IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 10, Issue 11 Ver. III (Nov. 2016), PP 15-28
www.iosrjournals.org

Seasonal Variation of Physico-Chemical Parameters of River Salandi from Hadagada Dam to Akhandalmani, Bhadrak, Odisha, India

Pratap Kumar Panda [1], Rahas Bihari Panda [2], Prasant Kumar Dash [3]
[1.] *Dept. of Chemistry, A.B. College Basudevpur, Bhadrak, Odisha, India.*
[2.] *P.G. Dept. of Chemistry, VSSUT Burla, Odisha, India.*
[3.] *P.G. Dept. of Chemistry, Bhadrak Autonomous College, Bhadrak, Odisha, India*

Abstract: *The River Salandi, originated from well-known biosphere of Similipal reserve forest of Mayurbhanj district and joins with the river Baitarani at Tinitar, near Akhandalmani of Bhadrak district, after passing through Hadagada Dam, Bidyadharpur barrage, Agarapada town and Bhadrak Municipality. The river Salandi, during the course of its journey, receives both treated and untreated effluents from the mines, industrial wastes from Ferro Alloys Corporation (FACOR), agricultural wastes, urban wastes, biomedical wastes as well as domestic wastes. In this paper physico-chemical and bacteriological parameters of the water samples, collected from nine different monitoring stations in the summer (April & May), rainy (August), post-rainy (October) and winter (December-2015 & January-2016) have been analyzed by using standard procedures and standard deviations for twelve parameters have been calculated. The result obtained reveals that the seasonal variation of different parameters takes place and the river Salandi is contaminated with different pollutants such as chromium, iron, calcium, organic materials and bacteria due to entry of industrial effluents, mining wastes, agricultural effluents, biomedical wastes and urban wastes. Hence the river water is unfit for the use of dwellers as it is polluted both chemically and bacteriologically and will pose a challenge on the survival of flora and fauna.*

Keywords: *Hexavalent chromium, standard procedures, standard deviations, standard limits, seasonal variations.*

I. Introduction

The fresh water is the one among the natural gifts of God, required for both macro and micro organisms to maintain and promote physiological as well as biological activities since time immemorial. It is an interesting fact that water covers 71% of total surface of Earth and 3% of water is fresh. Out of these 3% of water, 2.5% water is stored in Antarctica in the form of ice [1]. Now-a-days polluted water poses a great challenge on the survival of living system including flora and fauna due to rapid unplanned industrialization, urbanization [51] and other anthropogenic activities [2, 3]. A good quality of water implies that it is good in chemically, physically & bacteriologically. It is worth mentioning that water quality of the river changes with the change of seasons and geographic areas [27] as because with the change of season, there are several anthropogenic activities such as mining, agricultural, industrial as well as socio-cultural which contribute to change of water quality [5,26,34].

It can be emphasized that during rainy and post rainy seasons, the pollution due to mining activities [36] and agricultural activities increases [21, 30, 35] in comparison to summer and winter seasons and hence it is a paramount factor which is responsible for the increase of concentrations of heavy metal in the river water and it affects the health & life of animal and human by the way of food chain

[4]. Besides, anthropogenic activities such as open Defecations in the river bed [6], discharge of biomedical wastes etc.enhance the amount of pathogenic bacteria and protozoans in the river bed [7].The water quality of any water body in any season can be studied by observing important parameters like dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, total dissolved solids (TDS), total hardness (TH), sulphate, nitrate, chlorides, heavy metals and bacteria. In the present study, we have chosen the river Salandi, originated from well-known biosphere of Similpal reserve forest of Mayurbhanj district in Odisha and joins with the river Baitarani at Tinitar near Akhandalmani before its confluence in the Bay of Bengal at Dhamara. A dam was built across the river Salandi at Hadagada with longitude $86^{0}.18^{'}$ East and latitude $210^{0}.17'$ North in Anandapur sub-division of Keonjhar district for the irrigation purpose of Keonjhar and Bhadrak district. After Hadagada, the river receives mining effluents from Nuasahi chromite mining belt while passing through it as there are three chromite mines namely, Boula open caste and underground mines, Bangur chromite mines and Nuasahi chromite mines. It is only the Bangur chromite mine, that discharge one lakh tons' chromite ores per year and

seven lakh tons of over burdens are excavated, which is the prime cause for the pollution of the river Salandi by total chromium and hexavalent chromium in the form of mining discharges and surface run off [8,36].

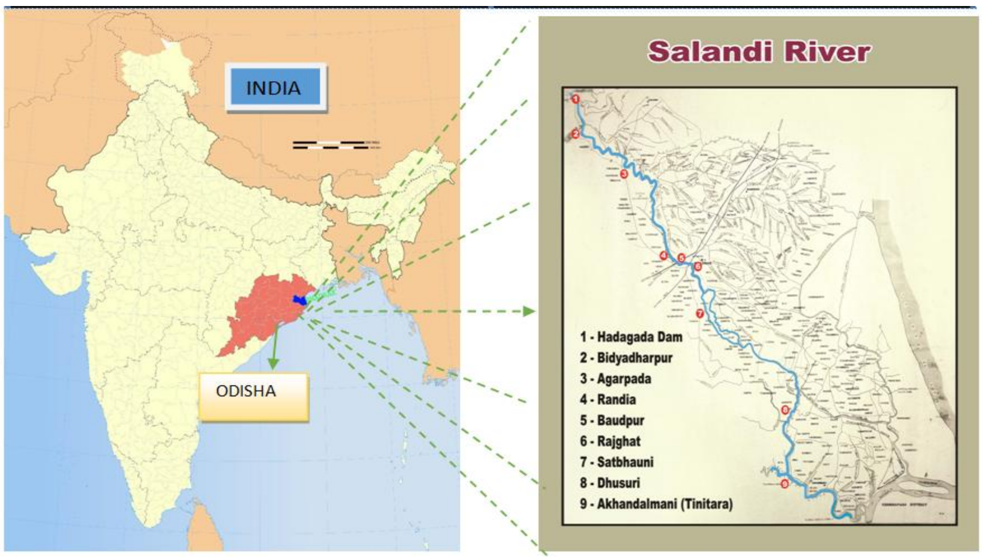
Thereafter, the river passes through Bidyadharpur barrage, Agarpada town, Randia (FACOR), Bhadrak municipality and finally meets with the river Baitarani at Tinitar before its confluence with the Bay of Bengal at Dhamara. The river, during its course of journey from Hadagada Dam to Tinitar (near Akhandalmani) travels more than 80 KMs and receives treated and untreated mining discharges, agricultural discharges, industrial wastes, forest run off, domestic wastes, biomedical wastes and urban wastes as it is the only natural drainage system in this area. The aforesaid factors are mainly responsible for the pollution of the river Salandi as reported in daily newspapers Samaj and Dharitri very often. In this paper, water samples from nine different selected monitoring stations have been collected during summer (April & May-2015), rainy (August), post rainy (October) and winter (December & January-2016) seasons and have been analyzed by using standard procedures [9] for study of physico-chemical and bacteriological parameters. Finally, standard deviations of twelve important parameters have been calculated by using mean values of corresponding parameters to study the seasonal variations and water quality of the river Salandi for the benefit of the society especially for the people those are directly dependent on it.

II. Materials & Methods

2.1 Sampling Stations: Selection of sampling stations have been done on the basis of gravity of more concentration of expected pollutants and to meet the purpose, nine different monitoring stations on the bank of the river have been selected. Water samples from nine different monitoring stations, as identified in the Map-1 and described in Table-1, have been collected during summer (April & May-2015), rainy (August), Post-rainy (October) and winter (December & January-2016) seasons for analysis and study of seasonal variations.

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 Physio-Chemical & Bacteriological parameters: Water samples collected in clean plastic bottles, by adding about 2ml of conc. HCl in each bottles to avoid precipitations, have been analyzed to study the physico-chemical and bacteriological parameters according to the procedures established by APHA, 1995 [9]. TDS has been measured by gravimetric method & total hardness has been measured by complexometric methods by using EDTA solution with Eriochrome Black-T as indicator. Further calcium content has been determined by using EDTA with murexide as indicator. Sulphate has been determined by turbidimetry method and iron has been measured by using phenanthroline as indicator with the help of spectrophotometer at 510nm. Total chromium and nitrate have been measured by spectrophotometer at 540nm and 275nm respectively [8, 10].

2.3: Fluoride, Chloride and Bacteria: Fluoride has been determined by SPAND reagent and acid zirconium chloride with the help of spectrophotometer at 570nm [11, 12]. Chloride and bacteria have been measured by titration method and H_2S kit method. respectively [8].The result of analysis of water samples for the month of April, May, August, October, December-2015 and January-2016 have been placed in Table 2-7 respectively.

2.4: Calculation of Standard Deviation: The calculated mean values of twelve important parameters for each monitoring station have been computed to determine standard deviations. Further, minimum values, maximum values and standard deviations (SD) for twelve important parameters for nine monitoring stations have been placed in Table 8 - 16 for study and conclusion of seasonal variations of physico-chemical parameters. The mean values and standard deviations (SD) for twelve important parameters for nine monitoring stations have been given in the Table-17 to make the study lucid and convenient.

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	0.08	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. 06	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	0.10	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. Water Analusis Report of River Salandi in January, 2016 Unit-except pH all concentration 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	Cr tot.	F^-	Cr^{6+}	DO	BOD
Hadagad	**6.9**	**07**	**100**	**60**	**42**	**6.2**	**12**	**4.8**	**3.9**	**30**	**0.32**	**0.02**	**0.24**	**<0.01**	**7.2**	**5.0**
Bidyadharpur	**7.2**	**06**	**97**	**66**	**46**	**6.1**	**12**	**4.7**	**3.7**	**25**	**0.54**	**0.30**	**0.24**	**0.01**	**6.8**	**5.3**
Agarapada	**7.1**	**05**	**91**	**64**	**48**	**5.5**	**12**	**4.6**	**3.5**	**20**	**0.44**	**0.15**	**0.28**	**0.01**	**6.8**	**5.1**
Randia	**7.3**	**05**	**95**	**72**	**50**	**5.7**	**13**	**4.6**	**3.4**	**35**	**0.51**	**0.18**	**0.14**	**0.07**	**6.6**	**5.3**
Boudpur	**7.2**	**05**	**93**	**70**	**47**	**5.5**	**12**	**4.5**	**3.4**	**25**	**0.48**	**0.16**	**0.14**	**0.05**	**6.9**	**5.1**
Rajghat	**7.1**	**05**	**92**	**74**	**58**	**5.1**	**13**	**4.5**	**3.6**	**20**	**0.48**	**0.15**	**0.13**	**0.01**	**6.5**	**5.2**
Satabhauni	**7.3**	**05**	**86**	**76**	**59**	**5.5**	**12**	**4.7**	**3.4**	**20**	**0.40**	**0.01**	**0.10**	**0.01**	**6.7**	**5.1**
Dhusuri	**7.4**	**05**	**86**	**82**	**63**	**5.6**	**12**	**4.7**	**3.5**	**20**	**0.40**	**0.01**	**0.10**	**<0.01**	**6.7**	**5.1**
Akhandalamani	**7.3**	**08**	**680**	**320**	**275**	**15**	**15**	**5.2**	**4.8**	**95**	**3.1**	**0.03**	**0.08**	**<0.01**	**7.1**	**4.8**
Bacteria	**Positive in all station**															
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-8: Standrd Deviations Of Various Parameters At Hadagada From April ,2015-January ,2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.7	7.1	6.95± 0.138
02	TDS	89	108	99.666±6.128
03	TH	30	140	82.666±38.992
04	SO_4^{2-}	08	20	12.833±3.847
05	NO_3^-	4.1	5.8	4.883±0.638
06	PO_4^{3-}	2.8	4.8	3.666±0.755
07	Cl^-	15	30	22.5±3.813
08	Fe	0.30	0.59	0.40±0.095
09	F^-	0.24	0.98	0.6516±0.298
10	Cr^{6+}	0.009	0.01	0.0093±0.00047
11	DO	7.0	7.2	7.133±0.093
12	BOD	2.5	5.2	4.216±1.18

TABLE-9: Standrd Deviations of Various Parameters At Bidyadharapur from April, 2015-January, 2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.8	7.3	7.066±0.177
02	TDS	95	104	98.333 ±2.981
03	TH	30	155	78.5 ±40.778
04	SO_4^{2-}	07	18	11.333 ±3.636
05	NO_3^-	4.2	5.4	4.616 ±0.453
06	PO_4^{3-}	2.5	4.6	3.533±0.679
07	Cl^-	15	25	21.666 ±3.726
08	Fe	0.20	0.59	0.49 ±0.194
09	F^-	0.24	1.2	0.765 ±0.379
10	Cr^{6+}	0.01	0.06	0.036 ±0.018
11	DO	6.7	7.1	6.9 ± 0.141
12	BOD	5.0	5.3	5.133 ± 0.123

TABLE-10: Standrd Deviations Of Various Parameters At Randia From April ,2015-January ,2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	7.0	7.4	7.15±0.15
02	TDS	76	103	92.333±9.392
03	TH	60	110	79.333± 21.761
04	SO_4^{2-}	06	15	11.666 ± 2.748
05	NO_3^-	4.5	5.6	4.983 ±0.433
06	PO_4^{3-}	2.1	4.3	3.233 ±0.641
07	Cl^-	15	25	22.16±6.465
08	Fe	0.28	0.51	0.376 ±0.089
09	F^-	0.14	0.96	0.6566 ±0.362
10	Cr^{6+}	0.07	0.08	0.0783 ± 0.0037
11	DO	6.4	6.8	6.6± 0.152
12	BOD	3.7	5.5	4.766 ± 0.729

TABLE-11: Standrd Deviations Of Various Parameters At Agarpada From April ,2015-January ,2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.8	7.2	7.083±0.1445
02	TDS	73	102	90.333±9.285
03	TH	20	115	71.333±31.388
04	SO_4^{2-}	06	15	10.5 ± 2.929
05	NO_3^-	4.1	5.2	4.6 ±0.432
06	PO_4^{3-}	2.4	4.4	3.333 ±0.609
07	Cl^-	15	30	21.666 ±4.713
08	Fe	0.34	0.52	0.403 ±0.055
09	F^-	0.28	1.2	0.683 ±0.346
10	Cr^{6+}	0.01	0.07	0.045 ± 0.022
11	DO	6.6	7.0	6.8 ± 0.115
12	BOD	3.4	5.3	4.6 ± 0.816

TABLE-12: Standrd Deviations of Various Parameters Baudpur From April, 2015-January, 2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.8	7.2	7.116±0.145
02	TDS	73	102	90.0± 9.643
03	TH	50	106	74.333±23.213
04	SO_4^{2-}	06	14	11.133 ±3.197
05	NO_3^-	4.3	5.3	4.75 ±0.381
06	PO_4^{3-}	2.1	4.3	3.226 ±0.65

07	Cl^-	20	25	21.666 ± 2.356
08	Fe	0.14	0.44	0.295±0.098
09	F^-	0.14	0.95	0.06 ±0.344
10	Cr^{6+}	0.04	0.05	0.0533 ± 0.006
11	DO	6.8	7.0	6.883 ± 0.088
12	BOD	2.8	5.3	4.35 ± 1.09

TABLE-13: Standrd Deviations of Various Parameters At Rajghat From April, 2015-January, 2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.5	7.2	6.983± 0.2265
02	TDS	92	100	93.166 ± 4.524
03	TH	30	110	74±26.20
04	SO_4^{2-}	08	15	12±2.081
05	NO_3^-	4.1	5.4	4.75 ±0.457
06	PO_4^{3-}	2.9	4.2	3.433 ±0.4157
07	Cl^-	15	25	21.666 ± 4.7129
08	Fe	0.30	0.48	0.366±0.0674
09	F^-	0.13	1.2	0.746 ±0.4305
10	Cr^{6+}	0.01	0.03	0.016 ± 0.0074
11	DO	6.2	6.8	6.5 ± 0.1825
12	BOD	5.2	5.8	5.433 ± 0.2279

TABLE-14: Standrd Deviations of Various Parameters At Satabhauni From April ,2015-January, 2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.8	7.3	7.05 ± 0.3566
02	TDS	85	100	92.166 ± 5.81
03	TH	70	120	86.833 ± 20.251
04	SO_4^{2-}	07	16	10.833 ±2.881
05	NO_3^-	4.1	5.6	4.75 ±0.645
06	PO_4^{3-}	2.8	4.4	3.416 ±0.548
07	Cl^-	15	25	20 ±2.886
08	Fe	0.21	0.43	0.023 ±0.308
09	F^-	0.10	1.2	0.715 ±0.447
10	Cr^{6+}	0.009	0.01	0.0096 ± 0.00047
11	DO	6.7	7.0	6.716 ± 0.176
12	BOD	4.6	5.3	4.983 ± 0.377

TABLE-15: Standrd Deviations of Various Parameters At Dhusuri From April ,2015-January ,2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.9	7.4	7.1 ±0.16309
02	TDS	82	100	91.666 ± 8.777
03	TH	60	126	89.666 ± 24.695
04	SO_4^{2-}	07	17	11.0 ± 3.26
05	NO_3^-	4.2	5.6	4.85± 0.4716
06	PO_4^{3-}	2.6	4.5	3.7 ± 0.5744
07	Cl^-	20	25	20.833 ± 1.863
08	Fe	0.25	0.43	0.33 ± 0.056
09	F^-	0.10	0.96	0.66 ± 0.5304
10	Cr^{6+}	0.009	0.01	0.00916 ± 0.0003
11	DO	6.0	7.0	6.616± 0.301
12	BOD	4.2	5.2	4.8 ± 0.441

TABLE-16: Standrd Deviations of Various Parameters At Akhandalamani From April ,2015-January ,2016

SL No.	Parameters	Minimum	Maximum	Mean & SD
01	pH	6.9	7.3	7.216 ± 0.1462
02	TDS	500	820	666.666 ± 110.955
03	TH	320	500	422.5 ± 75.716
04	SO_4^{2-}	08	18	18.833 ±5.899
05	NO_3^-	4.2	5.8	5.216±0.5112
06	PO_4^{3-}	2.1	5.4	4.233 ±1.037
07	Cl^-	75	1760	1197.5±786.695
08	Fe	3.1	4.9	1.6416 ±1.746
09	F^-	0.05	0.95	0.4816 ±0.35927
10	Cr^{6+}	0.009	0.02	0.01083 ± 0.00409
11	DO	6.9	7.1	7.033 ± 0.0745
12	BOD	2.0	4.8	4.166 ± 0.9961

TABLE-17: Seasonal average variations of physico-chemical parameters of River Salandi from April 2015-January 2016

Name of parameters	Hadagada	Bidyadharpur	Agarapada	Randia	Baudpur	Rajghat	Satbhauni	Dhushuri	Akhandal mani
pH	6.95 ± 0.138	7.066 ± 0.177	7.083 ± 0.1445	7.15 ± 0.15	7.116 ± 0.145	6.983 ± 0.2265	7.05 ± 0.16062	7.1 ± 0.16309	7.216 ± 0.1462
TDS	99.666 ± 6.128	98.333 ± 2.981	90.333 ± 9.285	92.333 ± 9.392	90.0 ± 9.643	93.166 ± 4.524	92.166 ± 5.81	91.666 ± 8.777	666.666 ± 110.955
TH	82.666 ± 38.992	78.5 ± 40.778	71.333 ± 31.388	79.333 ± 21.761	74.333 ± 23.213	74 ± 26.20	86.833 ± 20.251	89.666 ± 24.695	422.5 ± 75.716
SO_4^{2-}	12.833 ± 3.847	11.333 ± 3.636	10.5 ± 2.929	11.666 ± 2.748	11.333 ± 3.197	12 ± 2.081	10.833 ± 2.881	11.0 ± 3.26	18.833 ± 5.899
NO_3^-	4.883 ± 0.638	4.616 ± 0.453	4.6 ± 0.432	4.983 ± 0.433	4.75 ± 0.381	4.75 ± 0.457	4.75 ± 0.645	4.85 ± 0.4716	5.216 ± 0.5112
PO_4^{3-}	3.666 ± 0.755	3.533 ± 0.679	3.333 ± 0.609	3.233 ± 0.641	3.226 ± 0.65	3.433 ± 0.4157	3.416 ± 0.548	3.7 ± 0.5744	4.233 ± 1.037
Cl^-	22.5 ± 3.818	21.666 ± 3.726	21.666 ± 4.713	22.166 ± 6.465	21.666 ± 2.356	21.666 ± 4.7129	20 ± 2.886	20.833 ± 1.863	1197.5 ± 786.956
Fe	0.40 ± 0.095	0.49 ± 0.194	0.403 ± 0.055	0.376 ± 0.089	0.295 ± 0.098	0.366 ± 0.0674	0.023 ± 0.308	0.33 ± 0.056	1.6416 ± 1.746
F^-	0.6516 ± 0.298	0.765 ± 0.379	0.683 ± 0.346	0.6566 ± 0.362	0.06 ± 0.344	0.746 ± 0.4305	0.715 ± 0.447	0.66 ± 0.5304	0.4816 ± 0.35927
Cr^{6+}	0.0093 ± 0.000469	0.036 ± 0.018	0.045 ± 0.022	0.0783 ± 0.0037	0.0533 ± 0.006	0.016 ± 0.0074	0.0096 ± 0.00047	0.00916 ± 0.0003	0.01083 ± 0.00409
DO	7.133 ± 0.093	6.9 ± 0.141	6.8 ± 0.115	6.6 ± 0.152	6.883 ± 0.088	6.5 ± 0.1825	6.716 ± 0.176	6.616 ± 0.301	7.033 ± 0.0745
BOD	4.216 ± 1.18	5.133 ± 0.123	4.6 ± 0.816	4.766 ± 0.729	4.35 ± 1.09	5.433 ± 0.2279	4.983 ± 0.377	4.8 ± 0.441	4.166 ± 0.9961

III. Result & Discussion

3.1. pH: The pH is an important parameter required for maintenance and promotion of both biotic & abiotic ecological system [13]. pH of any water bodies can be changed with the change of season as there are several factors which govern it [13,27]. The increase of pH of surface water is due to increase of photosynthetic activities by autotrophs, as they use dissolved CO_2 and release O_2 to the water surface and low pH at the bottom of water surface in due to the liberation of acids from the decomposition of organic matters under low O_2 concentration [13,14,33,34].

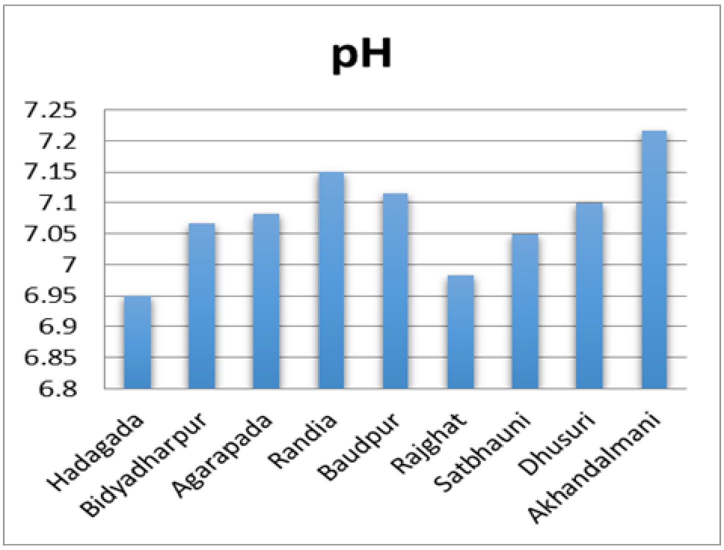


Figure-1. pH for nine different monitoring stations, April , 2015-January, 2016

The pH of water samples for nine monitoring stations The pH of water samples for nine monitoring stations was measured from the month of April 2015 to January -2016. It was observed that, although there are slight variations, but it is within the standard permissible limit. IS-10500 (6.5-8.5) [15]. Further higher pH (>7.0) is observed from upstream to downstream in the months from April-2015 to January-2016 except May with certain irregularities that at Hadagada Bidyadharpur, Satbhauni and Dhusuri slightly lower pH (<7.0) is observed during April and particularly at Hadagada lower pH in December (6.7) and January (6.9) is observed. The comparatively lower pH in the month of May can be attributed to low flow of water and decomposition of organic materials at high temperature that liberates acids and CO_2 [13,16,18,50]. The higher pH in rainy (August) and post-rainy (October) can be due to photosynthesis by autotrophs as myxophyceae bloom was observed in the river bed, high flow of water that dilutes the pollutants [4,7,10,16-18,33,34]. Besides, slightly lower pH at Hadagada in comparison to other stations only during April, December and January may be due to decomposition of organic materials [13,18] and other waste materials thrown off by the large number of picnic parties as because Hadagada is a good picnic spot and attracts large number of picnic parties during winter season (December & January) [6,10].

Similarly, the low pH of Akhandalmani during May (6.9) can be due to unseasonal rain fall run off in the coastal region as because Akhandalmani is vary nearer to the Bay of Bengal. The mean values of pH for nine monitoring stations has been given Figure-1. From the average variation data, it is evident that pH is lowest at Hadagada (6.95 ± 0.138) and Rajghat (6.983±0.2265). The lowest pH at Hadagada may be due to receiving of forest run off and mining run off and lowest pH at Rajghat may be due to receiving of biomedical wastes and urban wastes as district headquarter hospital and other private medicals are very close to it [8,10].

3.2. TDS & Turbidity: There is seasonal variation in TDS & turbidity in all monitoring stations as it is evident from the

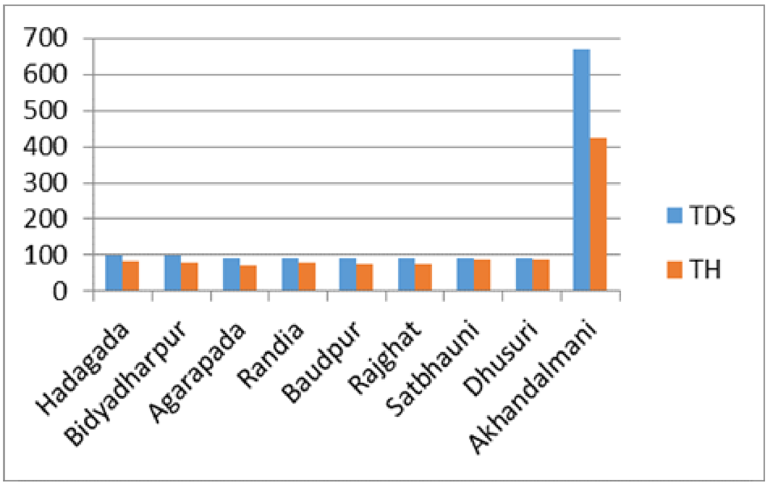


Figure-2. TDS & TH for nine different monitoring stations, April , 2015-January, 2016

analysis results. But from the month of August to October both TDS and turbidity are higher in all monitoring stations. It is due to entering of high rain fall run off causing erosion of soil, forest run off, industrial run off, mining run off, agricultural run off along with domestic run off to the river water in large scale [6, 8, 10]. The lower value of TDS & turbidity in summer (April & May) in comparison to other seasons may be due to silt & settling of dissolved salts [19,20]. The highest value of TDS & turbidity in the monitoring station Akhandalmani from the month of April-2015 to January-2016 is due to the back flow of sea water as because the station is nearer to Bay of Bengal [8,10,28]. The mean value of TDS from April-2015 to January-2016 for nine monitoring stations has been given in Figure-2. The seasonal variation of TDS is from 99.666 ± 6.128 (Hadagada) to 666.666 ± 110.955 (Akhandalmani) with higher values at Hadagada & its mining belt, Bidyadharpur (98.333 ± 2.98) and decreases towards downstream except Akhandalmani. It is due to entry of forest run off and mining effluents and it is gradually diluted towards diluted towards downstream [25,32].

3.3. TH, Ca & Mg: There is seasonal variations observed in case of TH for nine monitoring stations for the entire period of study from December-2015 to January-2016.But all the values are within permissible limit of IS-10500 (300mg/L) except Akhandalmani. But for the monitoring station Akhandalmani, the values are higher than the prescribed limit of IS-10500 for all the seasons, especially the values are much higher in rainy (August), post rainy (October) than summer and winter seasons. Further it is observed that mean values of TH changes from 82.666 ± 38.992 (Hadagada) to 422.5 ± 75.716 (Akhandalmani) in irregular manner. The highest value of TH at Akhandalmani is due to the back flow of sea water from the sea (Bay of Bengal) to the river [10,28]. The mean value of TH from the month of April-2015 to January-2016 for nine monitoring stations has been given in Figure-2. All the values of Mg are within the prescribed limit of IS-10500 (45mg/L) for entire period of study, though seasonal variations are observed. But the value of Ca in summer (April & May) is within permissible limit (75mg/L) and in rainy (August), post rainy (October) and winter (December & January) is higher than the permissible limit for all monitoring stations. This can be attributed due to the entry of agricultural effluents that contain certain calcium containing fertilizers such as calcium ammonium nitrate $[Ca(NO_3)_2.(NH_4)_2NO_3]$, basic calcium nitrate, calcium super phosphate$[Ca(H_2SO_4) + CaSO_{4.}2H_2O]$ used by the farmers for cultivation purpose [20-22,24,29].

3.4: NO^-_3, SO^{2-}_4, PO^{3-}_4 & Cl^- :- All the values for above parameters are within the permissible limit IS-10500. However, the values are higher in rainy (August), post rainy (October) than summer and winter seasons. It is due to entering of mining effluents, industrial effluents, urban wastes, agricultural wastes along with forest run off to the river and anthropogenic activities such as septic tank effluents, animal feeds [6,7,13,25,26]. The agricultural effluents contribute to pollution significantly as pesticides and certain fertilizers used by the farmers in large scale contain nitrate, sulphate and super phosphate which are mixed with river water as residues as because in ideal condition the plants use only 50%of nitrogenous fertilizers applied,2 – 20 % lost due to evaporation,15 – 25 % reacts with the organic compounds of the soil and remaining 2 - 10%interefere with the surface and ground water [20 – 23,29]. The variation of sulphate is from 12.833 $\pm$ 3.847 (Hadagada) to 18.833 $\pm$ 5.899 (Akhandalmani) and nitrate is from 4.883 $\pm$ 0.638 (Hadagada) to 5.216 $\pm$ 0.5112 (Akhandalmani). The concentration variation of chlorine is from 22.5 $\pm$ 3.818 (Hadagada) to 1197.5 $\pm$ 786.956 (Akhandalmani) & phosphate is from 3.666 $\pm$ 0.755 (Hadagada) to 4.233 $\pm$ 1.037 (Akhandalmani). The higher values of all the parameters at Akhandalmani are due to the back flow of sea water from the Bay of Bengal to the river [28]. The mean values of sulphate and nitrate for nine monitoring stations have been presented is Figure 3.

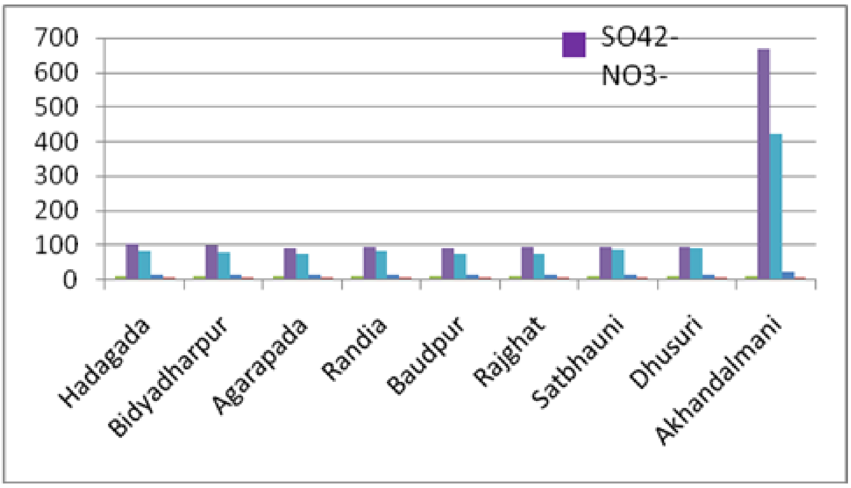


Figure-4. SO_4^{2-} &NO_3^- for nine different monitoring stations, April, 2015-January, 2016

3.5 Fe (>0.3) & Cr (>0.05):-

3.5: Fe(>0.3)& Cr^{6+}(>0.05):-

Iron is an important element required for both animals & plants especially in cellular process. The insoluble Fe^{3+} is reduced to soluble Fe^{2+} in water by bacteria [27] and Fe^{2+} plays a vital role in mammals as a major ingredient of hemoglobin in carrying out oxygen. Iron and hexavalent chromium are found to exceed permissible level or touching the permissible level in monitoring stations during summer, rainy, post rainy and winter seasons. This is mainly due to receiving of mining discharges from Nuasahi chromite mining belt, industrial wastes from industrial sector at Randia (FACOR) and agriculture wastes. It is observed that concentration of Fe is 0.40 & 0.43 in the month of April and May respectively at Hadagada and gradually decreases towards downstream except Akhandalmani. The higher concentrations of Fe in the month of May (0.43) than April (0.40) can be due to low flaw of water and decrease in concentrations towards downstream is due to dilution factor [10,30]. The high concentrations of Fe at Bidyadharpur in the month of August (0.59) & October (0.58) is due to mixing of mining discharges into the river water [36]. Further higher concentrations of Fe in the month of December & January from Hadagada to Akhandalmani in comparison to other months can be due to interaction of soil containing iron ore with water that increases the concentrations of Fe in the river and it happens at lower part of the river as water level is very low due to low flow of water [30]. The higher concentration of Fe at the monitoring station Akhandalmani from the month of April -2015 to January -2016 in comparisons to other monitoring stations is due to the back flow of sea water from the sea (Bay of Bengal) to the river that contains higher concentrations of Fe as it is confirmed from the experiment that in the month of January, water sample was collected from the monitoring station Akhandalmani at the time of back flow of sea water due to tide [28] and the analysis result shows the higher concentration of Fe at Akhandalmani (3.1). The mean value of Fe changes from 0.40 $\pm$ 0.095 at Hadagada to 1.6416 $\pm$ 1.746 at Akhandalmani during the April - 2015 to January-2016.

As regards hexavalent chromium, its permissible limit is 0.05 ppm (IS-10500) [15]. But at the monitoring station Randia, the river water contains more Cr^{6+} (0.08) than the permissible limit. The mean values of Cr^{6+} changes from 0.0093 $\pm$ 0.000469 at Hadagada to 0.01083 $\pm$ 0.00409 at Akhandalmani with maximum value at Randia (0.0783 $\pm$ 0.0037). It is due to entry of chromium effluents from Ferro – chrome Plant at Randia to the river [3, 36, 37]. Further, it is observed that concentration of hexavalent chromium is more in the month of August and October. It may be due to excessive use of chemical fertilizers and pesticides as in the rainy and post-rainy season farmers use maximum amount of fertilizers and pesticides that contains hexavalent chromium [21, 29, 30, 35, 37]. Presently, some chromite mines are not running due to lack of environmental and 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 [36]. Although, at present some chromite mines are not running, but mining effluents left by them earlier without proper treatment has resulted open exposure of chromite mixed soils to the atmosphere and pollute the river Salandi with chromium through atmospheric rain precipitations as the river Salandi is the only natural drainage system in the study area [30,37– 42]. Hence more concentrations of hexavalent chromium are found in the month of August and October from Bidyadharpur to Baudpur is due to entering of mining discharges, industrial discharges [26] and agricultural runoff, atmospheric rain precipitations, geology of river bed and catchment area [28,52]. The mean values of Fe & Cr^{6+} from the month of April-2015 to January-2016 for nine monitoring stations have been presented in the Figure 4.

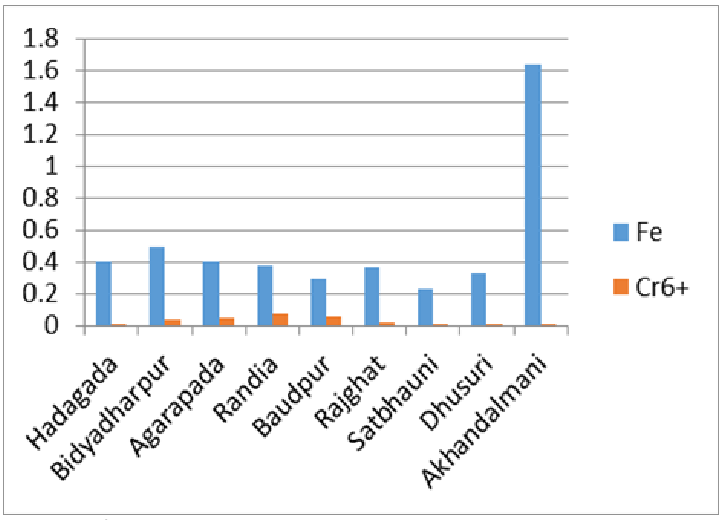


Figure-4 . Fe & Cr^{6+} for nine different monitoring stations, April, 2015-January, 2016

IV. Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a crucial parameter required to indicate the extent of pollution as well as survival and maintenance of flora & fauna. The major governing factors affecting the concentrations of DO are input sources such as dissolution of atmospheric oxygen in water, photosynthesis by autotrophs and output sources such as respiration, decomposition of organic matters by microorganisms and evaporation due to high temperature [7, 13, 14, 16]. Hence concentrations of DO in the water bodies increases if input sources are more than the output sources and its minimum requirement is 6 mg/L [15]. But due to continuous discharge of mining, industrial, Urban, agricultural and domestic wastes to the river, the DO values have been decreasing as it is being used in redox reaction process to stabilize the pollutants in water bodies [31]. Further anthropogenic activities such as open defection, picnic in the river bed and other socio cultural activities in the river bed at the time of occasions and festivals intensify the problem.

In the present study, it is evident that the DO values are constantly influenced from Hadagada to Akhandalmani by the aforesaid factors. The mean values of DO change from 7.133 $\pm$ 0.093 at Hadagada to 7.033 $\pm$ 0.0745 at Akhandalmani in gradually decreasing manner in the mining belt at Bidyadharpur(6.9 $\pm$ 0,141) and in the industrial belt at Randia (6.6 $\pm$ 0.152) and an increasing trend is observed towards downstream upto Akhandalmani due to dilution of pollution load with lowest value at Rajghat (6.5 $\pm$ 0.1825). Further, it is observed that DO values are lower in the mining belt (6.2 – 6.8 mg/L) and at Rajghat it is 6.2 to 6.6 mg/L in the month of April and May. It can be attributed due to mixing of mining effluents and urban wastes with the river water along with bacterial decomposition of organic matters and low rate of photo synthesis by autotrophs. Besides, higher values of DO in rainy (August) and Post-rainy (October) are due to high flow of water, flood that dilute the organic pollutants, aeration and more dissolution of atmospheric oxygen with the river water.

Moreover, it is needless to mention that, DO values are always higher at Hadagada with slightly seasonal variations (7.0-7.2 mg/L) for the entire period of study, can be attributed dues to high rate of photosynthesis by autotrophs as myxophyceae bloom has been observed in the river bed, low pollution load of the river in the upstream, more dissolution of atmospheric oxygen and low eutrophication because of dense forest environment [4, 7, 18]. The mean DO values from the month of April-2015 to January-2015 for nine monitoring stations have been given in the Figure 5.

4.2 Biochemical Oxygen Demand (BOD):

Like Dissolved oxygen, BOD is in important indicator of water pollution. For any water body, the BOD value, if more than 3 mg/L, will be treated as polluted [15], Higher the BOD value, more the water polluted by the organic materials and vice versa. It is observed that mean of the BOD values changes from 4.216 $\pm$ 1.18 at Hadagada to 4.116 $\pm$ 0.9961 at Akhandalmani with highest value at Rajghat (5.433 $\pm$ 0.2279) and Bidyadharpur (5.133 $\pm$ 0.123). Further it is observed that the BOD values are either close to the standard permissible limit (3 mg/L) or exceeding the permissible value in some stations and the values are more in rainy (August), post rainy (October) and winter (December & January) than Summer Seasons (April & May). It is much interesting to highlight that the average variation of BOD is lower at Hadagada (4.216 $\pm$ 1.18) and rises in mining belt at Bidyadharpur (5.133 $\pm$ 0.123), industrial belt at Randia (4.767 $\pm$ 0.729) due to receiving of industrial effluents from Ferro-Alloys Plant at Randia and in

urban belt at Rajghat (5.433 $\pm$ 0.2279) and decreases towards downstream up to Akhandalmani due to dilution and self-stabilization capacity of the river [7,10]. The higher value of BOD at Bidyadharpur (mining belt) may be due to entering of mining discharges to the river and higher value at Rajghat may be due to receiving of biomedical wastes and Urban wastes [8,10] and washing residues by the launders as the District Head Quarter Hospital and other private medicals very close to it and lenders use this spot for the washing in large scale [18].

The higher values during rainy and post rainy can be attributed due to of high flood and rain water that carries more forest runoff containing biological residues as study area is close to Similpal reserve forest, mining effluents, agricultural runoff, urban wastes, industrial wastes and domestic wastes [6, 21, 31]. Further higher values are the month of December and January may be due to throwing off picnic wastes [6], washing of motor vehicles to the river as Hadagada is big picric spot and attracts large number of parties to it during winter season [31], open defecation [6], burning and throwing of dead bodies to the river bed. Besides, row flow of river water and precipitations of contaminated dusts through rain water pollutes the river Salandi [30, 38, 39, 41, 42]. The mean values of BOD for nine monitoring stations from April – 2015 to January – 2016 have been given in the figure 5.

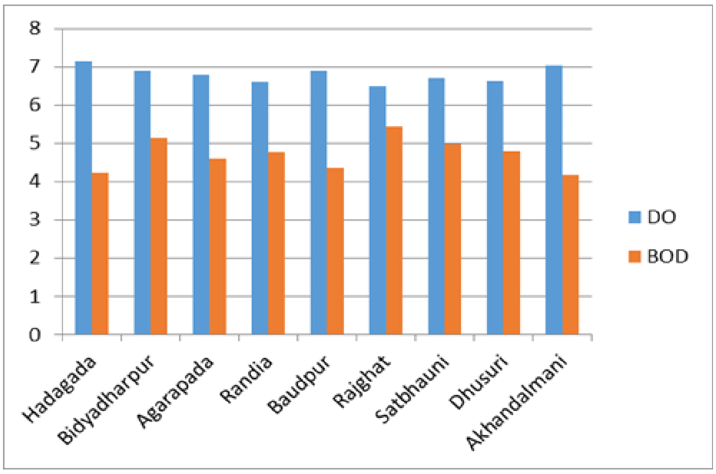


Figure 5. DO & BOD for different monitoring stations, April, 2015-January, 2016

4.3 FLUORIDE (F^-):-

The fluoride, responsible for fluorosis is within the permissible limit (< 1.5 mg/L) according to WOH guide lines–2004 [46] and BIS-2003 [15]. It is observed that value of fluoride is more in mining belt (Bidyadharpur) & Agarapada (1.2 mg/L) and decreases towards downstream except Rajghat (1.0) and Satabhauni (1.1) in the month of April and there is slight variation in the month of May. Further, it can be highlighted that value of fluoride is lower in rainy (August) & post rainy (October) in comparison to summer season except Rajghat (1.1 in August & 1.0 in October). The mean value of fluoride changes from 0.6516 $\pm$ 0.298 at Hadagada to 0.4816 $\pm$ 0.35927 at Akhandalmani with higher values at Bidyadharpur (0.765 $\pm$ 0.379), Rajghat (0.746 $\pm$ 0.4305) and Satbhauni (0.715 $\pm$ 0.447).

The high value of fluoride at Bidyadharpur and its neighboring station Agarapada may be due to the availability of highly water soluble compounds of fluorine such as sodium Fluoride (NaF), Fluorosilisic acids H_2SiF_6 and sparingly soluble compounds of fluorine such as CaF_2 & Cryolite (Na_3AlF_6) in the soil & rocks

[47,48]. The phosphate fertilizers also contain an average of 3.87% of fluorine which can be released to the river as agricultural effluents [48]. Water, when passes through and over the soil and rocks containing fluorine, may dissolve it and carries to the river. The comparatively high value during summer season may be due to low flow of water and that of lower value in the rainy & post-rainy is due to high flow of water that dilutes it.

Irrespective of nature of season, the high value of F^- at Rajghat and its neighboring station Satbhauni might be the mixing of medical wastes and urban wastes to the river as because, the District Head Quarter Hospital and Several Private Medicals are closer to Rajghat and hence F^- appears at Satbhauni accordingly and subsequently it is stabilized due to self-stabilization capacity of the river water [7, 10-12].

4.4 Bacteriological Tests: -

Bacteriological tests have been done through H_2S kit method and it is found that bacteria are positive in nine monitoring stations starting from Hadagada to Akhandalmani. It may be due to the mixing of biomedical waste, human and animal excretion, 0pen defecation in river bed that might contains pathogenic bacteria [16].It confirms that the river water is not only contaminated with heavy metals and other polluting radicals, but also contaminated with bacteria and hence unfit for drinking purpose without proper treatment [8,10].

V. Conclusion

The river Salandi originated from Hilly and dense forest areas of Similpal reserve forest, after passing through Hadagada Dam, mining belt at Nuasahi chromites mines, Agarapada Town, industrial sector at Randia, Bhadrak Municipality (District Head Quarter) and finally meets with the river Baitarani at Tinitar (near Akhandalmani) just before Dhamara Port, the confluence place with the Bay of Bengal. The river during its course of journey, receives forest run off, treated and untreated mining discharges in the mining belt, industrial effluents at Randia (FACOR), urban wastes at Agarapada and Bhadrak Municipality and agricultural residues and after all domestic wastes. Further, the bacteriological tests are positive in all monitoring stations. It is observed from the careful analysis of the result that the seasonal variations in physico- chemical parameters are found within certain range, may be high or low and the river is more polluted from Bidyadharpur to Randia (FACOR) due to receiving of mining discharges, industrial wastes and agricultural effluents [36, 49]. The contamination of monitoring station Rajghat can be construed as a result of mixing of biomedical wastes, municipality discharges and laundering residues as because the monitoring station is in the heart of the municipality and District Head Quarter Hospital and other private medicals are very nearer to it [2, 10]. Besides, it is under observation that the gravity of pollution gradually decreases from Bhadrak to the downstream, except Akhandalmani due to dilution and self-stabilization capacity of the river [7, 8]. The contamination at Akhandalmani is due to the back flow of sea water to the river as because the monitoring station is nearer to see (Bay of Bengal). Hence the river water is unfit for human consumption according to the standard prescribed by IS-10500[15] & WHO guidelines [46].

Hence urgent steps such as disinfection and electro dialysis and particularly for hexavalent chromium, reduction with SO_2 in acidic medium, followed by lime treatment to precipitate as chromium hydroxide, ion-exchange method along with other approved modern technologies shall be carried out to treat the water carefully by the appropriate authorities, otherwise it will pose a serious problem on the dwellers as well as flora & fauna [2, 5, 34]. Further investigation may please be done by any organization or authority to study the availability of other heavy metals such as Pb, As, Cd & Sb whose presence must create severe health hazards. The last but not least, this work finds a very good application to the society as a whole and particularly for the people of the District of Keonjhar and Bhadrak those are directly dependant on the river Salandi.

Acknowledgement

The authors are thankful to the Vice Chancellor, VSSUT, the Principal, Bhadrak Autonomous College, Bhadrak, and Executive Engineer, RW&SS for providing laboratory facilities for carrying out this research work. Further the first author is thankful to Mr. C. K. Sahoo, HOD chemistry, A.B. College, Basudevpur for constant cooperation and encouragement. No fund has been received from any source for this work.

References

[1] Bhadra A K, Sahu B & Rout S P: A study of water quality index(WQI) of the river Brahmani, Odisha(India) to assess its potability: Int J of Current Engg. & Tec, Vol-4(06), (2014).

[2] Dash M C: Ecology, Chemistry & Management of Environmental Pollution, 1st Edition, Mac Millan India Limited, New Delhi, 82-85 (2004).

[3] Kaur H, Environmental Chemistry, 5th revised Edition, Pragati Prakashan, India, 233-224(2010).

[4] Xie P, Zhuge Y & Dai M: Impact of eutrofication on biodiversity of Plankton Community, Acta Hydrobiol Sinica,20,30-37(1996).

[5] Waste Water Concept & Design Approach by Karia G L & Christian R A, 1st Edition, Prentice Hall of India, Ltd., New Delhi (2006).

[6] Kalavathy S, Sharma T R & Kumar P S: Water quality index of River Cauvery in Tiruchirappli, Tamilnadu, ARCH ENVIRON Sci, 5, 55-61(2005).

[7] Pardeshi D S & Baidya S: Physico-chemical assessment of Waldhuni River Ulhasnagar, Thane, India- A case study: Int. J of Current Research & Academic Review, 3(4), 234-248(2015).
[8] Panda P K, Panda R B & Dash P K: Pollution Load of river Salandi in Boula Nuasahi mining belt, urban area at Bhadrak & it's down streams in Odisha: IJIEASR, 4(12), 15-23(2015).
[9] American Public Health Association (APHA), AWWA, Standard methods of the examination of water & waste water, Washington DC, 7th edition (1995).
[10] Panda P K ,Panda R B & Dash P K: Assessment of Water Quality Index of river Salandi at Hadagada Dam & its Downstream upto Akhandalmani , Bhadrak , Odisha ,India, American J of Water Resources , 4(2), 44-53(1016).
[11] Panda R B et al , Occurrence of fluoride in ground water of Pratipal Panchayat in Balasore Disctrict , Odisha ,India , Journal of Environment , 01(02),33-39(2012).
[12] Oberoi J & Gupta K C: Occurrence fluoride in ground water of various villages of District Ambala , Haryana, Poll res , 29(3), 435-440(2010).
[13] Ishaq F & Khan A: Heavy Metal analysis of river Jamuna & their relation with some physico chemical parameters, Global J of Environmental research, 7(2), 34-39(2013).
[14] Kaul V & Handoo J K: Physico-chemical characteristics of Nilnag , a high altitude forest lake in Kashmir & its comparison with valley lakes,Proc. Indian National Sci. Academy D 46(4),528-541(1980).
[15] BIS IS -10500, Indian standard for Drinking Water Bureau Of Indian Standards (IS -10500-91), New Delhi(1991).
[16] Mishra A & Tripathi B D: Seasonal & temporal variation in physico-chemical & bacteriological characteristics of river Ganga in Varanasi, Current World Environment, 2(2), 149-154(2007).
[17] Hujare M S: Seasonal variation of physico-chemical parameters in perennial tank of Talsande, Maharastra , Ecotoxicol ,Environ.Monit , 18(3) ,233-242(2008).
[18] Ganie M A ,Khan M I & Muni P: Seasonal Variation in physico-chemical characteristics of Pahuja Reservoir , Jhansi , Bundelkhand region , Central India , Int J of Current Research,4(12), 115-118(2012)
[19] Ndubi D,Oyaro N,Giathane E & Afullo A:Detemination of physico-chemical properties of sources of water in Narok North Sub country ,Kenya,Int Research J of Enb. Sciences,4(1),47-51(2015).
[20] Moshood K M:Assessment of water quality of Oyun Reservoir,Offa, Nigeria using selected physico-chemical parameters ,Turkish J of Fisheries & Aquatic Science,8,309-319(2008).
[21] Serpil S: An agricultural pollutants-chemical fertilizer, Int Env & Dev, 3(1), (2012).
[22] Satya Prakash's Modern Inorganic Chemistry by R D Madan,2nd Edition,S Chand & Co., India, 1077-1088 (2006).
[23] Adeyemo O K, Adedokun O T, Yusuf R K & Adeleye E A: Seasonal changes in physico-chemical parameters & Nutrients load of river sediments in Ibadan city, Nigeria, Global NEST Journal, 10(3), 326-336(2008).
[24] Murhekar G H: Determination of physico-chemical parameters of surface water samples in and around .Akot city, Int J Res chem., 1(2), 183-187(2011).
[25] Mwangi J K,Thiongo G T & Gathenya J M :Assessment of water quality status of Sasumua watershed ,kenya,e-learning J kuat .ac.ke/journal (2012).
[26] Ewa E E ,Iwara A I,Adeyemi J A ,Eya E I,Ajake A O & Out C A:Impact of Industrial activities on water quality of Omuko Creek,Sacha J of Environmental Studies ,1(2),08-16,(2011).
[27] Lawson E O: Physico-chemical parameters & heavy metal contents of water from the mangrove swamps of Lagos lagoon, Lagose, Nigeria, Advances in Biological Research, 5(1), 08-21(2011).
[28] Kar D, Sur P, Mandal S K, Saha T& Kole R K: Assessment of heavy metal pollution in surface water, Int J Environ.Sci Tech, 5(1), 119-124(2008).
[29] Rim-Rukeh A , Lkhifa O G, & Okokoyo A P:Effect of agricultural activities on the water quality of Orogodo river , Agbor Nigeria , J Appl Sci Res ,2(5), 256-259(2006).
[30] Reza R & Sing G: Heavy metal contamination & its indexing approach for river water, Int J Environ. Sci Tech, 7(4), 785-792(2010).
[31] Pradhan U K, Shirodkar P V & Sahu B K:Physico-chemical evaluation of its seasonal changes using Chemo metric techniques, Current Science ,96(9),1203-1209(2009).
[32] Martin P & Haniffa M A: Water quality profile in South India river Tamiraparani , IJEP, 23,286-292(2003).
[33] Begum A & Harikrishna M: Study of quality of water on some stream of Cauvery River, E J Chemistry ,5,377-384(2008).
[34] Gray N F: Water Technology: An introduction for Environmental Scientists & Engineers, 2nd Edition , Elsevier India Pvt. Ltd., New Delhi(2005).
[35] Hatje V , Bidone E D & Maddock J : Estimation of natural & anthropogenic components of heavy metal fluxes in fresh water Sinos river, Rio Griande do Sul State, South Brazil, Environ. Tech., 19(5), 483-487(1998).
[36] Environmental Impact Assessment & Environmental Management plan of Boula Chromite mines, FACOR Ltd., Source, State Pollution Control Board, Odisha (1994).
[37] Ammann A A , Michalke B & Schramel P: Specification of heavy metals in environmental water ion-chromatography coupled to ICP-MS, Anal. Bional.Chem, 372(3), 448-452(2002).
[38] Bird G, Brewer P, Macklin M, Balteanu D, Driga B , Serban M & Zaharia S: The solid state partitioning of contaminant metals and as in river channel sediments of mining affected Tisa drainage basin, North Western Romania and Eastern Hungary, Appl. Geo Chem,18(10),1583-1595(2003).
[39] Kraft C, Tumpling W & Zachmann D W: The effect of mining IN Northern Romania on the heavy metal distribution in sediments of river Szamos & Tisza, Hungary, Acta Hiroshima Hydrobiol, 43,257-264(2006).
[40] Pandey J, Subhashish K & Pandey R: Metal contamination of Ganga river as influenced by atmospheric deposition, Bull Environ Contamination Toxicol, 83(2), 204-209(2009).
[41] Wu Y F, Liu C Q & Tu C L: Atmospheric deposition of metal in TSP of Guiyang, PR China, Bull Environ Contamination Toxicol, 80(5), 465-468(2008).
[42] Wong C S C, Li X D, Zhang G, Qi S H & Peng S Z: Atmospheric deposition of heavy metals in Pearl river delta, China, Atmos Environ, 37(6), 767-776(2003).
[43] Laluraj C M, Padma P, Sujatha C H, Nair S M, Kumar N C & Chacko: Base line studies on the chemical constituents of Kayamkulam Estuary near to newly commissioned NTPC power station, Ind J of Envtl. Prten.,22(7),721-731(2002).
[44] Koshy M & Nayar P V: Water quality of river Padma at Kozencherry, Pol Res, 19(4), 665-668(2000).
[45] Samantray P, Mishra B K, Panda C R & Rout S P: Assessment of water index in Mahanadi & Atharabanki rivers & Taladanda canal in Paradeep Area, Odisha,India, J Hum Ecol, 26(3),153-161(2009).
[46] WHO guidelines for drinking water quality, 3rd Edition, World Health Organization, Geneva, (2004).

[47] Sadat Nazneen: Study of fluoride concentration in the river Godavari & ground water of Nandeed city, Int J of Engg. Inventions, 1(1), 11-15 (2012).
[48] Fluoride in Drinking water, Back ground document of development of WHO guidelines for drinking water quality, WHO/SDE/WSH/03.04/96.
[49] Goel P K: Water pollution causes, effect and control, Revised 2nd Edition, New Age International Pvt. Ltd., 233(2009).
[50] Saikh N & Yeragi S G: Seasonal temperature changes and their influence on free carbon dioxide, dissolved oxygen and pH in Tansa, Thane District, Maharastra J Aqua.Biol., 18, 73-75(2003).
[51] Patil P L, Sawant D V & Deshmukh R N: Physico-chemical parameters for testing of water .A review, Int J Environmental Sciences, 3(3), 1194-1207(2012).
[52] Wani Y H, Jatayana M, Kumar S & Ahmad S: Assessment of water quality of Dal lake, Srinagar by using water quality indices, IOSR J of Environmental Science, Toxicology & Food Technology, 10(7), 95-1021(2016).