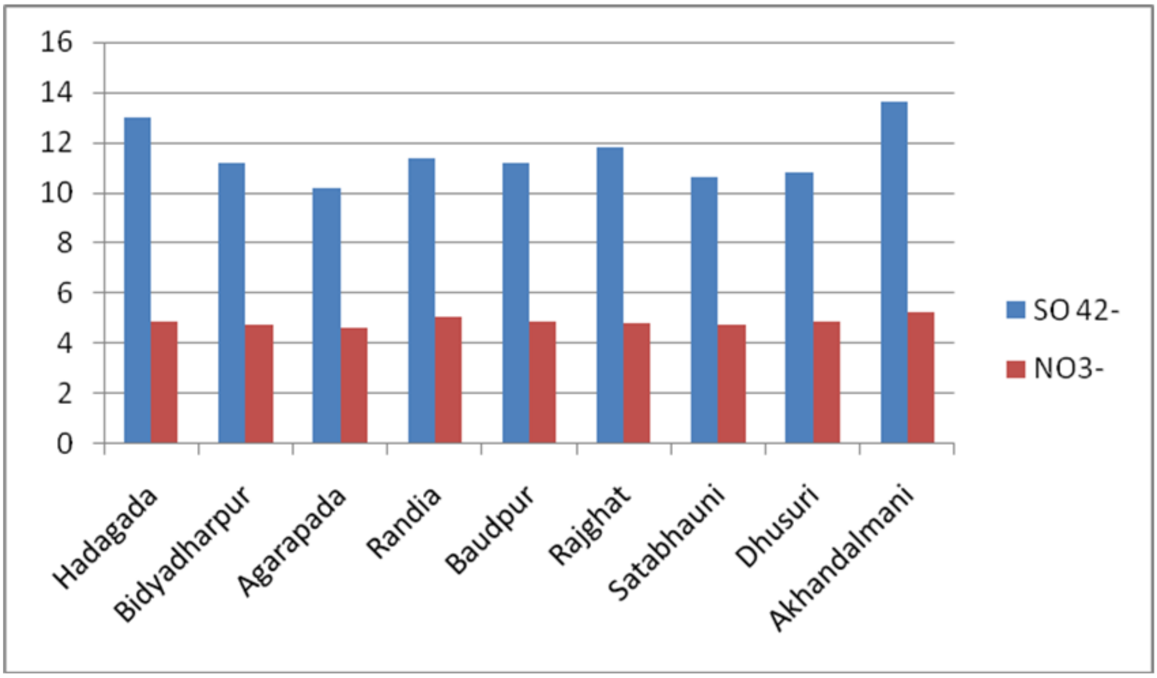

Figure 3. $SO4^{2-}$ & NO_3^- for nine different sampling stations, 2015

Fe (>0.3) & Cr (>0.05)

Iron & hexavalent Chromium are found to exceed permissible level or touching the permissible level in the monitoring stations during summer, rainy, post rainy & winter season. This is mainly due to the receiving of mining effluents from Nuasahi Chromite belt, Industrial sector at Randia (FACOR), urban effluents of Bhadrak Municipality and agricultural effluents. The high concentration of Iron (> 0.3) at Bidyadharapur in the month of August (0.59) and October (0.58) is due to the mixing of the mining effluents in the river water and particularly in the month of December, it is much more in all monitoring stations (0.59 at Hadagada to 4.9 at Akhandalmani) in comparison to other months. It may be due to interaction of soil containing iron ore with water that promotes the mixing of iron with river water, happened at the lower part of the river as because water level is very low due to low flow of water [6].

As regards hexavalent chromium, its permissible value is 0.05ppm (IS-10500), but at the monitoring station Randia, the river water contains more than the permissible level. It is due to discharge of chromium effluents from ferro-chrome plant at Randia [28,29]. Further it is observed that Hexavalent chromium is more in the month of August and October. It may be due to the excessive use of some chemical fertilizers and pesticides that contains heavy metals chromium [7,9,14,21,36]. Presently some chromite mines are not running due to lack of environmental clearances as well as forest clearances. But earlier report of pollution control board revealed that they have discharged the effluents of high concentration of chromium to the river Salandi. Although presently some chromite mines are not running, but mining wastes left by them earlier without proper treatment has resulted open exposure of chromite mixed soil to the atmosphere and pollutes the river Salandi with chromium through atmospheric rain water precipitations as the river Salandi is the only natural drainage system in the study area. Hence more concentration of hexavalent chromium in the month of August and October is found in the monitoring stations from Bidyadharapur to Baudpur is due to the entering of mining run off, industrial runoff, agricultural runoff [8,10] & atmospheric precipitations [11,12,13] to the river Salandi. The mean value of Fe & hexavalent Cr from April to December, 2015 for nine different monitoring stations are given in Figure 4. From the mean values of iron it is evident that the concentration of iron increases from Hadagada to Bidyadharpur and decreases gradually and reaches maximum at Akhandalmani (1.35). It is due to entry of mining effluents to the river and it is diluted from upstream to downstream. The highest value of iron at Akhandalmani may be due to the back flow of sea water that might contain higher amount of iron [36].

3.1. Dissolved Oxygen (DO)

The dissolved oxygen is a crucial parameter for river water system which supports the survival of aquatic creatures & its value less than 6 mg/L (minimum requirement) will endanger the life of aquatic creatures [25]. But due to indiscriminant discharge of industrial, urban, mining, agricultural & domestic wastes to the river system, the dissolved oxygen value is decreased as it is used in redox reaction process to stabilize the pollutant in water bodies. Further anthropogenic activities such as washing of clothes, open defecation & picnic in river bed add fuel to the fire [19,21].

In the present study, it is seen from the monitoring values of river Salandi that dissolved oxygen values are constantly influenced from upstream to downstream by the aforesaid factors. The mean values of dissolved oxygen decreases gradually from Hadagada (7.12) to Akhandalmani (7.02) through mid stream with lowest at Rajghat (6.5). Further it is observed that lower value of dissolved oxygen from 6.7 to 6.8 in the mining belt & 6.2 to 6.6 mg/L at Rajghat during summer (April & May) may be due to eutrophication & mixing of mining & urban contaminants to the river water. The higher values of dissolved oxygen in rainy (August) & post rainy (October) is due to high flow of rain water, flood & aeration that dilute the organic pollutants in the river [1,35]. The mean DO value from April to December, 2015 for nine different stations is given in Figure 5.

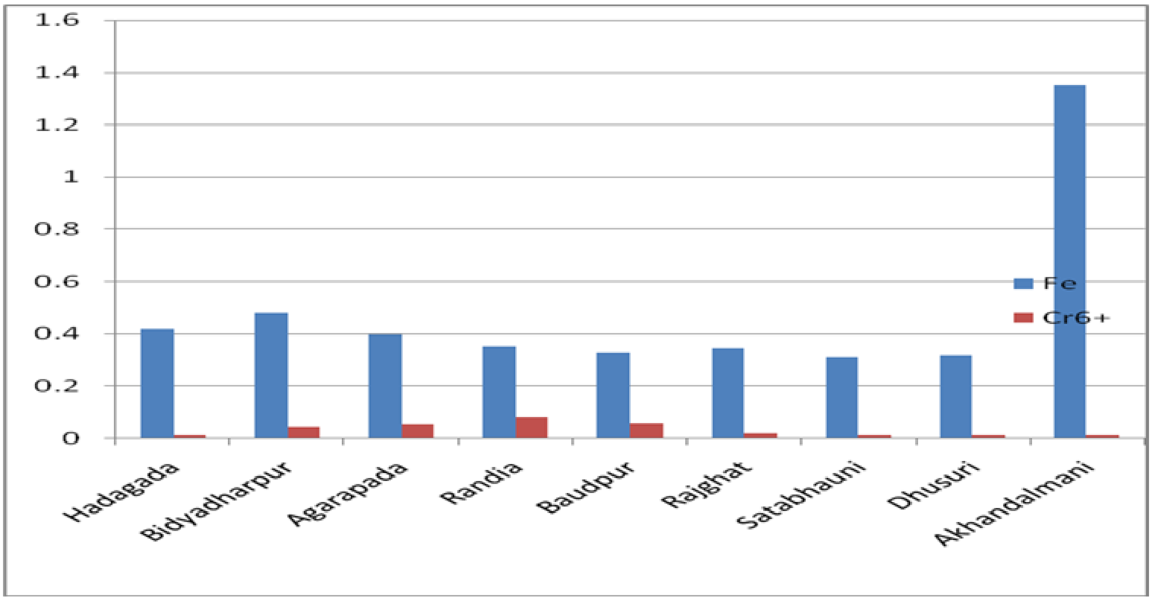

Figure 4. Fe & Cr^{6+} for nine different sampling stations, 2015

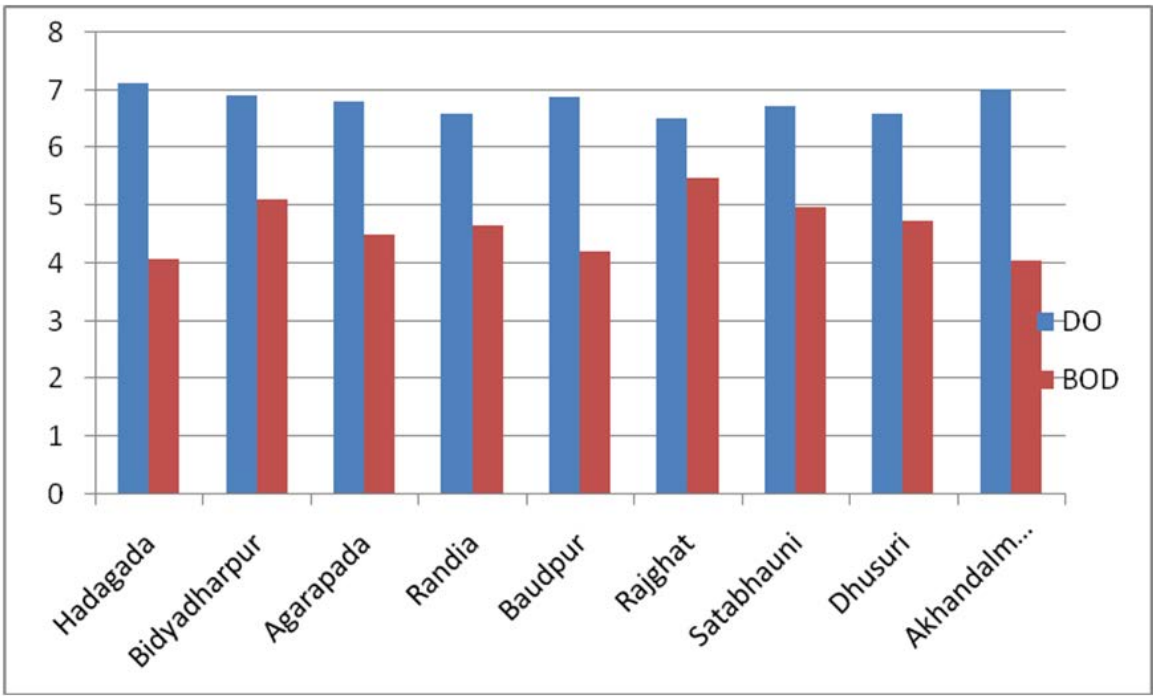

Figure 5. DO & BOD for nine different sampling stations, 2015

3.2. Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is an indicator of water pollution & BOD value (>3.0 mg/L) implies that water is polluted. More the value of BOD more the pollution & vice-versa [27]. It is seen from the mean value of BOD of nine monitoring stations that, BOD varies from 4.06 (Hadagada) to 4.04 (Akhandalmani) & highest 5.48 (Rajghat). From the data tables, it is further observed that, BOD values are either more than the permissible value

(3.0 mg/L) or close to the permissible value. & it is higher in rainy (August), post rainy (October) & winter (December) than the summer (April & May). The higher values in rainy season can be attributed to high rain water flow & flood in the river that carries more forest runoff containing biological residue as the study area is close to Similipal reserve forest, mining effluents, industrial effluents, agricultural runoff, urban wastes & domestic wastes [4,19,21]. Further, the higher value in the month of December may be due to discharge of picnic wastes & washing of motor vehicles to the river water as Hadagada is a very big picnic spot & attracts the thousands of picnic parties to it during winter season [4,19]. Besides, low flow of water & precipitations of contaminated dusts through rain pollutes the river Salandi. The mean BOD value from April to December, 2015 for nine different stations is given in Figure 5.

3.3. Fluoride (F)

The fluoride, responsible for fluorosis is within the permissible range (<1.5 mg/L), according to WHO guideline-2004 & BIS-2003 [25,32]. It is observed from the mean values calculated for the year 2015 for nine stations that it varies from 0.734 mg/L at Hadagada to downstream at Akhandalmani (0.562 mg/L) & highest at Bidyadharpur (0.87 mg/L) and at Rajghat (0.87 mg/L). The higher concentrations of fluoride [22,23] at Rajghat may be due to disposal of medical wastes to the river Salandi as District head quarter hospital & several private hospitals are nearest to Rajghat.

3.4. Bacteriological Tests

Bacteriological tests were done through H_2S kit method for nine monitoring stations & it was found that bacteria are positive in all stations starting from Hadagada to Akhandalmani. It confirms that the river Salandi is contaminated and unfit for drinking purpose without proper treatment [1].

4. Conclusions

The river Salandi, during its course of flow, starting from Hadagada to the confluence place Akhandalmani (Tinitar) receives mining effluents at Nuasahi chromites mining belt, industrial effluents at Randia (FACOR), urban wastes at Bhadrak Municipality, agricultural effluents [28] at Agarapada and domestic wastes. The WQI reveals that the quality of water is different at different monitoring stations that are good at Hadagada, Satabhauni and Dhusuri, very poor at Bidyadharpur, very poor and unfit for drinking use at Agarpada, Randia, Baudpur and Akhandalmani. The bacteriological test is positive in all monitoring stations. The contamination of river water takes place from Bidyadharpur to Randia at Ferro Alloys Corporation (FACOR) is due to receiving of mining effluents, industrial effluents, agricultural effluents as well as urban wastes. Further, at Rajghat, The pollution of river water is due to receiving of medical wastes and municipality discharges as because district head quarter Government hospital and other private hospitals are nearest to it [1,27]. The river after passing Bhadrak town is free from pollution. It is due to dilution and by natural processes where the pollutants are stabilized. But at Akhandalamani (Tinitar), again water is polluted due to back flow of sea water as it is nearer to the Bay of Bengal. Hence water will render unfit for human consumption according to standard prescribed by IS-10500 [25] and WHO guidelines [32].

Hence urgent measures such as disinfection and electro dialysis and particularly for hexavalant chromium reaction with SO2 in acidic medium, followed by lime treatment to precipitate as chromium hydroxide along with other approved modern technology shall be taken to treat the water carefully by the appropriate authorities otherwise it will pose a serious problem to the dwellers [18,27,33].

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