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The Qualitative Assessment Of Water Quality Of The River Salandi By Applying Three Different Water Quality Indices, Bhadrak, Odisha, India

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Abstract:
The river Salandi, from its source of origination in the Similipal reserve forest to Tinitaraf Ghat at Akhandalmani travels 134kms of long distance through forest, urban, agricultural area and mining and industrial belt, and finally meets with the Bay of Bengal at Dhamara port. The river during its course of journey from the Similipal reserve forest to Tinitaraf Ghat receives different hazardous pollutants from different places.
In this work, water samples collected from nine important monitoring stations during rainy, post rainy, winter and summer seasons in the year 2023 and 2024 have been analyzed by using the standard procedures available in APHA, 2022 to study the sixteen physico-chemical and biological parameters and out of which mean and standard deviations (S.D) of twelve important parameters have been calculated and computed for analytical 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 nine monitoring stations comes under class D for both the years of study through the NSF WQI and CCME WQI methods with higher values of WQI under CCME method whereas in case of WAWQI method, water quality changes from B to E and C to E during the year 2023and 2024 respectively. The season wise physico-chemical and bacteriological study confirms that the river water is polluted physically , chemically as well as bacteriologically with respect to chloride, fluoride, Cr(VI), iron ,BOD & pathogenic bacteria and ***it correlates with the results of WA WQI method very closely than the other two methods and hence the reliability factor is more for WA WQI method than the other two method.***
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 as well as economically for which human inhabitations, towns , industries and cities were grown up on the bank of the rivers and hence it is called elixir of life. We know that Indus Valley Civilisation known as Indus Civilisation, a Bronze Age Civilisation in the North Western region of South Asia was established on the bank of Indus River. 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 the 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 impact 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 in a modified manner 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 and bacteriological parameters and ranks the suitability of water for human, aquatic and wild life[22]. A number of water quality indices have been developed and applied by the researchers suitably to assess the water quality of water body.[19,32,33,34]

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 the 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 areas receives different untreated and semitreated 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 biomedical waste materials from Bhadrak municipality, agricultural wastes from the vast agricultural lands. Although quantity and type of pollutants are not same in all places and in 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 objective of this study is to assess the water quality of the river accurately by applying three important water quality indices as well as to critically examine the difference between three water quality indices.

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 this 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 2023 and 2024.

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 the Similipal biosphere & picnic waste materials.
02	Bidyadharpur	It is nearly 40Km from Bhadrak town and a barrage is on the river Salandi where it receives Mining and agricultural effluents
03	Agarpada	It is25Km from Bhadrak town where the river receives agricultural wastes &urban wastes primarily.
04	Randia (FACOR)	On the bank of river Salandi, the village Randia and Ferro Alloys Corporation Industry are established where the industrial and agricultural effluents enter in to 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 headquarter hospital where mainly urban and biomedical wastes enter into the river.
07	Satbhauni	It is around 20KM 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 30KM from Bhadrak town where the river receives mainly agricultural wastes and it is a agriculture based area.
09	Akhandalmani (Tinitaraf Ghat)	It is around 50 Km from Bhadrak town and is a confluence place of the river Salandi & the river Baitarani and thereafter the river runs towards Bay of Bengal where the river receives back flow of the sea water due to tide.

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

Map–1: Location of the different sampling stations across the river Salandi Analysis of the 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;2022[1]. TH and TDS have been measured in complexo metric 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 [1,5] 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[10]] The presence of bacteria has been assessed by H_2S kit method [1,5,17,18]

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

The mean and standard deviations (S.D)for twelve important parameters calculated for both years 2023 and 2024 have been presented in the Table-2 and 3 respectively.[17]. The season wise water analysis data for sixteen parameters have not been presented here so as to avoid the undue expansion of this paper.

Table-2. Mean values and S.D for nine monitoring stations for the year 2023

Name of the Parameters	Hadagada	Bidyadharpur	Agarpada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandlamani
pH	6.96± 0.139	7.067± 0.178	7.084± 0.1445	7.15± 0.15	7.115± 0.145	6.984± 0.2265	7.06± 0.1606	7.12± 0.16309	7.215± 0.1462
TDS	99.667± 6.128	98.334± 2.982	90.334 ± 9.215	92.334 ± 9.392	90.1± 9.643	93.167 ± 4.524	92.167± 5.82	11.667± 8.778	666.667± 110.956
TH	82.667± 38.992	78.6± 40.778	71.334 ± 31.388	79.334 ± 21.561	74.334 ± 23.13	74.1± 26.20	86.833± 20.251	89.666± 24.695	422.51± 75.716
SO_4^{-2}	12.834± 3.847	11.332± 3.636	10.51 ± 2.929	11.667 ± 2.748	11.334 ± 3.197	12.1± 2.081	10.834± 2.881	11.2± 3.26	18.834± 5.899
NO_3^-	4.884± 0.639	4.415± 0.454	4.6± 0.432	4.984 ± 0.433	4.76± 0.381	4.76± 0.457	4.76± 0.645	4.86± 0.4716	5.217± 0.5112
PO_4^{3-}	3.667± 0.775	3.534± 0.679	3.334± 0.609	3.234 ± 0.641	3.227± 0.65	3.434± 0.4157	3.415± 0.548	3.71± 0.5744	4.234± 1.037
Cl^-	22.51± 3.818	21.667± 3.726	21.667 ± 4.73	22.167 ± 6.465	21.67± 2.356	21.607 ± 4.7129	20.1± 2.886	20.834± 1.863	1197.51 ± 786.956
Fe	0.41± 0.095	0.49± 0.194	0.40± 0.055	0.378 ± 0.089	0.296± 0.098	0.368± 0.0674	0.024± 0.308	0.34± 0.056	1.6427± 1.746
F^-	0.6527± 0.298	0.766± 0.379	0.684± 0.346	0.6568 ± 0.362	0.61± 0.334	0.747± 0.0305	0.716± 0.447	0.67± 0.5304	0.4826± 0.3492
Cr(VI)	0.0093± 0.000469	0.036± 0.018	0.045± 0.022	0.0784 ± 0.0037	0.0534 ± 0.006	0.016± 0.0074	0.0096± 0.00047	0.00916 ± 0.00037	0.01084 ± 0.00409
DO	7.134± 0.093	6.91± 0.141	6.81± 0.115	6.61± 0.152	6.884± 0.088	6.51± 0.1825	6.717± 0.176	6.615± 0.301	0.734± 0.0704
BOD	4.218± 1.18	5.135± 0.123	4.62± 0.186	4.768 ± 0.729	4.36± 1.09	5.432± 0.2279	4.9824 ± 0.377	4.81± 0.441	4.168± 0.9961

Table-2. Mean values and S.D for nine monitoring stations for the year 2024

Name of the Parameters	Hadagada	Bidyadharpur	Agarpada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandlamani
pH	7.07± 0.1744	7.12± 0.1674	7.12± 0.0895	7.12± 0.1663	7.07± 0.0165	6.92± 0.2219	7.08± 0.229	7.14± 0.0757	7.01± 0.2924
TDS	98.41± 8.2617	99.41± 4.3635	9.1± 12.0166	92.1± 0.6583	90.21± 11.9398	94.41± 6.086	91.1± 13.5646	91.61± 6.6333	690.2± 100.7968
TH	88.1± 43.0282	82.5± 49.8838	74.1± 26.1762	81.9± 24.7257	76.5± 26.1502	74.81± 26.8303	86.1± 24.372	87.21± 30.3301	447.21± 64.1323
SO_4^{-2}	11.81± 4.8165	11.41± 5.4845	0.2± 3.61101	11.1± 2.9664	10.41± 3.3585	10.62± 3.4126	10.1± 3.5313	9.81± 4.4899	14.41± 3.7416

NO_3^-	4.79± 0.6555	4.75± 0.5953	4.61± 0.5656	5.03± 0.41	4.85± 0.4233	4.85± 0.4674	4.68± 0.6529	4.76± 0.5953	5.13± 0.4535
PO_4^{3-}	3.51± 0.8694	3.51± 0.7694	3.25± 0.6955	3.15± 0.6712	3.15± 0.0788	3.43± 0.4578	3.39± 0.6998	3.31± 0.6782	4.21± 1.0039
Cl^-	22.1± 4.0	21.1± 3.7416	20.61± 2.3323	21.1± 3.7016	19.1± 2.0	25.2± 3.1623	21.1± 3.7416	20.2± 0.0	1764.1± 19.3908
Fe	1.926± 1.952	1.756± 1.8973	1.57± 1.4408	1.736± 2.1332	1.678± 2.0878	1.414± 1.387	1.123± 0.9681	1.109± 0.9582	2.395± 2.3333
F^-	0.82± 0.993	0.982± 0.1284	0.873 ± 0.2109	0.895± 0.0365	0.84± 0.1314	1.16± 0.1029	0.942± 0.0949	0.9081± 0.0276	0.735± 0.2218
Cr(VI)	0.0095± 0.000489	0.403± 0.01833	0.406± 0.42059	0.08± 0.0	0.054± 0.008	0.014± 0.00489	0.0097± 0.000258	0.0092± 0.00406	0.0112± 0.0044
DO	7.0± 0.06324	6.91± 0.0296	6.76± 0.16	6.46± 0.172	6.73± 0.1624	6.36± 0.1939	6.73± 0.2039	6.65± 0.3097	7.1± 0.2449
BOD	4.09± 1.2528	5.17± 0.1777	4.55± 0.9002	4.78± 0.7605	4.25± **1.1825**	5.57± 0.2416	5.08± 0.2243	4.71± 0.456	3.99± 0.9495

Application of the three important water quality indices:

The three important water quality indices as briefed hereunder have been applied to study the water quality more accurately of the river Salandi because these water quality indices are being applied most commonly by the scientist and organizations all over the World.

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 into five categories according to degree of purity by using most commonly measurable parameters and it is widely used by the different scientists, workers and organizations [4,8,9,17,22,29,32]

This method includes following steps which is explained briefly hereunder:-
Quality rating scale of each parameter is calculated by using following formula.
Quality rating scale is (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 = 14.6mg/l.
Vs=Standard permissible value of particular parameter, determined by WHO.

Calculation of relative unit weight (Wi)-
The relative unit weight of any parameter (Wi)α1/Si or Wi=K/Si Where Si= standard permissible value of particular parameter
K=proportionality constant. **Hence more the parameter hazardous more the relative unit weight.**
For the sake of simplicity K is taken as1[17,18]

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 theTable-5.0

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
Above100	Very poor & unfit for drinking purpose	E

Table-5 Water Quality of river Salandi of nine monitoring Stations, 2023 & 2024

Sl No.	Name of Stations	WQI 2023	Water Quality 2023	Grade 2023	WQI 2024	Water Quality 2024	Grade 2024
1	Hadagada	43.8651	Good	B	101.7663	Unfit for drinking purposes	E
2	Bidyadharpur	98.6511	Very Poor	D	154.4589	Do	E
3	Agarapada	108.8951	Very Poor &unfit for Drinking purposes	E	150.3525	Do	E

4	Randia	147.2938	Very Poor & unfit for Drinking purposes	E	211.2257	Do	E
5	Baudpur	108.2103	Very Poor & unfit for Drinking purposes	E	167.7291	Do	E
6	Rajghat	55.5861	Class 'C' River water	C	101.2958	Do	E
7	Satbhauni	40.5642	Good	B	76.6944	Very Poor	D
8	Dhusuri	39.483	Good	B	73.6868	Poor	C
9	Akhandalmani (Tintarf Ghat)	84.5734	Very Poor & unfit for Drinking purposes	D	131.4806	Unfit for drinking purposes	E

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:[20,24,33,34]

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

Where,

Qi=Sub-index for i^{th} water quality 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

Table7: The Weight values of water quality parameters in the NSF 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	$NO3^-$	0.10
6	$PO4^{3-}$	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 2023 & 2024 by NSF-WQI method

Sl.No	Name of the station	WQI 2023	WQI 2024	Water Quality 2023	Water Quality 2024	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

Canadian Council of Ministers of Environment water quality index(CCMEWQI) 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 2023 & 2024 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[19,26]

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 the Twelve Parameters, studied

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 2023 & 2024 through CCME WQI method.

Name of Stati	2023			2024			WQI 2023	WQI2024	Waterquality2023	Waterquality2024	Remarks
	F1	F2	F3	F1	F2	F3					
Hadagada	58.333	29.62	0.863	58.333	29.62	5.445	62.326	62.32	D	D	Marginal
Bidyadharpur	58.333	29.62	1.48	58.333	29.62	5.532	62.33	62.22	D	D	Marginal
Agarapada	58.333	29.62	0.923	58.333	29.62	4.545	62.332	62.235	D	D	Marginal
Randia	58.333	29.62	1.462	58.333	29.62	5.762	62.43	62.188	D	D	Marginal
Baudpur	58.333	29.62	0.4652	58.333	29.62	4.863	62.32	62.227	D	D	Marginal
Rajghat	58.333	29.62	1.255	58.333	29.62	4.984	62.324	62.235	D	D	Marginal
Satbhauni	58.333	29.62	0.7648	58.333	29.62	3.862	62.321	62.263	D	D	Marginal
Dhusuri	58.333	29.62	0.7455	58.333	29.62	3.675	62.325	62.214	D	D	Marginal
Akhandalmani	58.333	29.62	8.268	58.333	29.62	11.856	62.313	62.245	D	D	Marginal

III. Results & Discussion:

WA WQI

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 2024 than the year 2023. The Comparatively the higher value of WQI (poorer quality) of the river water during the 2024 is due to the inflow of mining and industrial waste material to the river as a result of partial withdrawal of mining restrictions imposed by Saha Commission [14,20] and the Government has permitted certain mines for operation with reasonable restrictions. Panda it el while studying the water quality of said river during the year 2015-16 has reported same pollution trend as well as same intensity of the pollution.[17,18,19,26] Further it was monitored during the year 2022-23 with a view to study the change in water quality as a consequence operation of certain mines. In the year 2023, water quality of Hadagada comes under class B follows a gradual decreasing trend in the 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 the 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.[17,28,30] 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.[17,18] Hence water quality follows gradual decreasing trend from upstream Hadgada onwards and touches to peak position at the industrial belt Randia and thereafter upgraded gradually towards downstream and again touches to very poor quality at the last monitoring stations, Akhandalmani [17,18,19,20]

During the year 2024, 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 WA WQI method distinguishes the monitoring stations on the basis of quantity and nature of the pollutants .**

NSF WQI:

The WQI data presented in theTable-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 .**

CCME WQI:

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 from the physico – chemical study that water quality of the year 2024 is comparatively poorer than the year 2023. It is for higher values of F_3 due to the rise in concentrations of F^- and Fe. Besides, it is to be noted that higher value of F_3 in the mining and the industrial belt and it gradually deteriorates towards downstream due to dilution and self stabilization capacity of the river.[18,19] Under CCME method the water quality follows same trend as in case of WA WQI method from upstream to downstream for both the years of study. Although the values of F_3 are higher in the year 2024 but it belongs to class D as of 2023. Hence F_3 values are unable to change the classification of the quality of the river significantly. **Hence this method does not distinguish the monitoring stations on the basis of quantity and nature of pollutants entered to the river**. The WQI values under WA,NSF and CCME methods for the year 2023 and 2024 of the river Salandi have been presented in the figure-1 for study and conclusions.

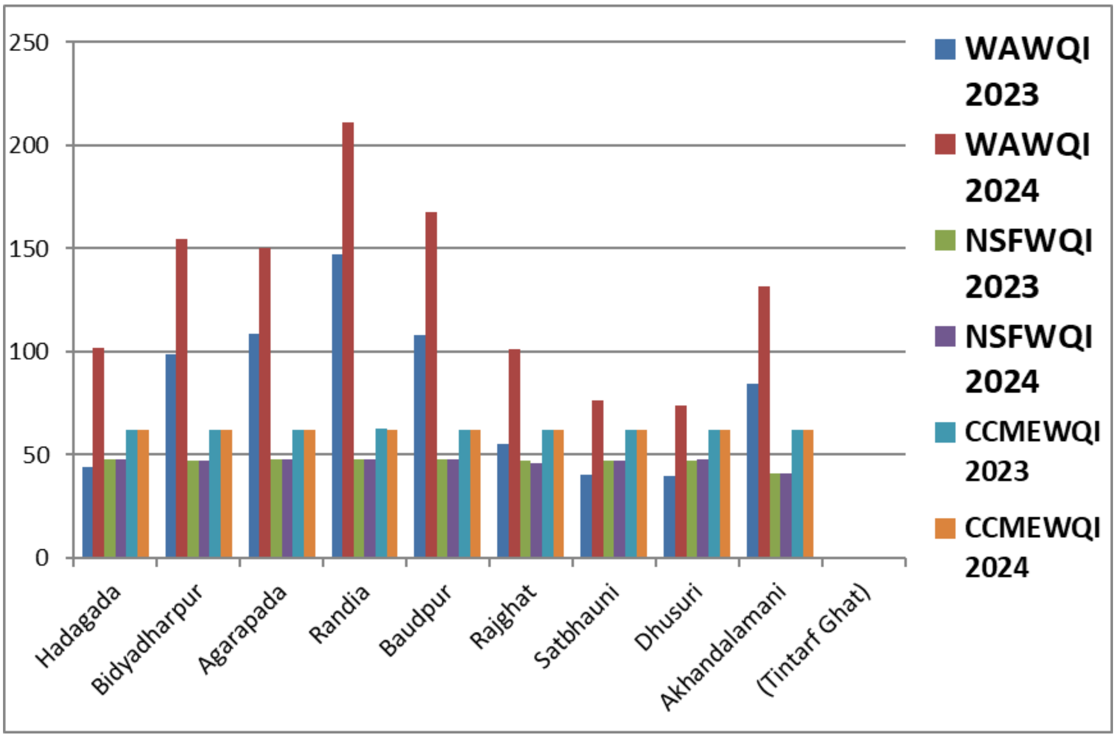

Figure-1. WQI Values under WA, NSF and CCME methods for the year 2023 & 2024.

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 2023 and 2024 respectively. But both NSF WQI and CCME WQI method classify the river water into same quality D during the two years of study with higher values of WQI under CCME method. The physico-chemical and bacteriological analysis of the river water concludes that it is polluted physically, chemically as well as bacteriological with respect to Cr(VI), iron , fluoride, chloride , bacteria and BOD with higher pollution intensity during rainy and post-rainy seasons than the summer & winter seasons and hence there is a very good correlation between physico- chemical analysis and WA WQI method study than the other two methods [17,18,19,20,23]. Hence t**he order of reliability factor among three methods can be stated as WAWQI>CCME WQI>NSF WQI.** [26]

Reliability factor determines the extent of reliability of any method. If reliability is more than 90%, R_f is taken as 1 and if reliability is less than 90%, R_f<1.[26]

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 [3,22,26].
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 quality ranking results derived from WAWQI method application show significantly higher variation compared to those derived from the other methodologies [25].
3- The higher F_3 values during the year 2024 in comparison to the year 2023 under CCME WQI method are unable to change the classification of the river water significantly according to the classification values in the reference Table -10. Hence, the classification value needs to be modified for the for potential and authentic classification.

IV. Conclusions & Recommendations:

The river Salandi ,from its source of origination to the confluence place at Tinitaraf Ghat runs 134kms of long distance and during its travelling receives forest decayed run off, mining waste materials, industrial discharges, urban effluents, biomedical wastes ,domestic discharges and after all agricultural wastes from the difference places 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 the two years of study and the deterioration trend in CCME WQI method indicates that the this 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 the two years of study and it is highly dependent on the quantity and nature of pollutants and correlates very closely with the physico-chemical study of the water. Further the water quality and deterioration trend during 2023 – 2024 is similar to water quality and deterioration trend during 2015- 2016 as reported by Panda et al.[17,18] It is because of non operational of some mines as a result of the restrictions imposed by the government. Hence the reliability factor for the WA WQI method is relatively higher than the 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 because the NSF WQI and CCME WQI method classify river water into same quality D and the values of F_3 under CCME WQI method do not have significant role in the proper classification of the quality of the river. 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 values to draw the confirmatory conclusion.

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