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ANALYTICAL ESTIMATION OF WATER QUALITY INDEX IN INDUSTRIAL ESTATE BHILAI, CHHATTISGARH AND CORRELATION BETWEEN VARIOUS WATER QUALITY PARAMETERS

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ABSTRACT

The present investigation estimates the Water Quality Index (WQI) for groundwater near to industrial estate Bhilai, Durg District Chhattisgarh. The Water Quality Index was investigated by taking eleven parameters TDS, pH, Turbidity, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, DO, BOD and COD. It was observed that the Water Quality Index values varied from 69.79 to 141.71. The value of the Water Quality Index in some areas shows the sample was unsuitable because of the high concentration of TDS, Hardness and COD. This study indicates a correlation between TDS vs. Chloride, BOD, Total Hardness and found a positive correlation among them except COD. The water quality index value of groundwater samples near to industries was unfit for drinking purpose, without any suitable treatment.

Keywords: Water Quality Index (WQI), Industrial Estate, Ground Water, Correlation

INTRODUCTION

Water is the precious, indispensable and dynamic renewable natural resource and water is often polluted in various ways.[1-6] The quality of groundwater is a most important for improving the quality of life.[7] The quality of water is describe by Chemical, Physical and Biological properties.[2] Based on World Health Organization (WHO) reports, diarrhea is a major killer in poor and developing countries approximately 4 billion cases of diarrhea worldwide reported each year and 2.2 million people killed annually, mostly children who were under 5 years of age and in living beings especially in human approx. 80% disease is found due to water.[8-10] The overall quality of water can easily estimate by the Water Quality Index.[11] One of the most serious environmental issues for the twenty-first century is clean and potable drinking water.[12] The water ecosystem has altered in several respects in the last decades due to the tremendous development in agriculture and industry.[13] Water quality is considered as an important factor for the judgment of environmental changes that are associated with economic and social development.[1] The studied data of various physiochemical parameters are useful for the study of the nature of the water environment. This type of study will be beneficial for the proper management strategies and monitoring of water quality assessment.[12] This study will provide specific information about the water quality of the industrial area.

EXPERIMENTAL

Selection of the Study Area

Water pollution arises due to an increase in the population, developing industries and urbanization. Details of the sampling station are shown in Table-1. Due to rapid changes in industrialization, it is necessary to monitor environmental pollution. Bhilai city is famous for the industries, so it has been selected as a study point. Bhilai is a famous area in the Durg District, Chhattisgarh, India. Bhilai city is located 25 km (16 mi) at the National Highway-6 in the west of the capital city of Raipur. Based on the 2011 census, the total population of the city Durg-Bhilai was 1,064,077.[14]

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Table-1: Detail of Sampling Station

Sample Code	Sampling Location Detail	Latitude and Longitude
GW_1	Near to Jaypee Cement Bhilai	21.186266, 81.358830
GW_2	Near to BE Industry	21.227744, 81.386734
GW_3	Near to Bhilai Engineering Corporation	21.2315 81.3828
GW_4	Rajiv Nagar Near to ACC Company	21.235316, 81.388754
GW_5	Near to Simplex Industry	21.232795, 81.383566
GW_6	Near to Shivnath Industry	21.228662, 81.392785
GW_7	Near to Beekay Industry	21.234581, 81.377448

About fifty thousand people come to Bhilai city in the Industrial area for employment because this city is surrounded by various industries. The work done at Bhilai is mainly in BSP. Other big and established units are Bhilai Engineering Corporation, Associated Cement Company (ACC), Simplex Engineering, Beekay Engineering, Jaypee Cement Bhilai and Automation etc. The sampling points are shown in Fig.-1.

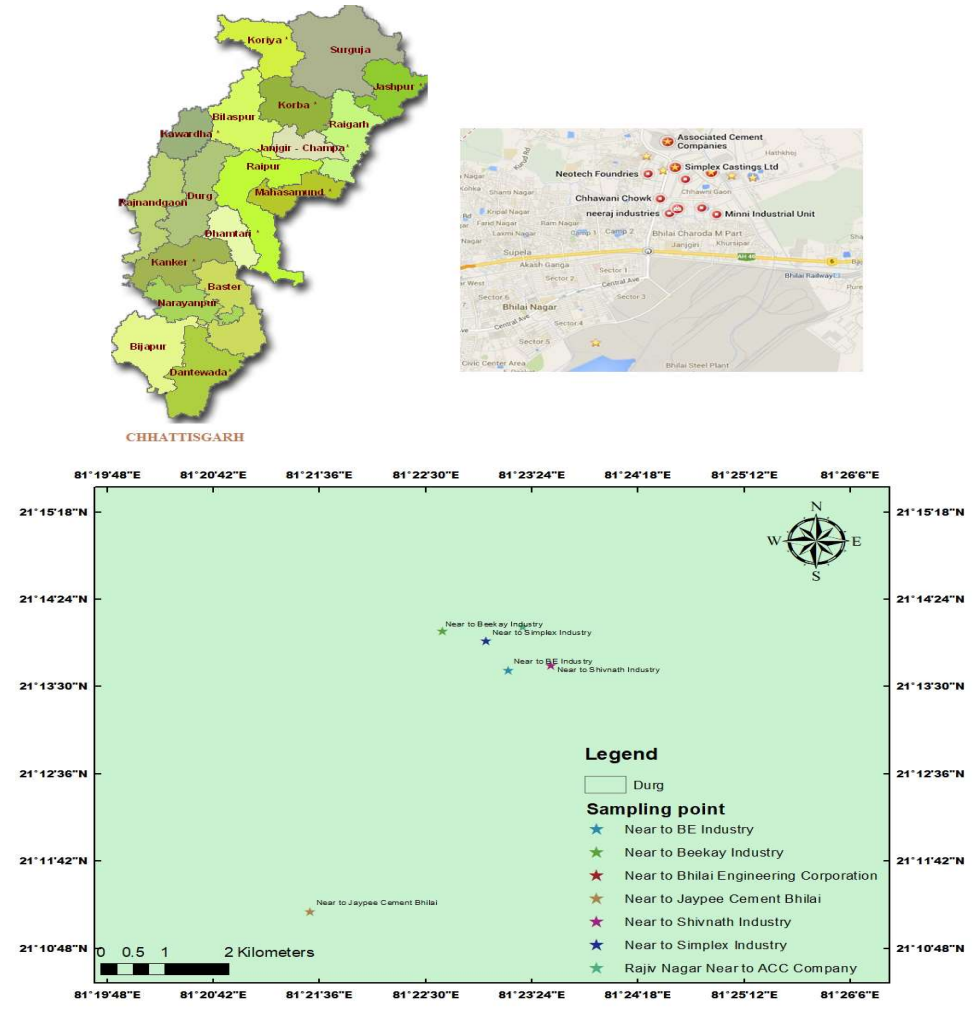

Fig.-1: Location of Study Spot Bhilai, Chhattisgarh India

Collection of Samples

The water samples were collected near to industrial area Bhilai from seven sampling points GW_1, GW_2, GW_3, GW_4, GW_5, GW_6 and GW_7. Polythene bottles were used for the collection of water samples, which were rinsed with 2% nitric acid and more than two times rinse with distilled water.[15] The sample bottles were immediately send in laboratory.[16-17] The standard methods were adopted for various water quality parameters. pH values of samples were determined by the apparatus of pH meter used with a buffer solution of 4, 7 and 9.2 pH. The turbidity meter was utilized for the measurement of turbidity of water

samples. Standard solutions of 200 NTU and 400 NTU were prepared by using Hydrazine sulphate and Hexamethylene Tetramine. TDS values were measured by TDS meter, whereas TS and TSS were analyzed by the classical method. EDTA method was adopted for the determination of Total Hardness, Magnesium and Calcium Hardness by using EBT and Patton and Reader as an indicator. Acid-Base titration method was used for estimation of Total Alkalinity and Total Acidity by the use of Phenolphthalein and Methyl-Orange as an indicator. Agentometric titration method was used for the determination of Chloride with the help of Standard N/50 Silver Nitrate solution. Winkler method was used for the analysis of DO contain in the water sample. For the determination of BOD, the BOD incubator was used to incubate the sample for 3 days at 27 °C. COD test was carried out by the Refluxing of the sample for 2 hours in the presence of excess acidified potassium dichromate solution.[18]

Water Quality Index

WQI (Water Quality index) is an essential tool for monitoring the quality of groundwater pollution. This index has been accepted as a rating because it can show the overall effect of the precise quality of water.[19] WQI gives information about a rating scale of zero to a hundred. The arithmetic water quality index is used to determine the status of water quality.[20] Eleven water quality parameters Total Dissolved Solids (TDS), pH, Chloride, Turbidity, Total Hardness, Total Alkalinity, Magnesium, Calcium, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) were selected for the assessment of WQI in this study.

Quality Rating and Weight

The quality of water has been examined by the view of the suitability of use by humans. The value of quality rating (Q_n) of nth water quality parameters (n = 1, 2, 3,.....11) was estimated by eqn.-1.

$$Qn = 100\left(\frac{Vn}{Sn}\right) \quad (1)$$

Where V_n = value of *n*th water quality parameter of sampling point and S_n = Standard acceptable value of *n*th water quality parameters.

For the calculation of the value of quality rating of pH and DO need separate equation. The standard value of pH for drinking is 6.5 to 8.5. So the value of quality rating of pH calculated by using eqn.-2.

$$Qn = 100\left[\frac{(VpH-6.5)}{8.5-6.5}\right] \quad (2)$$

Equation (3) used for calculation of the value of quality rating Q_{DO}.

$$Q(DO) = 100[(V(DO) - 14.6)/(14.6 - 5)] \quad (3)$$

The values of unit weight of nth water quality parameters:

$$Wn = k/Sn \quad (4)$$

Where W_n = value of unit weight of *n*th water quality parameter (n = 1, 2, 3.....11), k = proportionality constant

Measurement of Water Quality Index (WQI)

The Arithmetical Water Quality Index calculated by using the quality rating Q_n and the unit weight Wn. Equation (5) used for calculation of the overall value of WQI.[20-21]

$$WQI = \sum_{n=1}^{11} Qn.Wn / \sum_{n=1}^{11} Wn \quad (5)$$

The value of WQI shows the status of the quality of water and it only shows the quality of water by single values.

RESULTS AND DISCUSSION

The data obtained in terms of water quality from seven sampling locations are presented in Table-2. The Temperature of water has extreme ecological consequences.

Table-2: Experimental Values of Water Quality Parameters for the Study Areas

Sample Code	GW_1	GW_2	GW_3	GW_4	GW_5	GW_6	GW_7
Whether used for Drinking	YES	YES	YES	YES	YES	YES	YES
Depth of Water Level (feet)	200	250	180	300	220	280	250
Temperature	27.5°C	28°C	28.5°C	31°C	29.5°C	30.5°C	28.5°C
pH	7.78	7.3	7.16	6.86	7.02	7.33	7.13
TDS (ppm)	732	680	701	2150	973	450	750
TS (ppm)	1050	1100	1200	4100	3500	600	1000
TSS (ppm)	318	420	499	1950	2527	150	250
Turbidity (NTU)	3	5	6	7	7	5	6
Total Hardness (ppm)	60	260	265	865	365	205	325
Total Alkalinity (ppm)	320	300	310	280	300	260	250
Chloride (ppm)	68.16	88.75	92.3	599.95	142	49.7	88.75
DO (ppm)	25.6	22.4	20.8	19.2	25.6	22.4	22.4
BOD (ppm)	4.48	4.8	3.2	6.4	8	5.6	4.8
COD (ppm)	6.4	14.4	6.4	16	4.8	8	52.8
Calcium (ppm)	14	91.67	77.08	250	122	62.5	94
Megnesium (ppm)	6	9.62	19.23	63.7	14.42	13.2	21.63
Total Acidity (ppm)	15	15	15	25	20	10	10

The variation in groundwater and the atmospheric temperature influences by the specific heat of the water. In this study, the temperature of groundwater was found to be 27.5 to 31 degrees Celsius. The lowest Temperature recorded was 27.5°C in a water sample near to Jaypee Cement Bhilai; however, the maximum Temperature observed was 31 °C in a water sample from Rajiv Nagar near ACC Company. The temperature of the water body was enhanced due to the mixing of hot waste coming from industrial unit.[22] pH based on the concentration of hydrogen ions; it is a scale for the intensity of acidity and alkalinity of water. In the present investigation, pH values of the groundwater are neutral or close to it as they all were ranged from 6.86 to 7.78, which are within the permissible limits. Only one water sample has pH value 6.86 (less than 7), Sample from Rajiv Nagar, near ACC Company, Bhilai Industrial area. The maximum value recorded was 7.78 in the groundwater sample near Jaypee Cement Bhilai. TDS values are direct depends on inorganic salt and a low amount of organic compounds present in a sample of groundwater. This study represented a correlation between TDS vs. BOD, COD, Chloride, and Total Hardness; and shown by scatter plot in Fig.-2. It indicates a positive correlation among them except COD; this means as the value of TDS increased the value of BOD, Chloride and Total Hardness was also increased.[24]

The present study shows TDS value found to be range from 450 to 2150 ppm. The permissible level of TDS based on the WHO report is 500 ppm. TDS concentration below the permissible limit was found 450 ppm near to Shivnath Industry. Remain all samples have high TDS value as compared to an acceptable value. The maximum value of TDS was found to be 2150 ppm in Rajiv Nagar near to ACC Company, Bhilai Industrial area, which shows higher pollution in water. Total dissolved Solids include factors that produce disease and oxygen demanding waste, which can be health hazardous.[25] TS and TSS are also key factor for the determination of solid contamination in water samples. Turbidity directly measures the transparency of water. Turbid water is unfit for human consumption in terms of health hazardous. It ranges from 3 to 7 NTU/JTU. However, the standard value for drinking water of Turbidity is 5 NTU given by WHO. Values of Turbidity were found to be 3NTU, 5NTU, 6NTU, 7NTU, 7NTU, 5NTU and 6NTU in sampling points GW_1, GW_2, GW_3, GW_4, GW_5, GW_6 and GW_7 respectively. Total hardness indicates the hydrogeology and aesthetic quality of water. Hard water carries salt of Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+} are the most abounded in groundwater present in divalent and polyvalent metallic cations. Total Hardness values were observed from 60 to 865 ppm. The acceptable limit of Hardness in drinking water is 300 ppm. The highest value of Total Hardness recorded was 865 ppm in GW_4 sample, which indicates the water is unfit for drinking. The minimum value of Total Hardness observed was 60 ppm in the groundwater GW_1 sample. It represented a positive correlation with TDS. Calcium and Magnesium value

are high in groundwater because of rapid Industrialization, Urbanization and industrial waste because industries used calcium and magnesium compounds. In this investigation, calcium and magnesium values were recorded between 14 ppm - 250 ppm and 6 ppm - 63.70 ppm, respectively. In all samples, Phenolphthalein Alkalinity was nil, whereas Methyl Orange alkalinity was ranged between 250 to 320 ppm. For RCC work, Total Acidity should be less than 50 ppm. Total Acidity values were observed between 10 to 25 ppm. Chloride is widely distributed elements in all types of rocks.[19] Maximum value of Chloride observed 599.95 ppm in GW_4 sample. BOD value in the study area varied from 3.2 to 8.0 ppm. However, the acceptable value for BOD is 6 ppm prescribed by Indian Standard[23] and 5 ppm by WHO. The observed data indicated BOD values increase with the increase of TDS that formed a positive correlation. The COD estimates the total amount of oxygen used for oxidation of all organic compounds in water. The decomposition of organic compounds disturbs the aquatic life due to high COD value in water as a result of the depletion of oxygen.[7] The COD value recorded from 4.80 ppm to 52.80 ppm. However, the maximum acceptable limit of COD is 10 ppm prescribed by Indian Standard. The maximum value of COD was found 52.80 ppm in GW_7 sample. Based on the individual value of WQI, the status of water quality of the sampling points is shown in Table-3.

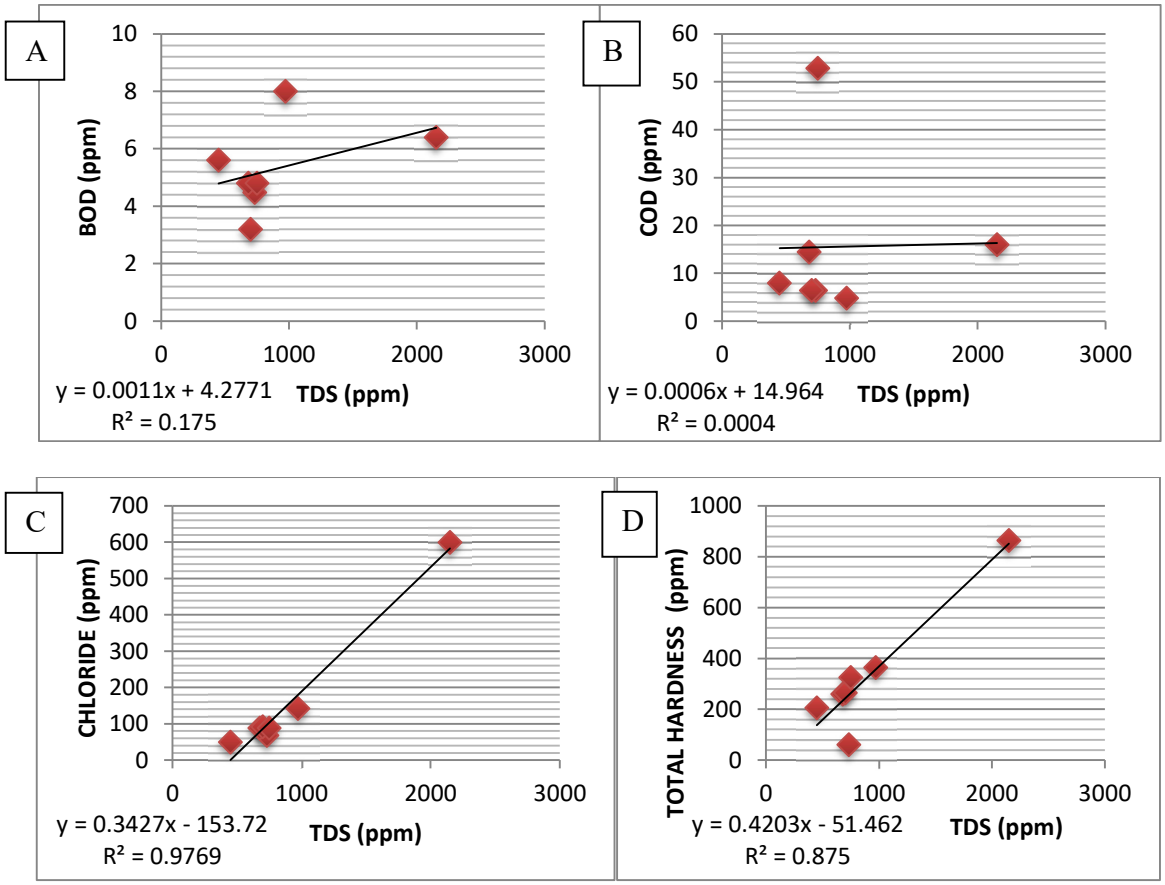

Fig.-2: Correlation between Water Quality Parameters

Standard values of Water Quality parameters recommended by Indian Standard/WHO with their potential effects are shown in Table-4. The quality of water is symbolized as a WQI. It found to be more than 100 in sample GW_4 and GW_7, which indicates the quality of water in that area found very poor and unfit for the consumption before proper treatment.

WQI found to be less than 100 in the remaining sample indicates the water quality of these areas have not polluted as compared to the above mentioned two areas, which have WQI more than 100. Variations of values of the Water Quality Index with their locations are shown in Fig.-3.

Table-3: Water Quality Index for the Sampling Locations

S. No.	Water Quality Parameters	Sampling Locations														
		W_n	G_1		G_2		G_3		G_4		G_5		G_6		G_7	
			Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$	Q_n	$Q_n.W_n$
1	pH	0.175	64	11.18	40	6.99	33	5.77	18	3.15	26	4.54	41.5	7.25	31.5	5.5
2	Total Dissolved Solid	0.003	146.4	0.38	136	0.36	140.2	0.37	430	1.13	194.6	0.51	90	0.24	150	0.39
3	Turbidity	0.262	60	15.73	100	26.21	120	31.45	140	36.7	140	36.7	100	26.21	120	31.45
4	Total Hardness	0.004	20	0.09	86.7	0.38	88.33	0.39	288.3	1.26	121.7	0.53	68.33	0.3	108.3	0.47
5	Total Alkalinity	0.007	160	1.05	150	0.98	155	1.02	140	0.92	150	0.98	130	0.85	125	0.82
6	Calcium	0.017	18.66	0.33	122	2.14	102.8	1.8	333.3	5.82	162.7	2.84	83.33	1.46	125.3	2.19
7	Magnesium	0.044	20	0.87	32.1	1.4	64.1	2.8	212.3	9.28	48.07	2.1	44.06	1.92	72.1	3.15
8	Chloride	0.005	27.26	0.14	35.5	0.19	36.92	0.19	240	1.26	56.8	0.3	19.88	0.1	35.5	0.19
9	Dissolved Oxygen	0.134	114.6	15.32	81.3	10.87	131.3	17.55	47.9	6.41	114.6	15.32	81.25	10.87	81.25	10.87
10	Biochemical Oxygen Demand	0.218	74.66	16.31	80	17.47	120	26.21	106.7	23.3	133.3	29.13	93.33	20.39	80	17.47
11	Chemical Oxygen Demand	0.131	64	8.39	144	18.87	64	8.39	160	20.97	48	6.29	80	10.48	528	69.2
		$\sum W_n$= 1.00	$\sum Q_n.W_n$ = 69.79		$\sum Q_n.W_n$ = 85.86		$\sum Q_n.W_n$ = 95.93		$\sum Q_n.W_n$ = 110.18		$\sum Q_n.W_n$ = 99.25		$\sum Q_n.W_n$ = 80.07		$\sum Q_n.W_n$ = 141.71	
Water Quality Index			69.79		85.86		95.93		110.18		99.25		80.07		141.71	

Table-4: Water Quality Parameters and their Potential Effects.

S. No.	Water Quality Parameter	Standard Values (WHO/IS)	Samples Code (where values found high as compare permissible limit)	Potential Effects	Reference
1	pH	6.5 - 8.5	Nil	Skin Disorder, affect mucous membranes, bitter test, Corrosion of metal	9, 26, 27
2	Total Dissolved Solid	500 ppm	GW_1, GW_2, GW_3, GW_4, GW_5, GW_7	Undesirable taste, Coronary heart disease, arteriosclerotic heart disease, Cardiovascular disease	9, 28
3	Turbidity	5 NTU	GW_3, GW_4, GW_5, GW_7	Increasing Micro-organisms, gastrointestinal illness and disease-causing bacteria's	29
4	Total Hardness	300 ppm	GW_1, GW_4, GW_5, GW_7	Cardiovascular disease, Risk of gastric cancer, Central nervous system, Alzheimer's disease, diabetes, Poor lathering with soap, deterioration of the quality of clothes, scale forming	12, 30
5	Total Alkalinity	200 ppm	All Samples	Digestion problems, Embrittlement of boiler steel, Boiled rice turns yellowish	9
6	Calcium	75 ppm	GW_2, GW_3, GW_4, GW_5, GW_7	Interference in dyeing, textiles, hypercalcemia	28
7	Magnesium	30 ppm	GW_4	Diarrhoea, hypermagnesaemia, Paper Industries affected	28
8	Chloride	250 ppm	GW_4	Hypertension, eye/nose irritation	9, 10
9	Dissolved Oxygen	5 to 14.6 Ppm	Nil	Corrode water lines, boilers and heat exchangers, low-level marine animals cannot survive.	31

10	Biochemical Oxygen Demand	6 ppm	GW_4, GW_5	Causes of Human health Problems, Decrease level of Oxygen.	26
11	Chemical Oxygen Demand	10 ppm	GW_2, GW_4, GW_7	Causes of Human Health Problems	31

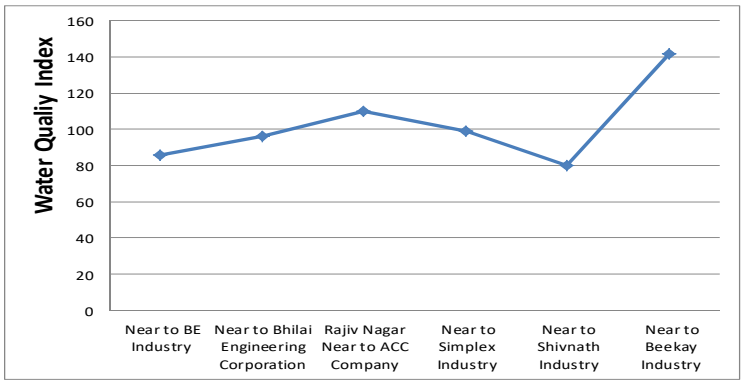

Fig.-3: Variation of Values of Water Quality Index with their Location

CONCLUSION

The present study indicates the water samples from near to BE industry, Bhilai Engineering Corporation, Simplex and Shivnath industry are not suitable for daily consumption due to very poor quality with high WQI. Among all water samples near the ACC Company and the Beekay industry are indicates the very worst quality due to the water quality index value is more than 100. Some water quality parameters are strong or weak associated with each other. Proper continue observation of water quality is required to monitor the suitability for drinking purposes. This study will be useful for policymakers for implementing monitoring industry wastewater treatment and management adopted in the industry. Authors suggest either the residence situated far away from industries or use properly treated water.

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