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The Study of Water Quality of the River Salandi by Using Modified Canadian Council of Ministers of the Environment Water Quality Index Method, Bhadrak, Odisha, India

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Abstract The river Salandi after its source of origin from Meghasana hill of Similipal reserve forest travels 134kms of long distance through mining belt, industrial belt, urban area, vast agricultural area and finally meets with the river Baitarani at Tinitaraf ghat before the merging with Bay of Bengal at Dhamara Port. The river during its course of journey from Similpal reserve forest to Tinitaraf ghat receives forest decayed residues from the forest area, mining discharges from the mining belt, industrial discharges from the industrial area, urban waste materials from the urban area, agricultural residues from the agricultural fields and after all domestic waste materials from the inhabitants situated on the bank of the river. In this work, water samples collected from nine different places during summer, rainy, post-rainy and winter seasons in the year 2015 and 2016 have been analysed to study the sixteen physico-chemical parameters by using standard procedures, prescribed by APHA-2012 and out of which mean and standard deviations (SD) of twelve parameters have been calculated and computed to study Water Quality Index (WQI) through Canadian Council of Ministers of Environment (CCME) method in a modified manner for the year 2015 and 2016. The study reveals that water quality of both the years is marginal and belongs to class-D. Further, it is concluded that comparatively poorer water quality of the year 2016 than the year 2015 is due the higher amplitude (F_3). Besides, analysis of physico-chemical parameters confirms that the river Salandi is polluted with respect to Cr(VI), iron, chloride, fluoride and pathogenic bacteria and gravity of pollution is more during rainy, post-rainy than the summer and winter seasons and pollution follows a decreasing trend from upstream to downstream.

Keywords: *CCME, WQI, hexavalent chromium, pathogenic bacteria, river water pollution*

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1. Introduction

The pragmatic importance of water has been understood by the human since ancient times with respect to culturally, socially as well as economically. In addition to this, aquatic creatures and wild lives are also potential beneficiaries of good quality of water and hence it is called elixir of life. After industrial revolution, the unplanned industrialisation followed by urbanisation grown up for the socio-economic development along with large scale application of chemical fertilisers and pesticides in agricultural sector after green revolution have imposed a great threat on the quality of water for which water pollution is a gigantic problem, not only for India but also for entire world.

The World Bank report released on 20.8.2019 says that heavily polluted water is reducing economic growth by up to one third in some countries, calling for action to address human and environmental harm. The report envisages that when BOD crosses 8mg/l, GDP growth in downstream regions drops by 0.83%. It is because of impacts on health, agriculture and ecosystem. It is therefore, highly indispensable to monitor water quality on regular basis and for this purpose, newly established procedures and methodologies have been developing in a modified manner to meet the need of the time. The Canadian Council of Minister of Environment (CCME) is one among the latest water quality indices to describe the water quality of any kind of water body.

The water quality index is a useful tool that describes the water quality of any water body by means of a single number on combining the different physico-chemical parameters and ranks the suitability of water for human, aquatic life and wild life. The CCME WQI developed in 2001, after modifying BC index, tells that at least four variables, sampled for a minimum of four times be taken and maximum number of variables or samples has not been specified [1,2].

In the present study, the river Salandi, originated from famous biosphere of Similipal reserve forest of Meghasana hill under Mayurbhanj district, Odisha, India meets with the river Baitarani at Tinitaraf ghat before confluence with Bay of Bengal at Dhamara. A dam has been built across the river Salandi at Hadagada in Anandapur sub-division of Keonjhar district for irrigation purpose of Bhadrak, Balasore and Keonjhar districts. This work studies the water quality of the river Salandi from Hadagada dam to Tinitaraf ghat, near Akhandalamani containing 134 km of long distance because the river during its course of journey receives forest run off from Similipal reserve forest, untreated mining wastes from mining belt at Bidyadharpur as there are three big chromite mines, viz Boula open caste and underground mines, Bangur chromite mines and Nuasahi chromite mines, industrial wastes from Ferro Alloys Corporation (FACOR) at Randia, urban wastes from Bhadrak municipality and after all agricultural run off from vast agricultural area as it is the only natural drainage system in the study area. The above polluting factors are mainly responsible for the pollution of the river which has been published in several daily news papers repeatedly.

2. Materials & Methods

The selection of nine sampling stations along the bank of the river has been done on the basis of availability of more expected pollutants to satisfy the aim and objective of this work. The water samples from nine different sampling stations as spotted in the Map 1 and as described in the Table 1 have been collected during summer (April & May), rainy (August), post rainy (October) and winter (December & January) seasons in the year 2015 and 2016.

Map 1. Location of different sampling stations across the river Salandi

Table 1. List of sample collection centres across the river Salandi

Sl No.	Name of Stations	Brief Description on Sampling Stations
01	Hadagada Dam	It is 50 KM from Bhadrak town and is a hilly area where the river receives forest effluents from Similipal biosphere & picnic waste materials.
02	Bidyadharpur	It is nearly 40 KM from Bhadrak town and a barrage is on the river Salandi where it receives mining and agricultural effluents
03	Agarpada	It is 25 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	Satbhauni	It is around 20 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 (Tinitaraf Ghat)	It is around 50 KM from Bhadrak town and is a confluence 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 .

2.1. Analysis of Physico-Chemical Parameters

Water samples collected in clean plastic bottles by adding 2ml concentrated HNO_3 in each bottle were analysed to study the physico-chemical parameters, according to the procedures established by APHA-2012. TDS & TH have been measured gravimetric and complexometric method respectively. Nitrate, iron and chromium have been measured with the help of UV-visible spectrophotometer at 275nm, 510nm & 540nm respectively. Sulphate has been measured by turbidimetry method [3,4].

2.2. Fluoride, Chloride & Bacteria

The fluoride and chloride have been measured by UV-visible spectrophotometer by adding SPANDS reagent and acid zirconium chloride at 570nm & titration method respectively [5]. The presence of bacteria has been done by H_2S kit method. [6]

2.3. Calculation of Water Quality Index

The calculation of CCME WQI is based on the combination of following three factors. [1,2,7,8,9]

1. Scope (F_1): The percentage of variables whose objectives are not met.
2. Frequency (F_2): The frequency with which objectives are not met.
3. Amplitude (F_3): The amount by which the objectives are not met. Hence F_3 is the major factor for the determination of water quality.

In this work, sixteen parameters have been studied during summer (April & May), rainy (August), post rainy (October) and winter (December & January) seasons in the year 2015 & 2016 and out of which mean values of twelve variables (Parameters) have been taken for the calculation of CCME WQI for the sake of the simplicity and water quality of the river has been classified into five categories from A to E, as specified in the Table 2.

Following formula has been used to calculate CCME WQI.

$$F_1 = \left(\frac{\text{number of variables or parameters, not meeting the objective}}{\text{total number of variable}} \right) \times 100$$

$$F_2 = \left(\frac{\text{number of tests, not meeting the objective}}{\text{totalnumberoftests}} \right) \times 100$$

F_3 has to be calculated by using following three steps

a) $\text{Excursion} = \left(\frac{\text{failed test values}_i}{\text{objective}_j} \right) - 1$

$$\text{Normalized sum of excursions} (nse)$$

b) $= \sum_{i=1}^{n} \frac{exeursion_i}{totalnumberoftests}$

$$F_3 = \frac{nse}{0.01 \times nse + 0.01}.$$

Higher the value of F_3, more the water polluted and vice-versa.

Hence, Intensity of pollution α F_3

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}.$$

The objective implies that the standard permissible value of any parameter and it is presented in the Table 6 and failed test is the test whose value exceeds the standard permissible limit. The excursions have been calculated for the parameters whose values exceed the standard permissible limit.

In this study total number of variables=12

Total number of tests =108

Total number of variables, not meeting the objective=7

Total number of tests, not meeting the objective=32

The water quality of the river Salandi has been ranked by using the reference Table 2 and presented in the Table 5 for study and conclusion.

Table 2. Reference Table under CCME WQI method, 2001

Rank	WQI value	Description	Class
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment, conditions are very close to natural or pristine levels, and this index value can be obtained if all measurements are within objectives virtually all of the time.	A
Good	80-94	Water quality is protected with only a major degree of threat or impairment; conditions rarely depart from natural or desirable levels.	B
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.	C
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.	D
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.	E

Table 3. Mean values and S.D for nine monitoring stations from April, 2015 to january, 2016

Name of Parameters	Hadagada	Bidyadharpur	Agarapada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandalmani
pH	7.06± 0.1743	7.1± 0.1673	7.1± 0.0894	7.1± 0.1673	7.08± 0.01649	6.92± 0.2219	7.06± 0.2290	7.12± 0.0748	7.02± 0.2925
TDS	98.4± 8.2607	99.4± 4.3634	90.0± 12.0166	92.0± 0.6583	90.2± 11.9398	94.4± 6.086	91.0± 13.5646	91.6± 6.6332	690.0± 100.7968
TH	88.0± 434281	82.5± 49.8838	74.0± 26.1763	81.8± 24.7256	76.6± 26.1503	74.8± 26.8303	86.0± 24.3721	87.2± 30.3301	447.2± 64.1323
SO_4^{2-}	11.8± 4.8166	11.4± 5.4845	10.2± 3.61101	11.0± 2.9664	10.4± 3.3585	10.6± 3.4117	10.0± 3.5213	9.8± 4.4899	14.4± 3.7416

Name of Parameters	Hadagada	Bidyadharpur	Agarapada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandalmani
NO_3^-	4.78± 0.6554	4.74± 0.5953	4.6± 0.5656	5.02± 0.44	4.84± 0.4223	4.84± 0.4673	4.66± 0.6529	4.76± 0.5953	5.12± 0.4534
PO_4^{3-}	3.5± 0.8694	3.5± 0.7694	3.24± 0.6945	3.16± 0.6713	3.14± 0.7088	3.42± 0.4578	3.38± 0.6998	3.3± 0.6782	4.2± 1.0039
Cl^-	22.0± 4.0	21.0± 3.7416	20.6± 2.3323	21.0± 3.7416	19.0± 2.0	25.0± 3.1622	21.0± 3.7416	20.0± 0.0	1762.0± 19.3907
Fe	1.924± 1.951	1.754± 1.8972	1.55± 1.4408	1.734± 2.1931	1.678± 2.0878	1.414± 1.387	1.124± 0.9682	1.108± 0.9572	2.394± 2.3333
F^-	0.82± 0.0993	0.982± 0.1284	0.874± 0.2109	0.896± 0.0365	0.84± 0.1314	1.14± 0.1019	0.942± 0.0949	0.908± 0.0275	0.736± 0.2219
Cr(VI)	0.0094± 0.000489	0.402± 0.01833	0.406± 0.02059	0.08± 0.0	0.054± 0.008	0.014± 0.00489	0.0096± 0.000558	0.0092± 0.00406	0.0112± 0.0044
DO	7.1± 0.06324	6.92± 0.0296	6.78± 0.16	6.48± 0.1720	6.74± 0.1624	6.38± 0.1939	6.72± 0.2039	6.64± 0.3498	7.0± 0.2449
BOD	4.08± 1.2528	5.16± 0.1777	4.54± 0.9002	4.76± 0.7605	4.24± 1.1825	5.56± 0.2416	5.06± 0.2244	4.7± 0.456	3.98± 0.9495

Table 4. Mean values and S.D for nine monitoring stations from April, 2016 to December, 2016

Name of Parameters	Hadagada	Bidyadharpur	Agarpada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandalmani
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± 0.1606	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± 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	12.0± 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± 1.03709
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	20.0± 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	0.6± 0.344	0.746± 0.4305	0.715± 0.447	0.66± 0.5304	0.4816± 0.35927
Cr(VI)	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± 0.00037	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± 0.0704
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

Table 5. Water quality of the river Salandi during 2015 & 2016 through CCME WQI method

Name of Station	2015			2016			WQI 2015	WQI 2016	Water quality 2015	Water quality 2016	Remarks
	F_1	F_2	F_3	F_1	F_2	F_3					
Hadagada	58.333	29.62	0.754	58.333	29.62	5.375	62.226	62.21	D	D	Marginal &decrease in quality During 2016
Bidyadharpur	58.333	29.62	1.38	58.333	29.62	5.428	62.22	62.1	D	D	Marginal &decrease in quality During 2016
Agarapada	58.333	29.62	0.921	58.333	29.62	4.5364	62.223	62.137	D	D	Marginal &decrease in quality During 2016
Randia	58.333	29.62	1.361	58.333	29.62	5.651	62.22	62.088	D	D	Marginal &decrease in quality During 2016
Baudpur	58.333	29.62	0.4676	58.333	29.62	4.762	62.227	62.128	D	D	Marginal &decrease in quality During 2016
Rajghat	58.333	29.62	1.166	58.333	29.62	4.852	62.222	62.124	D	D	Marginal &decrease in quality During 2016
Satbhauni	58.333	29.62	0.7739	58.333	29.62	3.567	62.228	62.172	D	D	Marginal &decrease in quality During 2016
Dhusuri	58.333	29.62	0.7345	58.333	29.62	3.567	62.226	62.172	D	D	Marginal &decrease in quality During 2016
Akhandalmani	58.333	29.62	7.995	58.333	29.62	11.738	61.946	61.625	D	D	Marginal &decrease in quality During 2016

Table 6. Objectives of different parameters, analysed

Name of Parameter	pH	TDS	TH	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	F^-	Cr(VI)	DO	BOD
Objective	6.8-8.8	500	300	150	45	5.0	250	0.30	0.6	0.05	6.0	3.0

2.4. Calculation of Standard Deviations

The mean and standard deviations (SD) for twelve important parameters from April, 2015 to January, 2016 and April, 2016 to December, 2016 have been calculated and presented in the Table 3 and Table 4 respectively.

3. Results & Discussion

WQI: It is evident from CCME WQI data that, although water quality during both the years is marginal and belongs to class-D, but water quality during the year 2016 follows a more deteriorating trend with decreasing order from upstream (mining belt) to downstream except the monitoring station Akhandalamani. In Akhandalamani both the years exhibit comparatively bad water quality. Further amplitude (F_3), the key factor in the determination of water quality is higher during the year 2016. Panda et al while studying the water quality of the river Salandi through NSE-WQI method had reported class-D quality and exhibits the same deteriorating trend. The higher F_3 and deteriorated water quality during the year 2016 is due to higher value of Fe and F^- as a result of increase of mining activities after the partial withdrawal of mining restrictions imposed by Saha Commission. Irrespective of the year, the comparatively lower water quality in the monitoring station Akhandalamani is due to the back flow of sea water from the sea (Bay of Bengal) to the river [6]. The decreasing trend from upstream (mining belt) towards downstream is due to the dilution and self stabilization capacity of the river [10]. The values of WQI for both the years have been presented in Figure 1.

p^H: The p^H for nine monitoring stations was measured during the two years of study season wise and seasonal variation was observed with higher value (7.3) and lower value (6.8) in rainy and summer seasons respectively. The lower value in the summer season may be due to the low flow of water and decomposition of organic matters liberating acid and co_2 and higher value in the rainy season can be attributed to the high flow of water due to rain and flood that dilutes the pollutants and photosynthesis by autotrops that consumes CO_2 [11]. From the mean value data, it is evident that, there is slightly increase of p^H in the year 2016 than the year 2015. It may be due to the high water flow as a result of heavy rain in 2016. The values of p^H for all monitoring station during two years have been presented in the Figure 2.

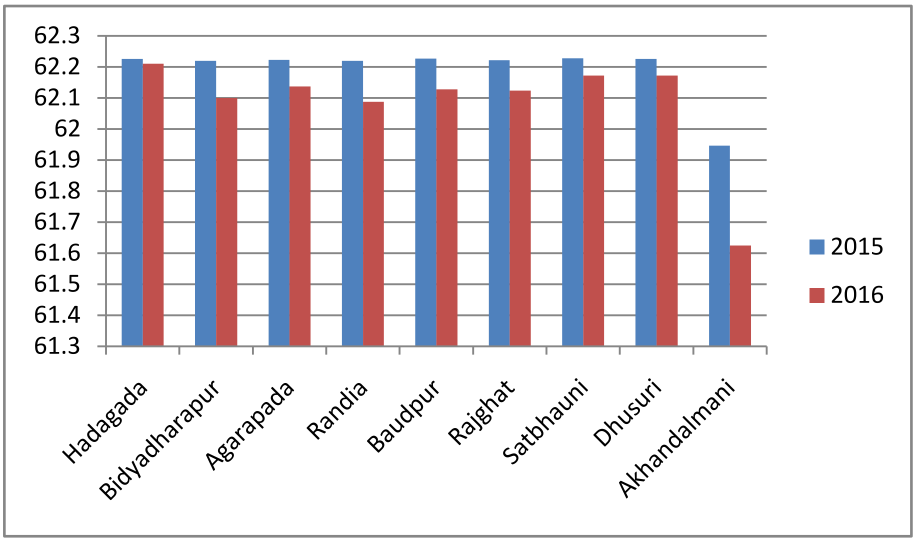

Figure 1. CCME WQI values of the river Salandi for the year 2015 & 2016

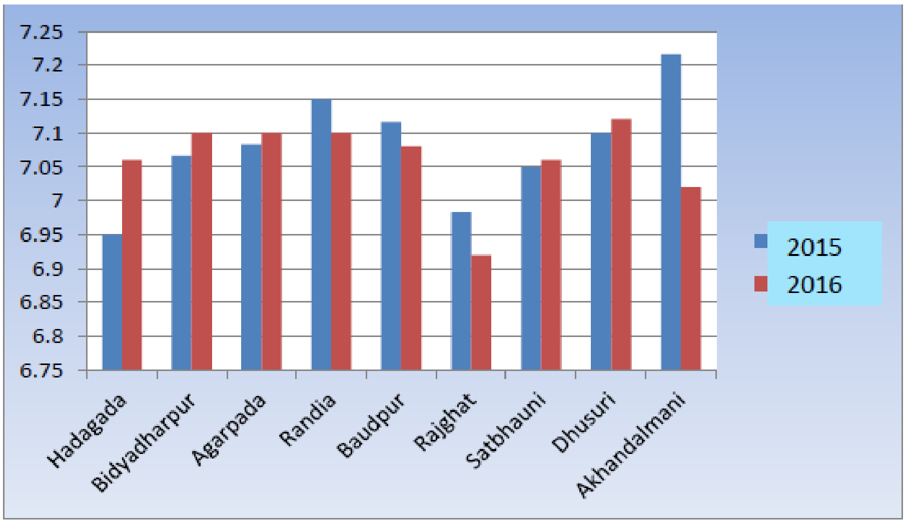

Figure 2. pH values of nine monitoring stations for the year 2015 and 2016

TDS & TH: It was observed that both TDS and TH change seasonally with lower value in the summer season and higher value in the rainy and post-rainy seasons during two years of study. The higher value during rainy and post-rainy seasons may be due to mixing of agricultural runoff, soil erosion materials due to rain water and flood, forest runoff, mining runoff, industrial waste material with the river water [12]. Further, it is observed that irrespective of nature of season, the high value of above parameters in the monitoring station Akhandalamani is due to the back flow of sea water from the sea (Bay of Bengal) to the river. The lower value during the summer season is due to the settling of the dissolved materials [13].

SO_4^{2-}, NO_3^-, PO_4^{3-}: The values for these parameters are within the standard permissible limit of IS-10500 during two years of study. But higher values for aforesaid parameters found, during rainy and post rainy seasons may be due to the mixing of agricultural residues containing SO_4^{2-}, NO_3^- and PO_4^{3-} along with forest, mining, industrial and domestic waste materials with the river water [14,15,16]. It can be mentioned that in ideal condition plant use only 50% of nitrogenous fertilizer applied, 2-20% is lost due to evaporation,15-20% react with organic compounds of the soil and remaining 2-20% intermix with surface and ground water [16]. The study of mean value data reveals that, irrespective of nature of season, higher concentration of above parameters were in the monitoring station Akhandalamani. Further, it is found that SO_4^{2-} and NO_3^- are higher in the monitoring station Hadagada and Randia respectively. It might be due to the mixing of biological residues from Similipal reserve forest and picnic waste materials with the river water at Hadagada and industrial waste materials containing NO_3^- from FACOR at Randia [10].

Cl^-: The values of chloride are within the standard permissible limit of IS-10500 in all monitoring stations during two years of study except Akhandalamani, although slightly seasonal variations are observed in irregular and insignificant order. The higher value of Cl^- at Akhandalamani is due to the back flow of sea water from the sea to the river. The comparatively higher value of chloride at Hadagada may be due the mixing of forest decayed residues and picnic waste materials and in case of Rajghat, it may be due to the mixing of biomedical wastes and cloth washing residues with the river water. [6,10]

F^-: The values of fluoride are within standard permissible limit of IS-10500 and WHO guide lines in all monitoring stations during two years of study, although seasonal variations are observed [3,4,17]. The study of mean value data reveals that the value of F^- is highest at Rajghat and lowest at Akhandalamani and higher in the year 2016 than the year 2015 in all monitoring stations. The higher value during the year 2016 may be due to the availability of more soluble salts of fluoride such as NaF, Flurosilisic acid (H_2SiF_6) and sparingly soluble salts such CaF_2 and cryolite (Na_2AlF_6) in the soil and rocks [5,18]. Not withstanding the season and year, the highest value of fluorine at Rajghat may be due to the mixing of biomedical wastes with the river as there are so many hospitals including both government and private on the bank of the river [13]. The values of F^- for both the years for nine monitoring stations have been presented in the Figure 3.

Fe: The value of Fe exceeds the permissible limit of IS-10500 (0.3mg/L) in all monitoring station during two years of study and much higher value of Fe is found during the year 2016 with highest value at Akhandalamani (2.394 ± 2.333). Besides, it is found that the value of Fe is more during rainy, Post-rainy and winter seasons.

Higher value of Fe during rainy and post-rainy seasons is due to the dissolution of more soil containing iron ore in the river water as a result of heavy rain fall and it happens significantly in the mining belt followed by gradual dilution towards downstream and in case of winter season, the interaction of ore mixed soil with water takes place at the middle part of the river because of low flow of water [19]. The unexpectedly higher value of Fe at Akhandalamani is due to the back flow of sea water from the sea to the river that might contain Fe as it was confirmed from the experiment that, during the time of tide, water sample was collected form Akhandalamani and was analysed. The analysis result shows the higher amount of Fe (3.1) in the sample. It is due to the fact that, the monitoring station Akhandalamani is the confluence of the river Salandi and Baitarani. In the upstream of the river Baitarani (Joda and Berbil area), there are so many iron mines which discharge a large volume of mining waste materials containing iron to the river that appears in the river water in the downstream. The higher concentration of Fe in the upstream has been reported by Das et al [20]. The much more higher value of Fe during the year 2016 is due to the increase in mining activities as a result of partial withdrawal of mining restrictions imposed by Saha Commission on mines [10]. The value of Fe for both the years has been presented in the Figure 4.

Cr: As regards to hexavalent chromium Cr (VI), its permissible limit is 0.05mg/L, according to IS-10500 [4]. It is found that the value of Cr (VI) is more during rainy and post rainy seasons than the summer and winter seasons and irrespective the nature of seasons, the value of Cr (VI) is highest at the monitoring station Randia. The higher value during rainy and post rainy seasons may be due to the excess use of chemical pesticides by the farmers that might contain Cr (VI) and mixing of chromite mining discharges with the river water as a result of heavy rain fall [12,16,21]. The highest value of Cr (VI) at Randia is due to inflow of Cr (VI) contaminated industrial discharges from Ferro chrome plant situated on the bank of river at Randia [22].

The insignificant amount of Cr (VI) in all monitoring stations except Randia and its neighbouring station Baudpur is due to the fact at present some chromite mines aren't running due to the restriction imposed by Saha Commission on certain grounds. But report of Pollution Board reveals that mining discharges left by them earlier without proper treatment has resulted open exposure of chromite mixed soil to the atmosphere and polluted the river Salandi through rainfall run off as it is the only natural drainage system in the study area [23,24].

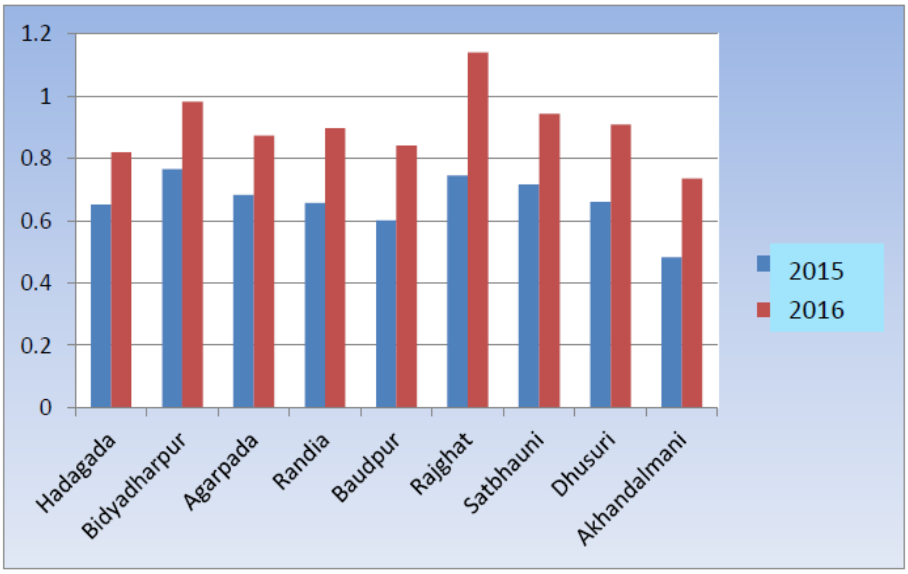

Figure 3. Concentration of F^- for the year 2015 & 2016 for nine monitoring stations

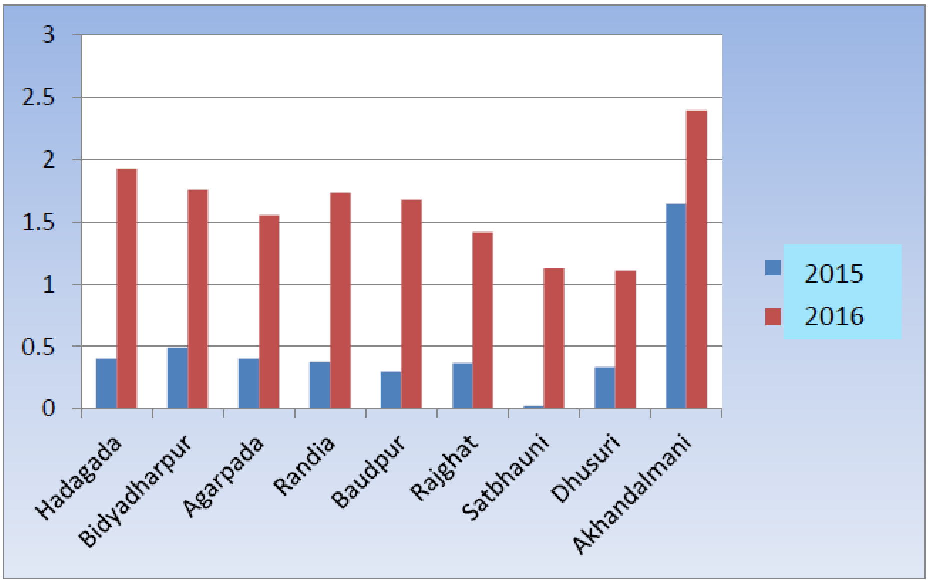

Figure 4. Concentration of Fe of nine monitoring stations for the year 2015 & 2016

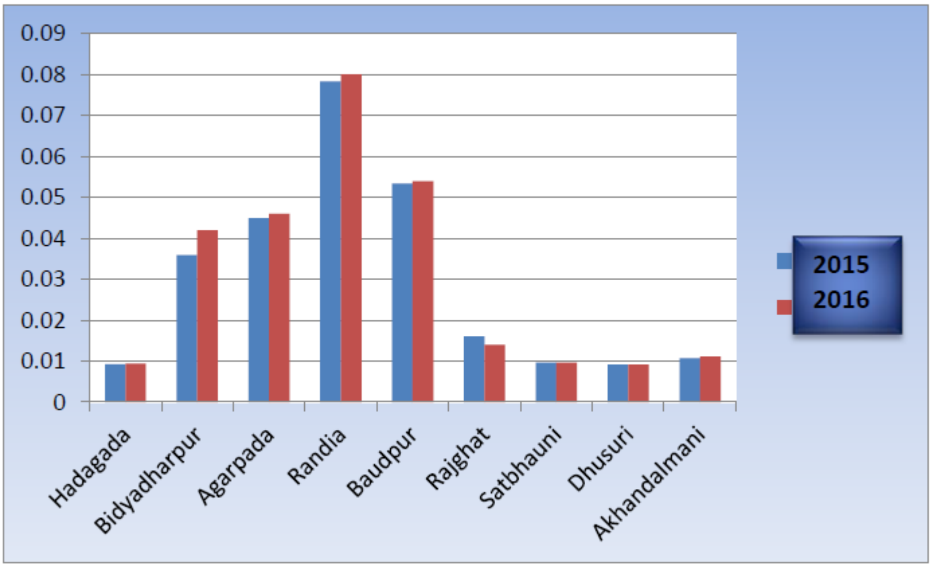

Figure 5. Concentration of Cr (VI) of nine monitoring stations for the year 2015 & 2016

3.1. Biological Oxygen Demand (BOD):

The BOD value of any water body if more than 3mg/l will be treated as polluted and it is seen that the BOD is higher during rainy, post rainy and winter seasons than the summer season. Further, it is observed that higher BOD value is found at Rajghat. The higher BOD value during rainy and post rainy seasons may be due to mixing of forest decayed run off containing biological residues, mining, industrial, agricultural, urban [12,14] and domestic waste materials with the river water and higher value during winter season may be effect of several factors such as throwing of picnic waste materials, holding of socio-cultural functions in the river bed, burning and throwing of dead bodies and after all open defecation in the river bed [6].

3.2. Dissolve Oxygen (DO)

It is found from two years of DO values that it decreases from upstream to downstream except Akhandalamani with lowest at Rajghat. The higher DO at Hadagada may be due to low rate of evaporation as a result of dense forest environment, stock of high volume of water and in case of Akhandalamani, it may be due to stock of high volume of water round the year as it is the confluence of two rivers, dilution of pollutants and aeration due to tide [6,10]. The lowest value at Rajghat may be due to mixing of biomedical wastes and washing residues as the launders use this place for washing purpose in large scale [12,25].

Further, it is observed from the seasonal variation that, the DO values are higher during rainy and post rainy seasons and vice-versa in the summer season. The former may be due to high flow of water, flood, and photosynthesis by autotrops and aeration and in case of latter, it is due to the low flow of water and high rate of evaporation because of high temperature [11,12,21,25]. Another important observation can be cited that during rainy season both DO and BOD value increase simultaneously.

3.3. Bacteriological Test

The bacteriological tests for two years from Hadagada to Akhandalamani have been done through H_2S kit method season wise and the result confirmed that the river Salandi is contaminated with respect to pathogenic bacteria. It is due to the collective effect of certain factor such as excretion by animals, open defecation in river bed, burning and throwing of dead bodies and mixing of biomedical wastes [6,12,21]. However, exact nature and amount of bacteria haven't been done due to inadequate laboratory facilities.

4. Conclusions & Recommendations

The river Salandi from its point of origination to Tinitaraf ghat travels 134KMs of long distance and during the course of journey, it receives forest decayed residues, picnic waste materials from forest area at Hadagada, mining discharges from the mining area at Bidyadharpur, industrial discharges from Ferro Alloys Corporation (FACOR) at Randia, urban and biomedical wastes from Bhadrak municipality, agricultural runoff from the vast agricultural fields as well as domestic waste materials from the inhabitants situated on the bank of the river, for which it is contaminated physically, chemically and bacteriologically with respect to Cr (VI), chloride, iron, fluoride and bacteria. Further, the study concludes that the gravity of pollution is more during rainy and post rainy seasons than the winter and summer seasons.

The CCME WQI study reveals that the river Salandi is polluted and belongs to class-D and marginal water quality. Further, the study confirms that the water quality is more deteriorated during the year 2016 in comparison to 2015.It is due to increase of amplitude (F_3) as a result of rising of mining activities after the partial withdrawal of mining restrictions imposed on Indian Ferro Metal Alloys Corporation (IMFA) and Odisa Mining Corporation (OMC) and gradual increase of water quality from upstream to downstream is due to the dilution and self stabilization capacity of river. Panda et al while studying the water quality of the same river through NSF-WQI method had also reported class-D water quality with same deteriorating trend. Hence the study of water quality of the river Salandi through CCME and NSF method as well as individual physico-chemical parameter analysis concludes and confirms that the river Salandi is polluted and belongs to class-D quality. Hence both the methods support each other and correlate with the individual physico-chemical parameter study.

Therefore, urgent measures on priority basis be taken so as to ensure zero entry of pollutants to the river, besides adopting modern methods such as disinfection, electro dialysis and for Cr (VI), reduction with SO_2 in acidic medium followed by lime treatment to convert Cr (VI) to Cr(III) as chromium hydroxide along with phytoremediation, bioremediation for the treatment of toxic substances, pathogenic bacteria and simultaneously to increase DO value by means of photosynthesis.

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