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Research Article

ASSESSMENT OF GROUNDWATER HARDNESS IN GULBARGA TALUK, KARNATKA, INDIA: AN INVERSE DISTANCE WEIGHTED (IDW) APPROACH

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ABSTRACT

Water is essential for the survival of organisms including human beings on earth. One of the important traditional parameter of groundwater quality is its hardness. Inverse Distance Weighted (IDW) approach is applied to study the spatial distribution of hardness in the Gulbarga Taluk. The present study shows the total hardness concentration in Gulbarga taluk is ranged between 24 and 1350 mg/l with a mean value of 352 mg/l and it is of non-carbonated type of hardness. The study helped to pinpoint the locations of higher concentrations of total hardness of groundwater. Majority of the people of the Gulbarga Taluk who are living in the neighbourhood of about 76% of the sampled wells of the study area are consuming very hard water. The author is of the opinion and suggests that there is an urgent need of educating people adopting to one of the hardness removal techniques for drinking water as well as domestic consumption at homes or use of water purifiers and the public administration in the public water supply system in the Gulbarga Taluk as a public health concern.

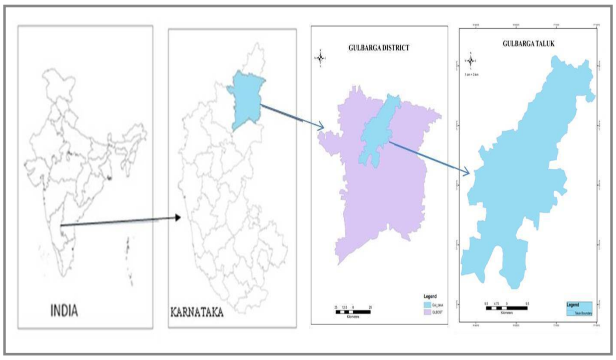
INTRODUCTION

Water is essential for the survival of organisms including human beings on earth. In the absence or scarcity of surface water, groundwater is used as an alternate source. Groundwater is an important source of drinking water for about 70% of Indian population (Shashikanth Majagi *et al.*, 2008). Access to good quality drinking water is everyone's right. The quality of groundwater depends on the number of natural and anthropogenic factors. These factors may change the quality and may pollute the groundwater making it unsafe for human consumption. One of the important traditional parameter of groundwater quality is its hardness. Hardness is defined as the capacity of the water to precipitate soap. Hardness in groundwater is a chemical parameter derived from dissolution of calcium and magnesium. Hard water forms scales and cause disruption in water circulation systems reducing efficiency; cause dry skin in humans. Though, there are number of water purification techniques and instruments available which may reduce the hardness, still a major section of the population in India is drinking groundwater directly without purification as it is considered clean and safe.

The author is of the opinion that, in the research articles generally hardness is reported as an integral part of the report as highest and lowest values in the research area and problems like formation of scales, some of the implication of hard water on circulation systems, boilers and domestic use. But some of the latest research reports suggest more health repercussions (World Health Organization, 2011; Sarala C and Ravi Babu P, 2012; C.B. Dissanayake and Rohana Chandrajith, 2017). Hence, the author felt that there is a necessity to discuss hardness of the groundwater in detail and pinpoint the locations where it is occurring and find out the causative parameters and type of hardness in the study area which ultimately benefit to locate soft water sources for human consumption.

Study Area

Gulbarga is one of the fast developing districts in the Hyderabad Karnataka.



Map 1 Location of the study area; Gulbarga Taluk.

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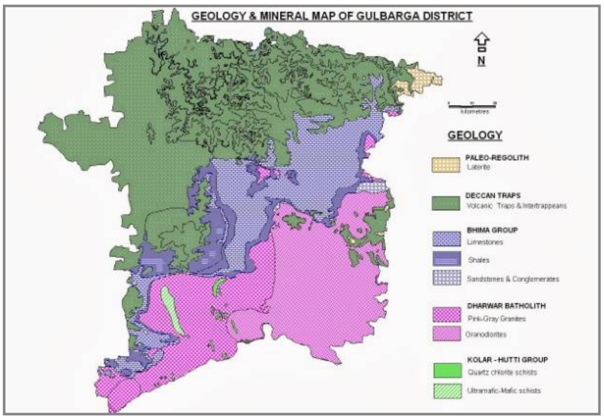
Gulbarga taluk is extended between the latitudes N17^{O}2'30" and N17^{O}41'43" and longitudes E76^{O}36'10" and E77^{O}9'52" comprising a geographical area of 1741 sq km. Map 1, shows the location of the study area. As per the 2011 census of India the total population of Gulbarga taluk is 829830. Annual temperature range for Gulbarga taluk is 19^{O}C during winter and 46^{O}C during summer. Annual average rainfall is about 750mm and most of it precipitates during monsoon season. Gulbarga is situated in the semi arid region of peninsular India and declared as one of the chronic drought affected areas of Karnataka state. The mean elevation of the study area is about 450m above MSL.

Geology of the Study Area

The Gulbarga District is covered by the rock types ranging from Archean to Recent. The entire area of the Gulbarga taluk is predominant by basaltic lava flows except a small area in the south where limestone are deposited. Basaltic lava flows belong to the Deccan traps of Deccan volcanic province and limestone belongs to the Bhima group of rocks. The major rock types of sedimentary formations of Bhima group are conglomerate, sandstones, shales and limestone. Limestone are fractured and sheared due to tectonic disturbances are exposed subhorizontally with a local northward dip of less than 5^{O} overlying the Archean basement rocks and are traversed by pegmatite veins filled with fluorite associated minerals (S. Sumalatha *et al*., 1999; Vivek S Kale *et al*., 1990). A part of the present study area at the southern portion is covered by these limestones which are inter-bedded with shales. Map 2, shows the geology of the Gulbarga district.

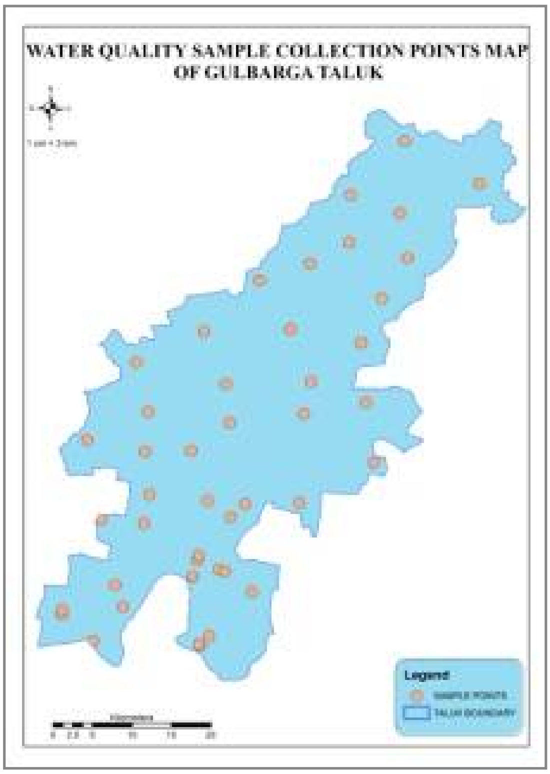


Map 2 Geology of Gulbarga District

METHODOLOGY

A total of 46 samples are collected from both bore wells as well as dug wells from different villages. Standard procedures of the sample collection are followed for the collection of groundwater samples. Samples are collected in 1 litre PVC cans. The cans are thoroughly washed and rinsed twice with the water of sample collecting wells before filling to the brim. Care has been taken to avoid presence of any air gap in the sample cans. Sample cans are properly sealed first with airtight cork and then closed with a cap. Samples are properly labelled and date and location are mentioned on it for future reference. Such collected water samples are sent to the laboratory for the groundwater quality analysis immediately and are analysed within 24 hours.

ArcGIS 10.5 Evaluation version is used for the present study. GIS is a powerful tool to analyse distribution of elements through different techniques. The location of the sample collection wells are obtained by using a handheld Garmin GPS instrument. GPS technology enhances the spatial accuracy of the data integrated in the GIS environment. Using the GPS data the well location map is created. Map 3, shows the locations of the groundwater sample collecting points in the Gulbarga Taluk.



Map 3 Location of the groundwater sample collecting points.

The non spatial data of water quality is tabulated in the Microsoft Office excel file which is linked to the spatial data in the GIS environment. The integrated spatial and non spatial database is used for the generation of spatial distribution map of concentration of different physicochemical parameters. Elemental distribution maps are delineated using the interpolation technique by adopting the Inverse Distance Weighted (IDW) approach which uses the data of the neighbouring wells. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. The closer a point is to the centre of the cell being estimated, the more influence, or weight; it has in the averaging process (Muzafar N Teli *et al*., 2014). Finally, various thematic maps for available physicochemical parameters are created and used for the assessment of groundwater hardness and locating the places of soft water occurrence in Gulbarga Taluk.

RESULTS AND DISCUSSION

Various thematic maps for available physicochemical parameters are created using the IDW interpolation technique to study the groundwater hardness and its relation with some of the other related parameters in Gulbarga Taluk. Table 1, shows the sampling locations along with some of the groundwater quality parameters of the study area with its acceptable and permissible limits as per WHO standards (World Health Organization, 2011). Table 2, shows some of the statistical parameters of above mentioned groundwater parameters of the study area.

the carbonate and bicarbonate salts of calcium and magnesium present in the water.

Table 1 Sampling locations along with some of the groundwater quality parameters of the study area with its acceptable and permissible limits.

Acceptable Limit		**6.5-8.5**	**250**	**200**	**250**	**200**	**75**	**30**	**200**
Permissible Limit		**6.5-8.5**	**1000**	**400**	**1000**	**400**	**200**	**100**	**600**
Sample No	**Location**	**pH**	**CO3 mg/L**	**HCO3 mg/L**	**Cl mg/L**	**SO4 mg/L**	**Ca mg/L**	**Mg mg/L**	**TH**
1	Khanadal	7.29	0	378.2	207.02	51.12	196.8	76.12	550
2	Itaga	7.55	0	195.2	60.974	28.968	160	29.046	316
3	Farhatabad	7.61	0	346.4	402.712	96.702	62.4	39.062	234
4	Farhatabad	7.36	0	280.6	181.504	67.308	38.4	52.083	256
5	H Saradagi	7.35	0	204.96	73.13	49.416	48	64.024	316
6	H Saradagi	7.55	0	224.48	62.392	51.12	64	56.089	304
7	Tilgul	7.6	2.4	249.85	49.63	90.738	40	27.544	160
8	Tilgul	7.82	7.2	195.2	43.958	45.156	24	55.089	250
9	H Kirangi	7.48	0	280.61	52.461	64.752	40	40.64	210
10	Firozabad	7.42	0	312.3	153.14	100.536	128	56.59	386
11	Firozabad	7.33	0	292.8	153.14	100.11	176	37.56	370
12	Firozabad	7.43	0	309.8	140.38	99.684	52.8	53.585	280
13	Sarana Saradgi	7.1	0	224.48	653.69	109.908	387.2	216.46	1350
14	H Haroti	7.17	0	219.6	174.41	37.062	259.6	93.1488	694
15	Kadani	7.14	0	200	300.6	118.854	336	64.1024	676
16	Minajagi	7.32	0	263.52	49.63	24.708	88	34.52	298
17	Garur	7.28	0	173.24	418.3	81.366	257.6	32.552	452
18	Bidanur	7.44	0	219.6	56.72	40.896	96	52.584	330
19	Kavalagi cross	7.47	0	180.56	34.03	16.614	89.6	29.547	230
20	Jogur	7.13	0	222.04	63.81	24.708	94.4	46.574	304
21	Jogur	7	0	244	233.97	76.254	201.6	52.083	460
22	Herur	7.2	0	175.68	174.414	92.868	155.2	31.55	320
23	Basavapattana	7.33	0	222.4	36.868	17.892	99.2	11.518	170
24	Panigaon	7.36	0	231.8	148.89	26.412	152	33.052	322
25	Sultanpur	7.41	0	192.76	155.98	64.752	128	37.059	308
26	Jambaga	7.45	0	192.76	367.2	86.478	225.6	92.147	650
27	Babalad	7.84	0	51.24	131.87	41.748	65.6	9.515	120
28	Mahagaon	7.84	0	392.84	130.45	51.972	41.6	34.555	190
29	Navadagi	8.3	9.6	31.72	333.23	117.15	73.6	0	92
30	Okali	8.62	26.4	61	83.66	40.044	11.2	2.504	24
31	Dongargaon	7.65	0	222.04	35.45	11.928	40	29.046	166
32	Sauntha	7.81	0	204.96	187.17	60.492	72	60.096	330
33	Antapnala	8.11	9.6	21.96	53.88	11.076	59.2	6.51	100
34	Jeevanagi	7.59	0	275.72	311.96	84.348	168	104.166	626
35	Nagur	7.73	0	297	70.9	23.856	48	36.057	204
36	Pattana	7.58	2.4	202.52	126.202	35.358	216	36.057	414
37	Melakunda	7.64	4.8	187.88	73.318	17.466	56	23.036	162
38	Savalagi	8.49	16.8	34.16	184.34	69.864	46.4	0.5	58
39	Aurad	7.65	0	292.8	195.68	87.756	276.8	57.592	576
40	Harasur	7.44	0	280.6	273.67	67.734	270.4	96.654	724
41	Bhopal Tegnur	7.21	0	305	360.17	87.33	145.6	148.373	776
42	Khaja Kotnur	7.48	0	292.8	141.8	45.582	153.6	61.097	436
43	Hagaraga	8.22	7.2	107.36	144.63	43.026	38.4	1.0016	52
44	Sannur	7.63	0	300	131.87	35.358	68.8	116.185	550
45	Nandur B	8.05	4.8	75.64	219.79	63.9	49.6	4.507	80
46	Gulbarga City	7.63	0	336.72	256.65	90.312	94.4	58.092	350

Table 2 Statistical parameters of physicochemical parameters of groundwater in the study area.

For 46 samples	**pH**	**CO3 mg/L**	**HCO3 mg/L**	**Cl mg/L**	**SO4 mg/L**	**Ca mg/L**	**Mg mg/L**	**TH**
Average	7.57	1.98	221.89	171.64	59.80	121.64	50.00	352.74
Median	7.48	0	222.22	146.76	56.232	92	39.851	312
Max	8.62	26.4	392.84	653.69	118.854	387.2	216.46	1350
Min	7	0	21.96	34.03	11.076	11.2	0	24
StDev	0.36	5.04	89.59	127.89	30.58	89.59	40.45	244.18

Hardness is defined as the capacity of the water to precipitate soap. Hardness in groundwater is a chemical parameter derived from dissolution of calcium and magnesium salts. All groundwater naturally contain some amount of hardness due to the presence of cations like calcium and magnesium and anions like carbonate, bicarbonate, chloride and sulphate. These ions are derived in to groundwater during its travel and stay due to interaction with geological formations through dissolution. Hardness is categorized into carbonate hardness and non-carbonate hardness. Carbonate hardness is caused by

Non-carbonate hardness is caused by the chloride and sulphate salts of calcium and magnesium present in the water. Further, it is also categorized as calcium hardness and magnesium hardness. Calcium hardness is caused by the calcium salts and magnesium hardness is caused by the magnesium salts; where salts may be carbonate, bicarbonate, chloride or sulphate salt. A sum of calcium and magnesium hardness which is expressed as an equivalent quantity of calcium carbonate is known as 'total hardness' (TH) (World Health Organization, 2011). Groundwater is categorized into soft and hard water based on the total hardness. If the total hardness is below 60 mg/l the water is considered as soft; 60-120 mg/l, moderately hard; 120-180 mg/l, hard; and if it is more than 180 mg/l water is considered as very hard (World Health Organization, 2011).

Carbonate Hardness

Carbonate hardness is the sum of carbonate and bicarbonate salts of calcium and magnesium present in the water. Figure 1, and figure 2, shows the bar graphs of concentration of carbonate and bicarbonate respectively in the study area. The acceptable and permissible limits for carbonate are 250 and 1000 mg/l and for bicarbonate, it is 200 and 400 mg/l. In the present study area all the samples are having the acceptable limits for carbonate and 19 for bicarbonate and remaining 27 samples are within the permissible limits. Bicarbonates are dominating the area than the carbonate ions suggest that the water is fresh.

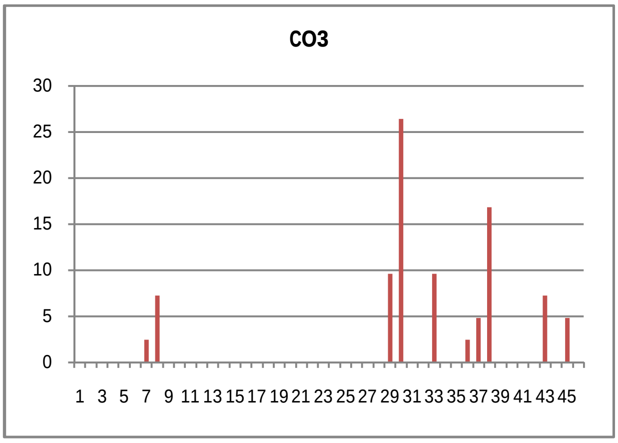


Figure 1 Concentration of carbonate in Gulbarga Taluk

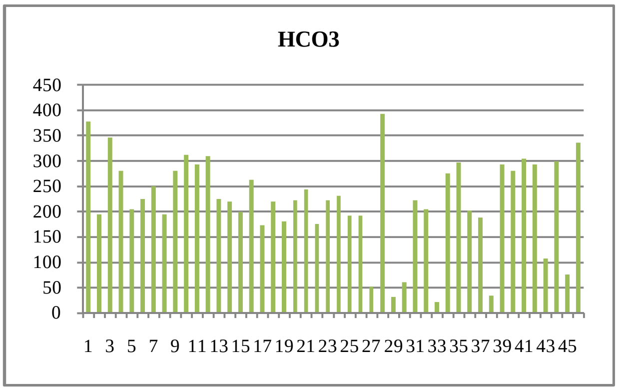
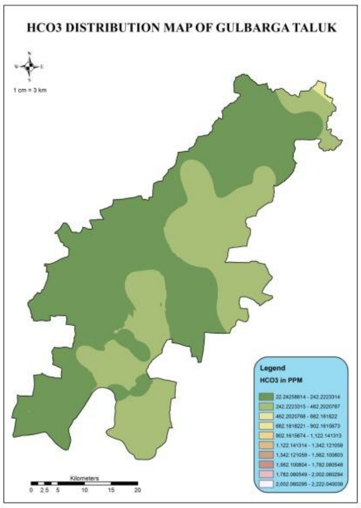


Figure 2 Concentration of bicarbonate in Gulbarga Taluk

Map 4, shows the spatial distribution of bicarbonate in the study area. It is inferred from the above map that the bicarbonates are uniformly distributed in the entire study area and showing low concentration.

Non-Carbonate Hardness

Non-carbonate hardness is the sum of chloride and sulphate salts of calcium and magnesium present in the water. Figure 3, and figure 4, shows the bar graphs of concentration of chloride and sulphate respectively in the study area. The concentration of chloride is low in water unless the water is brackish or saline and it is usually less than 100 mg/l (Bilgehan Nas and Ali Berktay, 2010). No health based guidelines are proposed for chloride and sulphate; and high concentration of chloride imparts a salty taste to water.



Map 4 Spatial distribution of bicarbonate in Gulbarga taluk.

Chloride plays an important role in balancing levels of electrolytes in blood plasma but excess consumption may lead to hypertension, osteoporosis, renal stones and asthama (Sarala C and Ravi Babu P, 2012). Sulphate ion is derived from the sulphide minerals present in the rocks through oxidation process. Excess consumption of sulphate may cause laxative effect, catharsis, dehydration and gastrointestinal irritation (Sarala C and Ravi Babu P, 2012; Bilgehan Nas and Ali Berktay, 2010). The acceptable and permissible limits for chloride are 250 and 1000 mg/l and for sulphate, it is 200 and 400 mg/l. In the present study area 36 samples are having the acceptable limits and remaining within the permissible limits for chlorides and all the samples are within the acceptable limits for sulphates. A recent report also reported the similar range for chloride and samples are falling within the permissible range in Gulbarga District (Rekha .S.Choudhary and Dr. Mohan I Naik, 2017). It is noticed that, the sulphate in the present area is uniformly distributed in the entire taluk. Since the major portion of the study area lies in the basaltic terrain, it is assumed that the basaltic rocks are may be containing a large amount of sulphidic minerals like pyrites or sulphur may be present in the reduced form as metallic sulphides. On chemical weathering in the presence of water this might turn into sulphate or might have derived from these minerals through oxidation. Another possibility for the occurrence of high concentrations of chloride in the study area may be attributed to agricultural activity.

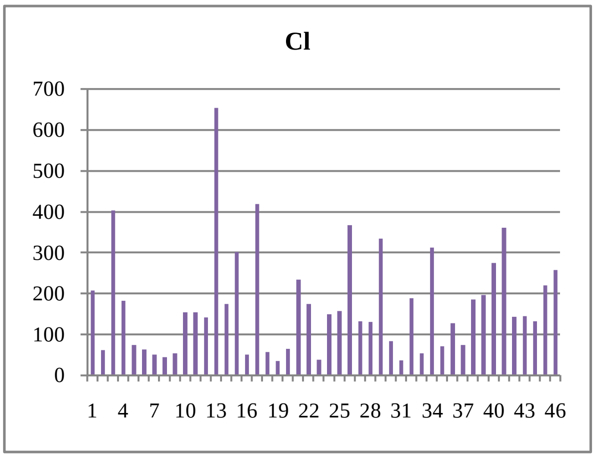


Figure 3 Concentration of chloride in Gulbarga Taluk.

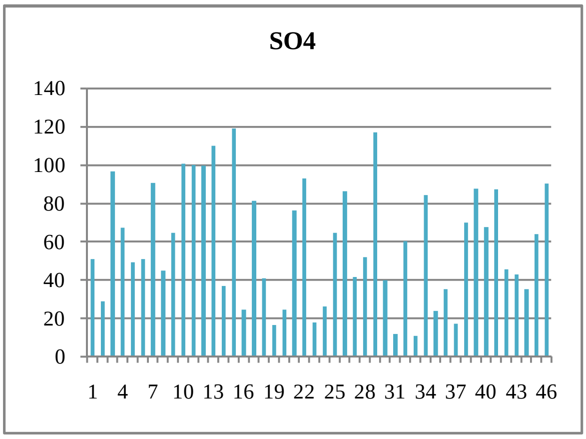
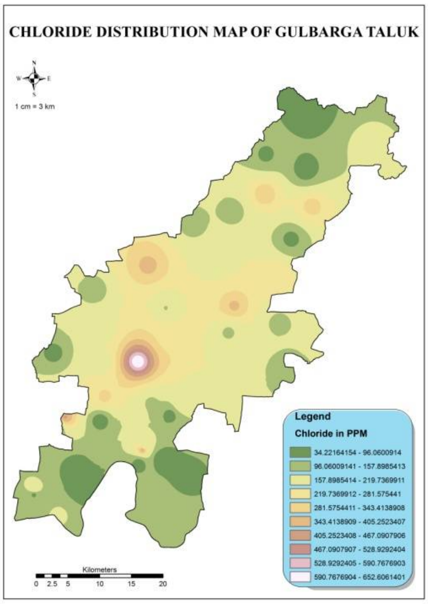


Figure 4 Concentration of sulphate in Gulbarga Taluk.

Map 5, shows the spatial distribution of concentration of chloride in the study area. It is inferred from the above map that the chloride having a relatively high concentration as pockets at the central part of the study area.



Map 5 Spatial distribution of chloride in Gulbarga taluk.

pH

In the study area the pH of the groundwater varies from 7 to 8.62 which are falling well within the permissible limit except one sample which is showing the highest value collected at Okali. The relatively higher concentration of pH is noticed in the northern portion and a small pocket in the western portion of the study area.

Calcium

Calcium is abundantly found in groundwater as it is one of the important and widespread elements in minerals present in almost all types of rocks. Major source of calcium is silicate minerals of igneous and metamorphic rocks and carbonate minerals of sedimentary rocks. Its abundance in water is due to its widespread occurrence and higher solubility and the range of its availability depends on the solubility of calcium carbonate and sulphate (Sarala C and Ravi Babu P, 2012). Calcium is one of the essential nutrients required for the normal growth in humans especially bones. The total body store is about 1200 g of which about 99% is stored in bones and teeth (World Health Organization, 2011). Inadequate intake may cause osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity (World Health Organization, 2011). Figure 5, shows the bar graph of concentration of calcium in the study area. The calcium concentration is ranged between 11 and 387 mg/l in the study area. In the present study it is observed that 21 samples are within the acceptable limits and 17 are within permissible limits and reaming 8 are beyond permissible limits. Higher concentration of calcium is noticed in the basaltic terrain suggesting that the calcium might have derived from the calcium bearing minerals like plagioclase present in the basalts.

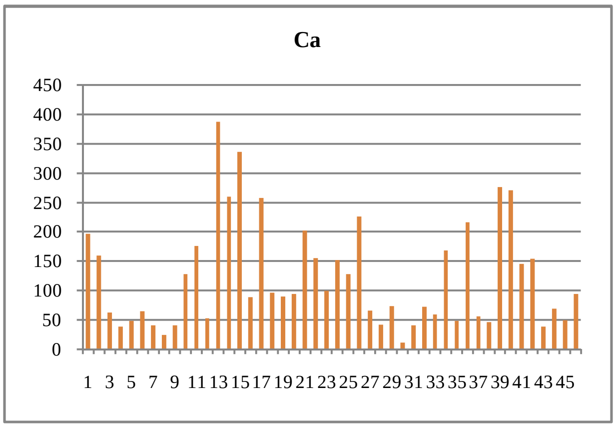
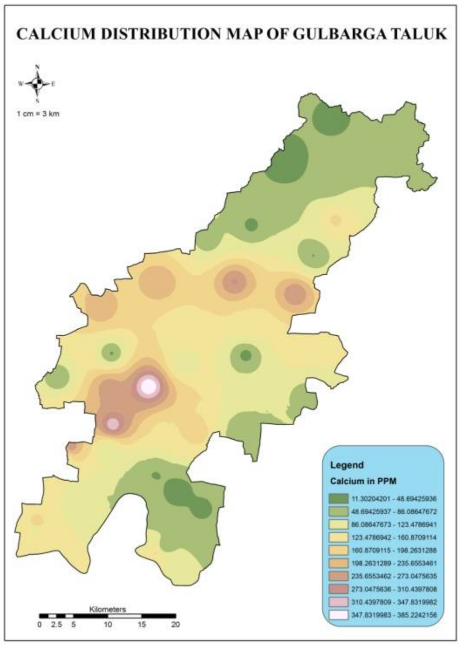


Figure 5 Concentration of calcium in Gulbarga Taluk.

Map 6, shows the spatial distribution of concentration of calcium in the study area. It is inferred from the above map that the calcium having a relatively high concentration is noticed as pockets at the central part of the study area.



Map 6 Spatial distribution of calcium in Gulbarga taluk.

Magnesium

Magnesium usually occurs in lesser concentration than calcium in groundwater, so calcium-based hardness usually predominates (World Health Organization, 2011; Sarala C and Ravi Babu P, 2012). Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intracellular fluid. Total body stores are on the order of 25 g, with about 60% in bone (World Health Organization, 2011). Concentrations higher than the permissible limits impart water an unpleasant taste and make the water unfit for drinking (Sarala C and Ravi Babu P, 2012; Rekha .S.Choudhary and Dr. Mohan I Naik, 2017). Recent reports suggest an inverse relationship between magnesium and coronary heart disease mortality and type 2 diabetes mellitus is noticed (World Health Organization, 2011). Drinking-water in which both magnesium and sulfate are present at high concentrations (above approximately 250 mg/l each) can have a laxative effect (World Health Organization, 2011; Sarala C and Ravi Babu P, 2012; Rekha .S.Choudhary and Dr. Mohan I Naik, 2017). Figure 6, shows the bar graph of concentration of magnesium in the study area. The magnesium concentration is ranged between 0 and 216 mg/l in the study area. In the present study, approximately 50% of the samples are well within the acceptable limits and 4 samples are showing high concentration of magnesium which is above permissible limit. Similarly, a recent study also reported about 8.33% of the samples crossed the permissible limits in Gulbarga District (Rekha .S.Choudhary and Dr. Mohan I Naik, 2017).

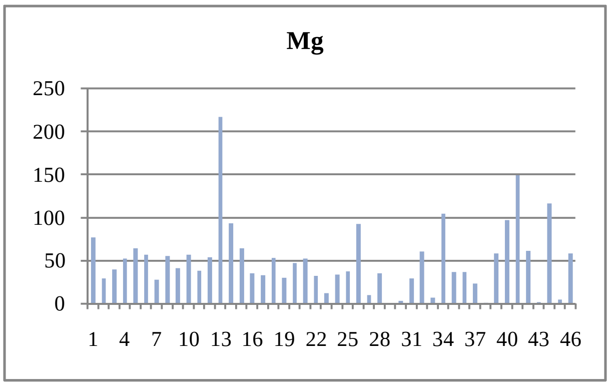
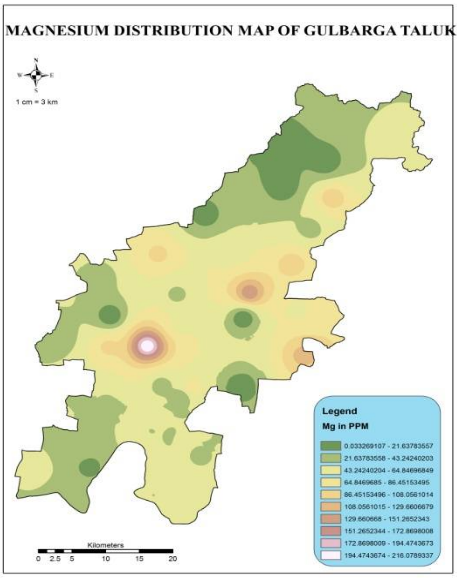


Figure 6 Concentration of magnesium in Gulbarga Taluk.

Map 7, shows the spatial distribution of magnesium in the study area. It is inferred from the above map that the magnesium having a relatively high concentration is noticed as pockets at the central part of the study area.



Map 7 Spatial distribution of magnesium in Gulbarga taluk.

Total Hardness (TH)

Total hardness is a sum of calcium and magnesium hardness which is expressed as an equivalent quantity of calcium carbonate (World Health Organization, 2011). Carbonate related hardness is temporary and bicarbonate related hardness is a permanent hardness. The high hardness may cause precipitation of calcium carbonate and encrustation on water supply distribution systems (D. K. Verma *et al*., 2017). Figure 7, shows the bar graph of concentration of TH in the study area. Map 8 shows the thematic map generated for TH applying IDW method in the study area. Previous reports show the TH range between 611 to 930 mg/l in Gulbarga District and 52 to 1184 mg/l in Gulbarga city (Shashikanth Majagi *et al*., 2008; P. Balakrishnan *et al*., 2011). A recent study reported that all the samples showed the values within the permissible limit ranging from 132 to 228 mg/l in Gulbarga District (Rekha .S.Choudhary and Dr. Mohan I Naik, 2017). In the present study the TH range between 24 mg/l and 1350 mg/l for Gulbarga Taluk and out of 46 samples 14 samples are under acceptable limits, 25 samples comes under permissible limits and 7 samples are showing the values above permissible limits. Table 3, shows the details of type of water available in the study area. It is observed from the table that people living in the vicinity of only 6.52% of the sampled wells in the study area is having accessibility for soft water, people living in the neighbourhood of approximately 17% of the sampled wells in the study area are consuming hard water and people in the remaining area of about 76% of the sampled wells are consuming very hard water. The thematic map shows the higher concentration of total hardness occurring at couple of pockets at the central portion of the study area. These high concentration pockets are the one where high concentration of magnesium, calcium, chloride and sulphur is also noticed. This suggests that, non-carbonated type of hardness is dominant in the study area. The non-carbonate hardness is harder than carbonate hardness. The presence of hardness in this location may be attributed to the presence of minerals like plagioclase, augite and pyrite or reduced metallic sulphides present in basalts.

Table 3 shows the details of type of water available in the study area.

Type of water	Range	No of samples in study area	Percentage of area of the study area
Soft	<60mg/l	3	6.52
Moderately hard	60-120 mg/l	3	6.52
Hard	120-180 mg/l	5	10.86
Very hard	>180 mg/l	35	76.08

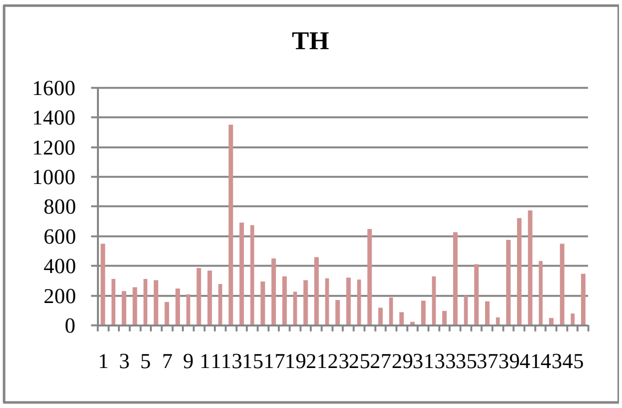
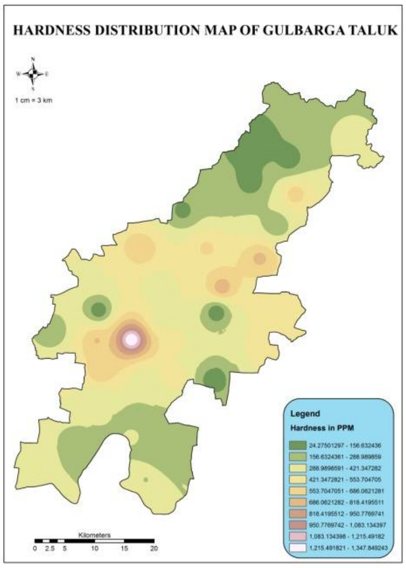


Figure 7 Concentration of magnesium in Gulbarga Taluk.



Map 8 Spatial distribution of total hardness in Gulbarga taluk.

It is observed that, 8 locations showed calcium concentration beyond the permissible limits and 4 samples showed the magnesium concentration above permissible limits. According to WHO reports the estimated daily intakes of magnesium from water of about 2.3 mg and 52.1 mg in soft-water and hard-water areas, respectively, have been reported, based on adults drinking 2 litres of water per day (World Health Organization, 2011). It has been observed that the dietary contribution of calcium and magnesium is only 5-20% of the daily intake requirements from water consumption (World Health Organization, 2011).

Hard water, by itself may not pose a serious threat to human health but its main components, Ca2+ and Mg2+ may interact with other species to form complexes that may be of significance in health issues (C.B. Dissanayake and Rohana Chandrajith, 2017). The excess intake of calcium and magnesium may cause following effects in human beings (World Health Organization, 2011; Sarala C, Ravi Babu P, 2012; C.B. Dissanayake and Rohana Chandrajith, 2017; Rekha .S.Choudhary and Dr. Mohan I Naik, 2017).

- The excess intake of calcium through water may cause some concern primarily to those who are prone to milk alkali syndrome and hypercalcaemia.
- Excess intake of calcium for a person with normal kidney functioning is not a problem but for others it may be a health concern and may form kidney stones.
- The excess intake of magnesium through water may cause hypermagnesaemia a renal insufficiency associated with a significantly dkecreased ability to excrete magnesium.
- Increased intake of magnesium salts may cause a temporary adaptable change in bowel habits (diarrhoea).
- Drinking-water in which both magnesium and sulfate are present at high concentrations (above approximately 250 mg/l each) can have a laxative effect.

The hardness also affects adversely on the following as mentioned by WHO (World Health Organization, 2011):

- Exposure to hard water has been suggested to be a risk factor that could exacerbate eczema.
- The hardness in water feels unpleasant on skin and may cause itching and drying of skin.
- Hard water form scales on plumbing fixtures and utensils.
- Scales that forms inside the water pipes due to encrustations reduces the carrying capacity and affects the water distribution system.
- Scale that forms within appliances, pumps, valves, and water meters causes wear on moving parts.
- On heating hard water forms scales much faster that creates an insulation problem inside boilers, water heaters, and hot-water lines, and increases water heating costs by increased power consumption.
- Hard water can cause increased soap consumption.
- May affect fabric, on washing it may cause yellowing, graying, loss of brightness, and reduced life of washable fabrics.

CONCLUSION

The study demonstrated that the IDW method could be effectively employed to understand the spatial distribution of hardness and other related parameters of the groundwater hardness. The study helped to pinpoint the locations of higher concentrations of total hardness of groundwater.

The present study shows the total hardness concentration in Gulbarga taluk is ranged between 24 and 1350 mg/l with a mean value of 352 mg/l and it is of non-carbonated type of hardness. The present study revealed that only 30% of the sampled wells of Gulbarga Taluk are yielding the water that is under the acceptable limits of total hardness. Approximately 54% of the sampled wells of the study area are yielding the water that is covered under permissible limits which suggest that in case of absence of water with safe limits one can go for exploiting this water. Remaining 16% of the sampled wells in the study area are having high hardness of water which is above the permissible limits and may not be suitable for consumption.

It is also observed that people living in the vicinity of only 6.52% sampled wells of the study area are having accessibility for soft water. People living in the neighbourhood of approximately 17% of the sampled wells of the study area are consuming hard water. Majority of the people of the Gulbarga Taluk who are living in the neighbourhood of about 76% of the sampled wells of the study area are consuming very hard water. It is observed in the present study with the help of GIS that the soft water occur in the northern parts of the taluk and a couple of pockets in the west, east and south indicated by the presence of low concentration of TH. The water in an extensive area situated at the centre of the taluk is hard to very hard. The pH in the study area is within the permissible limits.

The hardness of the water may cause some health concerns, affect the water distribution system and may increase the power consumption. Therefore, the author is of the opinion and suggests that there is an urgent need of educating people adopting to one of the hardness removal techniques for drinking water as well as domestic consumption at homes or use of water purifiers and the public administration in the public water supply system in the Gulbarga Taluk as a public health concern.

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