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Quality groundwater Assessment in Narayankher area Medak District, Telangana, India

Sudhakar A , Praveen Raj Saxena*
Department of Applied Geochemistry, Osmania University, Hyderabad, Telangana, India

ABSTRACT

The present paper deals with groundwater is a vital source of water for domestic and agricultural activities in Narayankher mandal, medak district due to lack of surface water resources groundwater quality and its suitability for drinking and agriculture usage were evaluated. Physical and chemical parameters of groundwater such as pH, Electrical Conductivity, Total Dissolved Solids (TDS), TH, Na+, K+, Ca $^{2+}$, Mg $^{2+}$, Cl-, HCO_3-, CO_3-, and, SO_4- and Chemical index like Percentage of Sodium (Na%), Chloro Alkaline Indices (CAI), Kelley's Ratio, Gibb's and Magnesium hazard were calculated based on the analytical results. High total hardness and TDS in a few places identify the unsuitability of groundwater for drinking and irrigation. Such areas require special care to provide adequate drainage and introduce alternative salt tolerance cropping. The overall quality of water in the Narayankher, medak district is high for all pollution constituents from extraneous source ruling was also carried out which has provided information regarding.

Key words: Groundwater, Drinking and irrigation water, Qualitative and quantitative analysis, Physiochemical.

I. INTRODUCTION

Global population growth and changing climatic conditions have resulted in water scarcity in many areas worldwide, especially in big cities which are growing fast and are often located in unfavorable places (Wolf et al., 2006). These drastic increases in population, modern land use applications (agricultural and industrial), and demands for water supply has limited the globally essential groundwater resources in terms of both its quality and quantity. Even though urban aquifers are the only natural resource for drinking water supply, they are often perceived as of lesser relevance for the drinking water supply, leading toward crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their portability (Dixit et al., 2005). Once contamination of groundwater in aquifers occurs by means of agricultural and industrial activities and urban development, it persists for hundreds of years because of very slow movement of water in them (Jerry, 1986) and prompts investigations on their quality (Aksoy and Scheytt, 2007). Since physico-chemical composition of groundwater is a measure of its suitability as a source of water for drinking, agriculture (irrigation), and industrial purposes (Babiker et al., 2007), an attempt has been made in the current study to assess the effects of natural and anthropogenic activities and increased human population on groundwater quality and their variation by defining the principal hydro-geochemical nature of the groundwater.

In the study area sufficient amount of groundwater is available for drinking, irrigation and industrial purpose. Research has shown that chemical composition of groundwater has marked impact on well of human beings. It is not necessary that a person falls ill soon after drinking contaminated water; rather it needs years before adverse effects appear. Similarly to achieve optimum yield from agriculture, water with specific chemical composition is recommended. Use of water with adverse chemical composition and quality (high sodium adsorption ratio) causes solidification of agriculture soil, and over period of time rendered it unusable for further use. Groundwater is a solvent that is in contact with various earth materials. As a result, groundwater naturally contains dissolved cations and anions. The major ion constituent of natural water includes calcium, zinc, fluorides, copper, magnesium, sodium, potassium, chloride, sulphate, carbonates, bi-carbonates and nitrates.

II. MATERIALS AND METHODS

The present study has been carried out to evaluate hydrochemical characteristics of groundwater of the granitic and basaltic aquifers in Narayankher mandal, Medak district. The study area in lies between North latitudes 18^0 2′ and East longitudes 77^0 46′ and is included in Survey of India topo sheet 56F/12 and 56F/16. It has an average elevation of 610 meters above mean sea level. The area comprises of several villages Malkapur, Baddaram, Shankarampet, Kamalapuram, Venkatapura, Kamalapur'X'road, Tenkati, Nizampet, Bachupalli, Mirkampet, Raparthi, Ankampalle, Krishnapuram, Kanapur, Narayankher, Thimmapur above villages are Granitic terrain. Kajapur, kadpol, Sirgapur villages are Granites-Basalts contact Rakal, Thurkapalle, Kondapur, Mansurpur, Gadidi Villages are having Basalts. Hukran, Abendda, Sheligera 'X' road villages are having Intratrappeans and in and around Narayankher town covering approximately 180 sq. kms. The area is significant due to the presence of fractured volcanic deposits and Precambrian crystalline basement rocks associated with the groundwater.

III. RESULTS AND DISCUSSION

Groundwater was collected after pumping the wells for 5–10 min and rinsing the bottles for two to three times with water to be sampled. For sample collection, preservation, and analysis, standard methods (APHA, 1995) were followed. The chemical analyses carried out for pH, electrical conductivity (EC), total dissolved salts (TDS), total hardness (TH) as well as sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-) and fluoride (F^-) according to the standard methods (APHA, 2005). All the experiments were carried in triplicate. Using pH/EC/TDS meter (Hanna HI 9811-5), the EC and pH of water samples were measured in the field immediately after the collection of the samples. Total hardness (TH) as $CaCO_3$ and Calcium (Ca^{2+}) were analyzed titrimetrically, using standard EDTA. TDS were computed from EC multiplied by a factor (0.55–0.75), depending on relative concentrations of ions. Magnesium (Mg^{2+}) was computed, talking the difference between TH and Ca^{2+} values. Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-) were estimated by titrating with H_2SO_4. Sodium (Na^+) and Potassium (K^+) were measured by flame photometer (Model-Mediflame 127). Chloride (Cl^-) was estimated by standard $AgNO_3$ titration. Sulphate (SO_4^{2-}) was measured by Spectrophotometer (Model Spectronic 21). Nitrate (NO_3^-) and Fluoride were analyzed, using an Ion selective electrodes (Model-Orion 4 star). This method is applicable to the measurement of fluoride in drinking water in the concentration range of 0.01–1,000 mg/L. The electrode used was an Orion fluoride electrode, coupled to an Orion electrometer. The spatial distribution for groundwater quality parameters such as, pH, EC, TDS, TH, CO_3^{2-}, HCO_3^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, Cl^- and F^- were done with the help of spatial analyst modules in Arc GIS 9.2 software.

The analytical results for the water samples collected from the study area were shown in Table 1. The minimum and maximum along with the averages are given in Table 1. Range in values of geochemical parameters in groundwater and WHO (2006) and Indian Standards (IS-10500; BIS 1991) for drinking water are shown in Table 1. Classification of groundwater for drinking based on EC (Table 2). Groundwater classifications of all groundwater on the basis of TDS and TH are presented in Table 1; Table 2). Sample locations of groundwater in the different aquifers are presented in Fig. 4.1 and topographic map of the study area is shown in Fig 4.1a. Spatial distribution maps of all physico-chemical concentration of groundwater are illustrated in Fig. 4.2 to 4.15.

Hydrogen Ion Concentration (pH):

The pH of water is very important indication of its quality and provides important piece of information regarding types of geochemical equilibrium (Hem, 1985). The pH of the groundwater is the measure of its acidity or alkalinity (Sherif *et al.,* 2006). The natural water H_2O contains H^+ ions and OH^- ions. The water becomes acidic (pH<7), when H^+ ions are in excess than OH^- and it becomes alkaline (pH>7) when reverse is the case. For neutral water (pH=7), the concentration of H^+ and OH^- are equal. The pH value sometimes is taken as measure of solvent power of water for various rock minerals, especially in limestone areas. Generally pH of water is influenced by geology of catchments area and buffering capacity of water. The effect of pH on the chemical and biological properties of liquids makes its determination very important.

The desirable limit for pH in drinking water is 6.5 to 8.5 according to BIS (2012) and WHO (1993). The pH of the groundwater in the granitic aquifers ranges from 6.79 to 7.87 with an average of 7.87 and the basaltic aquifers the pH ranges from 6.69 to 7.15 with an average of 7.58, which show that the groundwater quality is slightly acidic to slightly alkaline in nature, in majority of the samples, it is within the desirable limits (Fig 4.2a) of the WHO standards and Bureau of Indian Standards (BIS). A slight increase in pH was observed in the north and south-eastern part of the region (Fig 4.1).

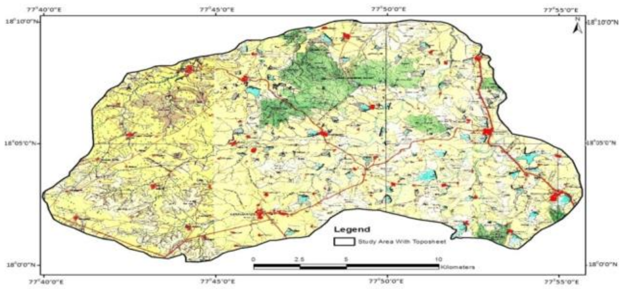

Figure 1. Toposheet map and Groundwater sample location of the Study Area

Table 1. Correlation matrix for physical and chemical parameters of groundwater samples in Narayankher, Telangana, India

	pH	*EC*	*TDS*	*Na^+*	*K^+*	*TH*	*Ca^{+2}*	*Mg^{+2}*	*CO_3^{2-}*	*HCO_3^-*	*Cl^-*	*SO_4^{2-}*	*NO_3^{2-}*
pH	1												
EC	0.45	1											
TDS	0.45	0.98	1										
Na^+	0.39	0.79	0.79	1									
K^+	0.45	0.19	0.19	0.33	1								
TH	0.47	0.44	0.44	0.14	0.15	1							
Ca^{+2}	0.29	0.56	0.56	0.56	0.19	0.11	1						
Mg^{+2}	0.51	0.66	0.66	0.48	0.24	0.7	0.77	1					

CO$_3^{2-}$	0.42	-0.18	-0.18	0.16	0.06	0.2	0.09	-0.2	1				
HCO$_3^-$	0.47	0.56	0.56	0.4	0.22	0.68	0.25	0.59	0.01	1			
Cl$^-$	0.57	0.55	0.55	0.48	0.42	0.57	0.32	0.58	-0.05	0.52	1		
SO$_4^{2-}$	0.67	0.52	0.52	0.37	0.53	0.46	0.48	0.62	-0.13	0.53	0.53	1	
NO$_3^{2-}$	0.48	0.57	0.57	0.67	0.34	0.5	0.24	0.5	-0.17	0.58	0.6	0.51	1
F$^-$	0.32	-0.08	-0.08	0.12	0.35	0.35	0.16	-0.32	-0.08	-0.13	0.25	-0.34	0.05

Table 2. Major ion concentrations of water samples in the Narayankher, Medak District, Telangana State

Sample ID	**Village**	**pH**	**EC**	**TDS**	**Na$^+$**	**K$^+$**	**Ca^{2+}**	**Mg^{2+}**	**TH**	**CO$_3^{2-}$**	**HCO$_3^-$**	**Cl$^-$**	**NO$_3^-$**	**SO$_4^{2-}$**	**F$^-$**
			µS/cm	mg/L											
MNG-1	Shankarampet	7.59	740	459	99	2	20	48	150	0	195	67	8	4	0.9
MNG-2	Malkapur	6.99	2500	1550	177	1	120	51	405	0	317	444	24	15	0.6
MNG-3	Baddaram	7.46	650	403	67	2	38	24	145	0	226	46	14	6	1.39
MNG-4	Baddaramvill	6.81	1700	1054	198	9	72	111	410	0	421	369	79	23	2.19
MNG-5	Shankarampet	7	1400	868	151	2	100	0	250	0	366	153	26	11	0.85
MNG-6	Kamalapuram	7.22	1200	744	159	2	36	27	145	0	476	131	16	7	1.5
MNG-7	Venkatapuram	7.87	300	186	54	2	14	22	80	90	305	124	11	5	0.4
MNG-8	Kamalapuram	7.39	900	558	125	2	32	39	160	0	201	32	13	10	1.78
MNG-9	Tenkati	7	400	248	154	37	48	41	205	0	366	53	41	16	0.73
MNG-10	Nizampet	6.96	1000	620	187	5	110	48	375	0	421	142	12	17	0.25
MNG-11	Nizampet	6.89	5100	3162	596	1	24	265	610	0	415	213	75	17	0.9
MNG-12	Nizampet	7.35	1030	639	92	2	148	140	660	0	311	50	8	7	0.78
MNG-13	Bachupalli	6.98	2500	1550	160	1	160	39	480	0	598	43	75	20	0.4
MNG-14	Bachupalli	7.14	1400	868	91	1	72	36	255	0	275	156	38	10	0.17
MNG-15	Mirkampet	6.79	800	496	160	53	90	142	520	0	366	440	80	23	0.22
MNG-16	Raparthi	6.88	3000	1860	191	2	246	36	525	0	653	568	71	25	0.15
MNG-17	Raparthi	7.22	1000	620	101	1	54	7	150	0	256	43	17	10	1.69
MNG-18	Ankampalli	7.06	1400	868	138	1	64	43	250	0	329	181	23	12	1.06
MNG-19	Kishnapura	7.19	1300	806	150	1	52	36	205	0	256	131	33	10	0.7
MNG-20	Kanapur.K	7.53	600	372	101	1	74	10	120	0	214	43	16	8	1.31
MNG-21	Kanapur	7.3	2300	1426	408	2	66	10	185	0	323	156	16	40	2.16
MNG-22	Kanapur Chrvuu	7.29	1100	682	109	1	54	39	215	0	275	53	27	13	0.5
MNB-23	Kajapur	7.25	900	558	151	2	38	14	125	0	275	67	16	8	1.38
MNB-24	Kajapur	7.3	1500	930	184	2	52	58	250	0	275	213	17	16	0.9
MNB-25	Kajapur Tank	7.07	2100	1302	294	1	102	82	425	0	305	369	9	18	0.36
MNB-26	Kadpol	6.8	700	434	306	94	88	63	350	0	397	351	74	21	0.14
MNB-27	Sirgapoor	7.46	700	434	50	2	50	24	175	0	214	36	8	6	0.68
MNB-28	Sirgapoor	7.21	700	434	72	1	40	24	150	0	214	67	15	8	1.52
MNB-29	Momya Tanda	7.22	600	372	80	2	44	12	75	0	207	50	12	10	0.12
MNB-30	Jamla Tanda	7.39	600	372	75	1	42	53	215	0	159	28	10	7	0.4
MNB-31	Rekhal Tanda	6.9	1300	806	114	54	68	17	135	0	293	117	44	8	0.22
MNB-32	Thurkpally	7.58	700	434	88	7	38	87	275	0	189	50	10	8	0.5
MNB-33	Thurkaplly	7.29	900	558	76	1	64	19	200	0	250	96	14	7	0.81
MNB-34	kondapur	7.17	1000	620	123	1	58	111	375	0	238	85	73	8	0.4
MNB-35	Mansurpur	7.03	1500	930	185	3	76	53	300	0	287	192	46	9	0.74
MNB-36	Gadidi Hukran	7.55	800	496	169	2	30	51	180	0	73	78	17	8	0.82
MNB-37	Abbanda	7.08	2100	1302	185	38	110	22	320	0	360	266	62	20	0.6
MNB-38	Abbanda Dargga	7.39	1100	682	246	4	40	0	100	0	146	209	8	13	2.3
MNB-39	Narayankher	6.83	3500	2170	360	126	96	101	450	0	378	405	84	21	0.4
MNB-40	Narayankher	6.69	100	62	26	3	20	0	50	0	31	64	20	3	0.5
MNB-41	Narayankher	7.02	2300	1426	318	21	88	80	385	0	342	337	10	16	0.5
MNB-42	Thimmapur	6.98	1900	1178	167	35	94	75	390	0	293	238	79	18	0.14
MNB-43	Sheligera	7.29	800	496	58	1	50	27	180	0	281	231	17	5	0.2
MNB-44	Sheligera	6.95	2000	1240	133	6	140	82	520	0	287	266	82	17	0.5

Electrical Conductivity (EC)

The electrical conductivity of water depends on the water temperature, types of ions present in the water and their concentration (Sherif et al., 2006; Hem, 1991). The maximum limit of electrical conductivity in drinking water is prescribed as 1500 µS/cm (WHO, 2004). EC of the groundwater is varying from 100 to 5100 µS/cm at 25ºC with an average value of 938 µS/cm (Table-4.1). The study area minimum value is observed granitic terrain is at Venkatapuram village with a value of 300 µS/cm and a maximum value is observed at 5100 µS/cm at Nizampet village (Table 4.1).

Spatial distribution, distribution map of EC is shown in Fig 4.3 & 4.3a. The classification of groundwater on the basis of EC is given in Table 4.2. It is found that only 72% of the samples are within the permissible limit, 22% of the samples fall in the not permissible limit but they are marginally poor in quality and 18% of the sample locations can be classified as hazardous according to the WHO standard (Table 4.1b). EC of the groundwater higher than 3000 µS/cm was recorded in three locations which are similar to the high values of EC reported by (Brindha and Kavitha 2015; Jameel and Hussain 2011). Higher EC of groundwater depends on the weathering of aquifer material and influence of anthropogenic activities polluting the ground and surface water.

Total Dissolved Solids (TDS)

The range of TDS values in granitic and basaltic aquifers was found to be in the range of 186-3162 mg/L with an average of 974 mg/L and 62-2170 mg/L with an average of 1263 mg/L respectively. The lowest value is observed at Narayankher town (MNB-18) and the highest concentration is observed at Nizampet (MNG-11) (Fig 4.5 & Table 4.1). According to the WHO and BIS specification, TDS up to 500 mg/L is desirable for drinking water. The spatial distribution of TDS in groundwater (Fig. 4.7) shows that 27 and 59% of the area falls in desirable (<500 mg/L) and permissible (500–1,500 mg/L) categories respectively, in granitic terrain, while 41, 55 and 4% of the area respectively fall in the desirable, permissible, and exceedingly permissible (>1,500 mg/L) categories in Basaltic terrain (Fig. 4.7). To determine the suitability of groundwater of any purposes, it is indispensable to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Freeze and Cherry 1979) which are presented in Tables 4.2a respectively.

Table 4.2 Classification of groundwater for drinking based on EC

EC (µS/cm)	Classification	No of Samples	% of samples
<750	Desirable	12	27
750-1500	Permissible	20	45
1500-3000	Not Permissible	9	22
<3000	Hazardous	3	7

Table 4.2 Groundwater classifications of all groundwater on the basis of TDS

TDS (mg/L)	Classification	% of samples		Reference
		Granitic region	Basaltic region	
<500	Desirable for drinking	27	41	Davis and DeWiest 1996
500-1000	Permissible for drinking	45	32	

1000-3000	Useful for irrigation	23	27	
>3000	Unfit for drinking and irrigation	5	Nil	
Total		100	100	
<1000	Fresh water	72	73	Freeze and Cherry 1979
1000-10,000	Brackish water	28	27	
10,000-100,000	Saline water	Nil	Nil	
>100,000	Brine water	Nil	Nil	
Total		100	100	

Table 4.2 Groundwater classification based on total hardness (TH)

TH (mg/L)	Classification	Percentage of samples		Reference
		Granitic region	Basaltic region	
<75	Safe	Nill	5	Sawyer and McCartly 1967
75-150	Moderately high	22	23	
150-300	Hard	32	37	
>300	Very Hard	46	35	
Total		**100**	**100**	

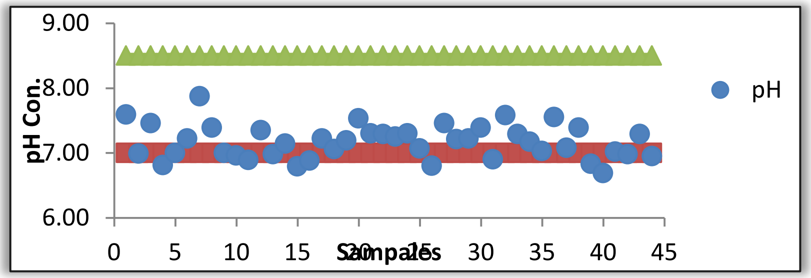

Figure 4.2 Distribution of pH (mg/L) in groundwater

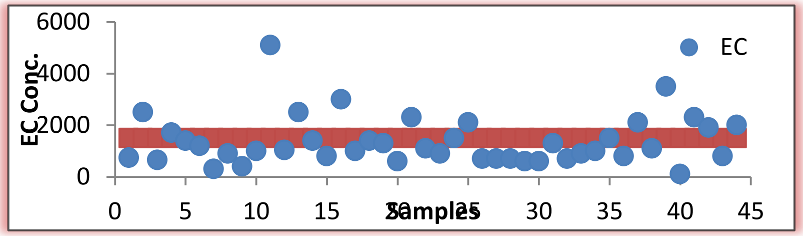

Figure 4.3 Distribution of EC (mg/L) in groundwater

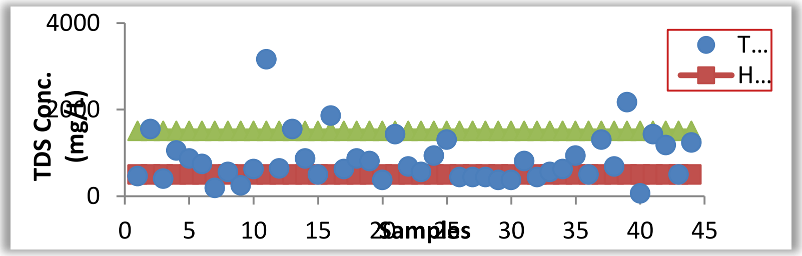

Figure 4.4 Distribution of TDS (mg/L) in groundwater

The high concentration of TDS beyond the permissible limit, observed in the northeastern part of the region (Fig 4.4), may be due to agricultural practices, leaching of salts from soil, and anthropogenic activities. The EC and concentration of TDS is more than the maximum permissible limit of 1500 µS/cm and 1500 mg/L, respectively, in 32 and 39% of the total groundwater samples (Table 4.2). The higher EC and TDS values may cause a gastrointestinal irritation in the consumers (Howard and Bartram 2003). Several processes include movements through rocks containing soluble mineral matter, concentration by evaporation and concentration due to influx of seawater, urban, industrial and agricultural waste disposals may cause the increase in the TDS content of groundwater.

Total Hardness (TH)

Hardness of the water is attributable to the presence of alkaline minerals primarily Ca and Mg and sometimes bicarbonates. The hardness is of two types (1) temporary hardness (2) permanent hardness. The first type is due to the presence of HCO_3 of Ca and Mg, which can be easily removed by boiling the water. The second type is due to the presence of SO_4, Cl and NO_3 ions of Ca and Mg, which cannot be removed by boiling the water. The total hardness in water is derived from the solution of CO_2 released by the bacterial action in the soil. In percolating rainwater in limestone area besides the different sources of pollutants also increases the concentration of total hardness in groundwater. The total hardness of groundwater samples from granitic aquifers was found in the range of 80-660 mg/L with an average of 302 mg/L, and from basaltic aquifers was found in the range of 50-520 mg/L with an average of 255 mg/L (Table 4.1). Spatial distribution of the TH concentration in the groundwater is illustrated in Fig. 4.5. The distribution map of the TH concentration (Fig. 4.5) shows that the area falls between the desirable (100 mg/L) and permissible limits (500 mg/L) as per WHO and BIS standards. The concentration of TH was relatively high in eastern and north-eastern parts of the study area such as Nizampet (610 mg/L), Nizampet crossroad (660 mg/L), Raparthi (525 mg/L), Mirkampet (520 mg/L) and Sheliger (520 mg/L; Table 4.1). However, in the remaining samples, the TH concentration was below the permissible limit of 500 mg/L (Table 4.1). The classification of groundwater (Table 4.2) based on TH shows that 46 and 35% the groundwater samples fall in the very hard water category, in granitic and Basaltic regions respectively. Groundwater exceeding the limit of 300 mg/l is considered to be very hard. Hardness has no known adverse effect on health, but it can prevent formation of lather and increase the boiling point of water. The high TH may cause encrustation on water supply distribution systems. There is some suggestive evidence that long-term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, parental mortality, some types of cancer, and cardio-vascular disorders (Durvey et al., 1991).

Sodium (Na^+)

Sodium is the most abundant alkali metal. The concentration of sodium varies from 54 to 596 mg/L with an average value of 180 mg/L, 26 to 360 mg/L with an average value of 157 mg/L in Granitic and Basaltic aquifers respectively (Table 4.1). The concentration of sodium was relatively high in eastern and northern parts of the study area such as Nizampet (596 mg/L), Kajapur (294 mg/L), Kanapur (408 mg/L), Kadpol (306 mg/L) and Narayankher (360 mg/L; Table 4.1). However, the concentration of sodium in almost all the samples (except above samples) was found well within the permissible limit of 200 mg/l. Such water should be treated before being used for domestic applications. Higher concentration of Na^+ may pose risk to persons suffering from cardiac, renal and circulatory diseases. Spatial distribution of the sodium concentration in the groundwater is illustrated in Fig. 4.6. The distribution map of the sodium concentration

(Fig. 4.6) shows that the area falls the permissible limits (200 mg/L) as per WHO standards (Table 4.1). Thus, the water in this area had high concentrations of sodium in groundwater and surface water which if consumed may have adverse health impacts.

Potassium (K^+)

The common source of potassium is feldspars (orthoclase and microcline), potash fertilizers, feldspathoids, some mica sand clay minerals. Although K^+ is nearly as abundant as Na in minerals of earth crust. It is also less than Na.

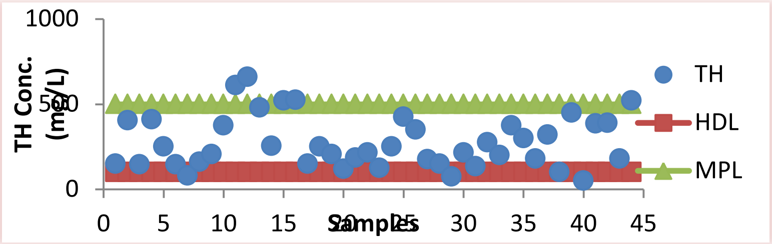

Figure 4.5 Distribution of TH (mg/L) in groundwater

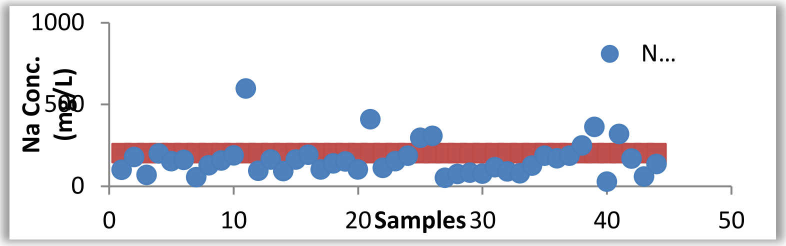

Figure 4.6 Distribution of Sodium (mg/L) in groundwater

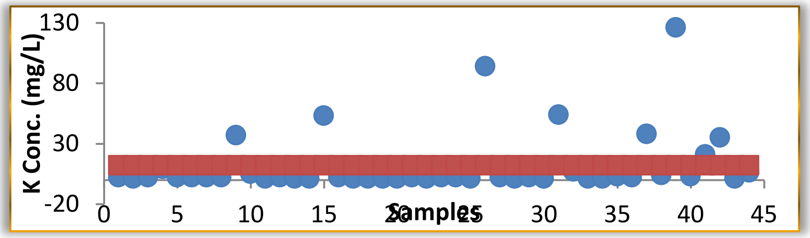

Figure 4.7 Distribution of Potassium (mg/L) in groundwater

In groundwater, its concentration is usually 10 mg/L and seldom exceeds 18 mg/L. Thermal and brine waters contain as much as 100 and 25,000 mg/L respectively. In the study area the minimum and maximum values of potassium are varying granitic aquifer range between 1 to 53 mg/L with an average concentration of 7.7 mg/L, and basaltic aquifer range between 1 to 126 mg/L with an average of 18 mg/L. Potassium is an essential nutrient but if ingested in excess may behave as a laxative. 6 samples out of 22 from basaltic aquifer and 2 samples out of 22 from granitic aquifer have potassium concentration above the recommended value of 12 mg/l according to WHO (Fig. 4.7). Furthermore, the potassium concentration has the highest variability in north, western and southern portions of the area (Fig. 4.7). The concentration of potassium at a few places (Narayankher 126 mg/L; Tanda 54 mg/L; Tenkati 37 mg/L; Thimmapur 35 mg/L) is unusually very high, which may be due to salt patches present geogenically and fertiliser leaching or return flow (Table 4.1). The higher concentration of sodium among the cationic concentrations reflects a rock weathering and/or dissolution of soil salts stored by the influence of evaporation (Stallard and Edmond 1983) and also indicates its higher solubility behavior, while the lower concentration of potassium (mostly less than 5 mg/l) is because of its fixation on clay minerals (Hem 1991).

Calcium (Ca^{2+})

Calcium is an essential nutritional element for humans. Thus, the optimum concentration of Ca^{2+} is required to prevent cardiac disorders and for proper functioning of metabolic processes (WHO 2011). Highest desirable level of calcium in drinking water is 75 mg/L and maximum permissible limit is 200 mg/L (BIS 2012). The maximum permissible limit is considered usually in the absence of any other source of water for drinking. Concentration of calcium ranged from 14 to 246 mg/L in granitic aquifer and from 20 to 140 mg/L for basaltic aquifer (Table 4.1). Only one (Raparthi 246 mg/L) groundwater sample was exceeding the limit of 200 mg/L prescribed by BIS & WHO, while all the basaltic region water samples were within the limit (Table 4.1b). Spatial distribution of the calcium concentration in the groundwater is illustrated in Fig. 4.8 and also distribution map is shown in Fig. 4.8.

Magnesium (Mg^{2+})

The concentration of magnesium in granitic and basaltic aquifer ranges from 0 to 265 mg/L and 0 to 110 mg/L, with an average value of 62 mg/L to 48 mg/L respectively (Table 4.1). The concentration of magnesium ion in this groundwater samples is relatively high when compared to calcium ion concentration and the magnesium concentration is mostly due to weathering of magnesium minerals and leaching of dolomites. The (Ca^{2+}+Mg^{2+}) vs (HCO_3^- +SO_4^-) scatter diagram (Datta and Tyagi 1996) shows that most of the samples are falling below the equiline. It is indicating that the silicate weathering is the dominant process for supply of the calcium ions to the groundwater (Fig. 4.9). In addition to silicate weathering, the carbonate weathering process is also a contributor for increasing of calcium ions in this groundwater. Spatial distribution of the magnesium concentration in the groundwater is illustrated in Fig. 4.9. The distribution map of the magnesium concentration

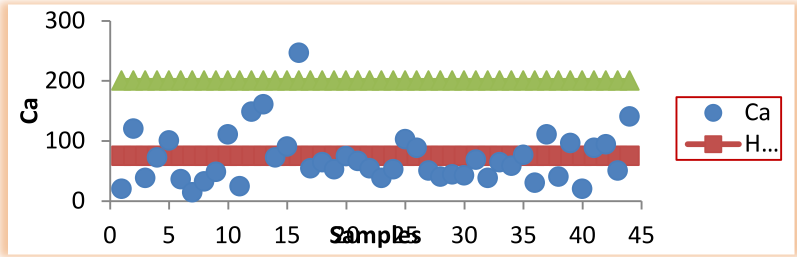

Figure 4.8a Distribution of Calcium (mg/L) in groundwater

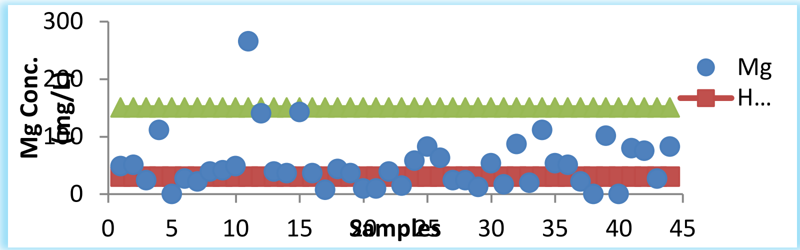

Figure 4.9a Distribution of Magnesium (mg/L) in groundwater

Carbonates and Bicarbonates (CO_3^{2-} and HCO_3^-)

The primary source of CO_3^{2-} and HCO_3^- ions in groundwater is due to the dissolved CO_3^{2-} in water. Decay of organic matter in the soil releases CO_3^{2-} for dissolution. Water charged with CO_3^{2-} dissolves the carbonate minerals to give HCO_3^-. The pH of the water indicates the form in which the CO_2 is present. The presence of carbonic acid is indicated, when the pH is less than 4.5, HCO_3^- if the pH is between 4.5 and 8.2 and CO_3^{2-} if the pH is over 8.2. In groundwater, the concentration of CO_3^{2-} generally does not exceed 10 mg/l. In the study area, HCO_3^- ranges between 195 to 652 and 30 to 396 mg/l in granitic aquifer and basaltic aquifer, respectively (Table 4.1). The concentration of carbonate value ranges from 0 to 90 mg/L with a mean value of 7.5 mg/L. Thus, the carbonates (HCO_3^- and CO_3^{2-}) are the dominated ions in the groundwater. They result from the CO_2 that is released from the decay of organic matter and root respiration in soil zone. This CO_2 combines with H_2O to form HCO_3^-, which in turn converts to CO_3^{2-} (Eqs. 1–3) in rock weathering during infiltration of recharge water (Jacks 1973).

$$CO2 + H2O \rightarrow H2CO3$$

$$H2CO3 \rightarrow H^{+} + HCO3^{-}$$

$$HCO_3^{-} \rightarrow H^{+} + CO_3^{2-}$$

The content of HCO_3^- has no known adverse health effects, but it should not exceed 300 mg/l (WHO 1997). In Figure 4.10 & 4.11, the result of water analysis for carbonates and bicarbonate concentration are shown as spatial distribution. The carbonate and bicarbonate concentration in groundwater is derived from carbonate weathering as well as dissolution of carbonic acid in the aquifers.

Chloride (Cl^-)

The limits of chloride ion have been laid down primarily from taste consideration. A limit of 250 mg/L chloride has been recommended as desirable limit for drinking water supplies (BIS 1991; WHO 1993). In excess of Cl^- in the water is usually taken as an index of pollution and considered as tracer for groundwater contamination (Loizidou and Kapetanios 1993). It varies from 32 to 568 mg/L in granitic aquifer, while 28 to 405 mg/L in basaltic aquifer groundwater of study area (Table 4.1). About 18% (Raparhi 568 mg/L; Malkapur 444 mg/L; Mirkampet 440 mg/L and Baddaram 369 mg/L) granitic aquifer and 26% (Narayankher 405 mg/L; Kajapur 369 mg/L; Kadpol 351 and Sheligera 266 mg/L) basaltic aquifer samples have chloride more than desirable limit (Table 4.1). The permissible limit of Cl^- in potable water is 250 mg/L, which may be further relaxed up to 1,000 mg/L for Indian conditions (Table 4.1). The spatial distribution of Cl^- is shown in Fig. 4.12. The high Cl^- concentration in groundwater comes from weathering of minerals like halite and other sources such as domestic effluents, fertilizers, septic tanks and leachates from landfills (Loizidou and Kapetanios 1993).

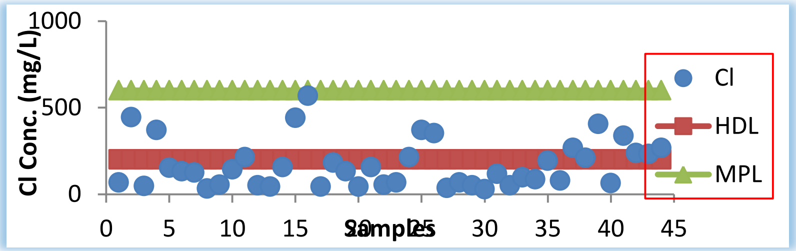

Figure 4.12 Distribution of Chloride (mg/L) in groundwater

Sulphate (SO_4^{2-})

The concentration of sulphate is likely to react with human organs if the value exceeds the maximum allowable limit of 400 mg/L and cause a laxative effect on human system with the excess magnesium in groundwater. High concentration of sulphate may cause respiratory problems (Maiti 1982; Rao 1993) and may have laxative effect on humans. It varies from 4 to 40 mg/L with an average of 15 mg/L in granitic aquifer, while basaltic aquifer recorded 3 to 21 mg/L with an average of 12 mg/L (Table 4.1) and found within the highest desirable limit 200 mg/L in all sample locations as per WHO and BIS specification. The spatial distribution of SO_4^{2-} (Fig. 4.13) indicates that the entire study area falls in the desirable category (<200 mg/L) as per WHO standards and BIS (Table 4.1).

Nitrate (NO_3^-)

Nitrate concentration of groundwater samples varied from 8 to 80 mg/L with an average value of 34 mg/L in the granitic aquifer and from 8 to 84 mg/L with an average value of 33 mg/L in the basaltic aquifer (Table 4.1). It is found that only 11 groundwater samples exceed the desirable limit of 45 mg/L as per WHO (1993) and BIS (1991) standard (Table 4.1b). The high nitrate concentration (Sheligera 82 mg/L; Narayankher 84 mg/L; Mirkampet 80 mg/L; Baddaram 79 mg/L; Nizampet 75 mg/L; Kadpol 74 mg/l; Timmapur 79 mg/L; Kodapur 73 mg/L and Mansurpur 46 mg/L) may occur due to leaching of NO_3^- from fertilizers and pesticides during the irrigation of agriculture land (Table 4.1). High nitrate concentrations in the groundwater are reported in many parts of India because of intensive agricultural practices which utilize nitrogen fertilizers changing the natural drainage patterns intensive urbanization and industrialization (Raju *et al.,* 2009). In contrast, samples taken from sampling points southwest and in agricultural areas (e.g., north-eastern of the study area) had clearly the highest nitrate concentrations.

Fluoride (F^-)

Fluorides are ubiquitous in the environment and the amount of fluoride occurring naturally is dependent upon the individual geological environment (Kahama *et al.,* 1997). Especially high fluoride levels in water have been found in India, China and Africa (Tirumalesh, 2007; Muralidharan *et al.,* 2002; Saxena *et al.,* 2001). The natural concentration of fluoride in water depends on several contributing factors such as pH, total dissolved solids, alkalinity, the porosity and acidity of the soil and rocks, the temperature, the depth of wells, etc. The occurrence of F^- in groundwater is mainly due to natural or geogenic contamination and the source of contamination is often unknown. Abnormal levels of fluoride in water are common in fractured hard rock zone with pegmatite veins. It occurs in the earth crust along with the fluoride rich mineral bearing rocks. Minerals like topaz, fluorite, fluor-apatite, villuamite, cryolite and fluoride replaceable hydroxide ion in ferro--magnesium silicates contribute to fluoride in groundwater.

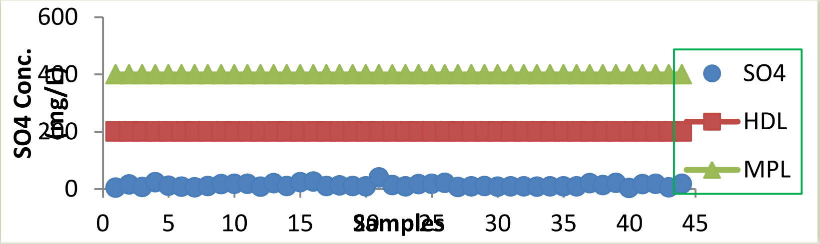

Figure 4.13 Distribution of Sulphate (mg/L) in groundwater

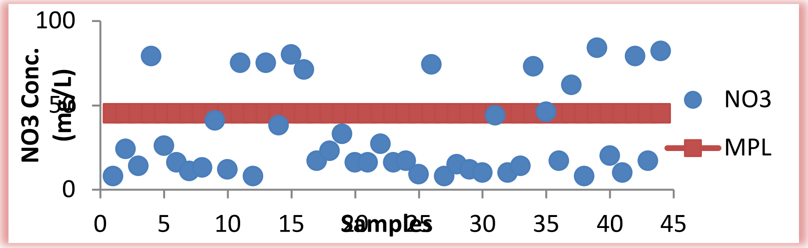

Figure 4.14 Distribution of Nitrate (mg/L) in groundwater

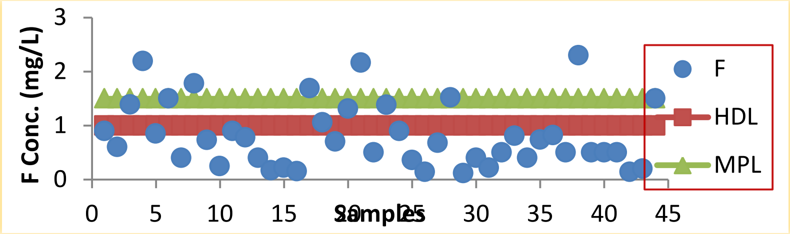

Figure 4.15 Distribution of Fluoride (mg/L) in groundwater

Fluoride (F^-) although helpful in dental health in low dosage (<1.5 mg/L), it causes endemic dental and skeletal fluorosis when it exceeds the limit. Fluoride occurs in natural waters due to its high electronegativity and solubility. Common natural sources of F^- in groundwater are the dissolution of fluorspar, fluorapatite, amphiboles (e.g., hornblende, tremolite) and some micas weathered from igneous and sedimentary rocks, especially shales (Datta *et al.,* 1996). For the general population the intake of fluoride derives mainly from drinking water and to a lesser extent from foodstaffs. Presence of fluoride ions ranging from 0.2 to 2.2 mg/L (Table 4.1) in the groundwater suggest that favorable conditions exist for the dissolution of fluoride bearing minerals present in the granite and gneissic rocks in the study area. High fluoride concentration in Narayankher are mostly found in gneissic and granitic areas; fluoride bearing minerals occupy the joints, fractures, faults and vertical openings in the gneissic and granitic formations which are the oldest geological formations in Narayankher and have undergone maximum weathering (Table. 4.1). Spatial distribution of the fluoride concentration in the groundwater is illustrated in Fig. 4.15. The distribution map of the fluoride concentration (Fig. 4.15) shows that the area falls between the desirable (1 mg/L) and permissible limits (1.5 mg/L) as per WHO and BIS standards.

IV. CONCLUSION

The final concluded that evaluate quality groundwater of region determined by the geological composition of the aquifers and human activities in the area. Standards for groundwater include quantitative and qualitative (water quality) standards. Groundwater quality is the composition of constituents dissolved or contained within the water in the functioning of natural processes and human activities. Chemical composition is the most common factor invoked to characterize water quality; however, biological, physical, and radiological factors should also be considered when describing water quality. The chemical analysis were carried out for pH, electrical conductivity (EC), total dissolved salts (TDS), total hardness (TH) as well as sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), chloride (Cl^-), sulphate (SO_4^-), nitrate (NO_3^-) and fluoride (F^-) according to the standard methods (APHA, 2005). GIS has been applied to visualize the spatial distribution of groundwater quality in the study area.

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