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Hydrochemical Characteristics and Groundwater Quality Assessment in Narayankher area Medak District, Telangana, India

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ABSTRACT

Groundwater is a vital source of water for domestic and agricultural and industrial activities in Narayankher area Medak District, Telangana due to lack of surface water resources groundwater quality and its suitability for drinking agriculture and industrial usage were evaluated. Physical and chemical parameters of groundwater such as pH, Electrical Conductivity, Total Dissolved Solids (TDS), TH, Na+, K+, Ca2+, Mg2+, Cl-, HCO3-, CO3-, and, SO4- and Chemical index like Percentage of Sodium (Na%), Chloro Alkaline Indices (CAI), Kelley's Ratio, Magnesium hazard were calculated based on the analytical results. The chemical relationships in Piper diagram identify Ca-Na-HCO3 and mixed Ca-Na-Mg-HCO3 as most prevent water types. Alkaline earths exceed alkalies and strong acids exceed weak acids. 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.

Keywords: Groundwater Quality, Hydrochemistry, Hydrogeology, Water Type

I. INTRODUCTION

Groundwater and surface water are the main sources of water supply for agriculture, industrial and domestic use. The quality of water is of vital concern for mankind, since it is directly linked with human welfare. Poor quality of water adversely affects the plant growth and human health [1, 2 and 3]. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Water quality analysis is an important issue in groundwater studies. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities [4]. Groundwater quality data give important clues to the geologic history of rocks and indications of groundwater recharge, movement and storage. The knowledge of hydrochemistry is essential to determine the origin of chemical composition of groundwater. The hydrology and geochemistry of waters have been further discussed in the classic works of [3, 4 and 6]. Determination of physical, chemical quality of water is essential for assessing its suitability for various purposes like drinking, domestic, agricultural and industrial uses.

Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry [7, 8]. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes [9, 10]. Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interaction. Such factors and their interactions result in a complex groundwater quality [11, 12 and 13]. Groundwater is an important water resource for drinking, agriculture and industrial uses in study area (Figure 1). In this study, physical, hydrogeological, and hydrochemical data from the groundwater groundwater system will be integrated and used to determine the main factors and mechanisms controlling the chemistry of groundwater in the area.

This has prompted author to take study related to the quality variations in Narayankher area Medak District, Telangana, 44 water samples were collected from bore wells and hand pumps in the vicinity of cultivated agricultural land, hand pumps in densely populated area. Present in this paper, an attempt is made to evaluate the quality indices of groundwater to understand the geochemical relationships of water quality for the suitability of groundwater resources. In view of this, an extensive survey has been conducted in order to know the quality of water for domestic, agriculture, irrigation and industrial use.

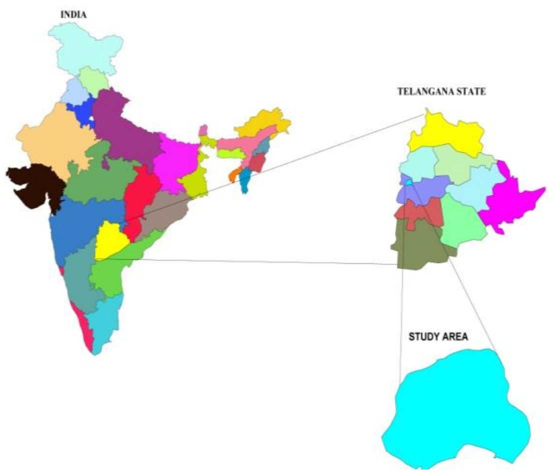

Figure 1. Location Map of the study Area

II. MATERIALS AND METHODS

Forty-four groundwater samples were collected from bore wells, dug wells and hand pumps of the following villages Malkapur, Baddaram, Shankarampet, Kamalapuram, Venkatapura, Kamalapur 'X'road, Tenkati, Nizampet, Bachupalli, Mirkampet, Raparthi, Ankampalle, Krishnapurm, Kanapur, Narayankhed, Thimmapur villages are in Granitic terrain. Kajapur, Kadpol and Sirgapur villages are in Granites-Basalts contact Rakal, Thurkapalle, Kondapur, Mansurpur and Gadidi Villages are having Basalts. Hukran, Abendda and Sheligera 'X' road villages are having Intratrappeans (Figure 2). Using pre-cleaned sterilized poly propylene plastic bottles with necessary precautions, among which twenty two sample, are from granitic aquifer and twenty two samples are from basaltic aquifers (2 Lit. Capacity) and numbered sequentially.

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 [14] were followed.

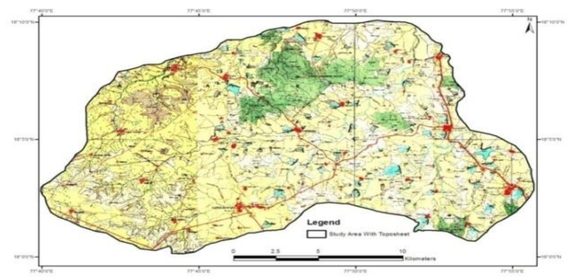

Figure 2. Sampling points with the Toposheet

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 [14] 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.

III. RESULTS AND DISCUSSION

A. Groundwater Chemistry

pH is varying between 6.70 to 8.60 with an average value is 7.27 respectively. The pH of groundwater in the study area is moderately alkaline (pH more than 7) in nature. Electrical Conductivity of the groundwater varies from 260 to 1830 micromhos/ cm at 250C (average 1115 micromhos/cm). The acceptable limit of EC in drinking water is less than 1500 micromhos/cm. 8% of samples show values higher than the prescribed limit. Higher concentrations indicate that the ionic concentrations are more in the groundwater.

B. Drinking Water Quality

Drinking water quality the analytical results of physical and chemical parameters of groundwater were compared with the standard guideline values as recommended by the World Health Organization for drinking and public health purposes [15] (Table 1 a&b). The table shows the most desirable limits and maximum allowable limits of various parameters. The concentrations of cations, such as Na+, Ca2+, and Mg2+, K+ and anions such as HCO3 -, CO3 2-, Cl- and SO4 - are within the maximum allowable limits for drinking except a few samples.

Table 1. Major ion concentrations of water samples in the Narayankher, Medak District, Telangana State

Sample ID	Village	pH	EC µS/cm	TDS mg/L	Na^+ mg/L	K^+ mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	TH mg/L	CO_3^{2-} mg/L	HCO_3^- mg/L	Cl^- mg/L	NO_3^- mg/L	SO_4^{2-} mg/L	F^- 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	Baddaram vill	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-1	Kajapur	7.25	900	558	151	2	38	14	125	0	275	67	16	8	1.38
MNB-2	Kajapur	7.3	1500	930	184	2	52	58	250	0	275	213	17	16	0.9
MNB-3	Kajapur Tank	7.07	2100	1302	294	1	102	82	425	0	305	369	9	18	0.36
MNB-4	Kadpol	6.8	700	434	306	94	88	63	350	0	397	351	74	21	0.14
MNB-5	Sirgapoor	7.46	700	434	50	2	50	24	175	0	214	36	8	6	0.68
MNB-6	Sirgapoor	7.21	700	434	72	1	40	24	150	0	214	67	15	8	1.52
MNB-7	Momya Tanda	7.22	600	372	80	2	44	12	75	0	207	50	12	10	0.12
MNB-8	Jamla Tanda	7.39	600	372	75	1	42	53	215	0	159	28	10	7	0.4
MNB-9	Rekhal Tanda	6.9	1300	806	114	54	68	17	135	0	293	117	44	8	0.22
MNB-10	Thurkpally	7.58	700	434	88	7	38	87	275	0	189	50	10	8	0.5
MNB-11	Thurkaplly	7.29	900	558	76	1	64	19	200	0	250	96	14	7	0.81
MNB-12	kondapur	7.17	1000	620	123	1	58	111	375	0	238	85	73	8	0.4
MNB-13	Mansurpur	7.03	1500	930	185	3	76	53	300	0	287	192	46	9	0.74
MNB-14	Gadidi Hukran	7.55	800	496	169	2	30	51	180	0	73	78	17	8	0.82
MNB-15	Abbanda	7.08	2100	1302	185	38	110	22	320	0	360	266	62	20	0.6
MNB-16	Abbanda Dargga	7.39	1100	682	246	4	40	0	100	0	146	209	8	13	2.3
MNB-17	Narayankher	6.83	3500	2170	360	126	96	101	450	0	378	405	84	21	0.4
MNB-18	Narayankher	6.69	100	62	26	3	20	0	50	0	31	64	20	3	0.5
MNB-19	Narayankher	7.02	2300	1426	318	21	88	80	385	0	342	337	10	16	0.5
MNB-20	Thimmapur	6.98	1900	1178	167	35	94	75	390	0	293	238	79	18	0.14
MNB-21	Sheligera	7.29	800	496	58	1	50	27	180	0	281	231	17	5	0.2
MNB-22	Sheligera	6.95	2000	1240	133	6	140	82	520	0	287	266	82	17	0.5

Table 1a. Drinking water specifications of the study area minimum, maximum, and mean and stranded deviation ion concentration in different aquifers

Parameters	Granitic aquifers				Basaltic aquifers			
	Min	Max	Average	St.Dev	Min	Max	Average	St.Dev
pH	6.8	7.9	7.2	0.3	6.7	7.6	7.2	0.2
EC	300.0	5100.0	1469.1	1080.6	100.0	3500.0	1263.6	781.7
TDS	186.0	3162.0	910.8	669.9	62.0	2170.0	783.5	484.6
TH	80.0	660.0	295.5	172.4	50.0	520.0	255.7	131.9
Ca^{2+}	14.0	246.5	77.2	54.6	20.0	140.3	65.0	30.6
Mg^{+}	0.0	265.3	55.1	60.5	0.0	111.0	47.9	33.7
Na^{+}	54.0	596.0	166.7	119.2	26.0	360.0	157.3	95.6
K^{+}	1.0	53.0	6.0	13.0	1.0	126.0	18.5	33.3
CO_3^{-}	0.0	90.0	4.1	19.2	0.0	0.0	0.0	0.0
HCO_3^{-}	195.2	652.7	343.8	119.1	30.5	396.5	249.5	91.7
Cl^{-}	32.0	568.0	165.4	152.7	28.4	404.7	173.5	121.4
SO_4^{2-}	4.0	40.0	14.0	8.4	3.0	21.0	11.6	5.7
NO_3^{-}	8.0	80.0	32.9	25.6	8.0	84.0	33.0	28.7
F^{-}	0.2	2.2	0.9	0.6	0.1	2.3	0.6	0.5

Table 1b. Statistical summary along with different official limits of drinking water quality.

Water Quality Parameters	Units	BIS (1991)		WHO (2006)		Concentration in the study area	Percentage of samples exceeding HDL	Percentage of samples exceeding MPL
		Higest Desirable Limit (HDL)	Maximum Permissible Limit (MPL)	Higest Desirable Limit (HDL)	Maximum Permissible Limit (MPL)			
pH	-	6.5	8.5	7	8.5	6.69 - 7.87	-	-
EC	µS/cm	-	-	-	1500	100 - 5100	12	32
TDS	mg/L	500	2000	500	1500	62 - 3162	5	39
TH	mg/L	100	500	100	500	50 - 660	5	39
Ca^{2+}	mg/L	75	200	75	200	14 - 246	1	43
Mg^{+}	mg/L	30	100	30	150	00 - 265	1	43
Na^{+}	mg/L	100	-	-	200	26 - 596	7	37
K^{+}	mg/L	10	-	12	-	01 - 126	8	36
CO_3^{-}	mg/L	10	-	10	-	00 - 90	1	43
HCO_3^{-}	mg/L	300	-	-	-	31 - 653	19	25
Cl^{-}	mg/L	250	1000	200	600	28 - 568	-	44
SO_4^{2-}	mg/L	200	400	200	400	3 t0 40	-	-
NO_3^{-}	mg/L	45	-	45	-	8 to 84	12	32
F^{-}	mg/L	0.6	1	1	1.5	00 - 2.30	5	39

C. Hydrogeochemical Facies of Groundwater

Geochemical graphic analyses methods, principally Piper diagram [16] have been widely used in groundwater studies to characterize a large number of water chemical data. This diagram reveals similarities and differences among groundwater samples because those with similar qualities will tend to plot together as groups [17]. Piper's trilinear diagram method is used to classify the groundwater, based on basic geochemical characters of the constituent ionic concentrations. The chemical data of the groundwater samples collected from the study area are plotted in the Piper's diagram (Figure 3), groundwater of study area is classified into different types according to the percentage of chemical constituents present in it (Table 2). 31.81% of the groundwater samples are falling in area 1 of subdivision of diamond-shaped field, which is characterized as Alkaline earths exceeds alkalis and 68.18% in the area 2 of where Alkalis exceeds alkaline earths, 61.36% in the area 3 that indicates weak acids exceeds strong acids, 38.63% in the field 4 indicates strong acids exceed weak acids, whereas 18.18% of the groundwater samples in area 5 are classified as carbonate hardness (secondary alkalinity) exceeds 50%, i.e. chemical properties of the groundwater are dominated by alkaline earths and weak acids and nil in the area 6 indicating no non carbonate hardness (secondary salinity) exceeds 50%, i.e. chemical properties of the groundwater are dominated by alkalis and strong acids. 25% of the groundwater samples falls in the area 7 indicating non carbonate alkali (primary salinity) exceeds 50%, i.e. chemical properties of the groundwater are dominated by alkalis and weak acids and nil in the area 8 indicating no primary alkalinity. 56.82% samples in the area 9 represent no one cation – anion exceeds 50% (Table 2).

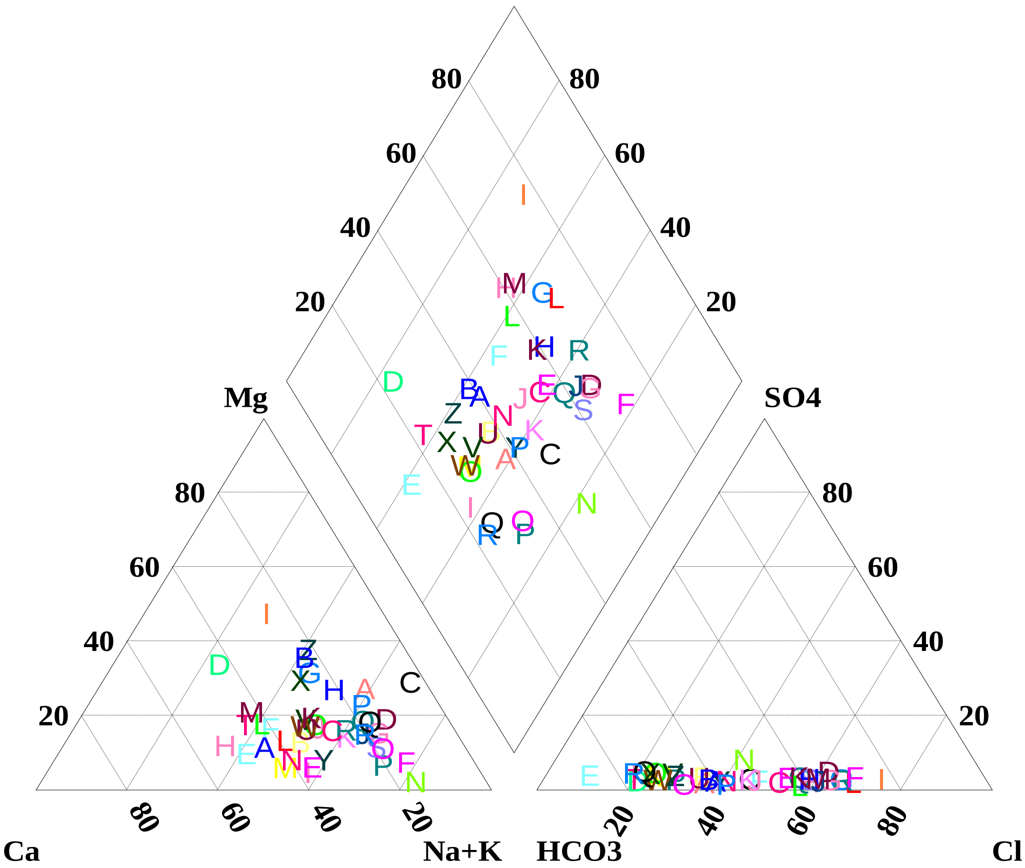

Figure 3. Piper Trilinear Diagram Representing the Chemical Analysis of the Study Area

Table 2. Distribution of Groundwater samples (%) in the subdivisions of Piper diagram [18]

Sub divisions of the diamond shaped field	Characteristics of corresponding sub division of diamond shaped fields	% of samples
1	Alkaline Earths (Ca^{2+} + Mg^{2+}) exceeds alkalis (Na^{+} + K^{+})	31.81
2	Alkalis exceeds alkaline earths	68.18
3	Weak acids ($CO3^{2-}$ + $HCO3^{-}$) exceeds strong acids ($SO4^{2-}$ + Cl^{-} + F^{-})	61.36
4	Strong acids exceed weak acids	38.63
5	Carbonate hardness (secondary alkalinity) exceeds 50% i.e. chemical properties of the groundwater are dominated by alkaline earths and weak acids	18.18
6	Non carbonate hardness (secondary salinity) exceeds 50%, i.e. chemical properties of the groundwater are dominated by alkalis and strong acids	0
7	Non carbonate alkali (primary salinity) exceeds 50%, i.e. chemical properties of the groundwater are dominated by alkalis and weak acids	25
8	Carbonate alkali (primary alkalinity) exceeds 50%, i.e. chemical properties are dominated by alkalis and weak acids	0
9	No one cation - anion exceeds 50%	56.82

D. 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) (Figure 6 & Table 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 (Figure 4) 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 (Figure 4). 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 [19] which are presented in (Tables 3a&b) respectively.

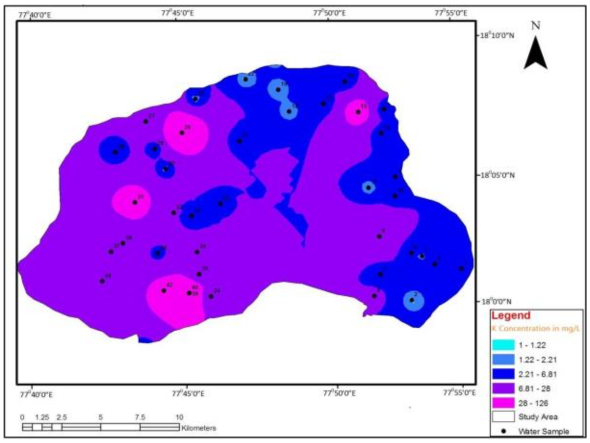

Figure 4. Spatial distribution of Potassium (mg/L) in groundwater

The high concentration of TDS beyond the permissible limit, observed in the northeastern part of the region (Figure 5), 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 3). The higher EC and TDS values may cause a gastrointestinal irritation in the consumers [20]. 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.

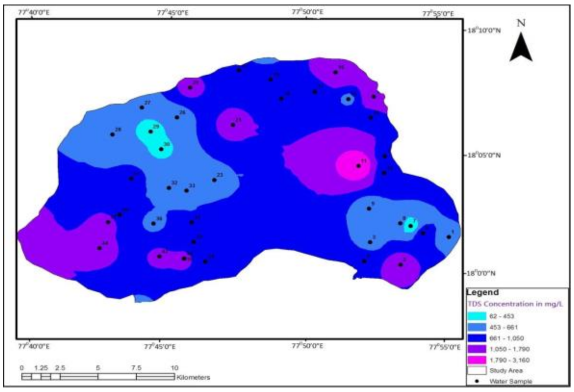

Figure 5. Spatial distribution of TDS (mg/L) in groundwater

E. 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 1). Spatial distribution of the TH concentration in the groundwater is illustrated in (Figure 6). The distribution map of the TH concentration (Figure 6) 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 1). However, in the remaining samples, the TH concentration was below the permissible limit of 500 mg/L (Table 1).

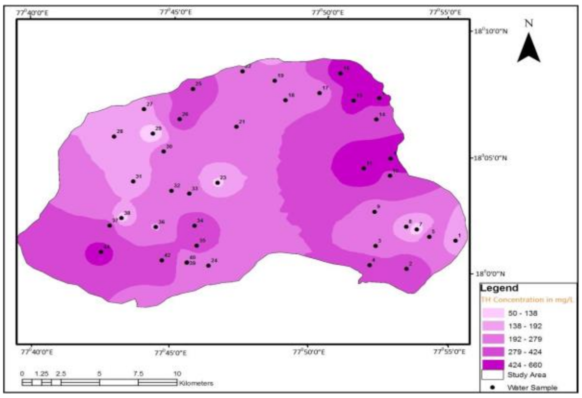

Figure 6. Spatial distribution of TH (mg/L) in groundwater

The classification of groundwater (Table 3) 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 [21]

Table 3. Classification of groundwater for drinking based on EC

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

Table 3a. Groundwater classifications of all groundwater on the basis of TDS [22, 23]

TDS (mg/L)	Classification	Percentage of samples	
		Granitic region	Basaltic region
<500	Desirable for drinking	27	41
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
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 3b. Groundwater classification based on total hardness (TH) [24]

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

F. Suitability for irrigation uses

The water quality evaluation in the area of study is carried out to determine their suitability for agricultural purposes. The suitability of groundwater for irrigation is contingent on the effects of the mineral constituents of the water on both the plant and the soil. In fact, salts can be highly harmful. They can limit growth of plants physically, by restricting the taking up of water through modification of osmotic processes. Also salts may damage plant growth chemically by the effects of toxic substances upon metabolic processes. EC and Na^+ play a vital role in the suitability of water for irrigation. The high salt content in irrigation water causes an increase in soil solution osmotic pressure. The salts, besides affecting the growth of plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth. The suitability of water for irrigation can be estimated by means of many determinants, though, Sodium Adsorption Ratio (SAR), Percent Sodium (Na%), Permeability Index (PI), Magnesium hazard (MH), Kelley's index (KI) and Residual Sodium Carbonate (RSC) usually rank high.

IV. SODIUM ADSORPTION RATIO (SAR)

Sodium adsorption ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops. SAR is defined by [25]

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

Where all concentrations are reported in meq/L. Most of the groundwater samples were excellent except for two samples which were good category, suitable for irrigation based on SAR (Table 4.). Salinity and sodicity hazards can be determined together by the United States Salinity Laboratory (USSL) diagram [26]. The total concentration of soluble salts in irrigation water can be expressed as low (EC = <250 µS/cm), medium (250-750 µS/cm), high (750-2250 µS/cm) and very high (>2250 µS/cm) and defined as C-1, C-2, C-3 and C-4 salinity zone respectively [27]. The US Salinity Laboratory's diagram [27] is used widely for rating the irrigation waters. SAR is plotted against EC. The plot of chemical data of the groundwater samples of the area in the US Salinity Laboratory's diagram is illustrated in (Figure 7). Distribution of percentage of water samples in the diagram is given in (Table 4). The plot of analysed data on the [27] diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that most of the water samples fall in the category of C3S1 and C2S1 denoting moderate to good quality of water for irrigation. The moderate water (C3S1) may be used to irrigate salt tolerant and semi-tolerant crops under favorable drainage conditions. The good water (C2S1) can be used for irrigation with little danger of harmful levels of exchangeable sodium and salinity [26]. Classified water quality on the basis of sodium absorption ratio (SAR) as illustrated in (Table 4). On the basis of EC, 57% of our groundwater samples were permissible, 25% were good and 16% were unsuitable (Table 4). According to Richard's classification, 95% of our groundwater samples were excellent and 5% were good.

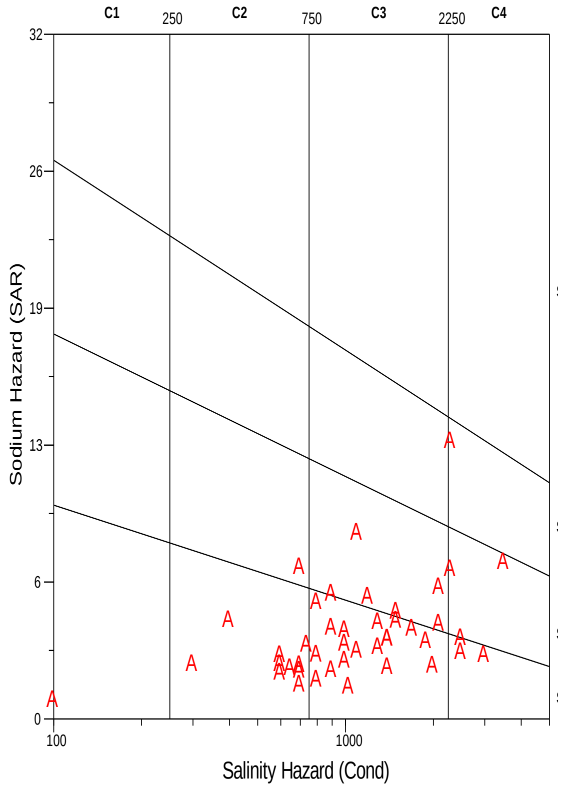

Figure 7. Plots of calculated values of SAR and EC of groundwater samples [27]

V. SODIUM PERCENTAGE (%NA)

Sodium content is usually expressed in terms of percentage of sodium or soluble-sodium percentage (%Na). Percentage of Na^+ is widely utilized for evaluating the suitability of water quality for irrigation [28].

$$\%Na = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} X100$$

The classification of groundwater on the basis of percentage sodium alone is given in (Table 5) and found that 11% of the samples are unsuitable for irrigation [28]. Propzosed a method for rating irrigation waters, based on percentage of sodium and electrical conductivity. The diagram consists of five distinct areas such as excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable. Data of the groundwater samples of the area are summarized in Table 4.6 and plotted in the Wilcox's Diagram (Figure 8). The [29] diagram (Figure 8) relating percentage sodium and EC shows that 68% of the ground water sample fall in the category of excellent to good and good to permissible for irrigation purposes. 23% of the samples have doubtful to unsuitable irrigation water quality, 5% of the samples have unsuitable irrigation water quality and only two samples have fall on permissible to doubtful category.

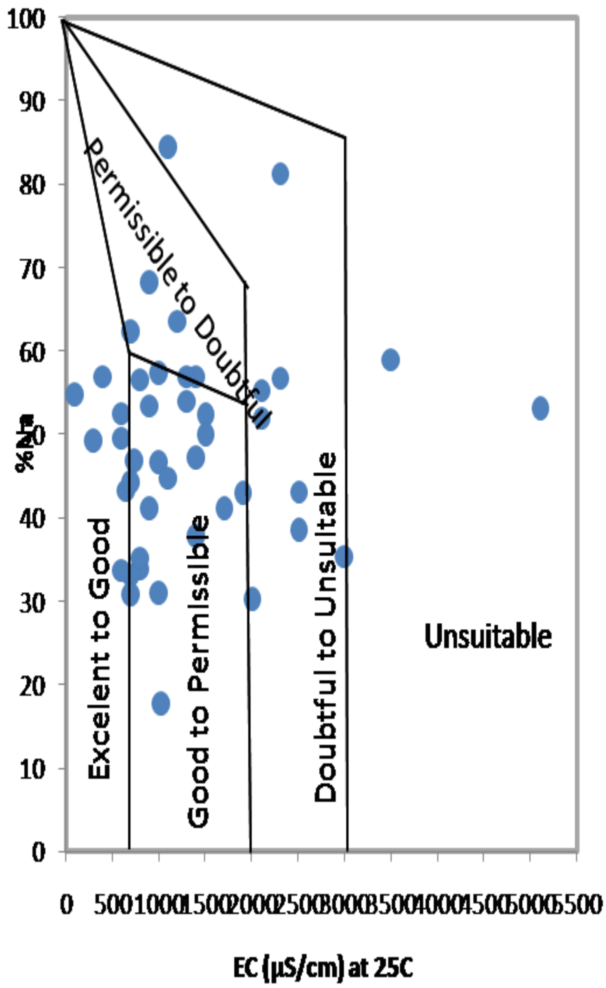

Figure 8. Electrical conductivity and percent sodium relationship for rating irrigation water [29]

Table 4. Quality of irrigation water based on electrical conductivity and Alkalinity hazard classes of groundwater

Zone	EC	Water Class	Sample numbers	Percentage of samples
C1	<250	Excellent	MNB-18	2
C2	250-750	Good	MNG-1,3,7,9,20 MNB-4,5,6,7,8,10	25
C3	750-2250	Permissible	MNG-4,5,6,10,12,14,15,17,18,19,22 MNG-1,2,3,9,11,12,13,14,15,16,20,21,22	57
C4	>2250	Unsuitable	MNG-2,11,13,16,21 MNB-17,19	16
Zone	SAR	Water Class	Sample numbers	Percentage of samples
S1	<10	Excellent	ALL	95
S2	10-18	Good	MNG-21 MNB-16	5
S3	18-26	Permissible	Nil	Nil
S4	>26	Unsuitable	Nil	Nil

Table 5. Ground water classification based on percent sodium

%Na	Water Class	Sample numbers	Percentage of amples
<20	Excellent	MNG-12	2
20-40	Good	MNG-13, 14, 15, 16 MNB-5,8,10, 12, 21, 22	23
40-60	Permissible	MNG-1 to 11, 17 to 20, 22 MNB-2,3,6,,7,9,11,13,14,15, 17,18,19,20	64
>60	Unsuitable	MNG-6, 21 MNB-1,4,16	11

I. Kelley's index (KI)

Kelley's index is the ratio of $Na^{+}/(Ca^{2+}+Mg^{2+})$ which is also used for the classification of water for irrigation. Water with >1.0 Kelley's ratio indicate an excess level of sodium and unsuitable for irrigation. Water with Kelley's ratio of <1.0 are only considered suitable for irrigation [30]. KI values in the groundwater of granitic aquifer varied from 0.02 to 4.3 with an average of 1.2 and from 0.42 to 5.35 with an average of 1.14. The highest value (K>1) are in MNG-5, 6, 8, 9, 11, 17, 21, 19 and MNB-1, 2, 3, 4, 7, 9, 14, 15, 16, 17, 18, 19 locations of groundwater samples, making it unsuitable for irrigation (Table 6) and remaining samples are suggest that groundwater of the area is suitable for irrigation (Table 6).

J. Magnesium hazard (MH)

Generally, alkaline earths are in equilibrium state in groundwater. If soils have more alkaline earths, they reduce a crop yield. [31] Have proposed a magnesium hazard in relation to the alkaline earths for irrigation. This hazard is expressed in terms of magnesium ratio (MR), which is computed, using the values of ions in meq/l.

$$MR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} X100$$

The computed values of MR from the groundwater of the study area are in between 17.66 and 94.79% (Table 6). If the water contains more than 50% of MR, such water quality is considered to be harmful for irrigation, as the MR adversely affects the crop growth. About 54% of the total groundwater samples of the study area are unsafe for irrigation, as the value of MR in them exceeds 50% (Table 6). The remaining groundwater samples (56%) show the value of MR less than 50% and hence they are safe for irrigation purpose.

K. Permeability Index (PI):

The Permeability Index (PI) values also depicts suitability of groundwater for irrigation purposes, since long-term use of irrigation water can affect the soil permeability, influenced by the Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-} contents of the soil. The PI can be expressed as

$$PI = \frac{(Na + K) + \sqrt{HCO_3}}{Ca + Mg + Na + K} X100$$

The concentrations are reported in meq/l. [32] developed a criterion for assessing the suitability of water for irrigation based on PI, where waters can be classified as classes I, II, and III. Accordingly, water can be classified as Class I, II and III. Class I and II water are categorized as good for irrigation with 75% or more of maximum permeability. Class III water is unsuitable with 25% of maximum permeability. The PI of the area varied from 27.32 to 96.45 and the average value is 65.57. According to PI values, 09% groundwater samples had fallen in class I, 64% in class II and 27% in class III of the Doneen's chart which is shown in (Figure 9).

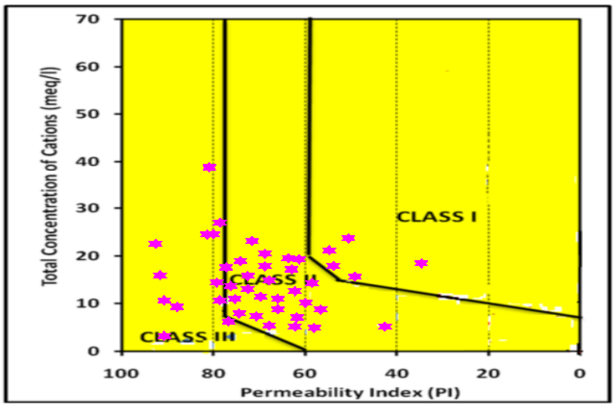

Figure 9. Classification [32] of Irrigation Water Based on, the Permeability Index of Study Area.

Table 6. Calculated values to assess the suitability of groundwater samples for irrigation use

Sample ID	EC	SAR	RSC	%Na	MH	PI	KI
MNG-1	740	2.73	-1.77	46.73	79.87	65.72	0.87
MNG-2	2500	3.41	-4.97	43.18	40.98	55.86	0.76
MNG-3	650	2.09	-0.18	43.30	51.08	71.16	0.75
MNG-4	1700	3.41	-5.83	41.00	71.71	52.67	0.68
MNG-5	1400	4.15	1.00	56.97	44.12	77.95	1.31
MNG-6	1200	4.90	3.82	63.63	54.80	89.08	1.74
MNG-7	300	2.11	2.51	49.12	71.84	94.83	0.95
MNG-8	900	3.52	-1.48	53.48	66.49	71.03	1.14
MNG-9	400	3.94	0.23	56.98	58.43	73.35	1.16
MNG-10	1000	3.74	-2.57	46.60	41.91	61.13	0.86
MNG-11	5100	7.64	-16.23	52.99	94.79	58.29	1.13
MNG-12	1030	1.30	-13.81	17.65	60.86	27.32	0.21
MNG-13	2500	2.94	-1.38	38.47	28.41	55.64	0.62
MNG-14	1400	2.18	-2.08	37.73	45.26	57.71	0.60
MNG-15	800	2.45	-10.21	33.91	72.23	40.62	0.43
MNG-16	3000	3.01	-4.58	35.37	19.48	49.10	0.54
MNG-17	1000	3.42	0.90	57.28	18.06	83.79	1.33
MNG-18	1400	3.26	-1.37	47.10	52.74	65.18	0.89
MNG-19	1300	3.91	-1.38	54.02	53.37	70.85	1.17
MNG-20	600	2.93	-0.99	49.58	17.66	70.49	0.98
MNG-21	2300	12.41	1.21	81.30	19.39	91.80	4.34
MNG-22	1100	2.77	-1.38	44.80	54.04	64.64	0.81
MNB-1	900	5.28	1.41	68.17	38.52	89.96	2.13
MNB-2	1500	4.17	-2.86	52.25	64.68	65.89	1.09
MNB-3	2100	5.25	-6.85	51.96	56.95	60.99	1.08
MNB-4	700	6.09	-3.06	62.18	53.97	69.35	1.39
MNB-5	700	1.45	-0.98	33.18	44.25	60.75	0.49

MNB-6	700	2.22	-0.48	44.21	49.80	70.30	0.79
MNB-7	600	2.75	0.21	52.52	31.08	79.79	1.09
MNB-8	600	1.81	-3.87	33.71	67.52	50.11	0.50
MNB-9	1300	3.20	0.01	56.97	29.00	73.35	1.04
MNB-10	700	1.80	-5.94	30.71	78.99	43.42	0.42
MNB-11	900	2.14	-0.69	41.04	33.16	65.86	0.69
MNB-12	1000	2.18	-8.13	30.89	75.89	42.15	0.44
MNB-13	1500	3.98	-3.47	49.87	53.46	63.01	0.99
MNB-14	800	4.37	-4.47	56.64	73.53	64.89	1.30
MNB-15	2100	4.22	-1.39	55.32	24.51	68.32	1.10
MNB-16	1100	10.70	0.40	84.38	33.53	96.45	5.35
MNB-17	3500	6.11	-6.93	58.98	63.45	63.03	1.19
MNB-18	100	1.60	-0.50	54.70	32.75	86.25	1.13
MNB-19	2300	5.91	-5.35	56.76	59.81	65.37	1.26
MNB-20	1900	3.12	-6.05	42.92	56.69	52.19	0.67
MNB-21	800	1.65	-0.08	35.24	46.61	64.78	0.54
MNB-22	2000	2.21	-9.05	30.17	49.08	40.72	0.42

VI. CONCLUSIONS

The final concluded that evaluate quality groundwater of Narayankher area Medak District, Telangana region determined by the geological composition of the aquifers and human activities in the area. 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. Alkaline earths exceed alkalies and strong acids exceed weak acids. Total Hardness is generally high in the groundwater thereby, causing the groundwater in one fourth of the study area to be unsuitable for drinking. Groundwater in one third of the study area exceeded the recommended limits of TDS as per the international drinking water standard. The concentrations of major ions in groundwater are within the permissible limits for drinking except in some places. Based on Wilcox classification ninety three percent of the waters belong to excellent to good which is indicate that groundwater suitable for irrigation, Chloro Alkaline Indices, Kelley's index and magnesium hazard suggest that the groundwater is not safe in 61%, 11% and 48% of groundwater respectively. According to PI values the groundwater in study area is suitable for irrigation purposes. Thus the study suggests appropriate remedial measures to improve the groundwater quality.

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