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Physico-Chemical cum Biological Characteristics & Water Quality Index (WQI) of Bhima River in Gulbarga District, Karnataka State, India

Shivashranappa[1], Anand Yalakpalli[2]
[1]*Associate Professor, Dept of Civil Engineering, P. D. A. College of Engineering (Autonomous Institution) Gulbarga, Karnataka State, India.*
[2]*Lecturer, Dept of Civil Engineering, Basavakalyan College of Engineering, Basavakalyan, Karnataka State, India.*

Abstract—The present work is aimed at assessing the water quality index (WQI) for the surface water of Bhima River near Hipperga village of Taluka Gulbarga, District Gulbarga, Karnataka State, India. Surface water samples were collected at three sampling points, S_1 upstream of village Hipparga, S_2 near village Hipparga and S_3 downstream of village Hipparga. The samples are subjected for comprehensive physical, chemical and biological analysis. For calculating the WQI, the following 14 parameters have been considered: pH, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Sulphate, DO, BOD, Alkalinity, Sodium, Potassium and Fluoride. The high value of WQI has been found to be mainly from the higher values of TDS, Hardness, BOD and Nitrate. The analysis reveals that the surface water of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

Keywords—Surface water, Water quality standards, Water quality characteristics, Water quality index.

I. INTRODUCTION

Surface water is used for domestic, industrial, water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers[1]. According to World Health Organization (WHO), about 80% of all the diseases in human beings are caused by water[2]. Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water to citizens and policy makers. The formulation and use of indices has been strongly advocated by agencies responsible for water supply and control of water pollution[3]. Although any environmental impact could be either beneficial or adverse, in environmental analysis, impacts are historically considered only to be of adverse type caused by our developmental activities. Impacts can be generally categorized as primary, secondary or tertiary. Primary impacts are those caused directly by project inputs such as loss of forests, or changing of a river regime due to the construction of a dam. As such primary impacts can be attributed directly to a project activity. They are usually easy to measure. Secondary impacts are those caused by project outputs such as water flow regulation and channelization. In other words, they are indirectly attributed to the project activity. If one of the project outputs is availability of irrigation water, secondary impacts could be more severe than primary impacts and unfortunately, often more difficult to predict and measure[4]. Secondary impacts in turn may lead to tertiary impacts. It should be noted that the distinction between primary, secondary and tertiary impacts could often be arbitrary. Various types of water related activities can cause beneficial or adverse impacts on the environment, water channelization, flood land alteration and changes in land use patterns. Water quality is a very important consideration for all water development projects as it affects all aspects of water use-for humans, for animals, for crops and even for industry. All natural waters containing soluble inorganic ions are mainly from the weathering of soil and rock minerals. The weathering products of the rock minerals are released and transported by the action of water. Hence the nature and concentration of an ion in water depends upon the nature of rock mineral, its solubility and its resistance to weathering in fresh water or carbonated water (due to dissolution of atmospheric carbon dioxide in rain water) climate and local topography. Apart from these major causes, solubility of minerals in influenced by pH, particularly of iron and manganese hydroxides that decreases and aluminium hydroxide which increase with the increase of pH. In recent years continuous growth in pollution, rapid industrialization and accompanying technologies involving waste disposal has endangered the very existence of human race.[5-7] Eventually the rate of clearance of forests for the purpose of different land uses is far higher than the methods that are implemented for aforestation. Among the different types of pollution, water pollution is one of the major causes, which creates immense public health hazards. Therefore, regional variations in surface water quality can be determined only by sampling water at sites intended to give representative coverage of the various conditions of occurrence. Partial analysis to determine the concentrations of the principal chemical constituents in water may provide sufficient data for many investigations and modeling studies. The present study highlights the WQI Model of surface water in Bhima River. Further, the information obtained from the study will be useful for local people, environmental departments, public health departments etc. The main objectives of the study are Physical, Chemical and Biological analysis of surface water samples and application of Water Quality Index (WQI) model. Water quality index is created to give the outlook of variation of chemical constituents of surface water in different sampling points. WQI also reveals the quality of water in different sampling points.

II. MATERIALS AND METHODS

The study area i.e. Bhima river is located 25 kilometers away from District Gulbarga, on National Highway No. 218. Gulbarga is 640 kilometers away from the capital city Bangalore, Karnataka state, India. Figure.1 shows the location map of Bhima River with sampling points. Gulbarga District lies at N: 17º 40’ latitude and E: 76º 80’ longitude. It is 454 meters above sea level, sloping North-West to South- East, has a. a. r of 832.3 mm and relative humidity varies from 26% in summer to 62% during winter. Minimum temperature is 15^o C and during peak summer it shoots up to 47^o C. Surface water samples were collected from Bhima River for two kilometer length of flow, three sampling points were selected. S_1 upstream of village Hipparga, S_2 near village Hipparga and S_3 downstream of village Hipparga. The water samples were collected for every three days in the morning at 08:00 to 10:00 am for a period of 2 months successively during April 2011 to May 2011. Two and half liters of water samples were collected in white colored plastic containers and were transferred to the laboratory at the earliest. Collected samples were subjected to chemical analysis while temperature and pH were determined in field. The water samples were then analyzed for following parameters: TDS, pH, TH, Ca, Mg, Cl, SO4, NO_3, BOD, Na, K, F, HCO_3 and DO using standard procedures of analysis recommended by APHA and compared with WHO and BIS.[8-10]

Water Quality Index (WQI) for Bhima River

Water quality affects the quality of drinking water and the capacity of the surface water to support wildlife and healthy ecosystems. Water quality can be degraded by many different stressors in the watershed, including poor development practices and sprawl, poor storm water management, destruction of wetlands, runoff from agricultural area, and point source pollution. Water quality indices aim at giving a single value to the water quality of a source. One can then compare different samples for quality on the basis of the index value of each sample. For computing water quality index three steps are followed[3]. In the first step, each of the 14 parameters has been assigned a weight (w_i) according to its relative importance in the over all quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium has been given weight of 2 as magnesium by it self may not be harmful. In the second step, relative weight (Wi) is computed from the following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad \text{-- (1)}$$

Where (Wi) is the relative weight, (w_i) is the weight of each parameter and ‘n’ is the number of parameters. In the third step, a quality rating scale (Q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result is multiplied by 100.[3]

$$Qi = (C_i/S_i) *100 \quad \text{--- (2)}$$

Where, $\mathbf{Q_i}$ is the quality rating, $\mathbf{C_i}$ is the concentration of each chemical parameter in each water sample in *mg/L*, except pH, and $\mathbf{S_i}$ is the BIS (Bureau of Indian standards) water standard for each chemical parameter in mg/l according to the guidelines of the BIS-10500-1991. For computing the WQI, the Sub Index (SI) is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$SI_i = W_i*Q_i \quad \text{--- (3)}$$

$$WQI = \Sigma SI_i \quad \text{--- (4)}$$

SI_i is the sub index of **I**th parameter, Q_i is the rating based on concentration of ith parameter and **n** is the number of parameter. The computed WQI values are classified into five types “excellent water”, “good water”, “poor water” “very poor water”, “water unsuitable for drinking” as shown in Table 1.

Table 1: Water quality classification based on WQI value

WQI value	Water quality
<50	Excellent
50 – 100	good water
100 – 200	poor water
200 – 300	Very poor water
>300	Water unsuitable for drinking

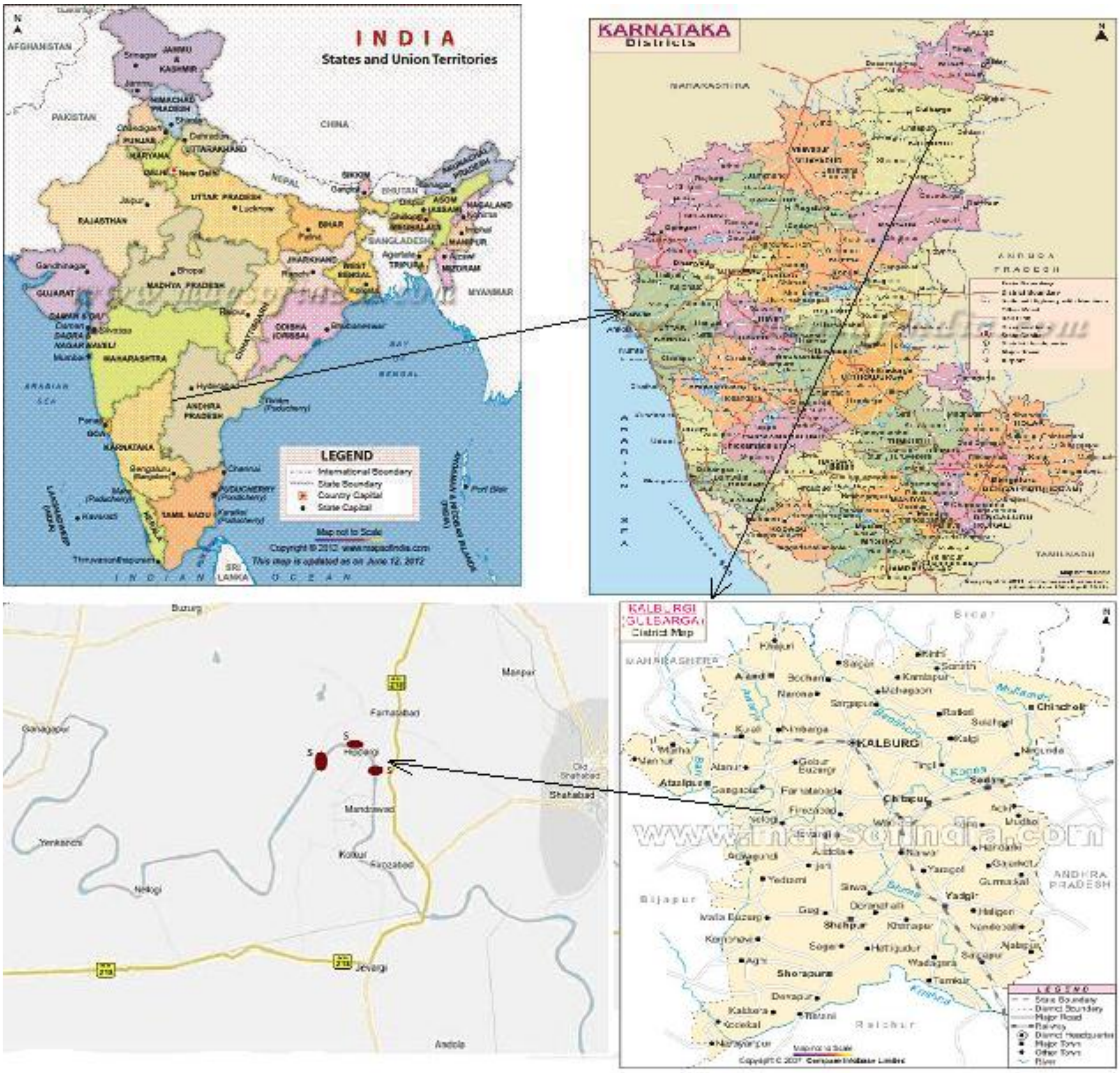

Fig.1: **Showing the Location of sampling points on Bhima River in Gulbarga District**

III. RESULTS AND DISCUSSIONS

The pH values of the samples varied between 6.30 to 7.90 at sampling point (upstream), 7.42 to 8.14 at sampling point (near village) and 7.20 to 8.05 at sampling point (downstream). It is observed that the pH of the surface water was slightly alkaline and only minor fluctuation in pH was recorded. The pH levels were within the limits set by the WHO and BIS. The permissible total dissolved salts for drinking water is 500 mgL^{-1}. In the absence of potable water source the permissible limit is up to 2000 mgL^{-1}. It is found from the analysis; all the water samples are within the maximum limit of 2000 mgL^{-1}. The range of TDS levels in the study area is 780.30 mgL^{-1} to 1020.0 mgL^{-1} at sampling point (upstream), 832.10 mgL^{-1} to 1160.30 mgL^{-1} at sampling point (near village) and 805.70 mgL^{-1} to 988.0 mgL^{-1} at sampling point (downstream). High values of TDS in surface water are generally not harmful to human beings but high concentration of these may affect persons who are suffering from kidney and heart diseases also water containing high solids may cause laxative or constipation effects. Natural hardness of water depends upon the geological nature of the drainage basin and mineral levels in natural water. The total hardness ranged between 630.90 mgL^{-1} to 800.40 mgL^{-1} at sampling point (upstream), 694.0 mgL^{-1} to 840.0 mgL^{-1} at sampling point (near village) and 647.0 mgL^{-1} to 791.70 mgL^{-1} at sampling point (downstream). Hardness is little more in this river water, a separate Geochemical/Hydro geochemical analysis is a must to arrive at the hardness nature of this river water. The magnesium hardness exceeds in all the samples, it ranges from 100.70 mgL^{-1} to 179.0 mgL^{-1} at sampling point (upstream), 86.0 mgL^{-1} to 160.0 mgL^{-1} at sampling point (near village) and 131.48 mgL^{-1} to 246.70 mgL^{-1} at sampling point (downstream). There are no known cases of magnesium poisoning. At large oral doses of magnesium may cause vomiting and diarrhea. High doses of magnesium in medicine and food supplements may cause muscle slackening, nerve problems, depressions and personality changes. The chloride content increases normally as the mineral content increases. The chloride level ranged between 34.50 mgL^{-1} to 153.10 mgL^{-1} at sampling point (upstream), 90.0 mgL^{-1} to 274.0 mgL^{-1} at sampling point (near village) and 94.60 mgL^{-1} to 170.80 mgL^{-1} at sampling point (downstream). Here it is observed that the chloride concentration in the samples fall well within the permissible limit. The total alkalinity of the water samples was below the permissible and desirable criteria for domestic water supply. The observed alkalinity was due to methyl orange alkalinity since phenolphthalein alkalinities were zero in all the water sampling points. Consequently, the water samples are not polluted with respect to alkalinity. Dissolved Oxygen present in drinking water adds taste and it is highly fluctuating factor in water. In this study dissolved oxygen content varied in a limited range of 5.91 mgL^{-1} to 8.97 mgL^{-1} at sampling point (upstream), 1.45 mgL^{-1} to 8.14 mgL^{-1} at sampling point (near village) and 5.23 mgL^{-1} to 5.92 mgL^{-1} at sampling point (downstream). The Biological Oxygen Demand (BOD) gives an idea of the quantity of biodegradable organic matter present in an aquatic system which is subjected to aerobic decomposition by microbes. Accordingly it provides a direct measurement of the state of pollution. The concentration of BOD ranged from 3.21 mgL^{-1} to 8.88 mgL^{-1} at sampling point (upstream), 0.77 mgL^{-1} to 7.5 mgL^{-1} at sampling point (near village) and 1.47 mgL^{-1} to 4.12 mgL^{-1} at sampling point (downstream). The concentration of fluoride in drinking water is critical considering health problems related to teeth and bones. High fluoride concentration causes dental fluorosis and skeletal fluorosis, whereas the absence or low concentration fluoride concentration (< 0.5 mgL^{-1}) cause tooth decay. The recommended desirable limit of fluoride is 1 mgL^{-1}. In present study area, fluoride content in all sampling points is well within the permissible standards. The sulphate and nitrate concentrations of all three sampling points are well within the permissible standards. The MPN index values at all the sampling stations are high; this shows that water is not fit for drinking as it is. Disinfection is necessary. The data of all sampling points are presented in Table No. 2, 3 & 4

Table 2: **Normal Statistics of Water Quality Parameters of Surface Water at sampling point S1 (Upstream)**

Sl. No	Parameters	Minimum	Maximum	Mean	S.D	C.V
01	Temp ^{0}C	20	28	23.75	1.99	0.083
02	pH	6.30	7.90	7.19	0.411	0.057
03	TDS mg/L	780.30	1020.0	910.05	57.75	0.063
04	TH mg/L	630.90	800.40	730.96	51.59	0.070
05	Ca mg/L	513.40	680.30	598.9	49.36	0.082
06	Mg mg/L	100.70	179.00	132.06	21.36	0.161
07	Cl mg/L	34.50	153.10	130.55	25.74	0.197
08	F mg/L	0.14	0.45	0.3155	0.079	0.250
09	SO_4 mg/L	20.40	34.80	25.51	4.70	0.184
10	NO_3 mg/L	16.90	18.80	17.90	0.58	0.032
11	Na mg/L	110.70	119.7	115.82	2.52	0.021
12	K mg/L	17.70	24.80	20.88	1.67	0.079
13	HCO_3 mg/L	60.70	89.0	78.70	9.14	0.116
14	DO mg/L	5.91	8.97	7.421	0.99	0.133
15	BOD mg/L	3.21	8.88	5.527	1.72	0.311
16	MPN	3	64	14.90	13.02	0.87

Table 3: **Normal Statistics of Water Quality Parameters of Surface Water at sampling point S2 (Near Village)**

Sl. No	Parameters	Minimum	Maximum	Mean	S.D	C.V
01	Temp ^{0}C	20	28	23.75	1.99	0.083
02	pH	7.42	8.14	7.79	0.222	0.028
03	TDS mg/L	832.10	1160.30	967.60	82.58	0.085
04	TH mg/L	694.00	840.00	766.15	28.90	0.037
05	Ca mg/L	540.00	680.00	648.80	29.95	0.046
06	Mg mg/L	86.00	160.00	116.35	17.68	0.151
07	Cl mg/L	90.00	274.00	187.60	51.87	0.276
08	F mg/L	0.11	0.87	0.543	0.21	0.403
09	SO_4 mg/L	32.00	168.00	89.85	37.70	0.41
10	NO_3 mg/L	27.60	39.90	32.79	3.18	0.096
11	Na mg/L	100.00	300.00	199.00	54.76	0.275
12	K mg/L	20.00	39.80	31.46	5.82	0.184
13	HCO_3 mg/L	100.00	220.00	149.25	33.80	0.226
14	DO mg/L	1.45	8.14	5.823	1.62	0.278
15	BOD mg/L	0.77	7.5	3.974	2.22	0.559
16	MPN	7	120	34.45	32.09	0.931

Table 4: **Normal Statistics of Water Quality Parameters of Surface Water at sampling point S3 (Downstream)**

Sl. No	Parameters	Minimum	Maximum	Mean	S.D	C.V
01	Temp ^{0}C	20	28	23.75	1.99	0.083
02	pH	7.20	8.05	7.56	0.22	0.029
03	TDS mg/L	805.70	988.00	893.21	52.68	0.05
04	TH mg/L	647.90	791.70	736.13	33.62	0.045
05	Ca mg/L	510.00	545.00	528.80	10.01	0.018
06	Mg mg/L	131.40	246.70	207.33	29.50	0.142
07	Cl mg/L	94.60	170.80	145.90	17.18	0.117
08	F mg/L	0.27	0.492	0.348	0.062	0.178
09	SO_4 mg/L	30.4	39.0	33.19	2.454	0.073
10	NO_3 mg/L	20.40	30.80	26.02	3.653	0.140
11	Na mg/L	85.20	109.40	95.84	8.176	0.085
12	K mg/L	19.2	35.2	23.40	4.40	0.188
13	HCO_3 mg/L	84.90	100.40	92.22	4.782	0.051
14	DO mg/L	5.23	5.92	5.691	0.20	0.035
15	BOD mg/L	1.47	4.12	2.448	0.785	0.32
16	MPN	7	120	34.45	32.09	0.931

The WQI of all samples taken were calculated according to the procedure explained above and are presented in Table 5, 6 and 7. The results obtained from this study revealed that WQI of Bhima river water is **"good water"** for all the three sampling points. The computed WQI was 61.09 in upstream of village Hipparga, 71.83 near village Hipparga and 62.60 in downstream of village Hipparga. All WQI values are between, 50-100 as per Table 1.

Table 5: **Relative Weight of Chemical Parameters at sampling point S1 (Upstream)**

Sl. No	Chemical parameters	Indian Standards	Weight age (w_i)	Relative weight (W_i)	Quality rating (Qi)	Sub index (SIi)
1	pH	6.5 – 8.5	3	0.068	84.58	5.751
2	Total Dissolved Solids (TDS)	500 – 2000	4	0.090	45.50	4.095
3	Total hardness	300 – 600	3	0.068	121.82	8.283
4	Calcium	75 – 200	3	0.068	299.45	20.360
5	Magnesium	30 – 100	2	0.045	132.06	5.940
6	Sodium	300 – 600	2	0.045	16.54	0.744
7	Potassium	15 – 20	2	0.045	83.52	3.758
8	Alkalinity	200 – 600	2	0.045	13.11	0.589
9	DO	4 – 8	2	0.045	92.76	4.174
10	BOD	0 – 30	3	0.068	18.42	1.252
11	Chloride	250 – 1000	4	0.090	13.5	1.174
12	Sulphate	200 – 400	4	0.090	6.37	0.573
13	Fluoride	1.0 – 1.5	5	0.113	21.03	2.376
14	Nitrate	45 – 100	5	0.113	17.90	2.022
			∑wi = 44	∑WI = 0.993	∑Qi= 966.56	∑SIi= 61.091

Table 7: **Relative Weight of Chemical Parameters at sampling point S2 (Near Village)**

Sl. No	Chemical parameters	Indian Standards	Weight age (w_i)	Relative weight (W_i)	Quality rating (Qi)	Sub index (SIi)
1	pH	6.5 – 8.5	3	0.068	91.647	6.231
2	Total Dissolved Solids (TDS)	500 – 2000	4	0.090	48.38	4.354
3	Total Hardness	300 – 600	3	0.068	127.70	8.68
4	Calcium	75 – 200	3	0.068	324.9	22.09
5	Magnesium	30 – 100	2	0.045	116.35	5.235
6	Sodium	300 – 600	2	0.045	28.42	1.278
7	Potassium	15 – 20	2	0.045	125.86	5.663
8	Alkalinity	200 – 600	2	0.045	24.875	1.119
9	DO	4 – 8	2	0.045	21.735	3.275
10	BOD	0 – 30	3	0.068	26.493	1.801
11	Chloride	250 – 1000	4	0.090	18.76	1.688
12	Sulphate	200 – 400	4	0.090	27.714	2.021
13	Fluoride	1.0 – 1.5	5	0.113	73.86	4.090
14	Nitrate	45 – 100	5	0.113	32.795	3.705
			∑wi = 44	∑WI = 0.993	∑Qi= 1085.45	∑SIi= 71.83

Table 8: **Relative Weight of Chemical Parameters at sampling point S3 (Downstream)**

Sl. No	Chemical parameters	Indian Standards	Weight age (w_i)	Relative weight (W_i)	Quality rating (Qi)	Sub index (SIi)
1	pH	6.5 – 8.5	3	0.068	88.941	6.047
2	Total Dissolved Solids (TDS)	500 – 2000	4	0.090	44.66	4.019
3	Total Hardness	300 – 600	3	0.068	122.68	8.342
4	Calcium	75 – 200	3	0.068	264.40	17.97
5	Magnesium	30 – 100	2	0.045	17.42	9.33
6	Sodium	300 – 600	2	0.045	13.691	0.616
7	Potassium	15 – 20	2	0.045	93.60	4.212
8	Alkalinity	200 – 600	2	0.045	15.37	0.691
9	DO	4 – 8	2	0.045	71.143	3.201
10	BOD	0 – 30	3	0.068	8.161	0.554
11	Chloride	250 – 1000	4	0.090	14.59	1.313
12	Sulphate	200 – 400	4	0.090	8.29	0.746
13	Fluoride	1.0 – 1.5	5	0.113	23.20	2.621
14	Nitrate	45 – 100	5	0.113	26.025	2.94
			∑wi = 44	∑WI = 0.993	∑Qi= 1002.086	∑SIi= 62.60

IV. CONCLUSIONS

After the careful study of analysis, interpretation and discussions of the numerical data it is revealed that water is hard in all the sampling points. The concentration of fluoride is well within the permissible limit. The concentration of Total dissolved solids in all sampling points is well within the permissible limit. The Water Quality Index (WQI) falls in the Good range at all the sampling points. Application of water quality index (WQI) in this study has been found useful in assessing the overall quality of water. This method appears to be more systematic and gives comparative evaluation of the water quality of sampling stations. The sulphate and nitrate concentrations of all three sampling points are well within the permissible standards. The BOD at all the three sampling points is higher, the reason might be anthropogenic, as villagers are in vicinity of river, activities viz., cloth washing, cattle rearing, bathing and even grey water of villagers also adding up in the river. From the MPN-Index, water is not suitable for drinking purpose. Hence water may be contaminated by airborne or anthropogenic activities. The analysis reveals that the surface water of the area needs some degree of treatment before consumption and it also needs to be protected from the perils of contamination.

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