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The Study of Water Quality and Pearson's Correlation Coefficients among Different Physico-chemical Parameters of River Salandi, Bhadrak, Odisha, India

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Abstract The river Salandi, originated from Meghasani hill of Similipal reserve forest, passes through Hadagada dam, Bidyadharpur barrage, Agarpara town, Bhadrak municipality, Satbhauni, Dhusuri and finally meets the river Baitarani at Tinitaraf ghat before merging with the Bay of Bengal at Dhamara. The river, during its course of flow, receives forest decayed run off, mining wastes, agricultural effluents, industrial wastes, urban wastes, biomedical wastes and after all domestic wastes. In this work, the water samples collected from nine different sampling stations during summer, rainy, post-rainy and winter seasons were analysed by using standard procedures for sixteen physico-chemical parameters and experimental data were operated to calculate mean and standard deviation (SD) and finally Pearson's correlation coefficients were calculated for twelve important parameters by applying SPSS-16 software. The analysis result shows that river water is polluted physically, chemically and bacteriologically with respect to iron, hexavalent chromium, chloride and bacteria, though the gravity of pollution was more during rainy and post-rainy seasons. The calculated Pearson's correlation coefficients show that there exist positive and negative correlation among certain parameters.

Keywords: *water pollution, heavy metals, pearson's correlation coefficients*

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1. Introduction

Like fresh air, the fresh water is one among the essential gifts of nature, required for the maintenance and management of living world including both micro and macro organisms and hence it is called elixir of life. According to the eminent Greek Philosopher Pindar, natural resources are the important wealth of our universe and water is the best of all things. The importance of water has been understood since ancient times both in economically as well as socio-culturally. It is an interesting fact that water covers 71% of total earth surface and 97% water is in ocean as salt water and remaining 3% water in fresh. Out of these 3%, 2.5% of water is stored in Antarctica in the form of ice and 0.5% is in the rivers, lakes and under grounds and only 0.26% of water is available for human consumption [1,2]. The rivers are the life line of our economy and culture.

Now-a-days, unplanned industrialisation and urbanisation established for the socio-economic developments have posed a great challenge on the very existence of living world by polluting the water largely [3]. A good quality of water implies that it is good in physically, chemically as well as bacteriologically. The quality of water changes with the change of season and geographical area as there are several anthropogenic activities such as agricultural, domestic and socio-cultural are changed with the change of season. [4,5]

It is worth mentioning that the gravity of pollution is more during rainy and post-rainy seasons in comparison to summer and winter seasons as because during rainy and post-rainy seasons agricultural activities are more and the fertilizers and pesticides used by the farmers to promote agricultural productivity releases heavy metals to the river water as agricultural runoff and enters to human body through food chain [6,7,8]. Besides, the open defecation in the river bed [5], discharge of bio-medical wastes and excretion of animals enhance the intensity of pathogenic bacteria and protozoa in the river water [9,10]. Approximately 30% of garbage generated, is not collected, remaining 70% collected is dumped in landfills or the space available in the nearby habitants which are washed away and mixed nearest water bodies at the time of heavy precipitations during rainy season [11]. According to statistical data that more than14,000 people die daily, 700 million Indians have no access to proper toilet and 1000 Indian children die of diarrhoea every day [12].

The river Salandi, originated from well-known biosphere of Similipal reserve forest of Meghasani hill under Mayurbhanj district and joins with the river Baitarani at Tinitaraf ghat before the confluence with the Bay of Bengal at Dhamara. A dam has been built across the river Salandi at Hadagada with longitude 86° .18' East and latitude 210° · 17' North in Anandapur sub-division of Keonjhar district for the irrigation purpose of Bhadrak, Balasore and Keonjhar districts. The present work is to study the water quality of the river Salandi from Hadagada dam to Tinitaraf ghat, near Akhandalmani.

The river, during its course of flow receives forest run off from Similipal reserve forest and untreated mining discharges while crossing the mining belt as there are three chromite mines, namely Baula open caste and underground mine, Bangur chromite mine and Nuasahi chromite mine. It is only the Bangur chromite mine that discharges one lakh tonnes of chromite ore per year and seven lakh tonnes of over burdens are excavated which is the major cause of pollution by total chromium and hexavalent chromium in the form of mining discharges and surface run off [13,14].

The river, there after runs through Bidyadharpur barrage, Agarapada town, industrial belt at Randia (FACOR), Bhadrak municipality (District Head Quarter), large agricultural area at Satbhauni and Dhusuri and finally meets with river Baitarani at Tinitaraf ghat before its confluence with Bay of Bengal at Dhamara. The river during its course of flow from Hadagada to Tinitaraf ghat travels 134 KMs of distance and receives both treated and untreated mining discharges, agricultural runoff, industrial wastes, urban wastes, biomedical wastes, forest run off and after all domestic wastes as it is the only natural drainage system in the study area. Therefore, the aforesaid factors are mainly responsible for the pollution of the river Salandi, as reported in daily odiya news paper "Samaj" very often.

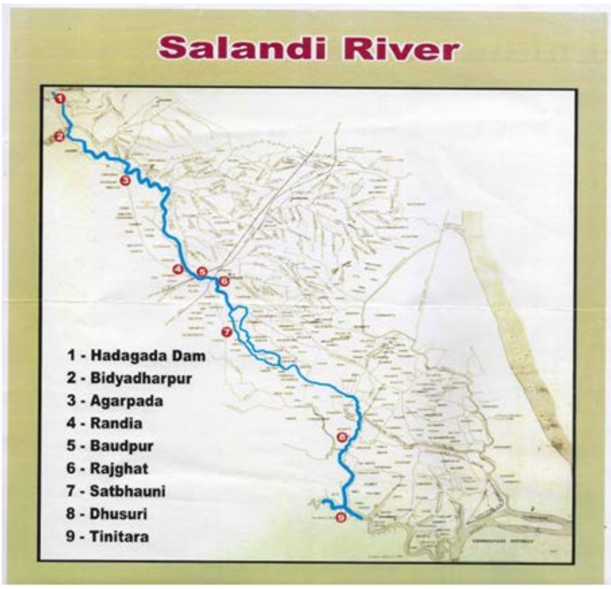
2. Materials and Methods

2.1. Selection of Sampling Stations:

The selection of nine sampling stations on the bank of river has been made on the basis of intensity of expected pollutants as well as the geography of river bed to meet the aim and objective of this work. The water samples from nine monitoring stations, as spotted in the Map 1 and described in the Table 1 have been collected during summer (April and May), rainy (August), post-rainy (October) and winter (December) seasons in the year 2016 for analysis and study of water quality of the river Salandi.

Table 1. Location of different sampling Stations across the river Salandi

Sl No.	Name of Stations	Brief Description on Sampling Stations
01	Hadagada Dam	It is 50 KMs from Bhadrak town and it is a hilly and mining area where the river receives mining and forest effluents from Similpal reserve forest
02	Bidyadharpur	It is nearly 40 KMs from Bhadrak town and a barrage is on the river Salandi where it receives mining effluents
03	Agarpada	It is 25 KMs from Bhadrak town where the river receives agricultural wastes
04	Randia(FACOR)	At the bank of river Salandi, the village Randia, Ferro Alloys Corporation Industry is established where Industrial effluents enters in to the river
05	Baudpur	It is 0.2 KMs from Bhadrak town where the river receives agricultural wastes
06	Rajghat	It is situated at the heart of Bhadrak Municipality and nearest to the district headquarter hospital where the river receives urban and bio-medical wastes
07	Satbhuani	It is around 20 KMs away from Bhadrak where the river receives agricultural runoff
08	Dhusuri	It is around 30 KMs from Bhadrak where river receives mainly agricultural effluents
09	Akhandalmani (Tintaraf Ghat)	It is more than 50 KMs from Bhadrak and is a confluence place of river Salandi and river Baitarani and thereafter the river runs towards Bay of Bengal



Map 1. Location of sampling stations across river Salandi

2.2. Analysis of Physico-chemical Parameters

Water samples collected in well-cleaned plastic bottles by adding 2 ml of concentrated HNO_3 in each bottle to avoid the precipitation of metal have been analysed to study the physico-chemical parameters, according to the procedures established by APHA, 2005 [15]. TDS and TH have been measured gravimetrically and complexometrically by using Eriochrome black-T as indicator respectively. Sulphate has been measured by turbidimetry method. Nitrate, iron and chromium have been measured by using UV-VIS spectrophotometer at 275 nm, 510 nm and 540 nm respectively [15,16].

2.3. Fluoride, Chloride and Bacteria:

The concentration of fluoride and chloride have been determined with the help of UV-VIS spectrophotometer by using SPAND reagent and acid zirconium chloride at 570 nm and titration method respectively [17,18]. Bacteria have been determined H_2S kit method [16].

2.4. Calculation of Standard Deviations and Pearson's Correlation Coefficients

The analysis of water samples, collected from nine monitoring stations during four seasons for sixteen parameters has been done and mean and standard deviations for twelve important parameters calculated from the analysis results, have been presented in the Table 2. Furthermore, Pearson's correlation coefficient for twelve parameters calculated, have been presented in the Table 3 for study of correlation among different physico-chemical parameters by using SPSS-16 software.

Table 2. Mean Values & S.D. from April, 2016-December,2016

Name of Parameters	Hadagada	Bidyadharpur	Agarpada	Randia	Baudpur	Rajghat	Satbhauni	Dhusuri	Akhandalmani
p^H	7.06 ± 0.1743	7.1 ± 0.1673	7.1 ± 0.0894	7.1 ± 0.1673	7.08 ± 0.1649	6.92 ± 0.2219	7.06 ± 0.229	7.12 ± 0.0748	7.02 ± 0.2925
TDS	98.4± 8.2607	99.4 ± 4.3634	90.0 ± 12.0166	92.0 ± 10.6583	90.2 ± 11.9398	94.4 ± 6.086	91.0 ± 13.5646	91.6 ± 6.6332	690.0 ± 100.7968
TH	88.0± 43.4281	82.5 ± 49.8838	74.0 ± 26.1763	81.8± 24.7256	76.6 ± 26.1503	74.8 ± 26.833	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 ± 3.61109	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 ± 0.0223	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 ± 0.7613	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 ± 1.9510	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
$Cr^{6\pm}$	0.0094 ± 0.000489	0.042 ± 0.01833	0.046 ± 0.02059	0.08 ± 0.0	0.054 ± 0.008	0.410 ± 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 ± 0.172	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. Pearson's Correlation coefficients among different physico-chemical parameters of river Salandi during April,2016-December, 2016

Name of parameters	p^H	TDS	TH	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Fe	F^-	Cr^{6+}	DO	BOD
p^H	+1											
TDS	-0.94221	+1										
TH	-0.951840	+0.994415	+1									
SO_4^{2-}	-0.439524	+0.41426	+0.413647	+1								
NO_3^-	-0.11085	+0.05146	+0.08546	+0.76659	+1							
PO_4^{3-}	+0.6010	-0.60699	-0.5693	+0.23017	+0.48875	+1						
Cl^-	-0.94924	+0.9987	+0.99558	+0.44210	+0.0757	-0.58934	+1					
Fe	-0.9500	+0.9912	+0.98266	+0.4514	+0.0441	-0.6178	+0.9943	+1				
F^-	+0.8873	-0.87089	-0.8700	-0.6077	-0.3273	+0.4847	-0.8751	-0.8743	+1			
Cr^{6+}	+0.2632	-0.2935	-0.2234	+0.2079	+0.4697	+0.6864	-0.2647	-0.2833	+0.2753	+1		
DO	-0.1741	+0.3311	+0.2935	+0.0510	-0.4486	-0.1057	+0.3272	+0.3713	-0.1293	-0.09322	+1	
BOD	-0.05533	+0.060	+0..441	+0.1257	+0.3542	-0.027	+0.0540	+0.01826	+0.0444	-0.3344	-0.3571	+1

3. Result and Discussion

3.1. p^H

The pH is a crucial parameter required for management and maintenance of both biotic and abiotic system. The p^H of any water body is not constant round the year; rather it is changed with the change of season because the factors responsible for the governance of p^H directly or indirectly are changed with the change of season [19]. Further, p^H of any water body increases with the increase of photosynthesis by autotrops [19,20]. On the other hand dissolution of CO_2 and Cl_2 in water decrease the p^H by forming carbonic acid and hypochlorous acid respectively.

The p^H of water samples for nine monitoring stations from the month of April to December during the year 2016 have been measured season wise. The result shows that although the seasonal variation of p^H is observed, it is within the standard permissible limit of IS -10500(6.5-8.5) [27]. The change of p^H is not significant in all monitoring stations (7.1-7.3), except in month of May. The comparatively lower p^H in the month of May (6.8-7.0) can be attributed due to low flow of water and decomposition of organic matters at higher temperature that forms CO_2 and acids [21,22,23]. However, the lower p^H at Akhandallmani in April (6.5) and at Hadagada in December (6.8) may be due to unseasonal rain fall run off [16] and mixing of picnic waste materials [5] respectively as Akhandalamani is nearer to the Bay of Bengal and Hadagada is a famous picnic spot [23]. Further, it is observed from the mean values that there is an increasing trend in p^H from Hadagada to Randia and decreasing trend from Baudpur to Rajghat followed by increasing from Satbhauni to Dhusuri except Akhandalmani. The lowest value of p^H at Rajghat (6.9 ±0.2219) may be due to higher chloride concentration (25.0 ± 3.1622) and highest BOD (5.56 ± 0.2414) as it is situated at the heart of the municipality where there are several private hospitals including district headquarter hospital and hence inflow of biomedical wastes takes place to the river water [23]. The increasing trend towards downstream is due to the dilution of pollutants in due course of river flow. The mean value of the p^H has been presented in the Figure 1 for study and interpretation.

3.2. TDS & Turbidity

The seasonal variations of TDS and turbidity are observed in all monitoring stations. It is also observed that the higher value of TDS and turbidity in all monitoring stations during rainy and post-rainy seasons than the summer and winter seasons [23]. It is due to the mixing of soil erosion materials, agricultural runoff, forest run off, mining run off, domestic run off, etc. with the river water in large scale [5,14,19,43]. Further, lower value of TDS and turbidity in summer, as observed, is due to the silt and settling of dissolved materials [24,25]. The mean value of TDS changes from 98.40 ±8.2607 at Hadagada to 690.0 ± 64.1323 at Akhandalmani with higher value in the forest and mining belt. The unexpectedly high value of TDS at Akhandalmani is due to the back flow of sea water from the sea to the river as the monitoring station Akhandalmani is nearer to the Bay of Bengal [18,26]. The mean values of TDS have been presented in the Figure 2.

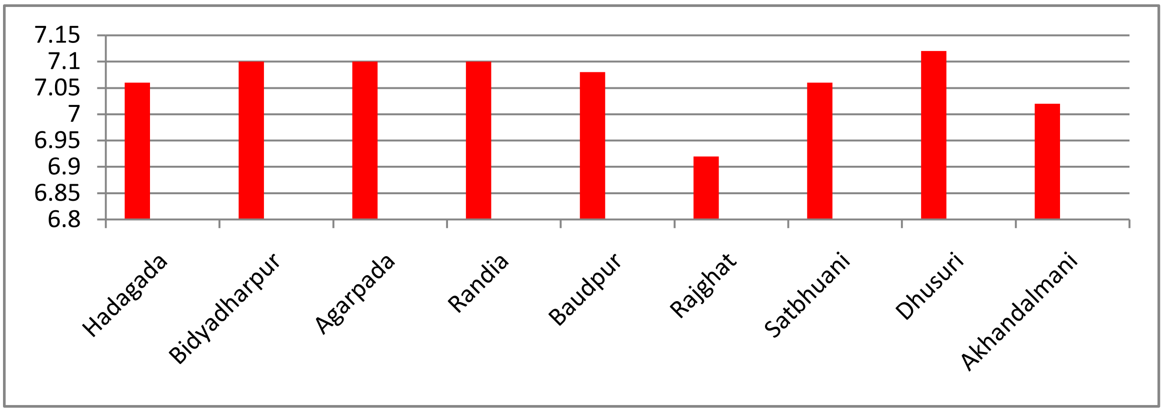


Figure 1. p^H for nine monitoring stations across the river Salandi, 2016

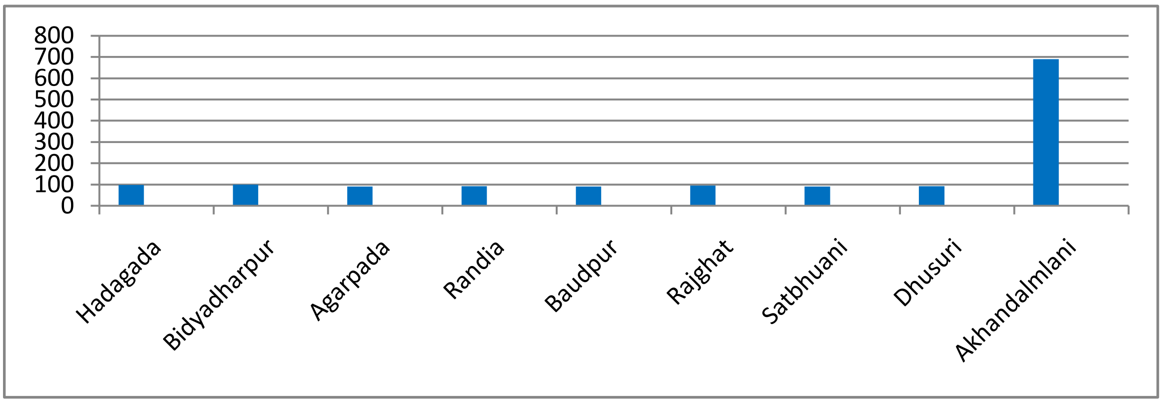


Figure 2. TDS for nine monitoring stations across the river Salandi, 2016

3.3. TH, Ca & Mg

The seasonal variations are observed for TH, Ca and Mg in all monitoring stations but the values are within the standard permissible limit of IS-10500 [27], except Akhandalmani. In the monitoring station Akhandalmani, the values are higher than the permissible limit of IS-10500 in all seasons; especially the values are higher in rainy and post-rainy than summer and winter seasons [23]. Further, it is observed that the mean value of TH changes from 88.0 ±43.4281 at Hadagada to 447.2 ± 64.1323 at Akhandalmani in an irregular manner. The highest value of TH at Akhandalmani in all seasons, as observed and presented in Figure 3, is due to the back flow of sea water from the sea (Bay of Bengal) to the river Salandi [23,26] and this back flow of sea water to the river with high intensity has been reported in daily "Samaj" and "Dharitri" on 4.7.2016, 8.9.2016, 12.9.2016 and 1.10.2016 respectively.

But in case of Mg, all the values are within the standard permissible limit of IS-10500 in all monitoring stations during the entire period of study, although the seasonal variations are observed. In summer season, the values of Ca are within the standard permissible limit of IS-10500 in all monitoring stations except at Akhandallmani and higher during rainy and post-rainy seasons. The higher values of Ca during the above periods in all monitoring stations can be attributed due to the mixing of residues of certain calcium containing fertilizers such as calcium ammonium nitrate, basic calcium nitrate, calcium superphosphate used by the farmers in large scale to promote the agricultural productivity with the river water [23,26,27,28,29,42,43].

3.4. NO_3^-, SO_4^{2-} & PO_4^{3-}

All the values for above parameters are within the standard permissible limit of IS-10500 except rainy (August) and post-rainy seasons (October) [23,27]. The higher values during rainy and post-rainy seasons may be due to mixing of agricultural residues that might contain sulphate, nitrate, phosphate [5,8,28,42,43] along with mining [19], industrial [30], forest and after all domestic effluents with the river water [23,30]. It is important to be noted that in ideal conditions the plants use only 50% of the nitrogenous fertilizer applied, 2-20% is lost due to evaporation , 15-20% react with organic compounds of the soil and remaining 2-20% interfere with the surface and ground water [8].

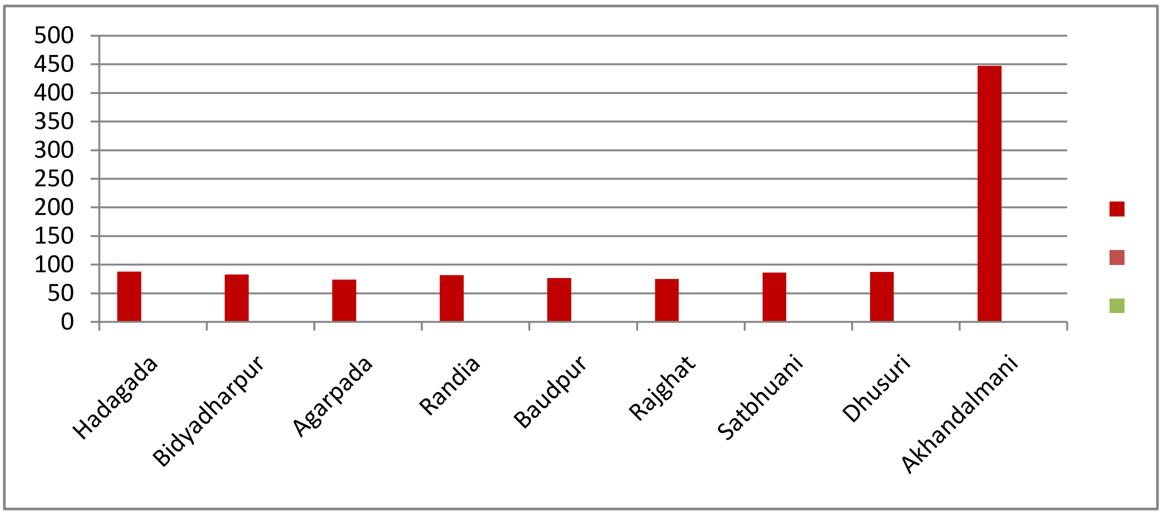


Figure 3. TH for nine monitoring stations across the river Salandi, 2016

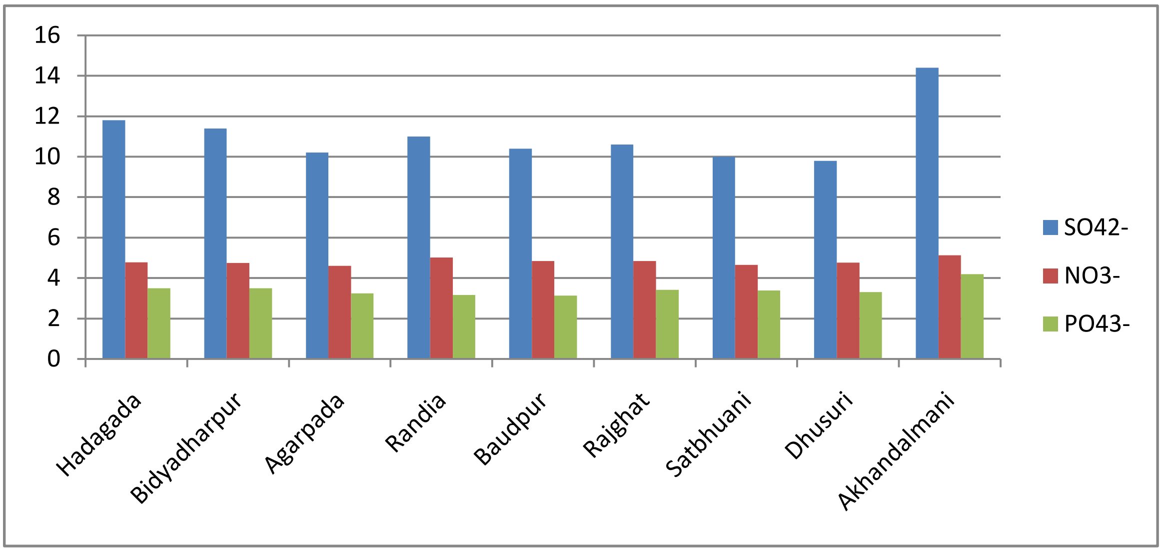


Figure 4. NO_3^-, SO_4^{2-} & PO_4^{3-} for nine monitoring stations across the river Salandi,2016

The mean value of nitrate changes from 4.78 ± 0.6554 at Hadagada to 5.12± 0.4534 at Akhandalmani with higher value at Randia (5.02 ± 0.44) followed by decreasing trend towards downstream due to dilution and self-stabilization capacity of the river and again it rises to maximum value at Akhandalmani (5.12 ± 0.4534) due to back flow of sea water [26]. The higher value at Randia may be due to mixing of industrial wastes in the river water as Ferro Alloys Corporation (FACOR) is in the bank of the river at Randia [16,30]. The mean value of sulphate changes from 11.8 ± 4.8166 at Hadagada to 14.4 ± 3.7416 at Akhandalmani in insignificant manner during the course of flow of river from upstream to downstream. The higher value at Hadagada and Akhandalmani may be due to mixing of forest run off that might contain animal and plant residues and picnic waste materials thrown off by picnic parties as Hadagada is a famous picnic spot [5,16] and back flow of sea water to the river respectively [26]. The mean value of phosphate changes from 3.50 ± 0.8694 at Hadagada to 4.20 ± 1.0039 at Akhandalmani with a decreasing trend from upstream to downstream except Akhandalmani. The higher value at Hadagada and its neighbouring station Bidyadharpur may be due to mixing of forest residues and picnic waste materials thrown off by picnic parties in the river water followed by dilution towards downstream and highest value at Akhandalmani can be due to back flow of sea water to the river [5,16,26]. The mean values of sulphate, nitrate and phosphate for nine monitoring stations have been presented in the Figure 4.

3.5. Chloride (Cl^-)

The values of chloride in all monitoring stations are within the permissible limit of IS-10500 [27], although seasonal variations are observed in irregular and insignificant order [23]. It is observed that the mean values of chloride change from 22.0 ± 4.0 at Hadagada to 1762.0 ±19.3907 at Akhandalmani. Further, it is construed that there is a decreasing trend from upstream to downstream expect Rajghat and Akhandalmani. The higher value at Rajghat (25.0 ±3.1622) may be due to anthropogenic activities such as mixing of washing residues, urban and biomedical wastes with the river water as Rajghat is situated at the heart of municipality where there are district head quarter hospital and other private medicals and after all launders use this spot for washing purpose in large scale[5,16,21,24]. The highest value at Akhandalmani is due to the back flow of sea water to the river [16]. The standard deviation (S.D) says that it is zero in the monitoring station Dhusuri.

3.6 Fluoride (F^-)

The fluoride, responsible for fluorosis when beyond certain limit is within the standard permissible value, according to the WHO [31] and BIS guide lines [27]. It is observed that the value of fluoride is more in mining belt followed by gradual decreasing trend towards downstream except at Rajghat due to dilution [23]. Further, it is observed that the value of fluoride is higher in summer (April & May) than rainy and post-rainy seasons except at Rajghat (1.1 in August, 1.0 in October and 1.2 in December) [23].

The higher value of fluoride in the mining belt may be due to availability of soluble compounds of fluorine such as sodium fluoride (NaF), fluorosilisic acid (H_2SiF_6), sparingly soluble compounds of fluorine such as CaF_2 and cryolite (Na_3AlF_6) in the soil and rocks. The phosphate fertilizers also contain an average amount of 3.87% of fluoride which can be released to the river as agricultural residues [18,32,33].

The higher concentration of fluoride in the summer season is due to low flow of water. The mean value of fluoride changes from 0.82 ± 0.0993 at Hadagada to 0.736 ± 0.2219 at Akhandalmlani with a decreasing trend from upstream to downstream except at Rajghat (1.14 ± 0.1019). The higher concentration of fluoride at Rajghat irrespective of nature of season may be due to mixing of biomedical and urban wastes with the river as district head quarter hospital and other private hospitals are very close to the river [10,16]. The mean value of chloride and fluoride have been presented in the Figure-5.(a) and (b) respectively.

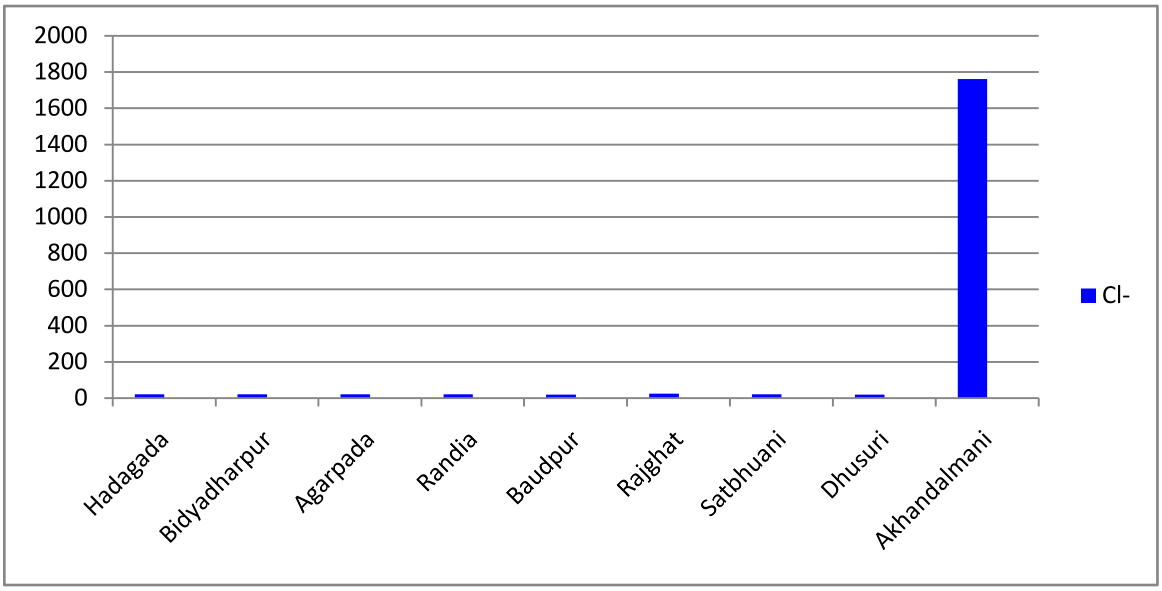


Figure 5. (a) Cl^- for nine monitoring stations across the river Salandi,2016.

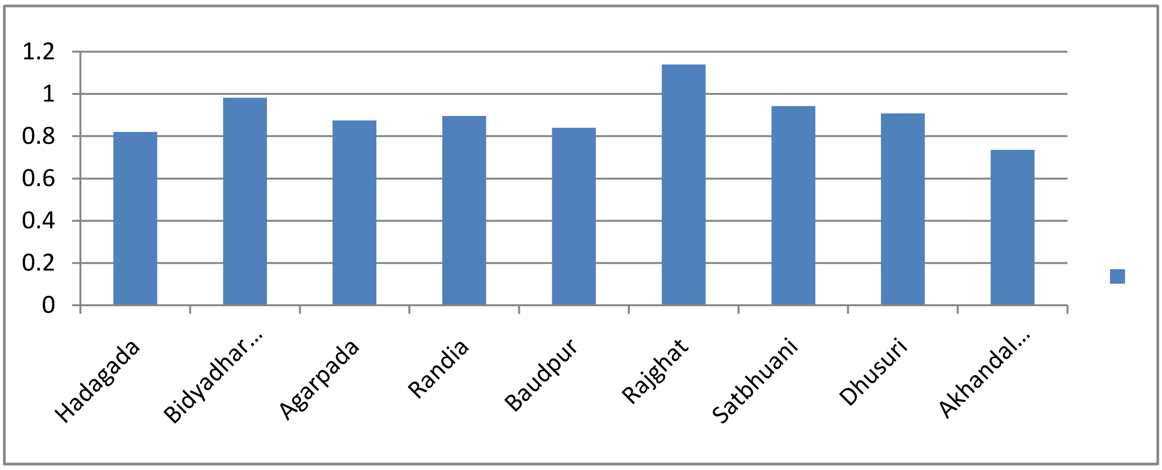


Figure 5.(b). F^- for nine monitoring stations across the river Salandi, 2016

3.7. Fe & Cr

Iron and chromium are essential elements for both human and animals as because Fe^{2+} and Cr^{3+} play a vital role in transportation of oxygen through haemoglobin and carrying out several biochemical functions respectively, whereas Cr^{6+} is carcinogenic in nature.

It is observed that both iron and hexavalent chromium are touching the permissible limit or exceeding the permissible limit of IS-10500 in certain monitoring stations during the four seasons [23,27]. Further, it is observed that the value of iron in rainy, post-rainy and winter seasons is higher than in the summer season. It may be due to the dissolution of more soil containing higher amount of iron ores in the river as a result of heavy rain fall. Also it is observed that the mean value of iron follows a decreasing trend from upstream at Hadagada (1.924 ± 1.951) to the downstream except at Akhandalmani (2.394± 2.3333) and the value of iron is always higher in the monitoring station at Akhandalmani irrespective of the nature of season [23]. The higher concentration of iron in the mining belts, Hadagada and Bidyadharpur is due to the receiving of mining discharges and it gradually diluted due to the dilution and self-stabilization capacity of the river [16,23,26].

The excessive higher concentration of iron in the monitoring station at Akhandalmani is due to the back flow of sea water to the river that might contain higher amount of iron, as it is confirmed from the experiment that water sample was collected from Akhandalmani at the time of back flow of sea water due to tide and was analysed. The analysis result shows that the higher concentration of iron (3.1) in the sample. Another factor may be cited that Akhandalmani (Tinitaraf ghat) is the confluence place of the river Salandi and the river Baitarani. In the upstream of the Baitarani (Joda & Barbil of Keonjhar district), there are large number of iron mines which release mining discharges heavily containing iron ore to the river and hence water and sediments of the river Baitarani contain higher concentration of iron at the confluence place, i.e, Tinitaraf ghat [10,23,39]. The higher concentration of iron has been reported by Das et al [34,35] for the river Baitarani at Joda area. As regards to hexavalent chromium, its permissible limit is 0.05 ppm according to IS-10500 [27]. It is observed that the value of hexavalent chromium is more in rainy and post-rainy seasons than in summer and winter seasons and it also confirms that irrespective of nature of season the value Cr^{6+} is more in the monitoring station Randia (0.08) in comparison to other sampling stations[23]. The mean value of Cr^{6+} highlights that it changes from 0.0094 ±0.000489 at Hadagada to 0.011± 0.0044 at Akhandalmani with highest value at Randia (0.08±0.0) exhibiting standard deviation (SD) as zero.

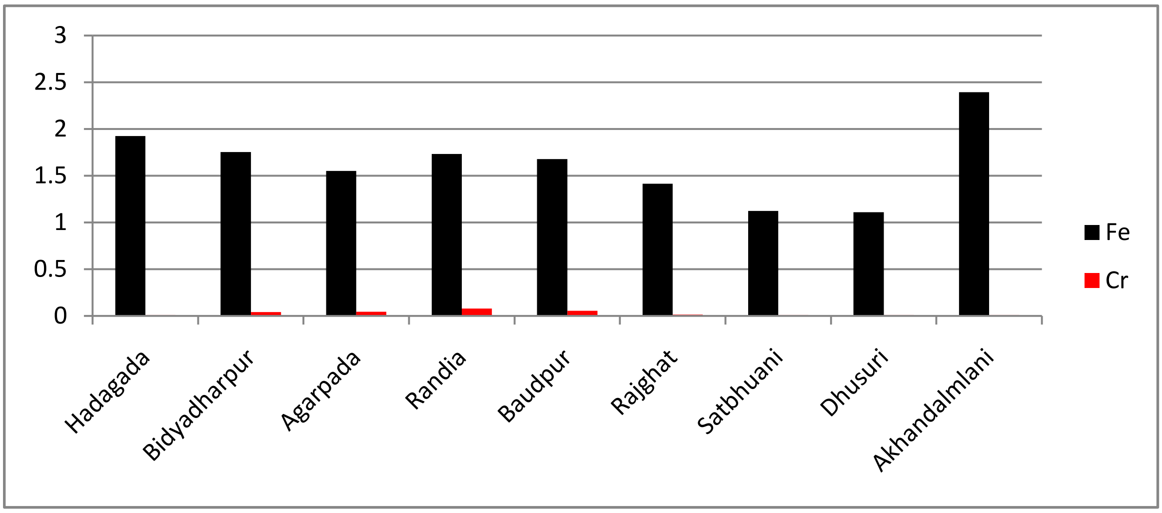


Figure 6. Fe & Cr for nine monitoring stations across the river Salandi, 2016

The higher value of Cr^{6+}during rainy (August) and post-rainy (October) seasons is due to excessive use of chemical pesticides by the farmers to promote agricultural productivity that might contain hexavalent chromium as well as mixing of chromite mining runoff with the river as a result of heavy rain fall [5,6,7,8,23,26,28,36]. Besides, highest value at Randia is the consequence of mixing of chromium contaminated by industrial waste materials from the Ferro Alloys Corporation (FACOR), established at Randia with the river water [16,39]. At present, some chromite mines are not running due to environmental, forest and other legal restrictions imposed by Saha Commission. But report of pollution control board reveals that the mining discharges left by them earlier without proper treatment has resulted open exposure of chromite mixed soil to the atmosphere and pollute the river Salandi with the chromium through rain water precipitations as the river Salandi is the only natural drainage system in the study area [7,13,37,38]. Hence more concentration of hexavalent chromium is found from Bidyadharpur to Baudpur during rainy and post-rainy seasons due to entry of mining, industrial and agricultural wastes, atmospheric rain precipitation and geology of river bed and catchment area. The mean value of Fe and Cr^{6+} has been presented in the Figure 6 for study and interpretation.

3.8. Dissolved Oxygen (DO)

The dissolved oxygen (DO) is an important parameter required for the survival and maintenance of aquatic system. The extent of pollution of any water body can be described by DO as higher the DO value, lower is the extent of pollution and vice-versa. The input sources of DO are dissolution of atmosphere oxygen in the water, aeration and photosynthesis by autotrops and output sources are respiration, decomposition of organic matters by micro organisms, evaporation at higher temperature etc. The higher value of DO of any water body increases if input sources are higher than the output sources. The minimum value of DO for healthy aquatic environment is 6mg/L [27].

In the present study, the DO values have been affected constantly from Hadagada to Akhandalmani due to the aforesaid factors. It is observed that DO values are lower in summer season (April & May) than in rainy (August), post-rainy (October) and winter seasons (December) in all monitoring stations [23]. The lower value during summer season is due to low flow of water, low rate of dissolution of atmospheric oxygen and higher rate of evaporation due to high temperature [5,9,14,21,40,41,42]. On the other hand higher value of DO during rainy, post-rainy and winter seasons can be attributed to aeration, high flow of water, dissolution of more atmospheric oxygen and after all low rate of evaporation of dissolved oxygen as a result of low temperature during winter seasons [4,9,20,21,22,23,25,40,41]. Moreover, it is needless to mention that the DO value is higher in the monitoring station at Hadagada irrespective of the season with slightly seasonal variations (7.0-7.2) [23]. The higher value may be due to low pollution load in the upstream and lower rate of evaporation owing to dense forest environment [16,23,41].

From this mean value of DO, it is evident that there is a decreasing trend from upstream at Hadagada (7.0 ± 0.0632) to the downstream except at Akhandalmani (7.0 ± 0.2449) with lowest at Rajghat (6.38 ±0.1939) and Randia (6.48 ± 0.1720) . The lowest value at Rajghat and Randia may be due to mixing of biomedical wastes and industrial wastes [6,21,30] with the river water respectively. The higher value of DO at Akhandalmani may be due to high flow and accumulation of water, dissolution of more atmospheric oxygen and after all low rate of evaporation as it is the confluence place of two rivers. [4,16,23].

3.9. Biological Oxygen Demand (BOD)

Like dissolved oxygen, BOD is an important parameter required to study water pollution and the value of BOD for any water body if more than 3mg/L will be treated as polluted [27]. It is observed that the BOD values are either approaching to the standard permissible limit or exceeding it in some monitoring stations and these values are more in rainy, post-rainy and winter seasons than the summer season [23].

The higher value of BOD during rainy and post-rainy seasons may be due to the mixing of forest run off containing biological residues as the river passes through the Similipal reserve forest, [14,16] urban wastes [5], mining wastes [39], industrial wastes [30], agricultural wastes [8,42] and after all domestic wastes with the river through the rain water and flood [26,28,29]. Another important observation can be cited that both DO and BOD increase simultaneously during rainy and post-rainy seasons [23]. Further, the higher values during winter season can be attributed to the throwing of picnic waste materials to the river [5] and washing of motor vehicles in the river [6,7,17] as Hadagada is a famous picnic spot and attracts a large number of picnic parties to hold picnic here during the winter season. Besides, open defecation in the river bed [5,35,40], burning and throwing of dead bodies [10] and holding of socio-cultural functions in the river bed [16] enhance the concentration of organic pollutants in the river water along with the low flow of water and precipitation of contaminated dust through the rain water during the winter season [10,16]. The mean value of BOD changes from 4.08 ± 1.2528 at Hadagada to 3.98 ± 0.9495 at Akhandalmani with highest value at Rajghat (5.56 ± 0.2416) followed by Bidyadharpur (5.16 ± 0.1777) and Satbhauni (5.06 ± 0.2244). The higher BOD at Bidyadharpur may be due to receiving of mining discharges from the mining belt as there are three mines namely Boula open caste and underground mine, Bangur chromite mine and Nuasahi chromite mine [10,13,14,39]. It is only the Bangur chromite mine that discharges one lakh tonnes chromite ores per year and seven lakh tonnes of over burdens are excavated [13]. The higher value at Rajghat may be due to mixing of biomedical wastes and urban wastes of the municipality as there are more than 107369 people live in the municipality along with the washing residues with the river water as launders use this spot in large scale for washing purpose [16,23] and insignificant change of BOD at Satbhauni in comparison to Rajghat may be due to slightly dilution of pollutants. The lowest value of BOD at Akhandalmani (3.98 ± 0.9495) might be due to the large scale dilution of pollutants as a result of high flow of water round the year because it is the confluence place of two rivers. The mean values of DO & BOD for nine monitoring stations have been presented in the Figure 7 for study and interpretation.

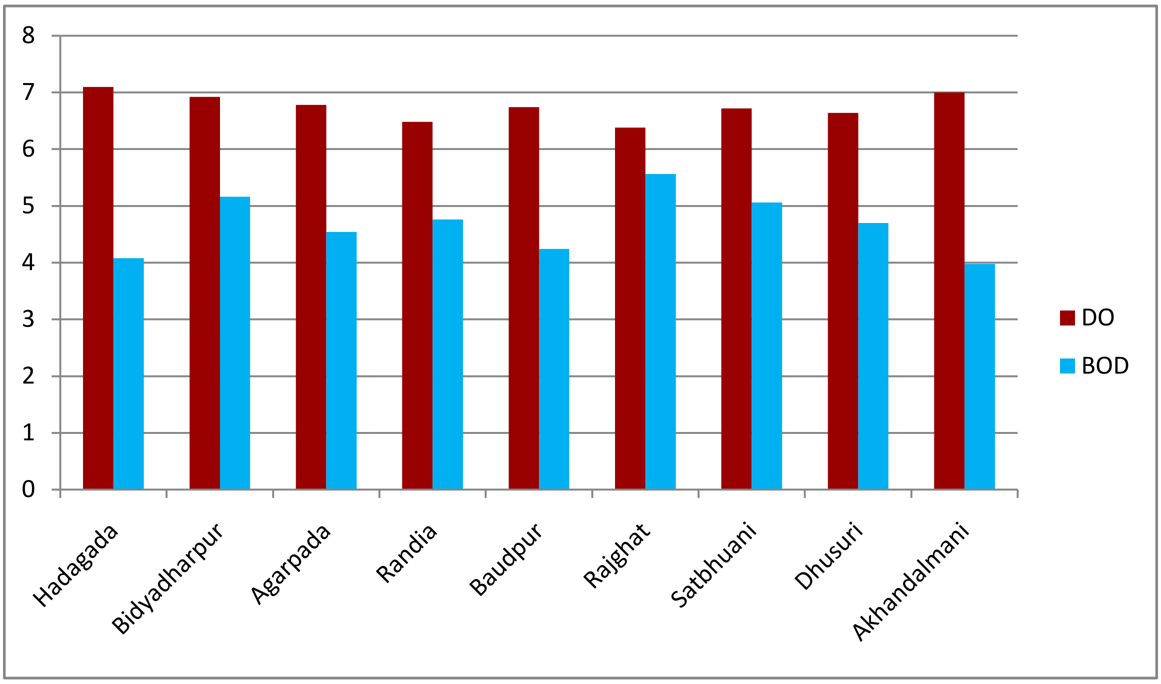


Figure 7. DO & BOD for nine monitoring stations across the river Salandi, 2016

4. Bacteriological Tests

The bacteriological tests have been carried out in nine monitoring stations season wise through H_2S kit method and the result confirms that the river water has been contaminated with pathogenic bacteria irrespective of the season. It may be due to the collective effect of several factors such as open defecation in the river bed, burring and throwing of dead bodies, throwing of residual waste material at the time of holding socio-cultural functions and after all excretions by the animals in the river [16,23,41]. However the exact type and amount of bacteria have not been done due to inadequate laboratory facilities.

4.1. Pearson's Correlation Coefficients

Pearson's correlation coefficients for twelve important parameters calculated with the help of SPSS-16 software have been presented in the Table 3. It is evident from the table that there exists a positive correlationship between p^H and PO_4^{3-}, p^H and F^-, p^H and Cr^{6+}, TDS and TH, TDS and SO_4^{2-}, TDS and NO_3^-, TDS and Cl^-, TDS and DO, TDS and BOD, TH and SO_4^{2-}, TH and NO_3^-, TH and Cl^-, TH and Fe, TH and DO, TH and BOD, SO_4^{2-} and NO_3^-, SO_4^{2-} and PO_4^{3-}, SO_4^{2-} and Cl^- ,$SO_4^{2-}$and Cr $^{6+}$, SO_4^{2-} and Fe, SO_4^{2-} and DO, SO_4^{2-} and BOD, NO_3^- and PO_4^{3-}, NO_3^- and Cl^-, NO_3^- and Fe,NO_3^- and Cr^{6+}, NO_3^- and BOD, PO_4^{3-} and F^-, PO_4^{3-} and Cr^{6+}, Cl^- and Fe, Cl^- and DO, Cl^- and BOD, Fe and DO, Fe and BOD, F^- and Cr^{6+}, F^- and BOD.

The negative correlationship exists between p^H and TDS, p^H and TH, p^H and SO_4^{2-}, p^H and NO_3^-, p^H and Cl^-, p^H and Fe, p^H and F^-, p^H and DO, p^H and BOD, TDS and p^H, TDS and PO_4^{3-} ,TDS and F^-, TDS and Cr^{6+}, TH and p^H, TH and PO_4^{3-}, TH and F^-, TH and Cr $^{6+}$, SO_4^{2-} and p^H, SO_4^{2-} and F^-, NO_3^- and p^H, NO_3^- and F^-, NO_3^- and DO, PO_4^{3-} and Cl^-, PO_4^{3-} and Fe, PO_4^{3-} and DO, PO_4^{3-} and BOD, Cl^- and F^-, $Cl^-$and Cr $^{6+}$, Fe and F^-, Fe and Cr $^{6+}$, F^- and DO, Cr^{6+} and DO, Cr^{6+} and BOD, DO and BOD. Hence the physico-chemical parameters are correlated among themselves in both positively and negatively.

5. Conclusion

The river Salandi, originated from well-known biosphere of Similipal reserve forest meets the river Baitarani at Tinitaraf ghat and running from Hadagada dam to confluence place, travels 134 KMs of long distance. The river, during its course of journey, receives forest run off at Hadagada, mining discharges in the mining belt at Bidyadharpur, industrial wastes at Randia (FACOR), urban and biomedical wastes at Bhadrak municipality, agricultural and domestic effluents while passing through vast agricultural land at Agarapada, Satbhauni and Dhusuri. As a result, it is contaminated physically, chemically as well as bacteriologically containing higher amount of hexavalent chromium, iron, chloride and pathogenic bacteria and the gravity of pollution is more during rainy and post-rainy seasons due to improper waste treatment and management. The water quality, according to IS-10500 [27] and WHO guide lines [31] is neither suitable for drinking, agriculture, fishing nor other domestic purposes.

Hence urgent measures are to be taken by the appropriate authority to treat the contaminated materials carefully so as to ensure the zero entry of pollutants to the river. Further, disinfection and electrodialysis are to be carried out properly and especially for hexavalent chromium, reduction with SO_2 in acidic medium followed by lime treatment [1,16] should be under taken so as to precipitate the chromium as chromium hydroxide along with other established modern technologies , otherwise it will pose a serious health hazard on the dwellers affecting them both physically and economically.

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References

[1] Karia, Y.L; Christian, R.A. (2006). Waste Water Concept and Design Approach, 1st Edition, Prentice Hall of India Ltd., New Delhi.

[2] Bhadra, A.K.; Sahu, B.; Rout, SP. (2014). A study of water quality index of the river Brahmani, Odisha to assess its potability, *Int. J. of Current Engg. & Tech.*, 4(6).

[3] Patil, P.L.; Sawant, D.V.; Deshmukh, R.N. (2012). A physico–chemical parameters for testing of water: A review, *Int. J. of Environmental Sciences, 3(3)*,1194-1207.

[4] Lawson, E.O. (2011). Physico-chemical parameters and heavy metal contents of water in the mangrove swamps of Lagos Lagon, Nigeria, *Advances in Biological Research*, 5(1), 08-11.

[5] Kalavaty, S.; Sharma, T.R.; Kumar, P.S. (2005). Water Quality Index of River Cauvery in Tiruchirapali, Tamilnadu, *ARCH. Environ. Sci.*, 05, 55-61.

[6] Akhinobare, S.M.O. (2011). Factors in the migration of heavy metals in the Otimari river system, *Int. J. of Sci. and Nature*, 2(4), 856-860.

[7] Reza, R.; Sing, G. (2010). Heavy metal contamination and its indexing approach for river water, *Int.J. of Environ. Sci.Tech.*, 7(4), 785-792.

[8] Serpil, S. (2012). An agricultural pollutants-chemical fertilizer, *Int.J. of Env. and Dev.*, 3(1).

[9] Pardeshi, D.S.; Baidya, S. (2015). Physico-chemical assessment of Waldhuni river, Ulashnagar, Thane, India-A case study, *Int.J. of Current Research and Academic Review*, 3(4), 234-248.

[10] Panda P.K.; Panda, R.B.; Dash, P.K. (2016). Seasional variation of physico-chemical parameters of river Salandi from Hadagadadam to Akhandalamani, Bhadrak, Odisha, India, *IOSR J of Environmental Sci., Toxicology and Food Technology*, 10(11), Ver III, 15-28.

[11] Mixed traffic in Recycle Path. (2014). The Times of India, Bennet Colemn & Company Ltd., Ahmadabad.

[12] Reporter, S. (2008). A special report on India : Cracking,growing infrastructure is India's biggest handicap, The Economist.

[13] Environmental impact & assessment & Environmental Management Plan of Boula Chromite mines, FACOR Ltd. (1994) State Pollution Control Board, Odisha.

[14] Panda, P.K.; Panda, R.B.; Dash, P.K. (2015) Pollution load of river Salandi in Boula Nuasahi mining belt, urban area at Bhadrak & its downstream in Odisha,*IJIEASR*, 4(12), 15-23.

[15] American Public Health Association (APHA), AWWA (2005) Standard methods for examination of water and waste water, Washington DC,21st Edition, USA.

[16] Panda, P.K.; Panda, R.B.; Dash P.K. (2016). Assessment of water quality of river Salandi from Hadagada dam to Akhandalmani, Bhadrak, Odisha, India, *American J of Water Resources*, 4(2), 44-53.

[17] Oberoi, J.; Gupta, K,C. (2010). Occurance of fluoride of ground water of various villages of district Ambala, Haryana, *Poll.Res.*, 29(3), 435-440.

[18] Panda, R.B. et al. (2012). Occurance of fluoride in ground water of Patripal panchayat in Balasore district, Odisha, India, *J of Env.*, 1 (2), 33-39.

[19] Ishaq, F.; Khan, A. (2013). Heavy metal analysis of river Jamuna and their relation with some physico-chemical parameters, *Global J of Environ.Res.*, 7(2), 34-39.

[20] Hujare, M.S. (2008) Seasonal variation of physico-chemical parameters in perennial tank of Talsande, Maharastra, *Ecotoxicol. environ. Monit*.,18(3), 233-242.

[21] Ganie, M.A.; Khan, M.I.; Muni, P. (2012) Seasonal variations of physico-chemical parameters of Pahuja reservoir, Jhansi, Bundelkhand region, Central India, *Int.J of Current Res.*, 4(12), 115-118.

[22] Sing, T.A.; Meetel, N.S.; Metel, L.B.; (2013). Seasonal variations of some physico-chemical characteristics of three rivers in Imphal, Manipur-A comparative evaluation, *Current World Environment*, 8(1), 93-102.

[23] Panda, P.K.; Panda, R.B.; Dash, P.K. (2017). The study of physico-chemical and bacteriological parameters of river Salandi and assessment of water quality index from Hadagada dam to Akhandalmani, Bhadrak, Odisha, India, *IOSR J of Env.Sci.. Toxicology and Food Tech.*, 11(4), Ver II, 31-52.

[24] Masood, K.M. (2008). Assessment of water quality of Oyan reservoir, Offa, Nigeria, using selected physico-chemical parameters, *Turkish J of Fisheries and Aquatic Science*, 8, 309-319.

[25] Ndubi, D.; Oyaro, N.; Giathane, E.; Affulo, A. (2015). Determination of physico-chemical properties of sources of water in Narok North sub country, Kenya, *Int. Research J of Env. Sciences*, 4(1), 47-51.

[26] Kar, D.; Sur, P.; Mandal, S.K.; Saha, T.; Kole, R.K. (2008) Assessment of heavy metal pollution in surface water, *Int. J of Environ.Sci.Tech*., 5(1), 119-124.

[27] BIS IS-10500. (2004). Indian Standard for drinking water,Bureau of Indian Standard, New Delhi.

[28] Rim-Rukeh, A.; Lkhifa, O.G.; Okokoya, A.P. (2006). Effect of agricultural activities on the water quality of Orogodo river, Agbor, Nigeria, *J of Appl. Sci. Res.*,2(5), 256-259.

[29] Madan, R.D. (2006). Satyaprakash's Modern Inorganic Chemistry, 2nd edition, S Chand & Co., India, 1077-1088.

[30] Ewa, E.E.; Iwara, A.I.; Adeyami, J.A.; Eya, E.I.; Ajake, H.O.; Out, C.A. (2011). Impact of industrial activities on water quality of Omuko Creek, *Sacha J of Environmental Studies*, 1(2), 8-16.

[31] WHO guidelines for drinking water quality (2004), 3rd Edition, World Health Organisation, Geneva.

[32] Fluoride in drinking water, back ground documents of development of WHO guidelines for drinking water, INHO/SDE/INSH/03-04/96.

[33] Sadat,N. (2012) Study of fluoride concentration in the river Godavari and ground water of Nandeed city,*Int. J of Engg. Inventions*, 1(1), 11-15.

[34] Dash, A.; Das, H.K.; Mishra, B. (2015). Hydrochemical characteristics and water quality of surface water in and around Joda, Keonjhar, Odisha, India, *Int. J of Energy, Sustainability and Environ.Engg*., 1(4), 128-136.

[35] Dash, A.; Das, H.K.; Mishra, B.; Bhuyan, N.K. (2015). Evaluation of water quality of local springs and river Baitarani in Joda area of Odisha, India, *Int. J of Current Res.*,7(3), 13559-13568.

[36] Ammaann, A.A.; Michal, B.; Scharmel, P. (2002). Specification of heavy metals in environmental water ion-chromatography coupled to 1CP-MS, *Anal. Bional. Chem*., 372, (3), 448-452.

[37] Wong, C.S.C.; Li, X.D.; Zohang, G.; Qi, S.H.; Peng, S.Z. (2003). Atmospheric deposition of heavy metals in Perl river delta, China, *Atoms. Environ*., 37(6), 767-776.

[38] Wu, Y.F.; Liu, C.Q.; Tu C.L. (2008) Atmospheric deposition of heavy metals in TSP of Quiyang, PR China, *Bull. Environ. Contamination Toxicol*., 80(5), 465-468.

[39] Kraft, C.; Tumpling, W.; Zachmann, D.W. (2006) The effect of mining in Northern Romania on heavy metals distribution in sediments of river Szamos and Tisza, Hungary. *Acta. Hirosima Hydrobiol*., 43, 257-264.

[40] Mishra, A.; Tripathy, B.D. (2007). Seasonal and temporal variation in physico-chemical and bacteriological characteristics of river Ganga in Varanasi, *Current World Environment*, 2(2), 149-154.

[41] Panda, P.K.; Panda, R.B.; Dash, P.K. (2018). The river water pollution in India and abroad:A critical review to study the relationship among different physico-chemical parameters, *American J of Water Resources*, 6(1), 25-38.

[42] Vadde, K.K.; Wang, J.; Cao, L.; Yuan, T.; Mc Carthy, J.A.; Sekar, R. (2018). Assessment of water quality and indentification of pollution risk locations in Tiaoxi river, China, *Water*, 10, 183, 01-18.

[43] Lata, S.; Mohan, A.; Khana, D.R. (2018). Physico-chemical characteristics of river Ganga at Chandighat in Haridwar, *IOSR J of Applied Chemistry*, 11(1), Ver-1, 22-27.