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The Comparative study of water quality of river Salandi by applying different water quality indices, Bhadrak, Odisha, India

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

1- *Department of Chemistry, A.B. College, Basudevpur, Bhadrak, Odisha, India .*
2- *Department of Chemistry, Bhadrak Autonomous College, Bhadrak, Odisha, India .*
3- *Department of Chemistry, VSSUT, Burla, Odisha, India.*

Abstract:
The river Salandi, from its source of origin to Tinitaraf ghat travels 134kms of long distance through forest area, mining and industrial belt, urban area, agricultural area and finally meets with the Bay of Bengal at Dhamara port. The river during its course of journey receives different hazardous pollutants from different places . In this work, water samples collected from nine different monitoring stations during rainy, post rainy, winter and summer seasons in the year 2015 and 2016 have been analyzed by using the standard procedures available in APHA, 2012 to study the sixteen physico-chemical and biological parameters and out of which mean and standard deviations (S.D) of twelve parameters have been calculated and computed for comparative study of water quality through Weighted Arithmetic water quality index method, National Sanitation foundation water quality index method and modified Canadian Council of Ministers of Environment water quality index method.

The study reveals that water quality of all monitoring stations comes under class D for both the years through the NSF WQI and CCME WQI methods with slight difference in WQI values in later one whereas incase of WAWQI method, water quality changes from B to E and C to E during the year 2015and 2016 respectively. The physico-chemical and bacteriological analysis confirm that river water is polluted physically , chemically and bacteriologically with respect to chloride, fluoride, Cr(VI), iron & pathogenic bacteria and it correlates with WA WQI method potentially and hence reliability factor is more for WAWQI method than other two.

Key Words: *river water pollution, WA WQI, CCME WQI, NSF WQI, hexavalent chromium, standard deviations.*

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I. Introduction:

Water is a unique natural resource which plays a paramount role in management and maintenance of human, wild and aquatic life and importance of water has been felt by the human since ancient times to the present in terms of socially, culturally and economically for which human habitations, towns and cities were grown up on the bank of the rivers and hence it is called elixir of life. After industrial and green revolution, the unplanned industrialization followed by urbanization and application of chemical fertilizers and pesticides in large scale have been imposing a great threat on the very quality of water for which water pollution is a gigantic problem not only for India but also for entire world.[20]

According to the World Bank report, released on 20.8.2019 tells 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. When BOD crosses 8mg/L, GDP growth in downstream regions drops by 0.83% , the report says. It is because of impacts on health, agriculture and ecosystem. It is therefore, highly essential to monitor the quality of water on regular intervals of any water body and for this purpose different water quality indices have been developing to meet the challenge.

Water quality index is a useful tool that depicts the water quality of any water body by means of a single number, calculated on considering the effect of several physico-chemical parameters and ranks the suitability of water for human, aquatic and wild life. A number of water quality indices have been developed and applied by the researchers suitably to assess the water quality of water body.[19]

The river Salandi, originated from famous biosphere of Similipal reserve forest of Meghasana hill of Mayurbhanj district merges with the river Baitarani at Tinitaraf ghat before confluence with Bay of Bengal at Dhamara port. A dam has been built across the river Salandi at Hadagada in Anandapur sub-division of Keonjhar district for the irrigation of Bhadrak, Balasore and Keonjhar districts. The longitude and latitude of the dam is $86^0 18'$ East and 217^0 $17'$ North respectively.

The present work studies the water quality of river Salandi from Hadagada dam to Tinitaraf ghat (Akhandalmani) containing 134Kms of long distance because the river during its course of journey in the aforesaid area receives different untreated pollutants from different places, that is forest decayed runoff from Similipal forest, mining discharges from the mining area at Bidyadharpur where there are three chromite mines, namely Boula open caste and underground mines, Nuasahi chromite mines and Bangur chromite mines, industrial discharges from Ferro Alloys Corporation (FACOR) at Randia, urban and bio medical waste materials from Bhadrak municipality, agricultural wastes from vast agricultural lands. Although quantity and nature of pollutants are not same in all places and all seasons, but the river receives entire pollutants because it is only the natural drainage system in the study area , which has been published in several daily newspapers. The objectives of this study is to assess the water quality of the river by applying three water quality indices as well as to compare the potential ranking of the river water on the basis of selected methodologies.

II. Materials & Methods:

The nine monitoring stations along the bank of the river have been selected on the basis of the gravity of the expected pollutants to meet objective of the work. The water samples from nine different monitoring 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 seasons (December & January) in the year 2015 and 2016.

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)	On 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 biomedical 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 .

Table – 1: List of sample collection centres across the river Salandi

Map – 1: Location of different sampling stations across the river Salandi

Analysis of physico-chemical and bacteriological parameters :

The study of physico-chemical parameters was done by analyzing water samples collected in well cleaned plastic bottles by adding 2 ml of concentrated HNO_3 in each bottle according to the procedures established by APHA;2012. TH and TDS have been measured in complexometric and gravimetric methods respectively. Chromium, iron and nitrate have been measured with the help of UV-Visible Spectrophotometer at 540nm,510nm and 275nm respectively. The turbidimetry method has been adopted for the measurement of sulphate.[APHA,2012, BIS IS-10500,2004] The measurement of chloride and fluoride have been done by titration and UV- visible spectrophotometer method by using SPANDS reagent and acid Zirconyl chloride at 570nm respectively[WHO,2004]. The presence of bacteria has been assessed through H_2S kit method[1,5]

Calculation of mean and standard deviations(S.D):

The mean and standard deviations (S.D) for twelve important parameters calculated for both years 2015 and 2016 have been presented in the Table-2 and 3 respectively.[17]

Table-2.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
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-3. 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

Application of different water quality indices:

Three different water quality indices as stated hereunder have been applied to study the water quality of the river Salandi because these water quality indices are being applied most commonly by the scientists and organizations all over the world.

(1)Weighted Arithmetic water quality index(WAWQI) method :

The Weighted Arithmetic Water Quality Index Method is a modern method developed by Brown et al in 1972 by considering the combined effect of several important physico-chemical & bacteriological parameters and depicts the water quality of any water body under study. 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 organizations[4,8,9,22].

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

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

iii) It reflects the suitability of both surface and ground water sources for human consumption.

This method includes following steps which is explained briefly.

(1) Quality rating scale of each parameter is calculated by using following formula. Quality rating scale

$(Qi) = [(V_0 – V_i) / (V_s – V_i)]100$

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 pH & DO

Vi for pH = 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 orWi= K/Si

Where Si= standard permissible value of particular parameter

K= proportionality constant.

For the sake of simplicity K is taken as 1[17,18].

(3) Water Quality Index(WQI) = $\frac{\sum WiQi}{\sum wi}$

Water quality of the river Salandi ranked according to the reference Table-4 has been presented in the Table-5.

Table –4 (Weighted Arithmetic WQI Method)

WQI value	Water quality	Grade
0 – 25	Excellent	A
26 – 50	Good	B
51 – 75	Poor	C
76 – 100	Very poor	D
Above 100	Very poor & unfit for drinking purpose	E

Table -5 Water Quality of river Salandi of nine monitoring Stations, 2015 & 2016

Sl No.	Name of Stations	WQI 2015	Water Quality 2015	Grade 2015	WQI 2016	Water Quality 2016	Grade 2016
1	Hadagada	43.1737	Good	B	101.6553	Unfit for drinking purposes	E
2	Bidyadharpur	98.3067	Very Poor	C	154.3589	Do	E
3	Agarapada	108.7467	Very Poor & unfit for drinking purposes	E	150.2525	Do	E
4	Randia	147.0829	Very Poor & unfit for drinking purposes	E	211.1157	Do	E
5	Baudpur	108.0049	Very Poor & unfit for drinking purposes	E	167.6191	Do	E
6	Rajghat	55.4871	Class ‘C ‘ River water	C	101.0958	Do	E
7	Satbhauni	40.3559	Good	B	76.5944	Very Poor	D
8	Dhusuri	39.2897	Good	B	73.5768	Poor	C
9	Akhandalmani (Tintarf Ghat)	84.49277	Very Poor & unfit for drinking purposes	D	131.3706	Unfit for drinking purposes	E

(2) National Sanitation Foundation water quality index (NSFWQI) method:

The water quality index of the river Salandi has been calculated with the help of National Sanitation Foundation (NSF) method, developed by Brown et al, 1970. This method has been briefed in the following

The NSF-WQI is an excellent method used worldwide to study the water quality if any water body polluted critically by using nine parameters[6,14,23]. In this study, six parameters have been taken (pH, TDS, NO_3^- , SO_4^{2-} , DO, BOD) for the assessment of the water quality of the river Salandi by applying following formula:[20]

$$\mathbf{WQI = \sum_{i=1}^{n} WiQi}$$

Where,

Qi = Sub-index for i^{th} water qualities parameter.

Wi = weight assigned with i^{th} water quality parameter.

n = no. of water quality parameters.

Water quality of river Salandi ranked according to the reference Table-6 has been presented in the Table-8.

Table – 6: Water quality criteria (NSF-WQI)

Sl. No	WQI Level	Water Quality	Grade
01	0 - 25	Very bad	E
02	26 - 50	Bad	D
03	51 - 70	Moderate	C
04	71 - 90	Good	B
05	91 - 100	Very good	A

Table 7 : The Weight values of water quality parameters in WQI system

Sl. No	Parameters	Weight
1	Dissolved oxygen(DO)	0.17
2	Fecal Coli	0.15
3	pH	0.12
4	BOD	0.10
5	NO_3^-	0.10
6	PO_4^{3-}	0.10
7	Temperature	0.10
8	Turbidity	0.08
9	Dissolved solids	0.08
	$\sum_{i=1}^{n} Wi$	1.00

Table 8 : Water Quality of the river Salandi during 2015 & 2016 by NSF-WQI method

Sl. No	Name of the station	WQI 2015	WQI 2016	Water Quality 2015	Water Quality 2016	Remarks
1	Hadagada	48	48	D	D	Bad
2	Bidyadharpur	47	47	D	D	Bad
3	Agarpada	48	48	D	D	Bad
4	Randia	48	48	D	D	Bad
5	Baudpur	48	48	D	D	Bad

6	Rajghat	47	46	D	D	Bad
7	Satbhauni	47	47	D	D	Bad
8	Dhusuri	47	48	D	D	Bad
9	Akhandalmani	41	41	D	D	Bad

(3) Canadian Council of Ministers of Environment water quality index(CCME WQI) method:

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 of the sample has not been specified[7,12,13,15,21].

The calculation of CCME WQI is based on the combination of following three factors.

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-10[19].

Following formula has been used to calculate CCME WQI.

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

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

F_3 has to be calculated by using following three steps

a) Excursion= $$\left(\frac{failed\ test\ values_i}{objective_j}\right) - 1$$

b) Normalized sum of excursions(nse)= $$\sum_{i=1}^{n} \frac{exeursion_i}{total\ number\ of\ tests}$$

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

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-9 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-10 and presented in the Table-11 for study and conclusion.

Table-9: 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	6.5-8.5	500	300	150	45	5.0	250	0.30	0.6	0.05	6.0	3.0

Table-10: 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-11: 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
	F1	F2	F3	F1	F2	F3					
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

III. Results & Discussion:

It is evident after careful analysis and interpretation of data, presented in the Table-5 under weighted arithmetic water quality index method (WAWQI) that WQI values are higher in the year 2016 than the year 2015. In the year 2015, water quality of Hadagada comes under class B follows a gradual decreasing trend in mining and industrial belt and touches to lowest quality E at the industrial area as a result of receiving of untreated mining and industrial waste materials in mining and industrial areas respectively. In the downstream, water quality is again upgraded to class B gradually due to dilution and self-stabilization capacity of the river. In the seashore belt(Akhandalmani) water quality becomes class D due to the back flow of sea water from the sea(Bay of Bengal) to the river. Hence water quality follows gradual decreasing trend from upstream Hadgada onwards and touches to peak position at industrial belt Randia and gradually diluted towards downstream and again touches to very poor quality at the last monitoring stations, Akhandalmani[17].

During the year 2016, all the monitoring stations come under class E except downstream monitoring stations (Satbhauni & Dhusuri). Further, the careful study indicates that although there are seven stations belong to same class E, but the WQI values increases gradually from upstream and touches to maximum value in the industrial belt at Randia and follows a decreasing trend towards downstream except seashore station, Akhamdalmani[18] . It therefore can be stated that both the years exhibit same pollution trend .Hence WAWQI method distinguishes the monitoring stations on the basis of quantity and nature of the pollutants .

The WAWQI data for the year 2015 and 2016 have been presented in figure-1

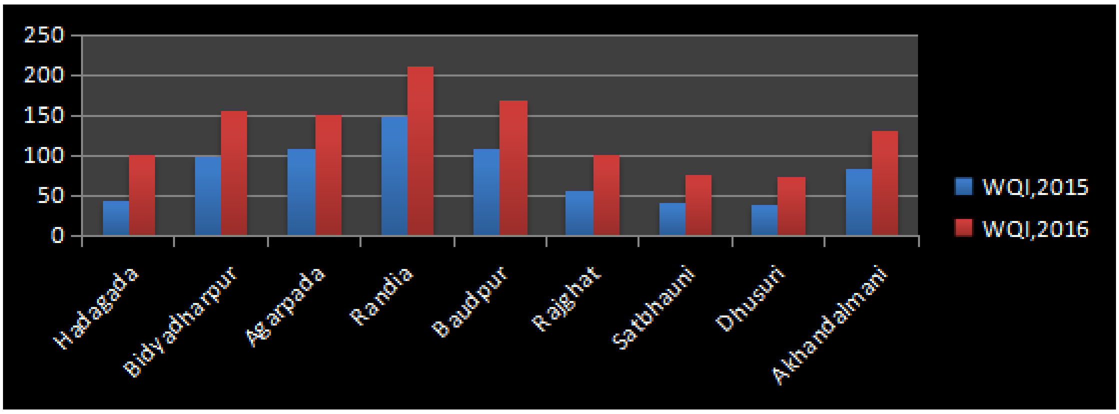

Figure-1: WQI values for the year 2015and 2016 of nine monitoring stations under WA method

The WQI data presented in the Table-8 under NSF method reveals that water quality for both the years belong to Class D without any significant deviations in values[20] .It may be emphasized that although the quantity and nature of the pollutants are not same in all monitoring stations , water quality of all station belongs to same bad quality (D). Hence NSF WQI method gives neither quantitative nor qualitative difference and is independent of on the quantity and nature of the pollutants .

The WQI data presented in the Table-11 under CCME WQI method reveal that water quality of nine monitoring stations for two years of study belongs to class D with slight difference in WQI values. Further it is observed that water quality of the year 2016 is comparatively poorer than the year 2015. It is for higher F_3 values due to the rise in concentrations of F^- and Fe as a result[19]of partial withdrawal of mining restrictions imposed by Saha Commission on certain grounds. Another important observation in values of WQI that, water quality is somewhat better in upstream (Hadagada) and follows a decreasing treand in mining and industrial belt and urban area and again it is upgraded in the downstream due to dilution and self- purification capacity of the river except the last monitoring station Akhandalamani . The lowest quality in the seashore belt, Akhandalmani is due to the back flow of sea water from the sea(Bay of Bengal) to the river. Hence this method distinguishes the monitoring stations on the basis of nature and quantity of pollutants entered to the river. The WQI values under NSF and CCME method for the year 2015 and 2016 of the river Salandi have been presented in the figure-2 for study and conclusions.

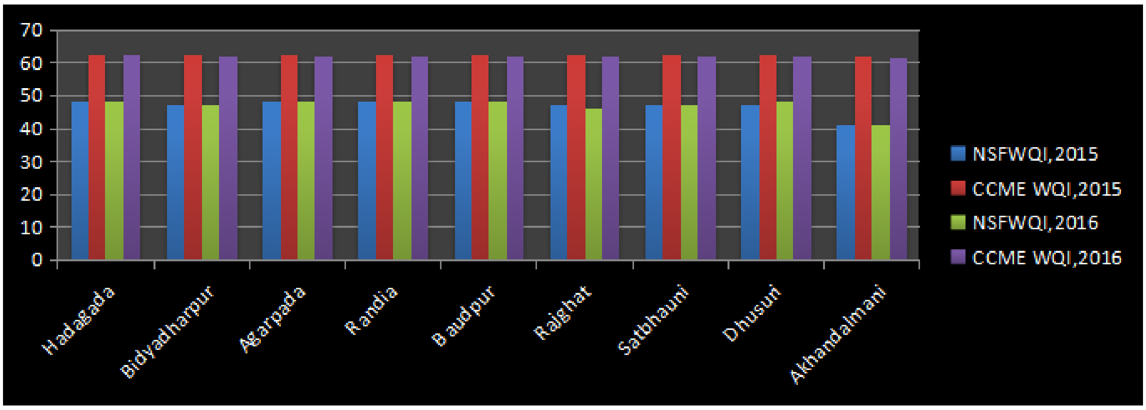

Figure-2: The WQI values under NSF & CCME method of the river Salandi for the year 2015 &2016

It is evident from the aforesaid discussions that WAWQI method distinguishes the monitoring stations of the river on the basis of water quality from B to E and C to E with significant difference in WQI values during the year 2015 and 2016 respectively. But both NSF WQI and CCME WQI method classify the river water into same quality D during two years of study with slight difference in WQI values of later method. The physico-chemical and bacteriological analysis of the river water concludes that it is polluted physically, chemically as well as bacteriologicaly with respect to Cr(VI), iron , fluoride, chloride and bacteria with higher amount during rainy and post-rainy seasons than the summer & winter seasons and hence there is a good correlation between physico- chemical study and WA WQI method study than the other two methods[17,18,19,20,23]. The order of reliability factor among three methods can be stated as WA WQI>CCME WQI>NSF WQI.

Reliability factor determines the extent of reliability of method. If reliability is more than 90%, R_f is taken as 1 and if reliability is less than 90%, $R_f<1$.

This may be due to the fact that

1- More number of variables are taken into consideration for calculating WQI under weighted arithmetic index method whereas only nine variables in case of NSF method and four variable to be sampled at least four times in case of CCME method.

2- More weightage has been given to hazardous variables under weighted arithmetic index method whereas equal weightage has been given to all the variables under CCME WQI method [3,22].

Sweta et al had stated that WAWQI method is relatively more reliable than other methods and hence it has been widely used by the various scientists[2,22]. Zatou et al had observed that there is deviation among the WQIs and qualitative ranking results derived from WAWQI method application present significantly higher variation compared to those derived from the other methodologies[25].

IV. Conclusions & Recommendations:

The river Salandi ,from the source of origin to the confluence at Tinitaraf ghat runs 134kms of long distance and during its travelling receives forest decayed runoff, mining waste materials, industrial discharges ,urban effluents biomedical wastes, domestic discharges and after all agricultural wastes for which it is polluted physically, chemically as well as bacteriologically with respect to chloride, fluoride, Cr(VI), iron & bacteria.

The WA WQI, NSF WQI and CCME WQI methods have been applied to study the water quality of the river and the NSF WQI and CCME WQI rank the river into same water quality D during two years of study with slight different in WQI values and deterioration trend in later method indicates that the later method is dependent on the quantity and nature of the pollutants whereas the WAWQI method ranks the water quality from B to E with significant deterioration trend during two years of study and it is highly dependent on the quantity and nature of pollutants and correlates with the physico-chemical characteristics of water. Hence the reliability factor for WAWQI method is relatively higher than other two methods for which it has been used largely by the various scientists and organizations all over the world.

However, the application of the WQIs on large number of water bodies be done with a view to draw a more reliable and authentic conclusion. Besides, instead of depending completely on a single WQI number, calculated by applying any WQI method, physico-chemical analysis of the sample must be done extensively and it is to be correlated with WQI number to draw a confirmatory conclusion.

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