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Major Ion Geochemistry of Groundwater in Parts of Govindaraopet Mandal, Warangal District, Telangana State, India

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Abstract: *Groundwater forms the major source of drinking water in the rural areas of most of the developing nations of the world. This study was carried out to assess the major ion concentrations in groundwater of* ***Govindaraopet Mandal*** *area, Warangal District, where groundwater is the main source of drinking water. Fifty six representative groundwater samples were collected from bore wells and dug wells were analyzed and analyzed for pH, EC, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO_3^{-}, HCO_3^{-}, Cl^{-}, TH, TDS, SO_4^{-}, NO_3^{-} and F. As per the desirable and maximum permissible limit for Fluoride (1.5 mg/l) and Nitrate (45 mg/l) in drinking water and prescribed by WHO (2004) and Bureau of Indian Standards (2009), 46% groundwater sources in the study area is unfit for drinking purposes. Due to the higher fluoride levels in drinking water several cases of dental and skeletal fluorosis have appeared at alarming rate in the investigated area. The study revealed that 43% of the samples were found to be unsuitable for drinking purposes due to excess nitrate (>45 mg/l) content in the groundwater. High Nitrate concentration may cause blue baby syndrome or methemoglobinemia. The wells in the investigated area have been demarcated into safe and unsafe wells for consumption of water with respect to fluoride and nitrate.*

Key Words: *Geochemistry, Major Ions,* ***Govindaraopet Mandal*** *area, Warangal District, Telangana State, India.*

1. INTRODUCTION:

Water is one of the most essential requirements of mankind to sustain all round activities like domestic, drinking, municipal, agricultural, industry, transport and other various needs**.** Water is one of the Earth's natural resources. It is a finite resource, which means that the total amount of water is limited. Most of the world's water supply is saltwater stored in the oceans converting saltwater to freshwater is generally expensive to be used for industrial, agricultural or household purposes. Land and water are two broad components on which the entire biotic community thrives. The available surface water resources are inadequate for the entire requirement of water for all purposes. Hence, the demand for groundwater has increased over the years. In most states in India withdrawal of groundwater both for agricultural and industry needs has been more than what can be recharged.

Groundwater has generally a uniform quality, clear and colorless although changes may occur in quality due to water logging, over draft from areas adjoining saline water resources, recycling of water applied for irrigation and seepage of industrial wastes. Hydrogeochemical studies explain the relationship of water chemistry to aquifer lithology (Sastri, 1976). Such relations not only explain the origin and distribution of the dissolved constituents but also elucidate the factors controlling the groundwater chemistry (Rangarajan and Balasubramanyam, 1990). Water quality studies bring out the concentrations of hazardous elements, based on which a water source can be accepted or rejected for domestic, irrigation or industrial purposes (Zaparozec, 1972).

Groundwater quality data gives important clues on the geologic history of rocks and indications of groundwater recharge, discharge, movement and storage (Walton, 1970). Wide spread occurrence of fluorosis and occurrences of higher concentration of fluoride in the Groundwaters of Kalwakurthy area of Mahabubnagar District of Andhra Pradesh were reported by (CGWB, 2007). However, no detailed investigations were taken up here in this area.

2. STUDY AREA:

The study area Govindaraopet Mandal is located in the north-eastern part of Warangal and southern part of Godavari River in Warangal District. The area falls in the Survey of India toposheet No: 65 B/4 and B/3. And the major part falls in 65 B/4 only. There are more than 50 habitats in the Study area. Govindaraopet and Pasra, Chalvai are the main Mandal Head quarters, situated in this area. The study area lies between latitudes 18°0'10" to 18°15'0" North and Longitudes 80°0'0" and 80°15'0" East. The total Geographical area covered **is 98 Sq. Kms.** The area is an undulating

terrain with a few hill ranges. The area comprises of three hill ranges trending NW-SE to NNW-SSE roughly parallel to the general strike, with intervening valleys/flat grounds. Along the southern margin of the area hills are occupied by Sullavai Formations ranging in heights from 200m to 300m above MSL. The central range of hills is mostly made up of Barren Measure and Barakar Formations and elevation rises upto heights of 200m to 350m above MSL. The third range of hills. occupied by Kamthi Formations and the elevation is in the range of 300m to 400m above MSL. Major part of the area mapped is a flat undulatory country at elevations of about 185m-275m above M.S.L. This area experiences a typical tropical climate with a distinct hot summer, the temperature shoots to a maximum of 49°C during March to June, a good rainy season from July to September(1300mm) and a mild winter during October to February (6°C to 22°C). The Sullavai Sandstone, Shale and Lower Gondwana Sandstone on weathering give black cotton and red loamy soils respectively. 30-40 per cent of the area is covered by deep to moderate black cotton soils ranging in thickness from 0.5 to 3.0 m. Isolated patches of red and red loamy soils is also observed around Central Part of the Block Cotton Soil as well as Borders of the study area.

3. GEOLOGY AND HYDROLOGY OF THE STUDY AREA:

Geology of the study area

In the Govindaraopet study area, rocks of the Precambrian Sullavai Formation form the basement for the Lower Gondwana sequence. The stratigraphic succession is as fallows.

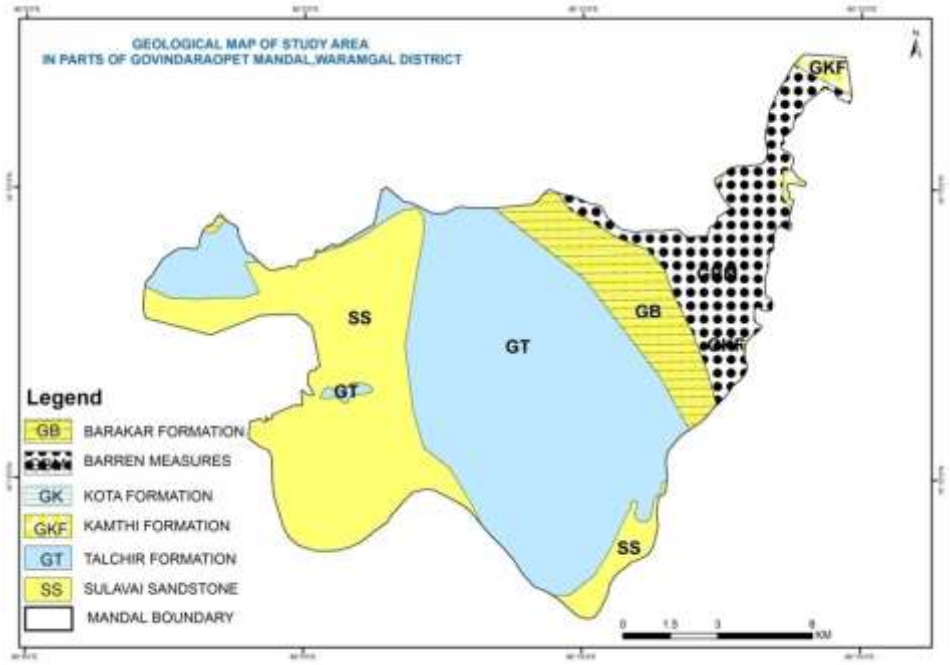

Figure 1 Geological map of the study

Table 1. Stratigraphic Succession of the study area

Age	Group	Formation	Thickness (m)
Upper Permian	Lower Gondwana	Raniganj Formation (Upper Coal Measure)	More than 400
Middle Permian		Barren Measure (Middle Measure)	450-475
Lower Permian		Barakar Formation (Lower Coal Measure)	250-300
Permo-carboniferous		Talchir Formation	
----------Unconformity----------			
Precambrian		Sullavai Formation	

GEOMORPHIC UNITS

Six geomorphic units were demarcated viz.

a. Pediplain Moderately Weathered (PPM)
b. Burried Pediplain Canal.(BPC)
c. Pediplain Shallow Weathered.(PPS)
d. Pediment(PD)
e. Valley Fill (VF)
f. Inselburg (I)

Apart from these, all the major lineaments are also demarcated as shown in fig:2

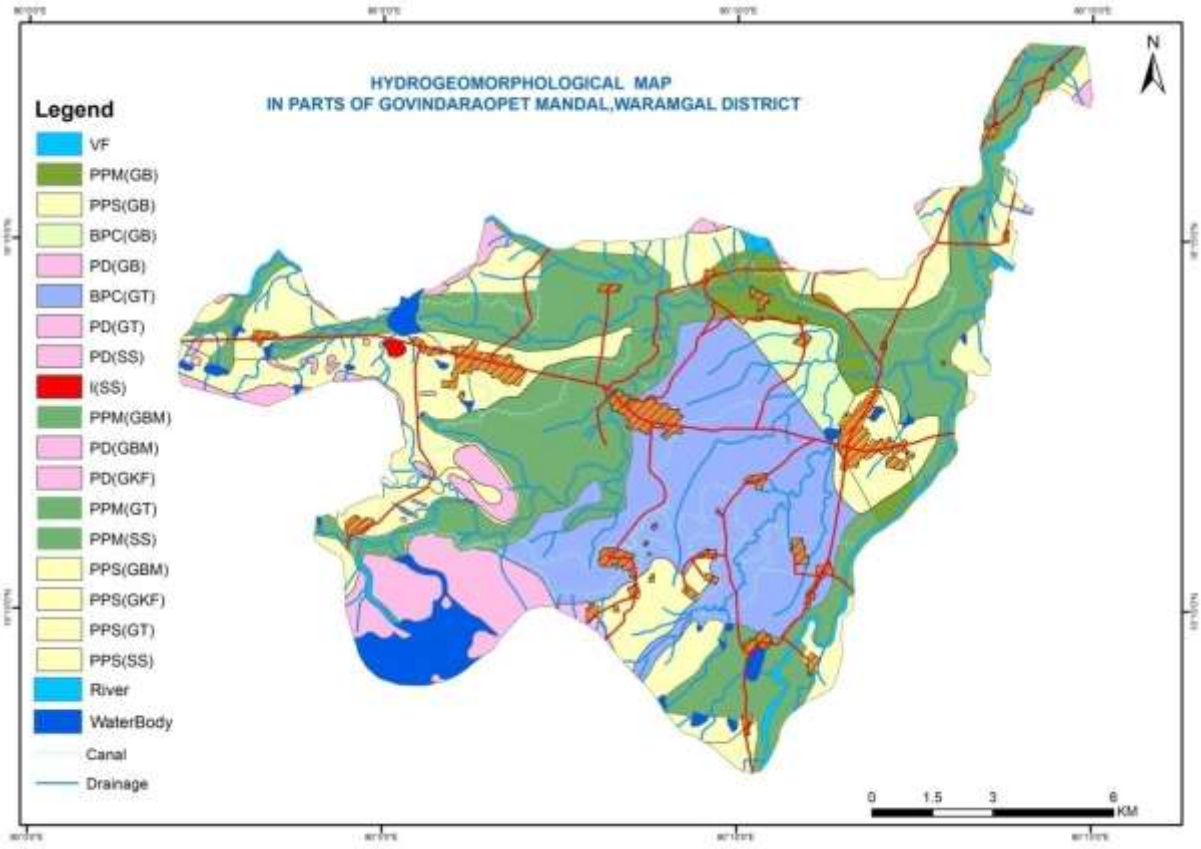

Figure 2 Hydrogeomorphological map of the study area.

In order to monitor groundwater level for pre monsoon and post monsoon periods, 28 monitoring wells (Open wells, bore wells and surface water) were established in the study area **(Fig 1 & 2 Table 1).** The well inventory includes, geo co-ordinates, location of the wells, type of well, purpose of well, well history, water sampling for chemical analysis in laboratory, insitu EC and pH.

4. LITERARY REVIEWS:

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5. SAMPLING AND ANALYSIS:

28 groundwater samples were collected from dug-cum-bore well during (June, 2013) in the study area (28 water samples from 16 Dug wells, 07 Bore wells,01 lake,01pool) covering Govindaraopet and the adjoining area of Warangal District. Sampling was carried out on 2km grid basis. At least one sample was collected in a 2 sq km area, wherever bore well/hand-pump was available. The samples were collected in clean two liter polythene bottles and analyzed for various chemical parameters as per standard methods (APHA, 1985).

The pH was measured with Digital pH Meter (Model 802 Systronics) and Ec was measured with Conductivity Meter (Model 304 Systronics), Sodium and Potassium were measured with Flame photometer (Model Systronics 130). Sulphates and Nitrates were measured with Spectronics 21 (Model BAUSCH & LOMB), Carbonate, Bicarbonate, Calcium, Magnesium, Total Dissolved Solids, Total Hardness, and Chloride by titrimetric methods, Fluoride concentration was measured with Orion ion analyzer with fluoride ion selective electrode. Nitrate was determined by spectrophotometer. The concentration of EC are expressed in microsiemens/cm at 25ºC and TDS, TH, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, $C1^{-}$, SO_4^{-}, NO_3^{-} CO_3^{-}, HCO_3^{-} and F^{-} are expressed in mg /l.

6. RESULTS AND DISCUSSION:

The results of the chemical analysis of groundwater are presented in Table.1.The statistical parameters of the variables viz., minimum, maximum mean and standard deviation of different chemical parameters of groundwater are summarized in Table.2. Correlation matrix (Table.3) is prepared to find out the relation between different parameters. Concentration maps are generated for different elements as per the procedure of Belanger (1988) to know the high concentration pattern of the concentrations (Figs. 3-16).

Hydrogen ion concentration (pH):

It is a measure of the acidity or alkalinity of water. The natural water H_2O contains H^{+} ions and OH^{-} ions. But the process of disassociation called hydrolysis takes place in water and hence it contains H^{+} and OH^{-} ions. The water becomes acidic (pH<7), when H^{+} ions are in excess than OH^{-} and becomes alkaline (pH>7) when reverse is the case. For the natural water (pH=7), the concentration of H^{+} and OH^{-} are equal. The pH value sometimes is taken as measure of solvent power for various minerals. In most groundwater the pH value is controlled by CO_2-CO_3-HCO_3 equilibrium.

The pH of water is a very important indication of its quality and provides important information regarding types of geochemical equilibrium or solubility calculations (Hem, 1985). The pH of the groundwater of the study area is varying from 7.1 to 8.2. Average pH value is 7.8. The limit of pH value of drinking water is specified as 7.0 to 8.5 (RGNDWM, 1993; WHO, 1963) while 0% of samples show values above the acceptable limit. 96% of pH values for the samples are within the desirable limits.

From the Concentration map it is observed that the high concentration of pH is in the south-eastern part of the area (Fig.3). Maximum concentration of pH is 8.2 mg/L is observed in the groundwater from Bollepally and minimum concentration 7.42 mg/L is observed in Balajinagar area. The Concentration levels of pH in all the samples are shown in Table. 1.

Electrical Conductivity (EC):

Concentration of water is generally measured with the help of Electrical conductivity which is directly proportional to the salt concentration and vice versa. Electrical conductivity of the groundwater is varying from 78.44 to 1568.8 microsiemens/cm at 25°C. The average EC concentrations are 1746 microsiemens/cm. It is observed that the EC has positive correlation with Cl^{-}(r=0.96), SO_4^{-}(r=0.94). Na^{+} (r=0.86), TH(r=0.84), K^{+}(r=0.68), Mg^{+2}(r=0.67), HCO_3^{-} (r=0.65) (Table. 3). The acceptable limit of EC in drinking water is less than 1500 microsiemens/cm (WHO, 1963). It is observed that nearly 50% of samples show concentrations higher than the prescribed limit. The higher concentrations indicate that the ionic concentrations are more in the groundwater. It depends up on temperature, concentration and types of ions present (Hem, 1985). From the Concentration map it is observed that the high concentration of EC is in the southern part of the area (Fig.4). Maximum concentration of EC is 4843 microsiemens/cm is observed in the groundwater from Papayyapally area and minimum concentration 156 microsiemens/cm is observed in the Laknavaram area. High conductance is attributed to high concentration in groundwater (Davies and Dewist, 1966). The Concentration levels of EC in all the samples are shown in Table. 1.

Total Dissolved Solids (TDS):

Total dissolved solids of the ground water is varying from 50.2 mg/l to 1004.03 mg/l with average concentration of 1083 mg/l. TDS shows positive correlation with Cl^{-}(r = 0.96), SO_4^{-}(r=0.94), Na^{+}(r=0.86), TH(V=0.84), K^{+}(V=0.68), Mg^{+2}(r=0.67), HCO_3^{-}(r=0.65), Ca^{+2}(r=0.54) (Table.3). The acceptable limit of TDS in drinking water is 500mg/l (RGNDWM, 1993). While 78% of the samples show values above the limit. The principal ions contributing to TDS are carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium (EPA,1976). Palatability of the water decreases when the concentrations exceed this limit and may cause gastro-intestinal irritation (ISI, 1983).

From the concentration map high concentration of Total Dissolved Solids is observed in the southern part of the area (Fig.5). Maximum concentration of 3100 mg/l is observed in the groundwater from Papayyapally area and minimum concentration of 100 mg/l is observed in the Laknavaram area. The Concentration levels of TDS in all the samples are shown in Table. 1.

Total Hardness (TH):

Total Hardness of the groundwater is varying from 75 mg/l to 560 mg/l. Average concentration of TH in the study area is 209.83mg/l. Total hardness has shown good positive correlation with SO_4^-(r=0.85), Mg^{+2}(r=0,78), Ca^{+2}(r=0.67), Na^+(r=0.59) (Table.3). The acceptable limit of TH in drinking water is 200 mg/l (RGNDWM, 1993; WHO, 1963). 38% of the groundwater of the area has more than the desirable limits. Water hardness is primarily due to interaction between water and the geological formations (Angino, 1983). The hardness of water is due to the presence of alkaline earths such as calcium and magnesium.

However, iron, strontium, barium, manganese and aluminum also contribute to hardness (Brown et al., 1970). From the concentration map high concentration of Total Hardness is observed in the south-western parts (above 500 mg /1) of the area (Fig.6). Where concentrations of calcium and magnesium are also high. Maximum concentration of 1436 mg /L of TH is observed in the groundwater and minimum concentration of 36 mg/1 is observed . It is evident that hardness is imparted to the groundwater by calcium and magnesium. The Concentration levels of TH in all the samples are shown in Table. 1.

Calcium (Ca^{+2}):

Calcium in the groundwater of the area is varying from 16.03 mg/l to 154.03 mg/l. Average concentration of Ca^{+2} is 10.08 mg /1. Calcium has shown good positive correlation with SO_4^- (r=0.55) (Table.3). The acceptable limit of Ca^{+2} in drinking water is 75 mg/l (RGNDWM, 1993, WHO, 1963) while 04% of groundwater exceeds the limit. From the concentration map high concentration of Ca is observed in the south-western parts of the area (Fig.7). The concentrations are within the desirable limits in north and north-eastern parts of the area. The maximum concentration of 107.7 mg/l is observed in Dumpillagudem area and minimum concentration of 3.5 Rangapur mg/l is observed in Rachalapally area. Calcium is derived mainly by weathering of silicate minerals like feldspars, amphiboles and pyroxenes. The Concentration levels of Ca in all the samples are shown in Table. 1.

Magnesium (Mg^{+2}):

Magnesium in the groundwater is varying from 2.91mg/l to 83.83 mg/1. Average value of Mg^{+2} in the study area is 72 mg/l. It is observed that magnesium shows positive correlation with SO_4^-(r=0.68), Na^+(r=0.56) (Table.3). The acceptable limit of Mg^{+2} in drinking water is 30mg/l (RGNDWM, 1993; WHO, 1963). It is observed that 68% of the groundwater from the area exceeds the desirable limits. From the concentration map high concentration of magnesium above 30 mg/l is observed in south and south-eastern parts of the area (Fig. 8). Maximum concentration of 345.5 mg/L is observed in Papayyapally area and minimum concentration of 16.24 mg/l is observed in Amruthanda area. The Concentration levels of Mg in all the samples are shown in Table. 1.

Sodium (Na^+):

Sodium concentrations are varying from 17mg/l to 182 mg/l. Average concentration of Na^+ in groundwater is 119 Mg/l. Sodium shows good positive correlation with SO_4^-(r = 0.79), K^+(r=0.54) (Table.3). From the concentration map high concentrations of Na is observed in south and south-eastern parts of the area (Fig. 9). Maximum concentration of 832.5 mg/l is observed from Papayyapally area and minimum concentration of 5.6 mg/l is observed in Laknavaram lake area. The Concentration levels of Na in all the samples are shown in Table. 1.

Potassium (K^+):

Potassium concentrations are varying from 10 mg/l to 47 mg/l. Average concentration of K^+ in the groundwater from study area is 37 mg/l. Potassium shows good correlation with SO_4^- (r=0.7) (Table.3). From the concentration map high concentration of Potassium in south-eastern parts of the area (Fig.10). The maximum concentration of 4.7 mg/l is observed in the groundwater collected from the southern part of Panjagul area and minimum concentration of 10 mg/l is observed in the groundwater collected from south-eastern part of Elikal area. The Concentration levels of K in all the samples are shown in Table. 1.

Bicarbonates (HCO_3^-):

Bicarbonate concentration in the groundwater of the area is ranging from 48.8 mg/l to 219.6 mg/l. Average concentration of HCO_3 in the study area is 503 mg/l. Maximum concentration of 1342 mg/l is observed in the groundwater in Somulagadda area and minimum concentration of 61 mg/l is observed in the groundwater in Laknavaramlake area. The Concentration levels of HCO_3 in all the samples are shown in Table. 1.

Chloride (Cl^-):

Chloride concentrations are varying from 21.3 mg/l to 678.05 mg/l. Average concentration of Cl^- in groundwater is 3216 mg/l. Chloride shows good positive correlation with SO_4^-(r=0.93), TH(r = 0.86), Ca^{+2}(r=0.62), Mg^{+2}(r= 0.61), K(r=0.61), Na+(r=0.7) (Table.3). The acceptable limit of Cl^- in drinking water is 200 mg/l (RGNDWM, 1993; WHO, 1963). It is observed that nearly 18 % of the groundwater from the study area exceeds the desirable limits. From the concentration map it is observed that the concentration of chloride is high (>250mg/l) in south and south western parts of the area (Fig.13).

Maximum concentration of 1413 mg/l is observed in Papayyapally area and minimum concentrations of 12 mg/l in Laknavarampool area. In the north-eastern, north-western parts of the area the concentration are within the permissible limits. Apart from the natural source, domestic sewage and industrial effluents (Karanth, 1987, Craig and Anderson, 1979). Similar sources are expected to cause the increase in chloride concentration in the groundwater of the study area. The Concentration levels of Cl in all the samples are shown in Table. 1.

Sulphates (SO_4^-):

Sulphate concentrations are varying from 4 mg /l to 180 mg/l. Average concentration of SO_4^- in the study area is 102 mg/l. The acceptable limit of SO_4^- in drinking water is 200 mg/l (RGNDWM, 1993; WHO, 1963). It is observed that the sulphate concentrations in the groundwater of the study area are within the permissible limits. From the concentration map high concentration of sulphates is observed in southern part of the area (Fig.14). Maximum concentration of 692.44 mg/l is observed from Papayyapally area and minimum concentration of 19.74 mg/l is observed from Laknavarampool area. Apart from these natural sources, sulphates can be introduced through the application of sulphatic soil conditioners (Karanth, 1987). Sulphates are also discharged into the groundwater from different industrial effluents. The Concentration levels of SO_4 in all the samples are shown in Table. 1.

Nitrate (N):

Nitrate concentrations are varying from 1.1mg/l to 112.5mg/l. Average concentration of NO_3^- in the study area is 40.21mg/l. The limit of nitrate concentration for drinking water is specified as 45 mg/l (ISI, 1983). It is observed that nearly 36% of the groundwater from the study area exceeds the permissible limit. From the concentration map it is observed that the concentration of Nitrate is high in the northern part of the area (Fig.15). Maximum concentration of 379 mg/l is observed in Lakshmipuram area and minimum concentration of 5.4 mg/l is observed in chalvai area. The Concentration levels of N in all the samples are shown in Table. 1.

Fluoride (F^-):

Fluorosis is a disease caused by excessive fluoride concentration in drinking water. Concentration above 1.0 mg/l give rise to mottling of enamel of teeth a condition known as “dental fluorosis”, still higher amounts in excess of 3.0 mg/l cause abnormalities in bone structure. These symptoms are known as ‘Skeletal fluorosis. Another symptom of fluorosis is ‘Knock Knees’ often observed in high fluoride areas. Fluoride concentration in the groundwater of study area varies from 0.2 mg/l to 2.5 mg/l with an average of 0.76. As per the desirable and maximum permissible limit for fluoride in drinking water determined by WHO (2004) or by Bureau of Indian Standards (2009), 07% of groundwater shows excess of fluoride prescribed for drinking purpose. From the concentration map it is observed that the concentration of F is high in the south western part of the area (Fig.16). The Concentration levels of F in all the samples are shown in Table. 1.

7. CONCLUSIONS:

The Hydrogeochemical investigations of the Parts of Govindaraopet Mandal area of Warangal District showed that the concentration of TH, Nitrate, Chloride, Calcium, Magnesium, TDS, EC, and Fluoride in groundwater is more than the permissible limits for drinking purposes in some areas. Sulphate concentration is within the desirable limit. The studies reveal that nearly 40% of groundwater has more than 45mg/l of nitrate which is a desirable limit. It is observed that the nitrate concentration is more in the Nehruthanda area. The fluoride concentration in groundwater is varying from 0.16 to 3.4 mg/l. The fluoride concentration is exceeding the desirable limit of 1.0 mg/l in 60 % of groundwater. In 45 %of groundwater the fluoride concentration is exceeding 1.5 mg/l which is the permissible limit. It is observed that the people living in high fluoride concentration areas are suffering from mottled teeths and also knee joint pains especially in younger people.

8. ACKNOWLEDGEMENTS:

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Table 2 Major ion chemistry of groundwater samples, post monsoon (All the parameters are in mg/l except pH)

Well	pH	EC	TDS	F	Cl	Br	NO3	SO4	LI	Na	Al	K	Ca	Mg	CO3	HCO3
1	8.5	1054	529	2.624	276.47	0.727	51.021	90.817	0.029	139.751	0.013	6.718	71.665	42.599	150	390
2	8.5	1372	687	1.37	352.075	0.766	61.469	148.902	0.052	246.597	NIL	1.9	93.489	34.093	60	427
3	8.3	586	293	0.438	78.304	0.245	67.878	52.464	0.021	51929	0.006	7.984	57.815	11.917	90	244
4	8.4	2.22	1.1	0.601	616.41	1.035	98.716	243174	0.041	384.847	NIL	8.242	111.072	35.561	120	396
5	8.4	428	214	0.357	67.841	0.281	1.27	25.784	0.017	40.36	0.05	5.887	36.835	16.014	120	305
6	8.7	846	423	0.986	144.877	0.559	4.117	25.915	0.052	165.872	NIL	1.792	44.174	17.825	60	610
7	8.3	577	289	0.572	80.819	0.236	77.76	29.224	0.02	47.099	0.032	0.851	112.501	28.044	60	305
8	7.9	2.46	1.23	0.591	828.835	1.498	357.455	170.7	0.056	78.805	0.379	6.198	325.085	98.216	60	152
9	8.3	123	62	0.258	13.565	0.114	4.794	16.447	0.011	7.14	0.076	1.518	17.498	5.031	60	152
10	8	1352	675	1.129	434.843	0.806	110.903	73.131	0.05	74.406	0.22	2.754	54.448	72.65	50	150
11	7.8	3.59	1.8	0.663	1069.222	1.425	710.289	345.385	0.065	192.896	NIL	202.87	308.311	105.375	40	213
12	8.4	600	298	1.33	96.852	0.419	12.514	41.33	0.05	88.733	0.042	4.131	65.697	24.081	90	396
13	8.5	608	306	1.124	104.814	0.451	1.942	21.571	0.051	55.449	0.05	2.53	103.382	53.151	120	396
14	8.1	1317	659	0.352	334.821	0.722	164.21	175.463	NIL	95.37	0.024	66.537	151.321	35.253	60	183
15	8.2	1025	513	0.74	259.31	0.644	66.38	79.72	0.036	89.353	0.017	59.984	101.681	33.134	50	305
16	7.9	2.47	1.24	0.559	862.73	1.92	269.756	101.754	NIL	174.753	NIL	4.995	84.619	66.182	**NIL**	366
17	8.1	2.45	1.22	0.596	888.1	1.899	133.373	176.423	0.034	236.035	NIL	2.032	228.985	69.053	**60**	244
18	8	2.17	1.09	0.659	621.668	1.343	480.676	161.142	NIL	115.976	0.018	1.445	219.846	86.85	**NIL**	152
19	8.2	1575	786	0.892	479.127	0.924	238.237	71.2	NIL	88.6	NIL	3.454	92.669	113.456	70	335
20	8	956	481	0.559	153.081	0.374	72129	45.062	0.029	93.712	0.11	8.121	57.094	29.38	NIL	457
21	8.8	2.78	1.39	2.155	638.311	1.416	32.966	112.706	0.149	585.438	NIL	2.952	18.684	52.08	150	1220
22	8.3	569	285	0.393	94.431	0.291	4.229	32.219	0.021	72.33	0.042	3.045	39.097	17.897	NIL	366
23	8.1	2.39	1.19	0.946	871.483	1.872	35.429	236.502	0.023	181.54	NIL	18.028	41.734	104.089	50	244
24	8	2.2	1.11	0.802	580.834	1.015	296.244	323.554	NIL	256.432	NIL	9.961	128.73	64	50	274
25	8.1	966	483	0.408	315.603	2.971	28.628	90.616	0.018	94.701	0.052	8.109	93.12	28.192	60	152
26	7.9	1424	713	0.85	464.292	0.476	156.572	119.89	0.052	47.387	0.214	1.913	161.088	67.293	40	305
27	7.9	2.21	1.1	0.715	812.313	1.658	25.803	218.269	0.09	173.44	NIL	48.408	33.275	96.276	120	244
28	8.9	3.71	1.86	1.512	1017.993	1.787	232.434	220.715	0.073	783.125	NIL	7.662	23.272	82.341	240	1281

Table 3. Showing the statistical parameter for the analytical results of groundwater

Parameters	Minimum	Maximum	Average	Acceptable Limit WHO (2004), BIS (2009)	% of samples exceeding the limit
pH	7.1	8.2	7.8	6.5-8.5	0
EC	156	4843	1746	1500	50
TDS	100	3100	1083	500	78
HCO_3^-	61	1342	503	500	50
Cl^-	12	1413	3276	250	43
Ca^{++}	3.58	107	10.8	75	04
Mg^{++}	17	346	72	30	68
Na^+	06	833	119	250	07
K^+	04	120	37	10	93
SO_4^-	20	692	102	200	04
F	0.21	2.56	0.76	1.5	07

Table 4. Correlation Coefficient of chemical parameters for groundwater samples post monsoon.

	PH	TDS	EC	Na	K	Ca_2	Mg_2	Cl	SO_4^2	CO_3
	HCO_3	NO_3	F	TH						
PH	1.000									
TDS	-0.032	1.000								
EC	-0.033	1.000	1.000							
Na	0.547	-0.430	-0.430	1.000						
K	-0.428	-0.154	-0.154	-0.018	1.000					
Ca_2	-0.591	-0.117	-0.117	-0.180	0.484	1.000				
Mg_2	-0.432	-0.186	-0.185	0.230	0.324	0.399	1.000			
Cl	-0.279	-0.488	-0.487	0.579	0.400	0.430	0.819	1.000		
SO_4^2	-0.381	-0.471	-0.471	0.463	0.531	0.444	0.598	0.835	1.000	
CO_3	0.696	-0.298	-0.299	0.688	-0.220	0.437	-0.008	0.149	-0.007	
	1.000									
HCO_3	0.797	-0.217	-0.217	0.857	-0.186	-0.385	0.019	0.222	0.025	
NO_3	0.752	1.000								
F	-0.460	-0.202	-0.201	0.143	0.713	0.752	0.593	0.618	0.667	-
TH	0.194	-0.092	1.000							
	0.538	0.107	0. 107	0.460	-0.186	-0.288	0.112	0.096	-0.039	
	0.525	0.607	-0.137	1.000						
	-0.626	-0.171	-0.170	-0.022	0.499	0.904	0.753	0.690	0.598	-
	0.317	-0.267	0.816	-0.154	1.000					

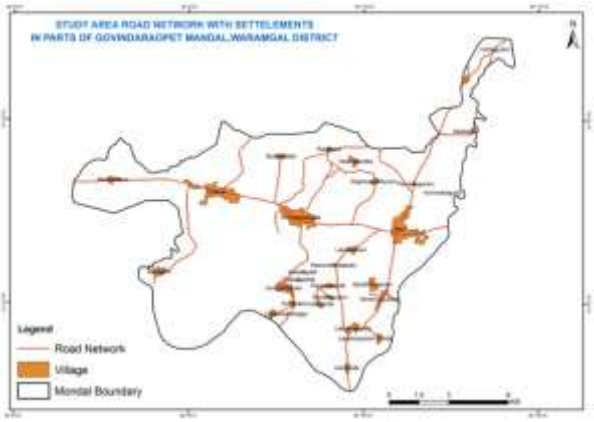

Fig.1. Location Map of the Study Area .

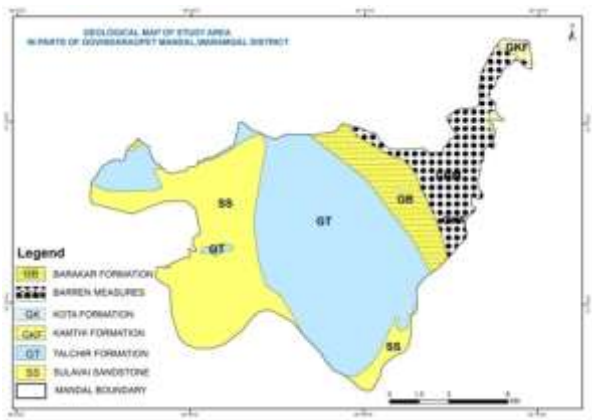

Fig. 2. Geological Map of the Study Area

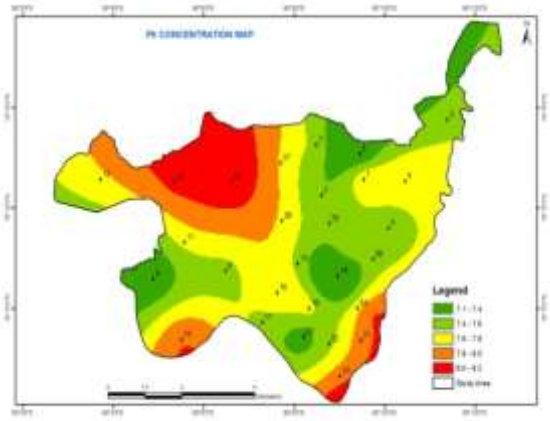

Fig.3. Map showing Concentration pattern of pH

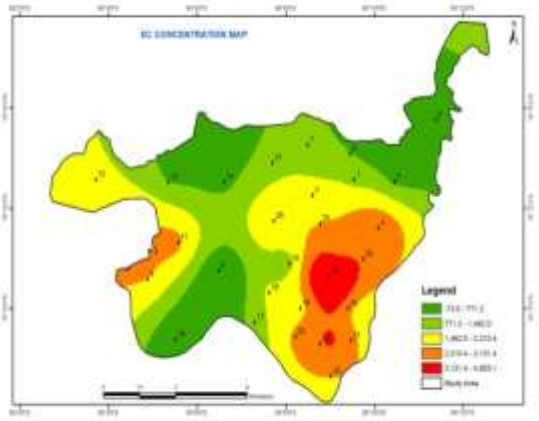

Fig. 4. Map Showing Concentration Pattern of EC

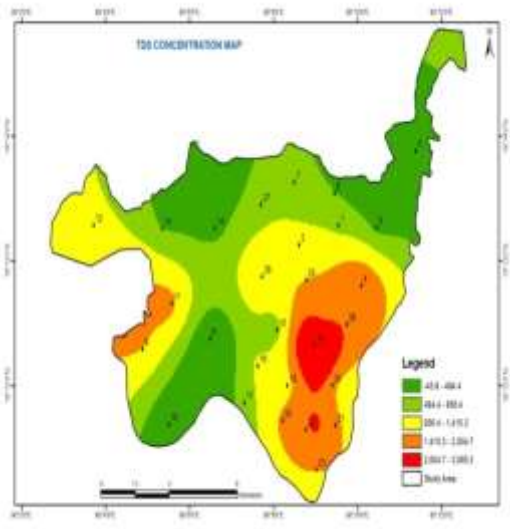

Fig.5. Map Showing Concentration Pattern of TDS

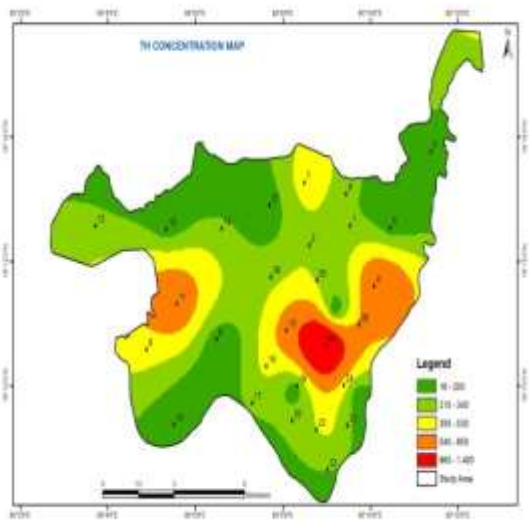

Fig.6. Map Showing Concentration Pattern of TH

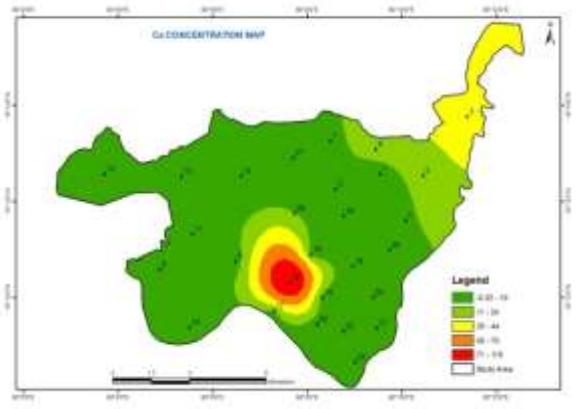

Fig.7. Map Showing Concentration Pattern of Ca

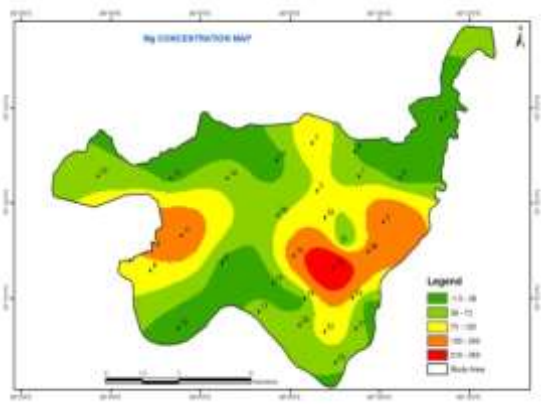

Fig.8. Map Showing Concentration Pattern of Mg

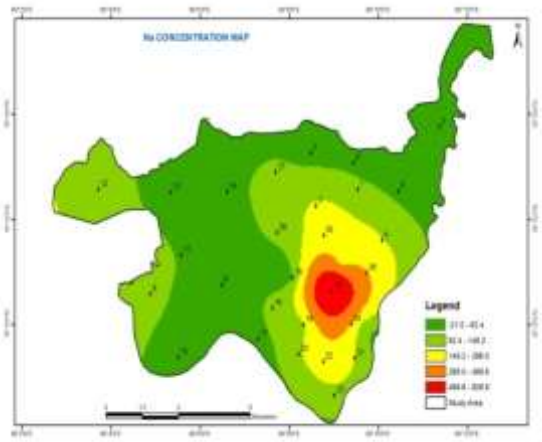

Fig.9. Map Showing Concentration Pattern of Na

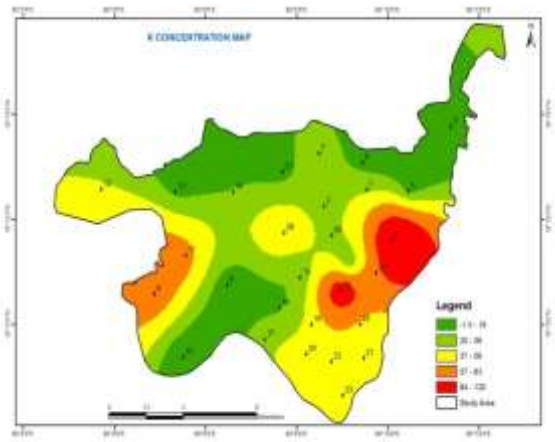

Fig.10. Map Showing Concentration Pattern of K

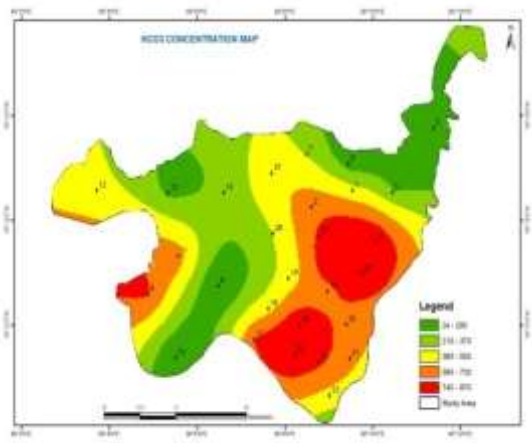

Fig.11. Map Showing Concentration Pattern of HCO_3

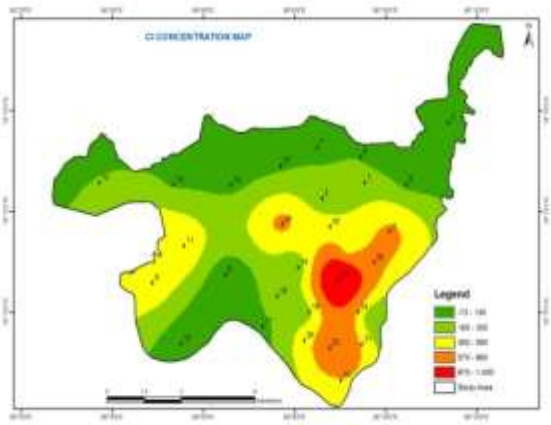

Fig.12. Map Showing Concentration Pattern of Cl^-

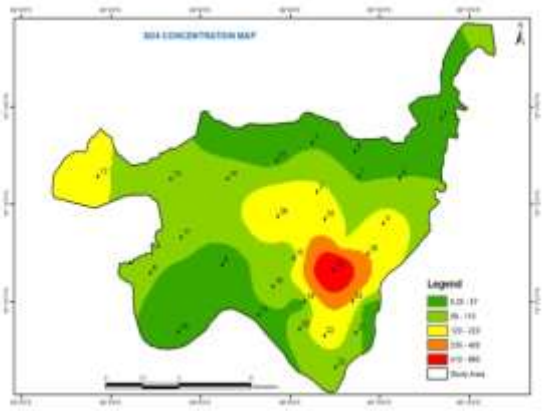

Fig.13. Map showing Concentration pattern of SO_4^-

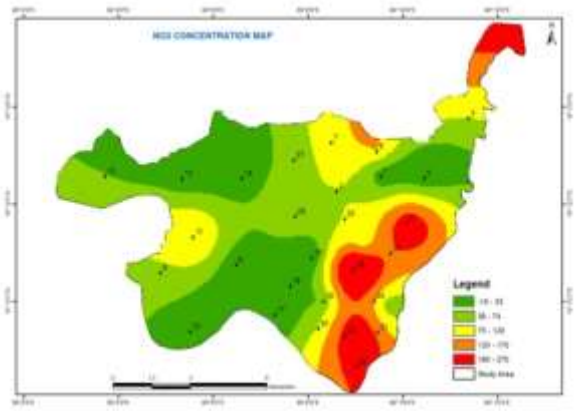

Fig.14. Map Showing Concentration Pattern of NO_3^-

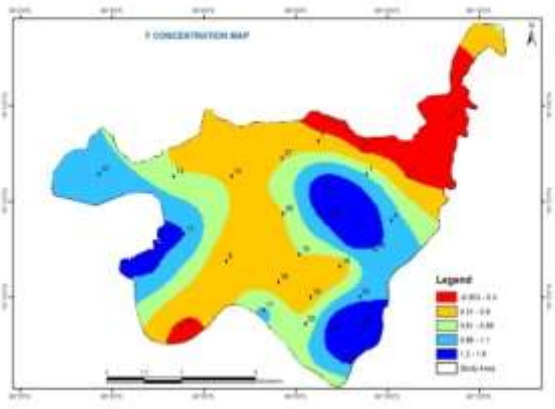

Fig.15. Map Showing Concentration Pattern of NO_3^-

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