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A Physico-Chemical Analysis of Groundwater Quality Index in Sugartown Area, Mandya

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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 Mandya. Mandya 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.

The present work is aimed at assessing the water quality index for the ground water samples of Sugar town, Mandya city. The groundwater samples of about 40 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.*

Keywords: *Groundwater, Water quality standards, Water quality characteristics, Water quality index*

1. 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. WQI is calculated from the point of view of the suitability of groundwater for human consumption. The objective of the present work is to discuss the suitability of groundwater for human consumption based on computed, groundwater characteristics, quality assessment and water quality index values.

2. MATERIALS AND METHODS

2.1 Description of the study area

Mandya district is lies between North latitude 12013' to 13004' and East longitudes 76019' to 77020' and is bounded on northwest by Hassan district, on the north and northeast by Tumkur district, on the east by Ramanagar district and south by Mysore and Chamarajnagar district. Total geographical area of the district is 4961 Sqkms. The city is situated at an elevation of 669.47 m above MSL.The district is divided into seven taluks coming under two subdivisions (Mandya and Pandavapura). The Mandya subdivision comprises Mandya, Maddur and Malavalli taluks. The Pandavapura subdivision comprises of Pandavapura, Srirangapattana, Nagamangala and K.R.Pet taluks.

2.2 Population growth and density

As per provisional reports of Census India, population of Mandya in 2011 is 1,37,735; of which male and female are 68,748 and 68,987 respectively. The sex ratio of Mandya city is 1003 per 1000 males. In education section, total literates in Mandya city are 105,938 of which 55,442 are males while 50,496 are females. Average literacy rate of Mandya city is 85.11 percent of which male and female literacy was 89.54 and 80.74 percent. Total children (0-6) in Mandya city are 13,269 as per figure from Census India report on 2011. There were 6,826 boys while 6,443 are girls. Child sex ratio of girls is 944 per 1000 boys. In Mandya city more than 99% of the population speaks Kannada.

Mandya City Municipality Council (CMC) is spread up to 17.03 Sq.km in which 1, 37,735 persons reside. The population density on an average in 8,629 per Sq.km which is thickly populated and the city is developing steadily; the projected population growth in the CMC is given in the Table2.1. Since the city is the district head quarter the floating population is moderate and works out to be 15000 per day. Table3.2 shows details of ward wise population distribution and there components, these details will be use full to design solid waste management system.

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 750- 900m above MSL. There are few sporadic out crops of rocks as hills and few fertile shallow valleys. In the south-eastern part of the district the Biligirirangana hill ranges extending from Mysore District tapers off here. In this portion Cauvery river breaks through the hill ranges and forms the famous Gaganachukki and Barachukki waterfalls. The Melukote range of hills fallen a broken series of conspicuous peaks, which reach the altitude of 1159m above MSL, 1064m above MSL, 1050m above MSL and 1046m above MSL.The Hulikere-Kartigatta hill range near S.R.Patna and bold rugged low peaks near Sindhugatta are also conspicuous. 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. 10 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.

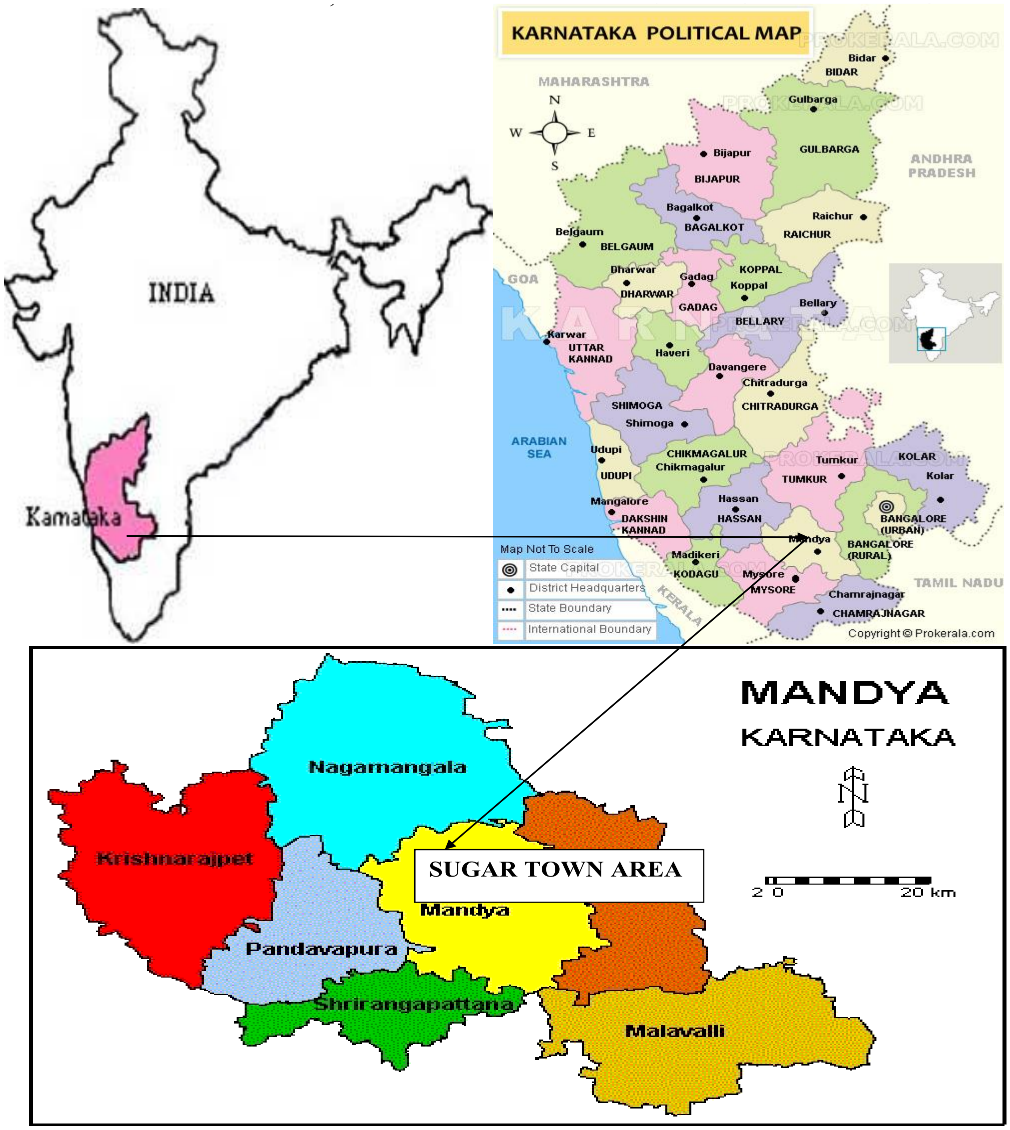

Figure: 1

2.6 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)

Sl. No	Physico-chemical Parameters	Methods
1	pH	Potentiometry (pH meter)
2	Conductivity	Conductivity probe
3	Alkalinity	Argentometry (Titration)
4	Chloride	Argentometry (Titration)
5	Total Hardness	Complexometry by EDTA titration
6	Calcium	Argentometry (Titration)
7	Magnesium	Argentometry (Titration)
8	Total Dissolved Solid	TDS Probe
9	Fluoride	Ion Analyser
10	Iron	Spectrophotometry

11	Nitrate	Spectrophotometry
12	Sulphate	Spectrophotometry

Table 2: Bureau of Indian Standards (BIS) for drinking water (IS 10500: 2003)

Sl. No.	Characteristics	Desirable limit	Permissible limit
1	Colour, (Hazen units)	5	25
2	Odour	Unobjectionable	Unobjectionable
3	Taste	Agreeable	Agreeable
4	pH value	6.5-8.5	No relaxation
5	Total hardness (mg/l as $CaCO_3$)	300	600
6	Iron (Fe), mg/l	0.3	1.0
7	Manganese (Mn), mg/l	0.1	0.3

8	Chloride, mg/l	250	1000
9	Total dissolved solids, mg/l	500	2000
10	Calcium, mg/l	100	200
11	Sulphate, mg/l	200	400
12	Nitrate, mg/l	45	100
13	Fluoride, mg/l	-	1.5
14	Alkalinity, mg/l	200	600
15	Mercury, mg/l	0.001	-
16	Cadmium, mg/l	0.01	-
17	Lead, mg/l	0.05	-
18	Zinc, mg/l	5	15

3. RESULTS AND DISCUSSIONS

In this chapter for the purpose of revealing the water quality of 10 bore wells of covering the study area have been established by determining the physical and chemical characteristics as per standard methods4. 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.

pH

pH is a measure of the hydrogen ion concentration of water. It is also chemical parameter being used in the assessment of borewell water quality. Bureau of Indian Standards (BIS) prescribes a pH range of 6.5-8.5 for drinking water. The table 4.1 to 4.3 shows the arithmetic mean value of the pH and Fig 4.21 shows the variation of arithmetic mean value of pH of borewell water.

The range of pH values in the study area was 6.7 to 7.24. The results of pH are within the desirable limits of BIS for drinking water in all the stations of around the sugar industries.

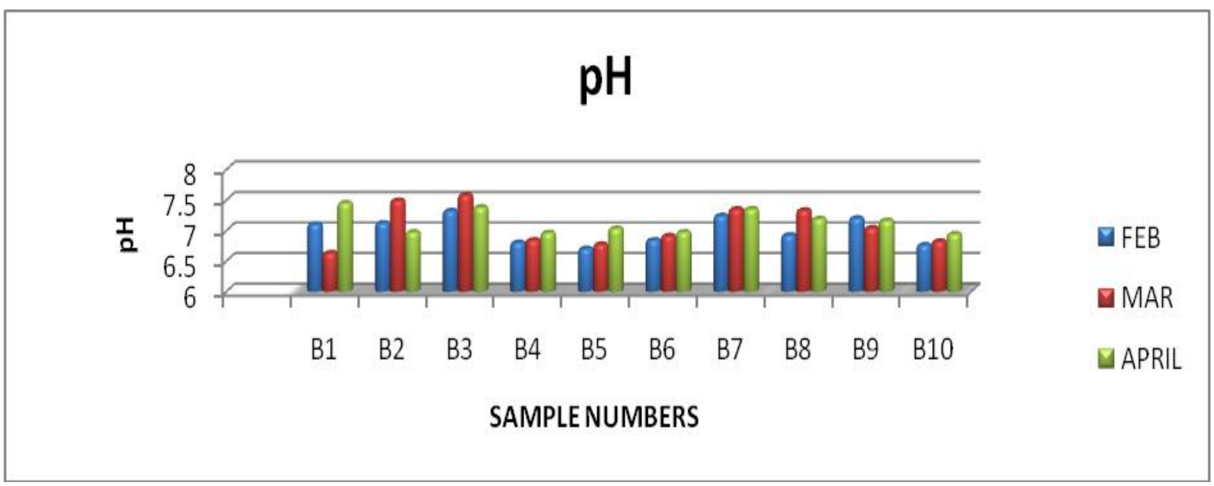

Figure 4.21: pH variation of groundwater Samples from 1-10

4.2.2 Electrical Conductivity (EC)

Electrical conductivity estimates the dissolved salts in water. Most of the inorganic salts, acids and bases when dissolved in water make it is a good conductor but organics do not change in conductivity samples may signal; changes in mineral composition of raw water and intrusion of domestic water. The variation of arithmetic mean value of EC was presented in table 4.1 to 4.3 and shown in Fig 4.2.

The desirable limit for Electrical Conductivity for drinking water is 2000 µS/cm (BIS 1991). Electrical Conductivity of the borewell water samples in the study area were in the range from 596 to 1038 µS/cm. The minimum value is 596 µS/cm and maximum value is 1038 µS/cm. The results of Electrical Conductivity are within the desirable limits of Bureau of Indian Standards (BIS) for drinking water in all stations. **See Figure 4.24**

4.2.3 Total Dissolved Solids (TDS)

In natural water, dissolved solids consists mainly of inorganic salts such as carbonates, bicarbonates, sulphates, phosphate, and nitrate of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases.

From the table 4.1 to 4.3 shows the variation of average value of total dissolved solids. Fig 4.3 depicts the variation of arithmetic mean value of total dissolved solids of borewell water. In the borewell water samples of the study area, the values of total dissolved solids vary from 399.6 to 622.8 mg/l in the study area.

The values of total dissolved solids of the study area exceed the desirable limits of 500 mg/l suggested by BIS for drinking water. Water containing more than 500 mg/l of total dissolved solids is not considered as desirable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500mg/l as the desirable limit and 2000 mg/l as the maximum permissible limit has been suggested for drinking water (BIS, 1991).

See Figure 4.25

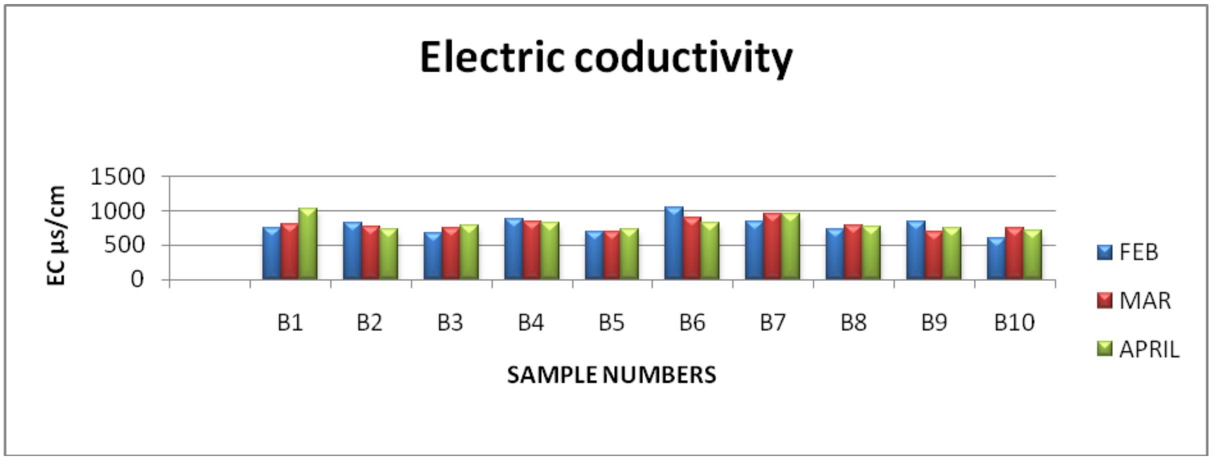

Figure 4.24: Electrical conductivity variation of groundwater Samples from1-10

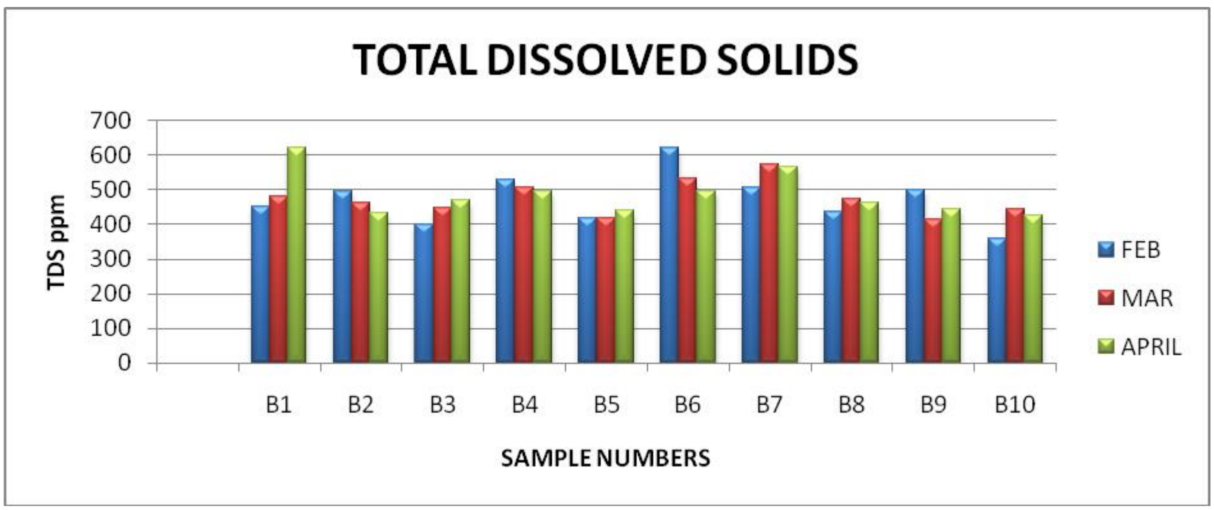

Figure 4.25: Total dissolved solids variation of groundwater Samples from 1-10

4.2.4 Total Hardness (TH)

Calcium and magnesium along with their carbonates, sulphates and chlorides make the water hard. The desirable limit is 300 mg/l and 600 mg/l as maximum permissible limit has been recommended for drinking water for total hardness (BIS, 1991).

From the table 4.1 to 4.3 shows the variation of average value of total hardness, calcium hardness, magnesium hardness. Fig 4.4 depicts the variation of arithmetic mean value of total hardness, calcium hardness, and magnesium hardness of borewell water. The total hardness values in the study area range from 264 to 435 mg/l for various sampling stations. The total hardness for all the samples exceeded the desirable limit. The desirable limit for calcium hardness and magnesium hardness for drinking water are 150 and 75 mg/l respectively (BIS, 1991). In borewell water study area, the values of calcium hardness and magnesium hardness range from 110 to 360 mg/l and 114 to 225 mg/L respectively.

Calcium hardness exceeding the desirable limits of 150 mg/l and magnesium hardness in all the station exceeds the desirable limit of 75 mg/l.

4.2.5 Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

The desirable limit for calcium and magnesium for drinking water are 75 and 30 mg/l and the maximum permissible limit for calcium and magnesium for drinking water are 200 and 100 mg/l respectively (BIS,1991). In the study area the value ranges 48 to 70.24 mg/l and 23.76 to 62.16 mg/l. Fig 4.5 depicts the variation of arithmetic mean value of calcium and magnesium of borewell water. About all the samples of the study area, during the study period for calcium fall above the desirable limit of 75 mg/l and magnesium fall above the desirable limit of 30mg/l.

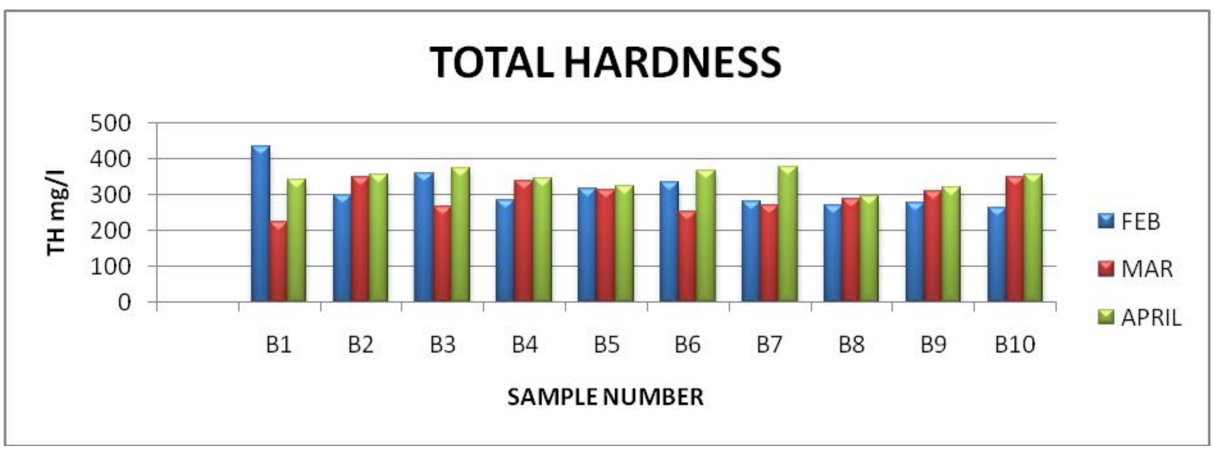

Figure 4.27: Total hardness variation of groundwater Samples from 1-10

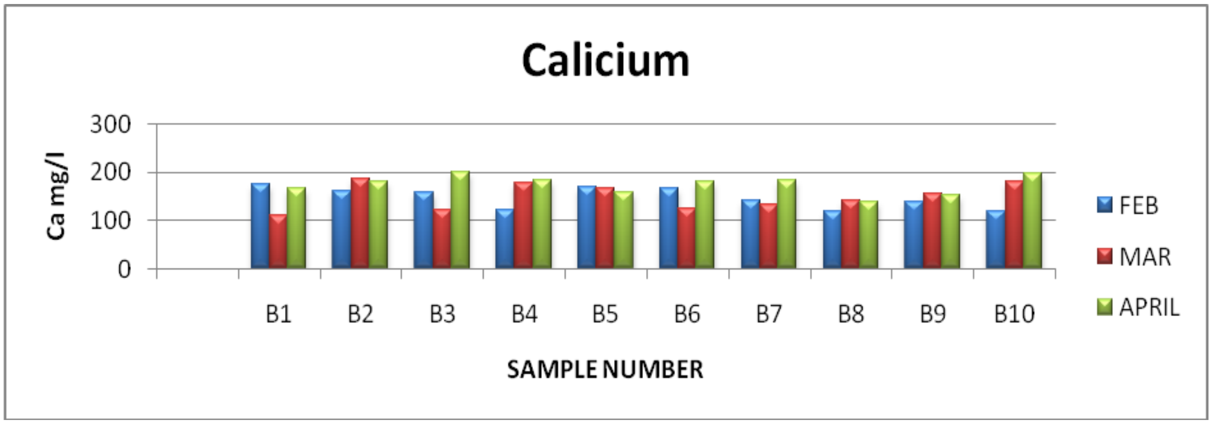

Figure 4.29: Calcium variation of groundwater Samples from 1-10

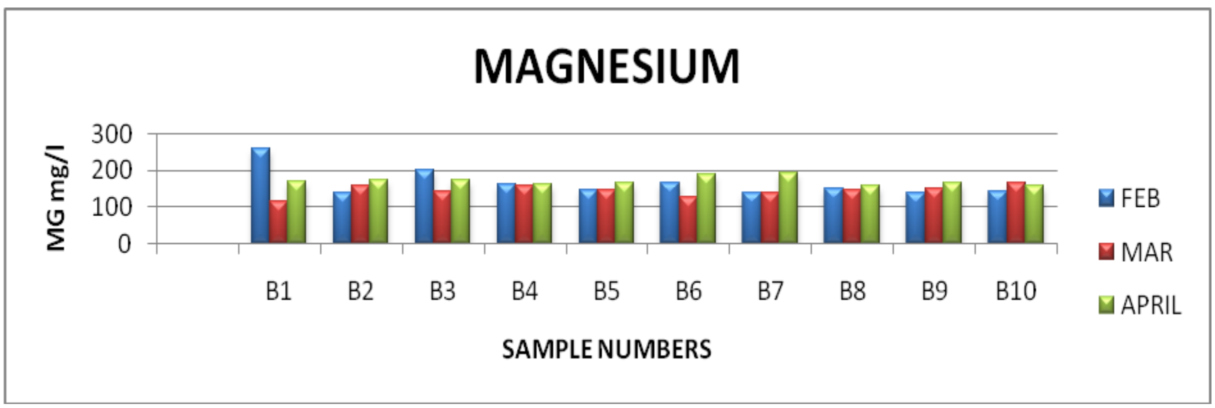

Figure 4.31: Magnesium variation of groundwater Samples from 1-10

4.2.6 Total Alkalinity (TA)

The presence of carbonates, bicarbonates and hydroxide are the main cause of alkalinity in natural water. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonate upon the basic materials on the soil. Fig 4.6 depicts the variation of arithmetic mean value of total alkalinity in the study area. The arithmetic mean value of total alkalinity is tabulated in the table 4.1 to 4.5.Total alkalinity value ranges from 338 to 399 mg/l.All samples of study area exceeded the desirable limit of 200 mg/l of BIS 10500:1991.

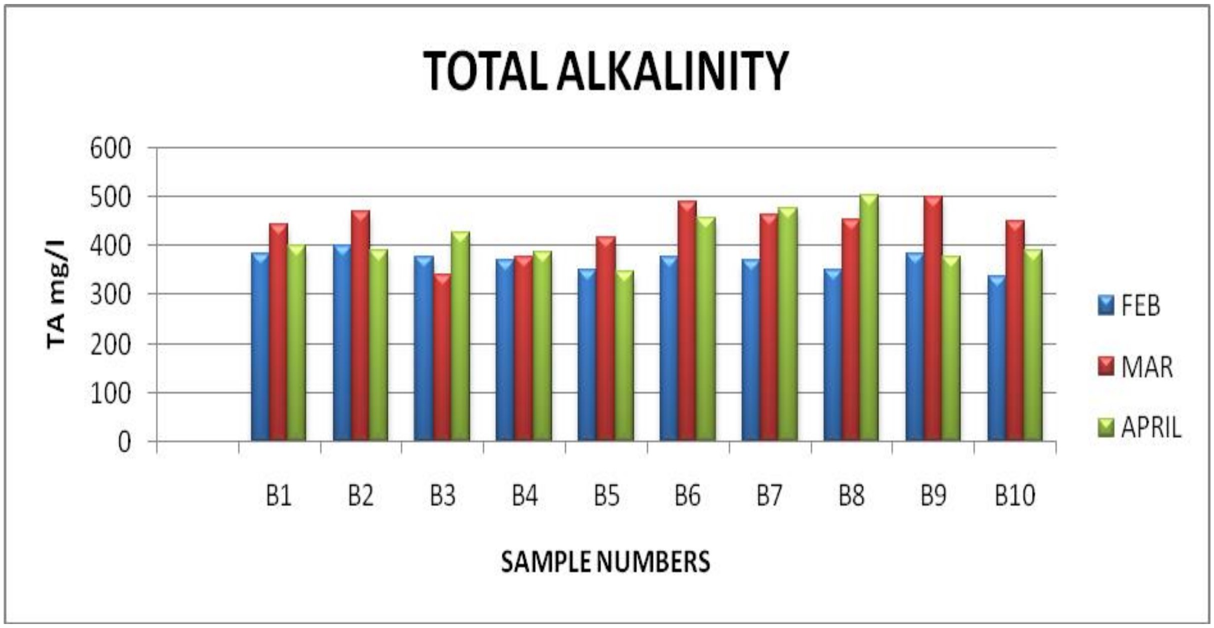

Figure 4.34: Total alkalinity variation of groundwater Samples from 1-10

4.2.7 Chloride (Cl^-)

Table 4.1 to 4.6 shows the variation of average value of chloride of borewell water. Fig 4.7 shows the variation of arithmetic mean value of chloride of borewell water. The concentration of chloride groundwater of the study area varies from 76.5 to 135.8 mg/l for various sampling stations. The desirable limit for the chloride is 250mg/l and 1000 mg/l as maximum permissible limit for drinking water has been recommended (BIS,1991). All the samples were found to be lower than the desirable limit of 250mg/l. **See Figure 4. 36**

4.2.8 Sulphate (SO_4^{2-})

From the table 4.1 to 4.3 shows the variation of average value of sulphate of borewell water.

Fig 4.8 depicts the variation of arithmetic mean value of sulphate of borewell water. The concentration of sulphate varies from 75 to 90.5 mg/l. The desired limit of sulphate is 200mg/l and maximum permissible limit of 400 mg/l suggested by BIS for drinking water (BIS, 1991). The values of sulphate are found lower than the desirable limit of 200 mg/l. **See Figure 4.37**

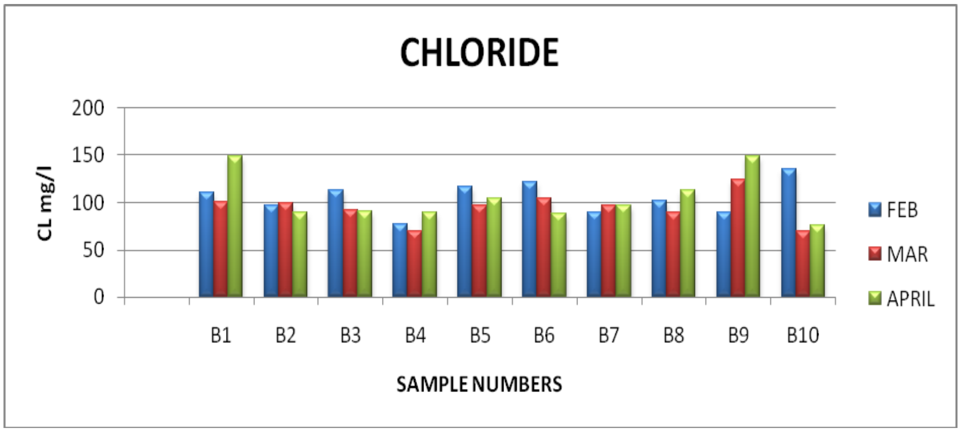

Figure 4.36: Chloride variation of groundwater Samples from 1-10

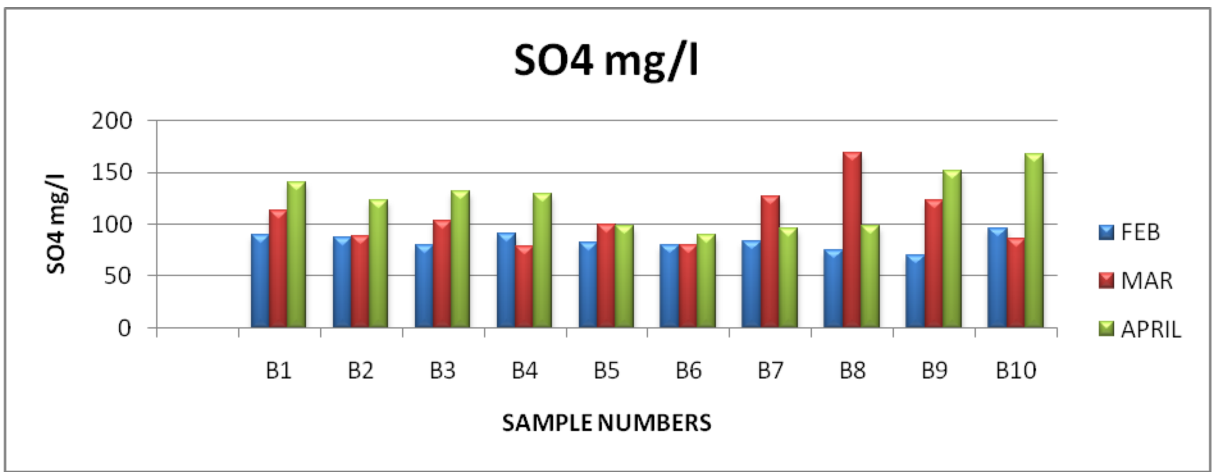

Figure 4.37: Sulphate variation of groundwater Samples from 1-10

4.2.9 Nitrate (NO_3^-)

Nitrate content in drinking water is considered important for its adverse health effects. The occurrence of high levels of nitrate in borewell water is prominent problem in many parts of the country. Water containing large amounts of nitrates (more than 100 mg/l) is bitter tasting and may cause physiological distress. Small amount of nitrate reduce cracking of high pressure boiler steel.

From the 4.1 to 4.3 shows the variation of average value of nitrate of borewell water.

Fig 4.9 depicts the variation of arithmetic mean value of nitrate of groundwater. The concentration varied from 4.08 to 6.91 mg/l and nitrate concentration in all the samples are within the desirable limits (45 mg/l) prescribed by BIS 10500:1991. The presence of nitrate indicates that there is past movement of pollutants. **See Figure 4.40**

4.2.10 Fluoride

The Fluoride content in the borewell water of the study area varies from 0.61 to 0.69 mg/l for various sampling stations. A limit of 0.6-1.2 mg/l fluoride has been recommended as desirable limit and 1.5 mg/l as the maximum permissible limit for drinking water. In the study area, all the samples analysed fall within the desirable limit. The variations of arithmetic mean value of fluoride of groundwater as shown in Fig 4.10.

The concentration of fluoride in drinking water is critical when considering health problems related to teeth and bones. Fluoride ions have dual significance: high concentration of fluoride causes dental fluorisis, concentration less than 0.8 mg/l results in dental carriers. **See Figure 4.41**

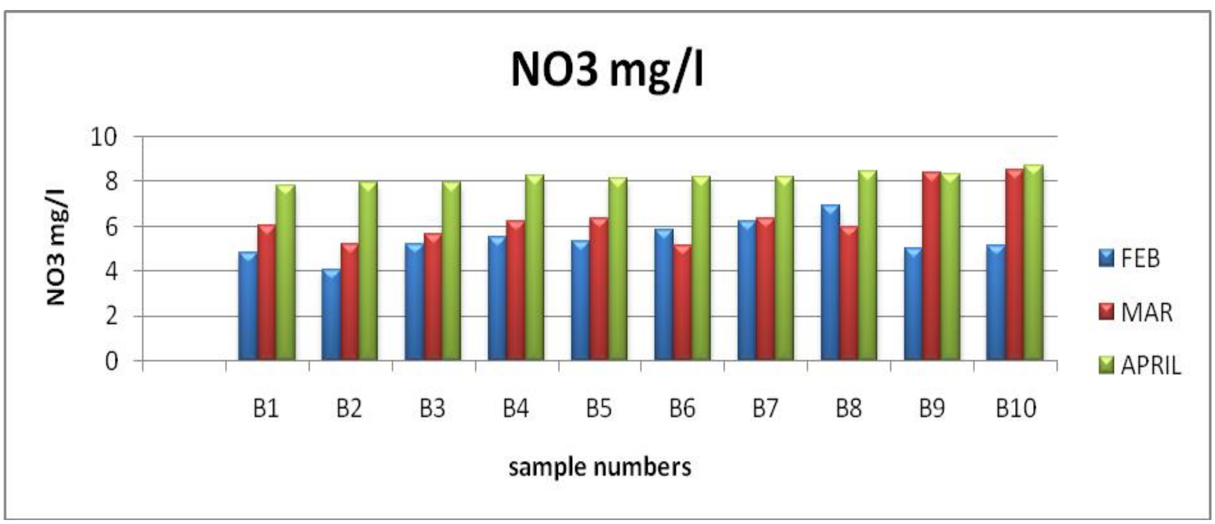

Figure 4.40: Nitrate variation of groundwater Samples from 1-10

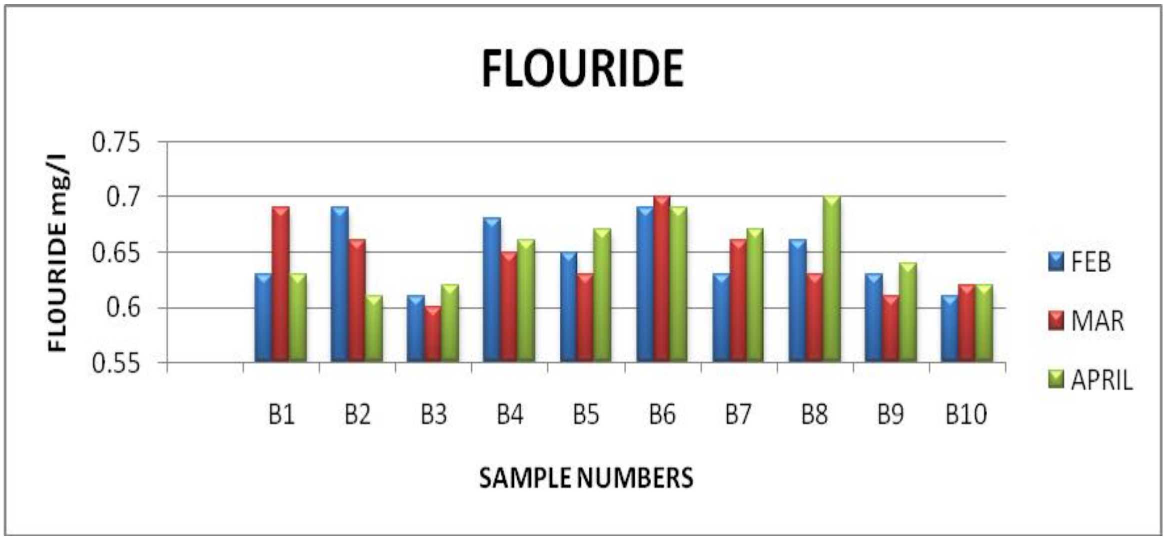

Figure 4.41: Fluoride variation of groundwater Samples from 1-10

4.2.11 Iron

From the table 4.1 to 4.5 shows the variation of average value of iron. Fig 4.11 shows the variation of arithmetic mean value of iron of borewell water. The concentration of iron in groundwater of the study area ranges from 0.32 to 0.58 mg/l. Distribution of iron in the groundwater of the study area indicates that all the samples fall above the desirable limit of 0.3 mg/l but is within the maximum permissible limit of 1.0mg/l.

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).

High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. It can also discolour clothes, plumbing fixtures and cause scaling which encrusts pipes. Excessive concentration may promote bacterial activities in pipe and service mains, causing objectionable odours and red rod disease in water. In the groundwater iron generally occurs in two oxidation states, i.e., Ferrous (Fe^{2+}) and Ferric (Fe^{3+}) forms.

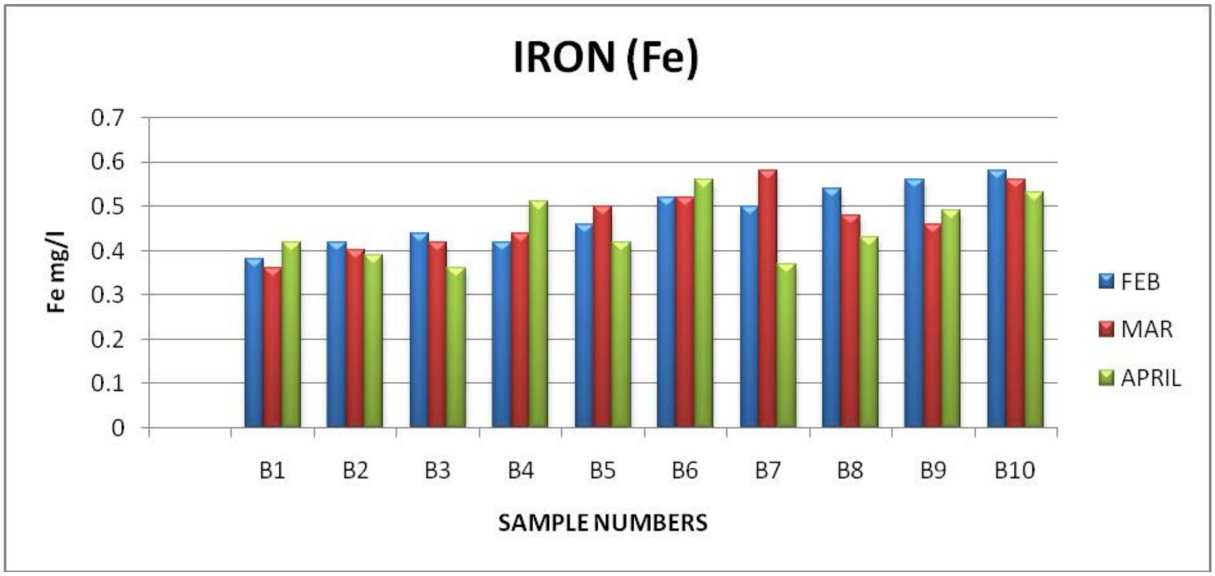

Figure 4.44: Iron variation of groundwater Samples from 1-10

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	-

Table 4.1: Results of groundwater quality analysis of March 2017

Sample number	pH	EC µs/cm	TDS ppm	TH mg/l	CH mg/l	MH 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	176	259	70.4	62.16	110.2	384	0.63	0.38	4.80	89.2
B2	7.12	825	495	300	160	140	64	33.6	96.8	399	0.69	0.42	4.08	86.9
B3	7.32	666	399.6	360	158	202	63.2	48.48	112.3	378	0.61	0.44	5.23	79.6
B4	6.8	882	529.2	286	122	164	48.8	39.36	76.8	369	0.68	0.42	5.54	90.5
B5	6.7	697	418.2	315	170	145	68	34.8	116.8	350	0.65	0.46	5.35	82.3
B6	6.84	1038	622.8	334	166	168	66.4	40.32	121.6	376	0.69	0.52	5.84	79.82
B7	7.24	844	506.4	282	142	140	56.8	33.6	89.8	372	0.63	0.50	6.24	83
B8	6.92	725	435	269	119	150	60	36	101.2	352	0.66	0.54	6.91	75
B9	7.2	833	499.8	278	140	138	55.2	33.12	88.9	384	0.63	0.56	5.01	69.5
B10	6.76	596	357.6	264	120	144	48	28.8	135.3	338	0.61	0.58	5.12	96.1

Table 4.2: Results of groundwater quality analysis of April 2017

Sample number	pH	EC µs/cm	TDS ppm	TH mg/l	CH mg/l	MH 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	6.63	800	480	224	110	114	44	27.36	100.2	444	0.69	0.36	6.01	113
B2	7.49	770	462	348	188	160	75.2	38.4	99.2	471	0.66	0.40	5.18	89
B3	7.58	745	447	265	123	142	49.2	34.08	92.3	342	0.60	0.42	5.64	103
B4	6.84	845	507	338	179	159	71.6	38.16	69.4	378	0.65	0.44	6.20	79
B5	6.77	695	417	314	168	146	67.2	35.04	96.2	417	0.63	0.50	6.32	99
B6	6.91	888	532.8	254	126	128	50.4	30.72	104.5	490	0.70	0.52	5.12	80.25
B7	7.35	954	572.4	272	133	139	53.2	33.6	96.8	464	0.66	0.58	6.33	126.8
B8	7.33	789	473.4	289	142	147	56.8	35.28	88.8	452	0.63	0.48	5.96	169
B9	7.04	688	412.8	308	156	152	62.4	36.48	124.2	499	0.61	0.46	8.38	123
B10	6.82	739	443.4	348	180	168	72	40.32	69.5	450	0.62	0.56	8.54	85.6

Table 4.3: Results of groundwater quality analysis of May 2017

Sample number	pH	EC µs/cm	TDS ppm	TH mg/l	CH mg/l	MH 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	7.45	1035	621	340	168	172	67.2	41.28	148.2	400	0.63	0.42	7.79	140.2
B2	6.97	723	433.8	357	182	175	72.8	42	88.9	390	0.61	0.39	7.92	123
B3	7.38	782	469.2	374	200	174	80	41.76	90.12	427	0.62	0.36	7.95	132
B4	6.96	829	497.4	346	185	161	74	38.64	88.95	387	0.66	0.51	8.23	129
B5	7.03	735	441	323	158	165	63.2	39.6	104.5	348	0.67	0.42	8.15	98.9
B6	6.97	826	495.6	368	180	188	72	45.12	88.25	458	0.69	0.56	8.18	89.5
B7	7.35	945	567	379	185	194	74	46.54	96.8	476	0.67	0.37	8.20	95.3
B8	7.19	768	460.8	297	140	157	56	37.68	112.3	504	0.70	0.43	8.44	98.7
B9	7.16	740	444	319	152	167	60.8	40.08	148.2	378	0.64	0.49	8.31	152
B10	6.94	712	427.2	356	199	157	79.6	37.68	75.82	390	0.62	0.53	8.69	168

Where **B** indicates borewell water

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:

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

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 sta ndard 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

$$\mathbf{SI_i = W_i * q_i} \quad \textbf{(3)}$$

....

$$WQI = \sum SI_i \quad \text{..........................} \quad (4)$$

Where, SIi is the sub index of Ith parameter, qi 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 and are as shown in table no. 6

Table 6: Water quality classification based on WQI value 2, 1

WQI Value	**Water Quality**
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Water Unsuitable for drinking

Table 7: Relative weight (Wi) of Chemical parameters

Table 4.4: Water quality index calculation for March 2017

Sl.Nos	Parameters	Indian Standards	Mean value	Min value	Max value	Weightage (w_i)	Relative Weight (W_i)	Quantity Rating (q_i)	Sub Index (SI_i)
1	pH	6.5-8.5	7	6.7	7.24	4	0.0952	78.82	7.50
2	EC, µS/cm	500-2000	785.6	596	1038	4	0.0952	39.28	3.74
3	TDS, ppm	500-2000	471.36	399.6	622.8	4	0.0952	23.56	2.25
4	TH, mg/l	300-600	312.3	264	435	3	0.071	52.05	3.70
5	Ca^{2+}, mg/l	75-200	60.08	48	70.4	2	0.0476	30.04	1.43
6	Mg^{2+}, mg/l	30-100	39.024	28.8	62.16	2	0.0476	39.024	1.86
7	Fe, mg/l	0.3-1.0	0.482	0.38	0.58	4	0.0952	48.2	4.59
8	TA, mg/l	200-600	370.2	338	399	3	0.071	61.7	4.38
9	Cl^{-}, mg/l	250-1000	104.97	76.8	135.3	3	0.071	10.50	0.75
10	F, mg/l	1-1.5	0.648	0.61	0.69	4	0.0952	43.2	4.11
11	NO_3^{2-}, mg/l	45-100	5.412	4.08	6.91	5	0.119	5.41	0.65
12	SO_4^{2-}, mg/l	200-400	83.192	75	90.5	4	0.0952	20.80	1.98
						w_i=42	W_i=0.998	q_i=452.5	SI_i=36.94

Hence, WQI for March 2017=36.94

Table 4.5: Water quality index calculation for April 2017

Sl.Nos	Parameters	Indian Standards	Mean value	Min value	Max value	Weightage (w_i)	Relative Weight (W_i)	Quantity Rating (q_i)	Sub Index (SI_i)
1	pH	6.5-8.5	7.076	6.33	7.58	4	0.0952	83.24	7.93
2	EC, µS/cm	500-2000	791.3	688	954	4	0.0952	39.58	3.77
3	TDS, ppm	500-2000	474.76	417	572	4	0.0952	23.74	2.26
4	TH, mg/l	300-600	296	224	338	3	0.071	49.33	3.50
5	Ca^{2+}, mg/	75-200	60.2	44	75.2	2	0.0476	30.1	1.43
6	Mg^{2+}, mg/l	30-100	34.944	27	40	2	0.0476	35	1.67
7	Fe, mg/l	0.3-1.0	0.472	0.36	0.58	4	0.0952	47.2	4.50
8	TA, mg/l	200-600	440.7	342	499	3	0.071	73.45	5.21
9	Cl^{-}, mg/l	250-1000	94.11	65.4	124	3	0.071	9.4	0.668
10	F, mg/l	1-1.5	0.645	0.6	0.7	4	0.0952	43	4.10
11	NO_3^{2-}, mg/l	45-100	6.368	5.12	8.58	5	0.119	6.368	0.76
12	SO_4^{2-}, mg/l	200-400	103.765	79	169	4	0.0952	25.94	2.47
						w_i= 42	W_i=0.9984	q_i= 466.348	SI_i=38.268

Hence, WQI for April 2017= 38.268

Table 4.6: Water quality index calculation for May 2017

Sl.Nos	Parameters	Indian Standards	Mean value	Min value	Max value	Weightage (w_i)	Relative Weight (W_i)	Quantity Rating (q_i)	Sub Index (SI_i)
1	pH	6.5-8.5	7.14	6.96	7.45	4	0.0952	84	7.80
2	EC, µS/cm	500-2000	809.5	712	1035	4	0.0952	40.47	3.85
3	TDS, ppm	500-2000	485.7	441	621	4	0.0952	24.28	2.31
4	TH, mg/l	300-600	345.9	297	374	3	0.071	57.65	4.10
5	Ca^{2+}, mg/l	75-200	69.96	63.2	80	2	0.0476	34.98	1.67
6	Mg^{2+}, mg/l	30-100	41.038	37.4	46.8	2	0.0476	41.03	1.96
7	Fe, mg/l	0.3-1.0	0.488	0.36	0.57	4	0.0952	48.8	4.65
8	TA, mg/l	200-600	415.8	348	504	3	0.071	69.3	4.92
9	Cl^-, mg/l	250-1000	105	75.8	148.8	3	0.071	10.5	0.744
10	F, mg/l	1-1.5	0.651	0.61	0.70	4	0.0952	43.4	4.13
11	NO_3^{2-}, mg/l	45-100	8.188	7.79	8.44	5	0.119	8.188	0.98
12	SO_4^{2-}, mg/l	200-400	122.66	89	168	4	0.0952	30.67	2.92
						w_i= 42	W_i=0.9984	q_i=462.598	SI_i=40.034

Hence, WQI for May 2017=40.034

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.
- 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.

- The total hardness exceeds the permissible limit at many places in about 10 sampling station. The higher hardness is mainly due to disposal of municipal and sewage waste.

- The ground water samples in Sugar town in Mandya and its environs have TDS within the permissible limit.

- The results of physicochemical analysis of ground water of Sugar town, Mandya region for year 2017 shows that observed mean pH values in Mandya region are within the permissible limit.

- Based on the analysis of borewell water lower concentration of Iron, Flouride and Nitrate were observed in the study area.

- Some of the samples have EC, total dissolved solids, hardness, TA, and sulphate values within the permissible limits as the prescribed by Indian Standards. However the WQI values in the present investigation were reported to be less than 20 for different samples indicating that the water is safe for human consumption.

- From the WQI of the water of Sugar town, Mandya is considered as POOR WATER.

SCOPE FOR FUTURE WORK

- To developed a groundwater quality management modelling methodology which can be used to any basin where groundwater quality problems arise from a source pollution and further analysis can be done by using piper trilinear diagram.

- To prepare groundwater quality maps using GIS technique.

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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 Journal of Applied Biology & Pharmaceutical Technology, 1(2): 519

9) Mumtazuddin S., Azad A.K., Bharti P and Ranjan R (2012) "Physico-

chemical analysis of groundwater of the Budhi Gandak belt in Muzaffarpur district, India", International Research Journal of Environment Sciences, 1(1): 7-11

10) Patil Shilpa G., Chonde Sonal G., Jadhav Aasawari S. and Raut Prakash D (2012) "Impact of Physico-Chemical Characteristics of Shivaji University lakes on Phytoplankton Communities, Kolhapur, India", Research Journal of Recent Sciences, 1(2):56-60

11) Rajiv P., Hasna Abdul Salam, Kamaraj M., Rajeshwari Sivaraj and Sankar A, I. (2012), 'Physico Chemical and Microbial Analysis of Different River Waters in Western Tamil Nadu, India, International Research Journal of Environmental Science., 1(1): 2-6

12) Patel Payal and Bhatt S.A(2010)., "Fluoride Contamination in Groundwater of Patan District, Gujarat, India International Journal of Engineering Studies, 1(2), 171–177

13) Abati T (2005)., "Water Sources and treatment, food forum", A publication of the Nigeria Institute of food science and Technology (NIFST), 4(1): 49

14) Iyer C.S., Sindhu M., Kulkarni S.G., Tambe S.S. and Kulkarni B.D (2003), "Statistical analysis of the physico-chemical data on the coastal waters of Cochin", Journal of Environmental Monitoring, 2(5): 324

15) Sawyer G.N., Carthy Mc D.L (1967) ., Chemistry of sanitary Engineers, 2ndEd., McGraw Hill, New York, 1(2): 518

16) Neeraj D., Dr. Patel J.N (2010), "Evaluation of Groundwater Quality Index of the Urban Segments of Surat City, India", International journal of geology, 2(4):58-62

17) Raval V.H., and Malik G.H (2010), "Physico- Chemical Characteristics of Groundwater in and around Surat City (India)", Journal of Environmental Science and Engineering, 52(4):43-348 .