An Assessment of Groundwater Quality Index in Bommasandra, Bengaluru City, Karnataka State, India

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Abstract:- **Groundwater is a natural resource for drinking water .In addition to the population growth, urbanization and industrialization also extend the demand of water. Providing safe drinking water supply to the ever growing urban and sub-urban population is going to be a challenge to the civil authorities, city planners, policy makers and environmentalists. Groundwater is a major source of drinking water in both urban and rural areas of Bommasandra. Bommasandra city is rapidly raising population, changing lifestyle and intense competition among users- agriculture, industry and domestic sectors is driving the groundwater table lower. Besides, discharge of untreated wastewater through bores and leachate from unscientific disposal of solid wastes also contaminate groundwater, thereby reducing quality of fresh water resources.**

Keywords—Groundwater, Water quality standards, Water quality characteristics, Water quality index.

INTRODUCTION

Groundwater 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 unsanitary conditions through open drain carrying and disposing wastewater into natural water bodies. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating, reflecting the composite influence of different water quality parameters.

RESEARCH ARTICLE OPEN ACCESS

The present work is aimed at assessing the water quality index for the ground water samples of Bommasandra industrial area. The groundwater samples of about 16 samples were collected and subjected for a comprehensive physicochemical analysis. The purposes of this investigation are to provide an overview of present ground water quality for the following 12 parameters such as pH, total hardness, calcium, magnesium, chloride, nitrate, sulphate, total dissolved solids, iron, fluoride, alkalinity are to be considered for calculating the WQI. The results are analyzed by WQI method for predicting water quality. Water Quality Index (WQI) is a very useful and effective way for assessing the quality of water. WQI is a very useful tool for communicating the information on overall quality of water.

2. MATERIALS AND METHODS

2.1 Description of the study area

Bommasandra village is lies between latitude 12.80º N and 77.69º E is bounded on northwest by Hosur and on the north and northeast by Tumkur district, on the east by district and south by Krishna giri and Channapatna. Total geographical area of the district is Sqkms. The city is situated at an elevation of 450 m above MSL.

2.2 Population growth and density:

As per provisional reports of census India, population of Bommasandra in 2011 is 28353; of which male and female 15973 (56%) and 12380 (44%) respectively. In education section, total literates in Bommasandra city are 28353 of which 15973 are males while 12380 are females. Average literacy Bommasandra city are is 72% percent of which male and female literacy was 80% and 61% percent. Total children (0-6) in Bommasandra city are 2500 as per figure from Census India report on 2011. In Bommasandra city more than 85% of the population speaks kannada.

2.3 Geomorphology

The district is located in the southern maiden region of the state. The surface topography is in the form of undulating plain situated at an average elevation of 400-550m above MSL. The range of hills fallen a broken series of conspicuous peaks, which reach the altitude of 400m above MSL, 100 the general slope in the district is in Southeast direction.

2.4 Groundwater sampling in the Study area

Careful planning and preparation of a groundwater-sampling trip was made to save time and help reduce the number of difficulties that commonly occur with fieldwork. Correct sampling procedure begins with thorough preparation in the office and laboratory before sample collection. Each sample bottle is to be thoroughly cleaned and protected from any contamination during sample collection, preservation, and shipment to assure a high quality sample. Filtering equipment is to be rinsed thoroughly to remove any mineral deposits in hoses or support container vessels. The sample containers and hoses for organic analyses are to be acid-washed and rinsed several times with deionised water. Grab sampling has been adopted to collect groundwater samples. 16 groundwater samples were collected in polythene containers of 2 litres capacity for chemical analysis after pumping out sufficient quantity of water from the source such that, the sample collected served as a representative sample. The samples thus collected were transported to the laboratory condition.

2.5 Analysis of Groundwater Samples

The groundwater quality was assessed by the analysis of chemical parameters such as pH, Electrical Conductivity, Total Dissolved Solids, Alkalinity, Chlorides, Total Hardness, Calcium Hardness, Nitrates, Sulphates, Iron and Fluorides. The Bureau of Indian Standards (BIS) for drinking water quality for various parameters is presented in the table 2.The analytical methods used to measure chemical parameters of groundwater samples collected from all the sampling stations are listed in the table 1.The water samples were analysed adopting standard methods in the Environmental Laboratory.

3. PHYSICO-CHEMICAL ANALYSIS OF GROUNDWATER SAMPLES

All the reagents used were of analytical grade and solutions were made of distilled water. Various water quality parameters such as alkalinity, hardness, chlorides etc., were determined using standard analytical methods and procedures (table-1). The instruments used were calibrated before use for observing readings. The repeated measurements were made to ensure precision and accuracy of results.

Table 1: Methods Used for Groundwater analysis (Laboratory analytical methods) & Bureau of Indian Standards (BIS) for drinking water (IS 10500: 2003)

S.N	Physico-chemic Parameters	Methods	Characteristics	Desirable limit	Permissible limit
1	pH	Potentiometry (pH meter)	Colour, (Hazen units)	5	25
2	Conductivity	Conductivity prob	Odour	Unobjectionable	Unobjectionable
3	Alkalinity	Titration	Taste	Agreeable	Agreeable
4	Chloride	Titration	pH	6.5-8.5	No relaxation
5	Total Hardness	Complexometry b EDTA titration	Total hardness, mg/l	300	600
6	Calcium	Argentometry (Titration)	Iron (Fe), mg/l	0.3	1.0
7	Magnesium	Argentometry (Titration)	Manganese (Mn), mg/l	0.1	0.3
8	Total Dissolved Solids	TDS Probe	Chloride, mg/l	250	1000
9	Fluoride	Ion Analyser	TDS, mg/l	500	2000
10	Iron	Spectrophotometr	Calcium, mg/l	100	200
11	Nitrate	Spectrophotometr	Sulphate, mg/l	200	400
12	Sulphate	Spectrophotometr	Nitrate, mg/l	45	100

3. RESULTS AND DISCUSSIONS

In this chapter for the purpose of revealing the water quality of 16 bore wells of covering the study area have been established by determining the physical and chemical characteristics as per standard methods[4]. They have been listed systematically and represented in table2. The parameters viz., pH, total dissolved solids and Electrical conductivity know the physical characteristics of the ground water under the study area. The chemical characteristics of the ground water under the study area are known by the parameters viz., total hardness, calcium hardness, magnesium hardness, iron, fluoride, nitrate, chloride, sulfate, and alkalinity.

The **pH** of the groundwater samples are neutral or close to it as they all range from 6.7 to 7.4 which are within the permissible limits 6.5- 8.5 given by Indian Standards, also complies with standard 0f 7.0-8.0 given by WHO[17]. One of the main objectives in controlling pH is to produce water that minimizes corrosion or incrustation. These processes, which can cause considerable damage to the water supply systems, result from complex interactions between pH and other parameters, such as dissolved solids, dissolved gases, hardness, alkalinity, and temperature. The variation of pH in the study period is shown figure 3.1

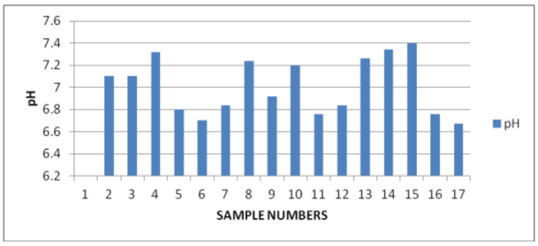


Figure 3.1: pH- Hydrogen ion concentration variations during the study period

The **Conductivity** of the groundwater in Sugar town, Mandya city ranges from 398-1038 µs/cm. Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. Water with high mineral content tends to have higher conductivity, which is a general indication of high dissolved solid concentration of the water[10]. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems. The variation of Electrical conductivity in the study period is shown figure 3.

Total dissolved solids level in ground water is 238.8-622 mg/L which exceeds the permissible limit of 500 mg/L as per Indian standards and 1000 mg/L as per WHO Standards. The term total dissolved solids refer mainly to the inorganic substances that are dissolved in water. The effects of TDS on drinking water quality depend on the levels of its individual components; excessive hardness, taste, mineral depositions and corrosion are common properties of highly mineralized water.
The variation of total dissolved solids in the study period is shown figure 3.2.

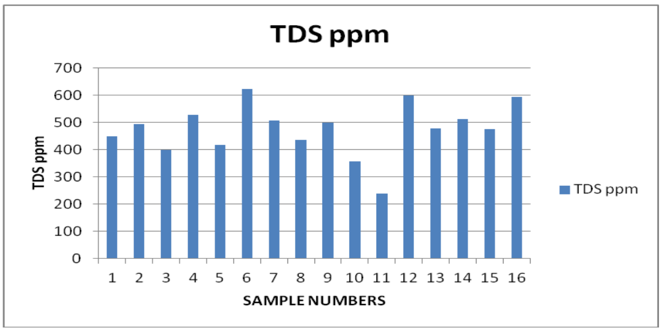


Figure 3.2: EC- Electrical conductivity, TDS- Total dissolved solids concentration variations during the study period

Total Hardness varies from 220-435 mg/L as CaCO3. The hardness values for the study area are found to be hard for almost all locations and determined to fall higher edge of the desirable limit of WHO specification and Indian standards. The variation of total alkalinity and total hardness in the study period is shown figure 3.3. Hardness is caused by polyvalent metallic ions dissolved in water, which in natural water are principally magnesium and calcium. So the adverse effects of such hard water are i. Soap consumption by hard water cause economic loss to water, ii. MgSO4 has laxative effects in person unaccustomed to it, iii. precipitation by hard water adhere to the surface of tubs and sinks and may stain clothing, dishes and other items[16].

Table-3: Classification of water based on hardness by Sawyer and McCarthy

Alkalinity of the samples are in the range of 286-399 mg/L. The alkalinity levels of all the water samples are high thus, resisting acidification of the groundwater samples. The variation of total alkalinity and total hardness in the study period is shown figure 4

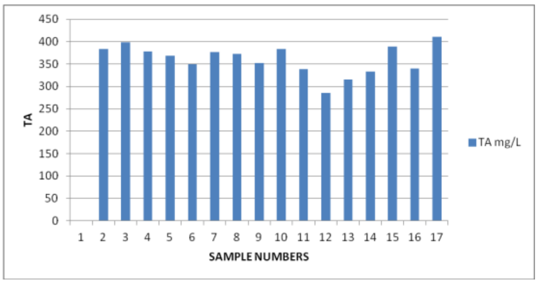


Figure 4: TH- Total Hardness, TA- Total Alkalinity variations during the study period

The presence of calcium in water results from its passage through the deposits of limestone, dolomite, gypsum and other calcium bearing rocks. Calcium contributes to the total hardness of water and is an important micro nutrient in aquatic environment. Small concentrations of calcium carbonate prevent corrosion of metal pipes by laying down a protective coating. But increased concentration of calcium precipitates on heating to form harmful scales in boilers, pipes and utensils. As per BIS and WHO standards, the permissible limit for calcium is 200 mg/l. In the present study, the groundwater samples have calcium concentration varying from 44-70.4 mg/l. Variation of calcium in the study area is shown in the figure 5

Magnesium is one of the abundant elements in the earth's crust, It is found in all natural waters and its source lies in rocks. It is an important element contributing to hardness and a necessary constituent of chlorophyll. High concentrations of magnesium reduce utility of water for domestic use, while a concentration above 500mg/l imparts an unpleasant taste to water and renders it unfit for drinking. As per IS 10500: (2003), the desirable limit of magnesium is 30 mg/l and permissible limit is 100 mg/l. In the present study, the groundwater samples have magnesium concentration varying from 24.48-62.16 mg/l. Variations of Magnesium in the study area is shown in the figure 5.

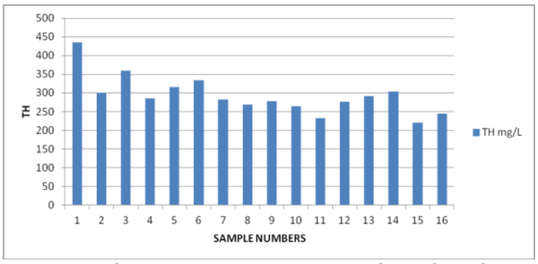


Figure 5: Ca- Calcium, Mg- Magnesium variations during the study period

Chloride present in ground water samples are in the range of 76.8-153 mg/L, which exceeds the permissible limit of 250 mg/L as per Indian standards as well as WHO Standards and this obviously affects the taste of the water. Similarly study of Chemical characteristics of groundwater in and around Bommasandra area chloride content is beyond the permissible limit[24]. This occurs may be due to saline water intrusion. Chloride is a widely distributed element in all types of rocks in one or the other form. Its affinity towards sodium is high. Therefore, its concentration is high in ground waters, where the temperature is high and rainfall is less. Soil porosity and permeability also has a key role in building up the chlorides concentration[17]. The variation of Chlorides in the study period is shown figure 6

Sulphate concentration in collected groundwater samples is ranged from 67.25-98 mg/l as in the permissible limit of 200mg/l as per Indian standards and 250mg/L as per WHO Standards. Health concerns regarding sulphate in drinking water have been raised because of reports that diarrhoea may be associated with the ingestion of water containing high levels of sulphate. The variation of Sulphate in the study period is shown figure 6

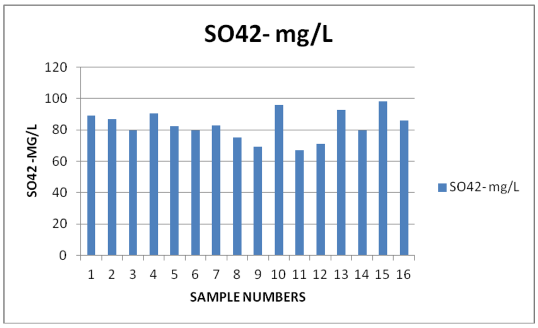


Figure 6: Cl- Chloride, SO_4- Sulphate variations during the study period

In the groundwater of Bommasandra **Nitrate** is varies from 4.31-6.91 mg/L which complies with the permissible limit of 45 mg/L as per Indian standards and 50 mg/L as per WHO Standards. Nitrates themselves are relatively non-toxic. Nitrogen essential component of amino acids, and therefore all proteins and nucleic acids, and therefore needed for all cell division and reproduction. The formation of nitrates is an integral part of the nitrogen cycle in our environment. Nitrate levels above 45 mg/l NO_3 may cause methemoglobinemia (Blue baby disease) in infants . The variation of Nitrate in the study period is shown figure7

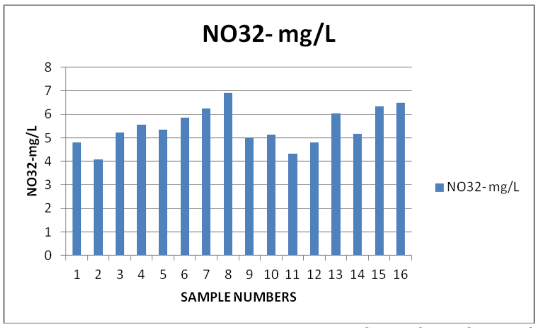
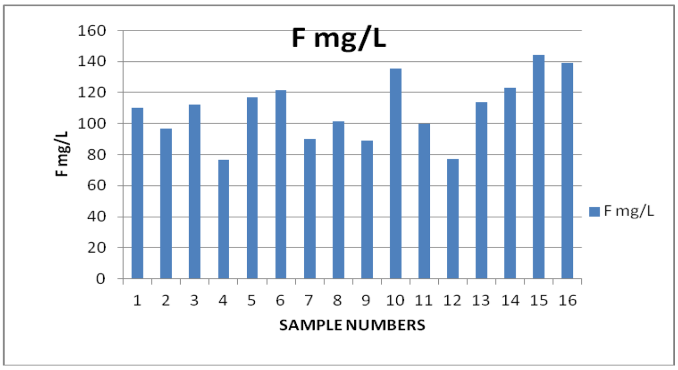


Figure 7: NO_3- Nitrate variations during the study period

The levels of **Flouride** in the groundwater samples ranged from 0.31-0.58 mg/L which are within the permissible limit of 1 mg/L as per Indian standards as well as WHO Standards.

The variation of fluoride is dependent on a variety of factors such as amount of soluble and insoluble fluoride in source rocks, the duration of contact of water with rocks and soil temperature, rainfall, oxidation- reduction process[12]. The presence of small quantities of fluoride in drinking water may prevent tooth decay. Fluoride is poisonous at high levels, and while dental fluorosis is easily recognized, skeletal damage may not be clinically obvious until advanced stages have occurred. Often, ground waters will contain more than 1.0 ppm, and in these cases, the water should probably be deflouridated for drinking. The variation of Fluoride in the study period is shown figure 8

Iron concentration of groundwater samples in the study area are varies from 0.31-0.58 mg/L and The Bureau of Indian Standards has recommended 0.3 mg/L as the desirable limit and 1.0 mg/L as the maximum permissible limit for iron in drinking water (BIS, 1991). Hence it is within the permissible limit. The ground water samples exhibited high Iron contamination which is an indication of the presence ferrous salts that precipitate as insoluble ferric hydroxide and settles out as rusty silt. High concentration of iron is may contributed by industrial estate located at the sampling site, Iron is an essential element in human nutrition**.** At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and cause undesirable tastes. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coat in piping[14] .The variation of Iron in the study period is shown figure 8



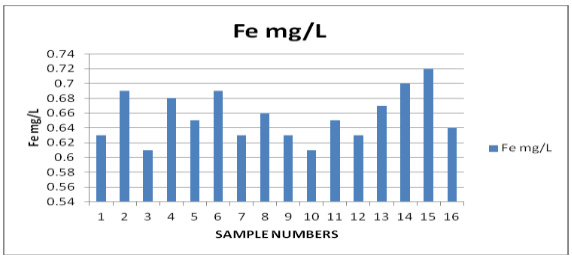


Figure 8: F- Fluoride, Fe- Iron variations during study period

Table-4: Comparison of groundwater quality with drinking water standards, Indian and WHO

Parameters	Indian Standard	Percentage compliance	WHO Standard
pH	6.5-8.5	100	7.0-8.0
TH, mg/L	300	100	100
Ca^{2+} ,mg/L	75	0	75
Mg^{2+},mg/L	30	100	30
Cl^- , mg/L	250	100	250
TDS, ppm	500	100	1000
Fe, mg/L	0.3	83	0.1
F, mg/L	1.0	100	1.0
NO_3^2,mg/L	45	100	50
SO_4^2,mg/L	200	100	250
TA, mg/L	200	100	-

Estimation of Water Quality Index (WQI)

For computing WQI three steps are followed. In the first step, each of the all parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (table-7). The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium which is given the minimum weight of 1 as magnesium by itself may not be harmful. In the second step, the relative weight (Wi) is computed from the following equation:

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

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.

Calculated relative weight (Wi) values of each parameter are also given in table-7 In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration of each water sample by its respective standard according to the guideline laid down in the BIS 10500 and the result is multiplied by 100.

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

Where, qi is the quality rating,

Ci is the concentration of each chemical parameter of each water sample in mg/l, Si is the standard value for each chemical parameter, mg/l according to the guidelines of BIS (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 using the following equation

$$SI_I = W_I * Q_I$$

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

Where, SI_i is the sub index of Ith 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 5 types and are as shown in table 6.

Table 6: Relative weight (Wi) of Chemical parameters

Table 6: Water quality classification based on WQI value

WQI Value	Water Quality
<50	GOOD
50-100	POOR
100-200	VERY POOR
>200	Water Unsuitable for drinking

Sl. Nos	Parameters	Indian Standards	Weightage (w_i)	Relative Weight (W_i)	Quantity Rating (q_i)	Sub Index (SI_i)
1	pH	6.5-8.5	4	0.0952	78.4	7.4
2	EC, µS/cm	2000	4	0.0952	76.36	7.27
3	TDS, ppm	500-1500	4	0.0952	76.36	7.27
4	TH, mg/L	300-600	3	0.0714	67.39	4.81
5	Ca^{2+}, mg/L	75-200	2	0.0476	79.40	3.77
6	Mg^{2+}, mg/L	30-100	2	0.0476	58.85	2.80
7	Fe, mg/L	0.3-1.0	4	0.0952	75.53	7.19
8	TA, mg/L	200-600	3	0.071	87.83	6.23
9	Cl^-, mg/L	250-1000	3	0.071	73.28	5.19
10	F, mg/L	1-1.5	4	0.0952	91.05	8.66
11	NO_3^{2-}, mg/L	45-100	5	0.119	78.91	9.39
12	SO_4^{2-}, mg/L	200-400	4	0.0952	84.63	8.05
			w_i=42	W_i=0.998	q_i=928	WQI=78.03

Sample no	pH	EC µs/cm	TDS ppm	TH mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Cl mg/L	TA mg/L	F mg/L	Fe mg/L	NO_3^{2-} mg/L	SO_4^{2-} mg/L
B1	7.1	750	450	**435**	**70.4**	**62.16**	137	384	0.63	0.38	4.8	89.2
B2	7.1	825	495	300	64	33.6	115	**399**	0.69	0.42	4.08	86.9
B3	7.32	666	399.6	360	63.2	48.48	**76.8**	378	0.61	0.44	5.23	79.6
B4	6.8	882	529.2	286	48.8	39.36	152	369	0.68	0.42	5.54	90.5
B5	**6.7**	697	418.2	315	68	34.8	110.2	350	0.65	0.46	5.35	82.3
B6	6.84	**1038**	**622.8**	334	66.4	40.32	96.8	376	0.69	0.52	5.84	79.82
B7	7.24	844	506.4	282	56.8	33.6	112.3	372	0.63	0.50	6.24	83
B8	6.92	725	435	269	60	36	76.8	352	0.66	0.54	**6.91**	75
B9	7.2	833	499.8	278	55.2	33.12	121.6	384	0.63	0.56	5.01	69.5
B10	6.76	596	357.6	264	48	28.8	88.9	338	**0.61**	**0.58**	5.12	96.1
B11	6.84	**398**	**238.8**	232	**44**	29.28	135.9	**286**	0.65	**0.31**	**4.31**	**67.25**
B12	7.26	998	598.8	277	44	40.08	99.8	316	0.63	0.42	4.81	71.2
B13	7.34	798	478.8	291	49.2	40.32	123	333	0.67	0.44	6.02	93
B14	**7.4**	852	511.2	303	67.6	32.16	144	389	0.70	0.33	5.15	79.65
B15	6.76	792	475.2	**220**	40.8	**24.48**	139	340	**0.72**	0.35	6.35	**98**
B16	6.67	989	593.4	245	48	28.8	**153**	411	0.64	0.37	6.49	86

4. CONCLUSIONS

The results indicate that most of the borewell water quality parameters were beyond the permissible limits in the industrial area and its enviorns. The overall view of the WQI of the present study zone had a poor WQI value. For any borewell water quality treatment programme the point of consideration is to bring the WQI below 100 so as to achieve poor quality of life. Therefore compressive sewerage system for safe disposal of wastes should be developed to safeguard ground water quality in the study area. The borewell water is crystal clear, odourless and palatable and at few sample points are of the salty taste. Borewell water is moderately hard in almost all the sampling points. The total hardness exceeds the permissible limit at many places in about 16 sampling station. The higher hardness is mainly due to disposal of municipal and sewage waste. The ground water samples in Bommasandra industrial area and its environs have TDS within the permissible limit. The results of physicochemical analysis of ground water of Bommasandra industrial region for year 2015 shows that observed mean pH values in Bommasandra industrial region are within the permissible limit. Based on the analysis of groundwater, higher concentrations of iron were observed and lower the concentrations of fluoride were recorded in the study area. Some of the samples have EC, total dissolved solids, hardness, TA, and sulphate values exceeding the permissible limits as the prescribed by Indian Standards. However the WQI values in the present investigation were reported to be less than 100 (ie.,78.03) for different samples indicating that the water is safe for human consumption.

At the few places there is considerable increase in chloride. This shows that there is a possibility of contamination of borewell water due to percolation of polluted surface water. Higher values of iron, nitrate, TDS, hardness, fluoride, and chloride in borewell water were observed at few sampling points. This reason may be due to contamination of sewage and drainage water. From the WQI of the water of Bommasandra is considered as POOR WATER.

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5. REFERENCES

[1] Mangukiya R., Bhattacharya T., and Chakraborty S (2012),"Quality Characterization of Groundwater using Water Quality Index in Surat city, Gujarat, India", International Research Journal of Environment Sciences, 1(4): 14-23

[2] Nagarajappa D P., Rajappa B., Manjappa s., and Puttaiah E T., (2011), "Physico chemical analysis of underground water of Harihara taluk of Davanagere district, Karnataka, India", Advances in applied science research, 2(5): 143-150

[3] Shivasharanappa., Srinivas P., and Mallikarjun Huggi S (2011), "Assessment of ground water quality characteristics and Water Quality Index (WQI) of Bidar city and its industrial area, Karnataka State, India", International journal of environmental sciences, 2(2): 965-976

[4] APHA, American Public Health Association (2003), standard method for examination of water & wastewater specifications, Washington DC, 6, 19th Edition.

[5] Bureau of Indian Standards, 1993, (IS 10500:1991), Edition 2.1

[6] WHO (World Health Organization) Guidelines for drinking water quality (1993), second edition, Vol. 1, 188.

[7] Shivasharanappa., Srinivas P., and Mallikarjun Huggi S (2011), "Study on physic-chemical characterictics of ground water of Bidar city and its Industrial area", International journal of applied biology and pharmaceutical technology, 3(1): 359-367

[8] Nirdosh P, Ahmed A, Sureshbabu H, Kottureshwar N M, Jayashree M., and Nijalingappa J. (2010), "Study on the PhysicoChemical characteristics of ground water of Gulbarga City (Karnataka)" International.

[9] Rui Lin, Philippa A. Martin, and Desmond P. Taylor, "Approximate Gaussian Density Evolution Based Analysis of Distributed and Adaptive Turbo Codes," in IEEE Transactions on Communications, Vol. 60, No. 8, August 2012.