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Major ion geochemistry of groundwater in Kalwakurthy area, Mahabubnagar 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 Kalwakurthy area, Mahabubnagar 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.

Keywords: Geochemistry, major ions, Kalwakurthy, Mahabubnagar 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) [16]. 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) [14]. 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) [19].

Groundwater quality data gives important clues on the geologic history of rocks and indications of groundwater recharge, discharge, movement and storage (Walton, 1970) [17]. Wide spread occurrence of fluorosis and occurrences of higher concentration of fluoride in the Ground waters of Kalwakurthy area of Mahabubnagar District of Andhra Pradesh were reported by (CGWB, 2007) [5]. However, no detailed investigations were taken up here in this area.

2. Location of the Study Area

The study area, covering about 237 sq.km, falls in Mahabubnagar district of Andhra Pradesh, India. It is located 80 km from Hyderabad. Kalwakurthy lies in between North Latitudes 16° 34′ 30″ to 16° 42′ 00″ and East longitudes 78° 24′ 00″ to 78° 28′ 48″ (figure 1) and falls in the Toposheet No. 56 L/6 and 56 L/10. The Mahabubnagar district occupies an area of nearly 18742 Sq.km. The district lies in between North Latitudes 18º 40' and 19º 50' and East longitudes 77º 46' and 80º 00'. The climate of the study area is generally hot. During summer the maximum temperature is around 44 ^{0}C and the minimum temperature is around 40 ^{0}C. May is the hottest month. During winter the maximum temperature is around 24 ^{0}C and the minimum temperature is around 19 ^{0}C. December is the coldest month. The annual rainfall of the district is 605 mm, (CGWB, 2007) [5].

3. Geology

The study area forms a part of the stable Dharwar craton of south Indian shield. Grey granite occupies dominant portion of the area (Fig.2). These rocks are composed of quartz, feldspars, and biotite. These are medium to course grained and equigranular in texture. The typical grey colour is due to the presence of the plagioclase feldspars and quartz. The potash feldspars that are present in the rock are orthoclase and microcline but in less abundance. Biotite is the most predominant mineral in these rocks. Mahabubnagar district forms a part of the stable Dharwar craton of south Indian shield. It exposes rocks of peninsular gneissic complex, Dharwar super group, Cuddapah super group, and Kurnool and Bhīma groups and also of Deccan traps. The Peninsular Gneissic Complex, which covers most of the area, comprises granites, gneisses and migmatites with undigested patches of older metamorphic rocks (Geotechnical map of India, G. S. I, 1995).

4. Hydrogeology

Groundwater occurs in all the geological formations in the district. The major rock types in the district are peninsular gneissic crystalline, limestones, conglomerates, sandstones, shales, basalts and alluvium. The occurrence and behavior of groundwater is an outcome of combined interplay of hydrological, geological, structural, climatologically factors, which together form dynamic integrated system. All these factors are inter-dependent and inter-related, each adding its contribution in functioning of the dynamic system. The yield of wells depend on recharge conditions, draft etc. In drought condition, the yield of wells will drastically dwindle in phreatic aquifers (CGWB, 2007) [5]

5. Sampling and Analysis

56 groundwater samples were collected from dug-cum-bore well during (June, 2011) in the study area (56 water samples from 54 bore wells, 2 dug wells) covering Kalwakurthy and the adjoining area of Mahabubnagar 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) [1].

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).

6.1 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) [11]. The pH of the groundwater of the study area is varying from 7.42 to 8.8. Average pH value is 8.04. The limit of pH value of drinking water is specified as 7.0 to 8.5 (RGNDWM, 1993; WHO, 1963) [15, 18] while 4% 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 8.8 mg/L is observed in the groundwater from Elikal Thanda and minimum concentration 7.42 mg/L is observed in Panjagul area. The Concentration levels of pH in all the samples are shown in Table. 1.

6.2 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 402. 86 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) [18]. It is observed that nearly 4% 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) [11]. 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 1568.8 microsiemens/cm is observed in the groundwater from Panjagul area and minimum concentration 78.44 microsiemens/cm is observed in the Kalwakurthy area. High conductance is attributed to high concentration in groundwater (Davies and Dewist, 1966) [8]. The Concentration levels of EC in all the samples are shown in Table. 1.

6.3 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 257.82 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) [15]. While 7% 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) [8]. Palatability of the water decreases when the concentrations exceed this limit and may cause gastro-intestinal irritation (ISI, 1983) [12].
From the concentration map high concentration of Total Dissolved Solids is observed in the southern part of the area (Fig.5). Maximum concentration of 1004.03mg/l is observed in the groundwater from Panjagul area and minimum concentration of 50.2 mg/l is observed in the Kalwakurthy area. The Concentration levels of TDS in all the samples are shown in Table. 1.

6.4 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) [15, 18]. 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) [2]. 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) [4]. 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 560 mg /L of TH is observed in the groundwater of Suddakallu and minimum concentration of 75 mg/1 is observed in Kalwakurthy. 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.

6.5 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 42.76 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) [15, 18] while 9% 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 154.03 mg/l is observed in Suddakallu area and minimum concentration of 16.03 mg/l is observed in Rachanapalli 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.

6.6 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 42.76 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) [15, 18]. It is observed that 32% 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 83.83 mg/L is observed in Panjagul area and minimum concentration of 2.91 mg/l is observed in Kotra area. The Concentration levels of Mg in all the samples are shown in Table. 1.

6.7 Sodium (Na^+): Sodium concentrations are varying from 17mg/l to 182 mg/l. Average concentration of Na^+ in groundwater is 57.10 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 182 mg/l is observed from Panjagul area and minimum concentration of 17 mg/l is observed in Jeedipalli area. The Concentration levels of Na in all the samples are shown in Table. 1.

6.8 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 15.62 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.

6.9 Carbonates (CO_3^-): Carbonate concentration in the groundwater of the area is ranging from 0 mg/l to 15mg/l. Average concentration of CO_3^- in the study area is 7.37mg/l. From the Concentration map high concentration of sulphates 15 mg/l is observed in southern part of the area (Fig.11). Maximum concentration of 15 mg/l is observed in the groundwater from Gundur, Panjagul area. The Concentration levels of CO_3 in all the samples are shown in Table. 1.

6.10 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 122.74 mg/l. Maximum concentration of 219.6 mg/l is observed in the groundwater in Panjagul area and minimum concentration of 48.8mg/l is observed in the groundwater in Rachapalli area. The Concentration levels of HCO_3 in all the samples are shown in Table. 1.

6.11 Chloride (Cl^-): Chloride concentrations are varying from 21.3 mg/l to 678.05 mg/l. Average concentration of Cl^- in groundwater is 131.8 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) [15, 18]. 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 678.05 mg/l is observed in Panjagul area and minimum concentrations of 21.3 mg/l in Kalwakurthy 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) [13, 7]. 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.

6.12 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 31.78 mg/l. The acceptable limit of SO_4^- in drinking water is 200 mg/l (RGNDWM, 1993; WHO, 1963) [14, 17]. 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 180 mg/l is observed from Panjagul area and minimum concentration of 4 mg/l is observed from Rankalmitta area. Apart from these natural sources, sulphates can be introduced through the application of sulphatic soil conditioners (Karanth, 1987) [13]. 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.

6.13 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) [12]. 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 112.5mg/l is observed in Kurimidda area and minimum concentration of 40.2mg/l is observed in Elikal area. The Concentration levels of N in all the samples are shown in Table. 1.

6.14 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 0.16 mg/l to 3.4 mg/l with an average of 1.86. As per the desirable and maximum permissible limit for fluoride in drinking water determined by WHO (2004) or by Bureau of Indian Standards (2009), 45% 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 Kalwakurthy area of Mahabubnagar 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 Kalwakurthy 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.

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Table 1: Analytical Data of the Groundwater in the Study Area

S. No	pH	EC	TDS	CO_3^-	HCO_3^-	Cl^-	TH	Ca^{++}	Mg^{++}	Na^+	K^+	SO_4^-	NO^-_3	F^-
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	8.28	235.3	150.6	6	94.5	21.3	140	40.08	9.72	24	10	9	25.2	1.36
2	8.22	156.9	100.4	6	73.2	31.95	110	120.2	19.44	33	11	4	25.2	0.59
3	7.78	549.1	351.4	9	106.8	188.2	300	72.14	2.91	58	13	40	88	0.17
4	7.92	235.3	150.6	0	106.8	42.6	150	40.08	12.15	38	12	9	9	1
5	7.85	235.3	150.6	0	106.8	53.25	145	36.07	13.36	35	12	12.5	13	0.58
6	8.28	156.9	100.4	6	67.1	24.85	95	22.04	9.72	23	12	4	22	0.64
7	8.48	156.9	100.4	9	57.95	24.85	90	20.04	9.72	33	13	4	5	0.83
8	7.88	470.6	301.2	6	122	145.6	197.5	42.08	22.47	85	13	40	66	0.51
9	8.25	313.8	200.8	12	152.5	53.25	160	24.04	24.3	57	13	9	9	1.73
10	8.05	313.8	200.8	9	131.2	49.7	175	30.06	24.3	41	13	9	15.1	1.89
11	7.86	313.8	200.8	9	146.4	42.6	170	26.05	25.51	47	13	4	8.2	1.69
12	7.49	627.5	401.6	10.5	137.3	387	310	102.2	13.36	79	10	52.5	1.1	0.17

13	7.79	549.1	351.4	6	115.9	198.8	305	46.09	46.17	84	10	47.5	66	0.81
14	7.78	392.2	251	12	155.6	78.1	190	40.08	25.51	42	26	9	66	0.7
15	8.17	235.3	150.6	9	97.6	24.85	125	32.06	10.93	22	10	4	1.1	0.54
16	7.9	627.5	401.6	6	180	259.2	385	50.1	63.18	71	10	47.5	6.1	1.71
17	8.2	313.8	200.8	10.5	152.9	42.6	180	26.05	27.94	36	10	9	13	0.82
18	8	235.3	150.6	9	149.5	31.95	125	20.04	20.65	77	11	4	20	2.24
19	7.43	1569	1004	10.5	201.3	678.1	540	84.16	83.83	182	45	180	66	0.56
20	7.42	1255	803.2	10.5	219.6	505.9	330	72.14	36.45	150	47	125	88	0.54
21	8.2	313.8	200.8	6	146.4	71	160	24.04	24.3	82	11	17.5	6.1	1.56
22	8.05	313.8	200.8	15	134.2	53.25	130	20.04	19.42	73	11	12.5	11	1.38
23	7.94	470.6	301.2	6	85.4	218.3	272.5	86.17	13.97	24	12	25	66	0.97
24	7.8	470.6	301.2	9	115.9	197	270	50.1	37.66	64	12	25	21	1.57
25	7.98	235.3	150.6	12	122	28.4	100	26.05	8.5	56	12	9	5.1	3.4
26	8.8	235.3	150.6	9	91.5	46.15	100	24.02	9.72	49	12	20	20	1.72
27	7.8	392.2	251	12	109.8	99.4	175	42.08	17.01	64	13	20	85	1.81
28	7.7	784.4	502	9	170.8	390.5	305	56.11	37.66	127	13	67.5	66	1.37
29	7.9	392.2	251	9	109.8	127.8	230	56.11	21.87	34	14	20	31	0.32
30	7.6	1020	652	6	140.3	376.3	350	68.13	43.74	155	17	100	66	0.36
31	7.71	627.5	401.6	9	122	232.5	280	58.11	32.81	75	27	90	66	0.19
32	7.76	706	451.8	6	140.3	358.6	560	154	42.52	53	14	95	88	0.22
33	7.96	392.2	251	10.5	94.55	113.6	210	44.08	24.3	32	15	20	31	0.29
34	8.12	392.2	251	3	112.9	88.75	280	48.09	67.68	31	14	25	35	0.23
35	8.2	313.8	200.8	0	125.1	46.15	170	30.06	23.08	60	14	20	15	0.72
36	8.5	235.3	150.6	15	140.3	49.7	150	18.03	25.51	62	14	17.5	7.5	0.74
37	8.3	156.9	100.4	9	85.4	35.5	160	26.05	23.08	22	14	20	75	0.53
38	8.2	156.9	100.4	0	109.8	21.3	100	24.04	9.72	34	14	9	28.1	0.9
39	8	313.8	200.8	0	128.1	81.65	275	42.08	43.74	40	15	27	100	1.44
40	7.88	470.6	301.2	6	201.3	106.5	300	36.07	51.03	63	15	60	112.5	1.78
41	7.97	392.2	251	6	164.7	142	220	32.06	34.02	61	15	32	24	1.83
42	8.35	156.9	100.4	3	73.2	28.4	105	30.06	7.29	20	15	9	41	1.34
43	8.2	156.9	100.4	6	82.35	21.3	115	32.06	8.5	25	15	4	32.5	0.96
44	8.13	156.9	100.4	6	54.9	35.5	100	22.04	10.93	17	15	4	75	0.82
45	8.17	232.3	148.7	6	85.4	49.7	150	22.04	23.08	34	16	27	75	0.78
46	8.13	470.6	301.2	9	170.8	145.6	265	34.06	43.74	73	16	52.5	28.1	1.69
47	8.34	313.8	200.8	9	134.2	85.2	200	30.06	30.3	63	16	25	3	0.92
48	8.47	156.9	100.4	6	79.3	39.05	140	30.06	15.78	23	15	9	67	0.74
49	8.31	470.6	301.2	9	201.3	124.3	230	16.03	46.17	103	16	27	50	2.14
50	8.28	470.6	301.2	6	158.6	188.2	200	26.05	32.8	105	16	36	3	2.52
51	8.11	232.3	148.7	6	115.9	35.5	155	40.08	15.79	31	17	12.5	20	1.76
52	8.22	156.9	100.4	9	73.2	28.4	120	22.04	15.8	21	16	4	28.1	1.91
53	8.2	232.3	148.7	6	97.6	60.35	165	26.05	24.3	25	16	12.5	67	1.76
54	8.48	156.9	100.4	6	128.1	53.25	120	26.05	13.36	33	16	17.5	24	1.61
55	7.8	549.1	351.4	6	122	234.3	375	26.09	63.18	42	16	60	112.5	0.88
56	7.48	78.44	50.2	6	48.8	28.7	75	16.03	8.5	20	16	4	20	2.56

Table 2: 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	7.42	8.8	8.11	6.5-8.5	5
EC	78.44	1568.8	823.62	1500	4
TDS	50.2	1004.03	527.1	500	5
CO_3^-	0	15	7.366	10	89
HCO_3^-	48.8	219.6	122.33	500	Nil
Cl^-	21.3	678.05	349.67	250	7
TH	75	560	317.5	200	39
Ca^{++}	16.03	154.03	85.16	75	5
Mg^{++}	2.91	83.83	43.37	30	29
Na^+	17	182	99.5	250	Nil
K^+	10	47	28.5	10	89
SO_4^-	4	180	92	200	Nil
NO_3^-	1.1	112	57.35	45	38
F	0.16	3.4	1.7	1.5	45

Table 3: Pearson Correlatissson Matrixes of Major Elements in Groundwater

	pH	EC	TDS	CO_3^-	HCO_3^-	Cl^-	TH	Ca^{++}	Mg^{++}	Na^+	K^+	SO_4^-	NO_3^-
pH	1.000												
EC	-0.67	1.000											
TDS	-0.67	0.203	ss1.000										
CO_3^-	-0.07	0.203	0.204	1.000									
HCO_3^-	-0.35	0.659	0.659	0.253	1.000								
Cl^-	-0.68	0.962	0.962	0.168	0.561	1.000							
TH	-0.61	0.844	0.844	0.042	0.574	0.861	1.000						
Ca^{++}	-0.5	0.54	0.54	-0.02	0.145	0.629	0.665	1.000					
Mg^{++}	-0.37	0.671	0.671	0.007	0.64	0.612	0.777	0.237	1.000				
Na^+	-0.49	0.86	0.86	0.263	0.739	0.797	0.594	0.278	0.563	1.000			
K^+	-0.41	0.68	0.681	0.172	0.42	0.612	0.406	0.203	0.392	0.542	1.000		
SO_4^-	-0.6	0.947	0.947	0.111	0.582	0.933	0.85	0.546	0.677	0.793	0.706	1.000	
NO_3^-	-0.36	0.383	0.383	-0.1	0.103	0.371	0.484	0.285	0.346	0.164	0.363	0.471	1.000

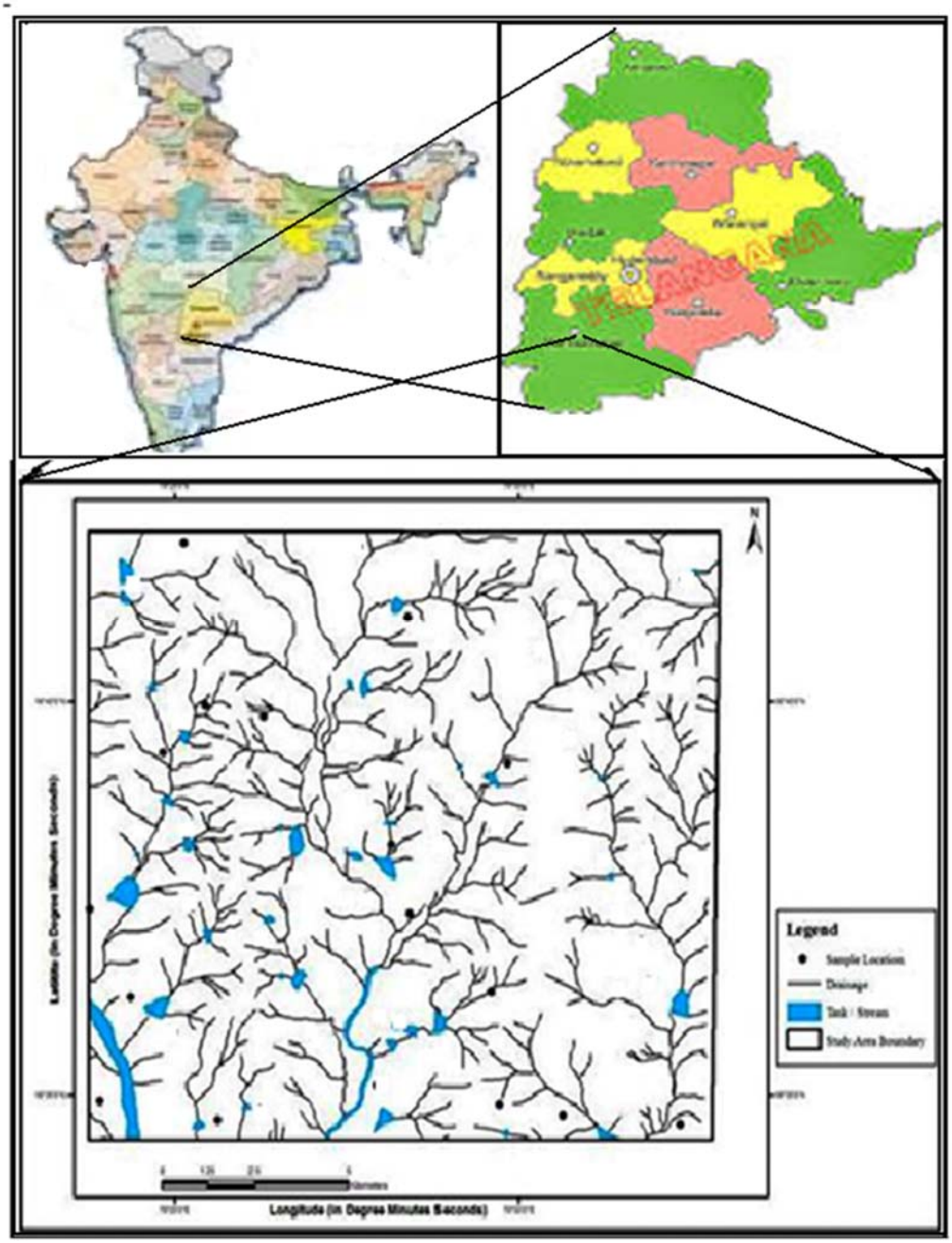

Fig 1: Location Map of the Study Area with Water Sample Points, Drainage and Tanks.

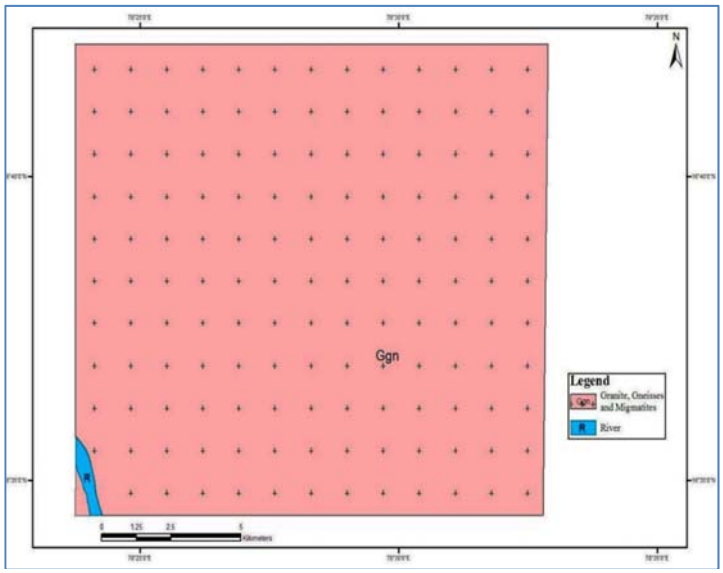

Fig 2: Geological Map of the Study Area

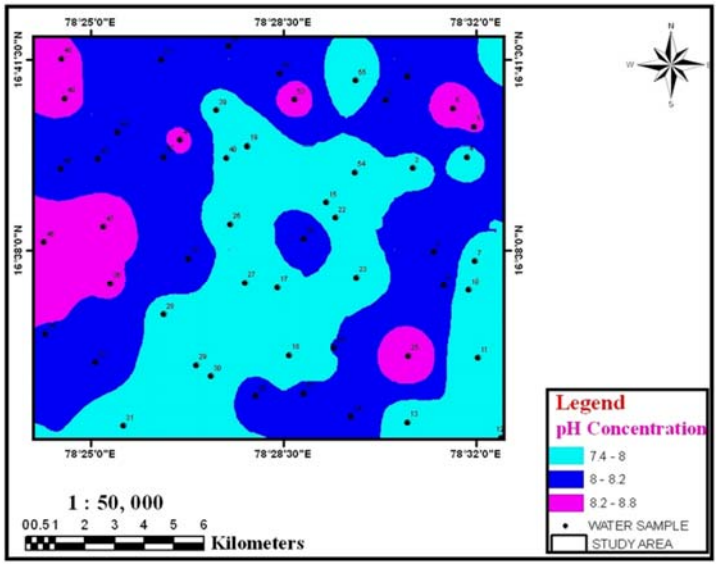

Fig 3: Map showing Concentration pattern of pH

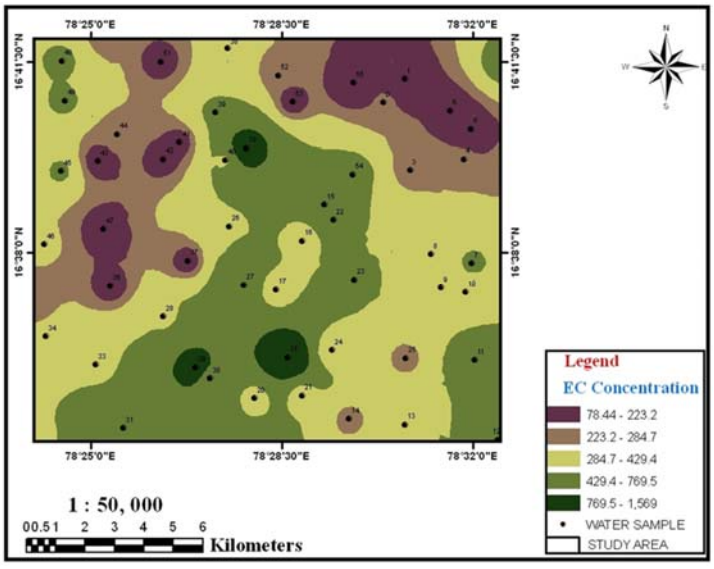

Fig 4: Map Showing Concentration Pattern of EC

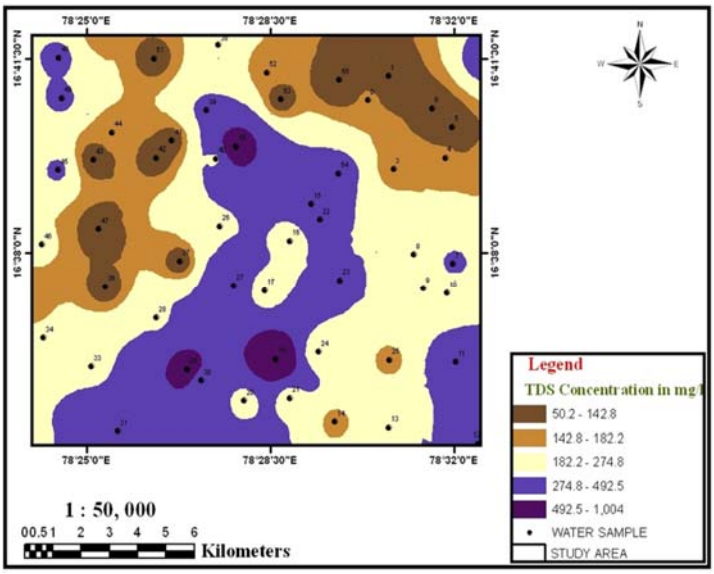

Fig 5: Map Showing Concentration Pattern of TDS

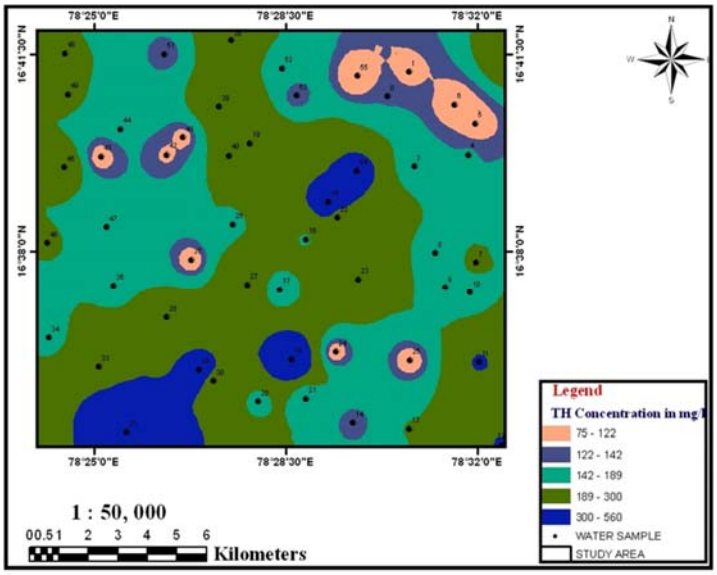

Fig 6: Map Showing Concentration Pattern of TH

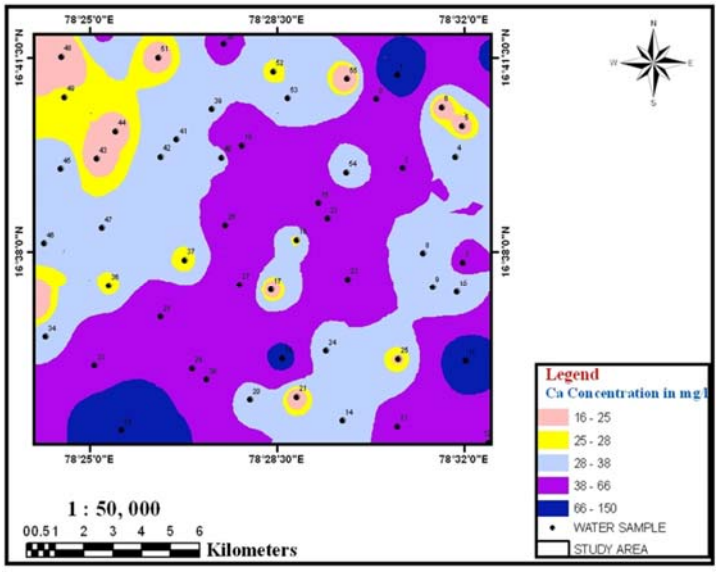

Fig 7: Map Showing Concentration Pattern of Ca

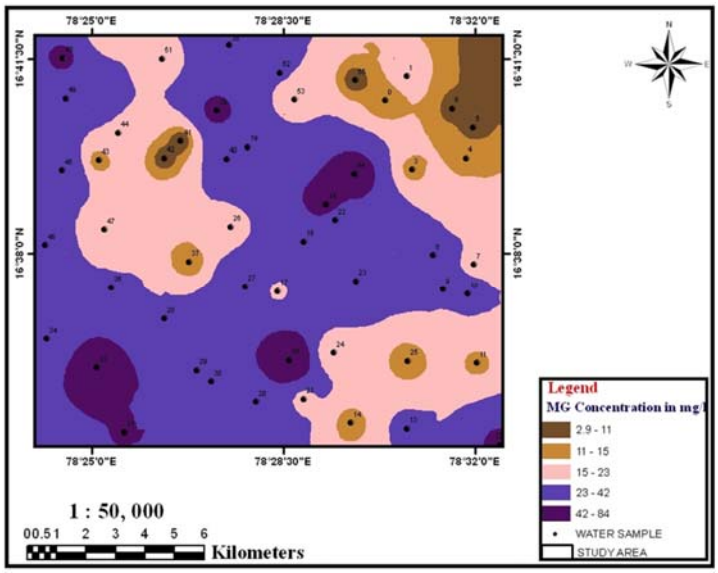

Fig 8: Map Showing Concentration Pattern of Mg

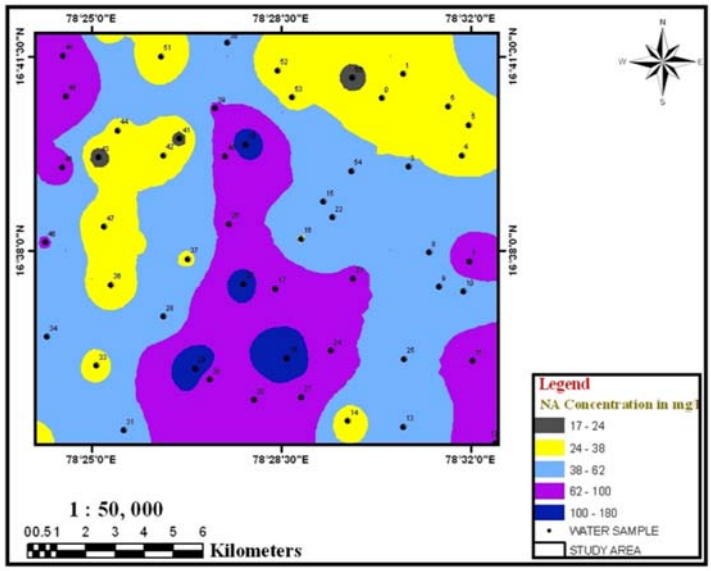

Fig 9: Map Showing Concentration Pattern of Na

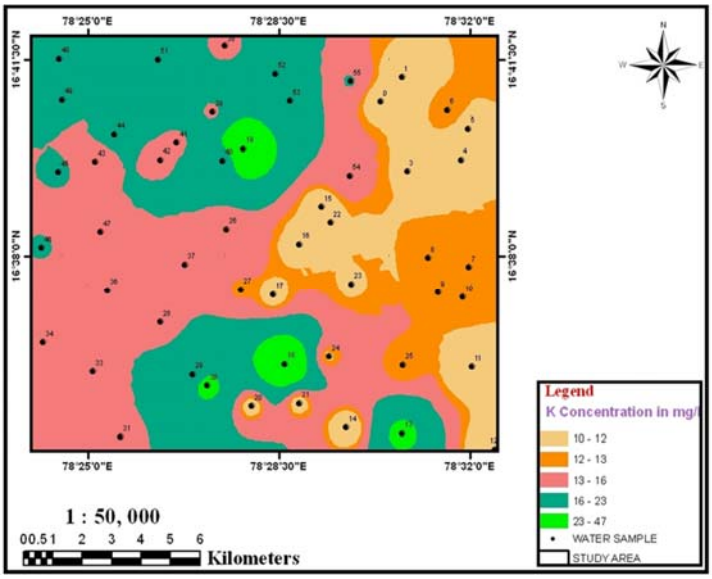

Fig 10: Map Showing Concentration Pattern of K

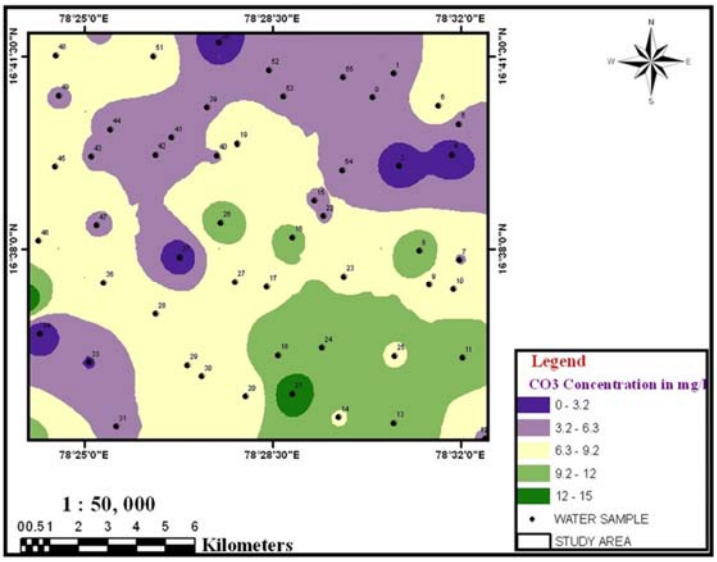

Fig 11: Map Showing Concentration Pattern of CO_3^-

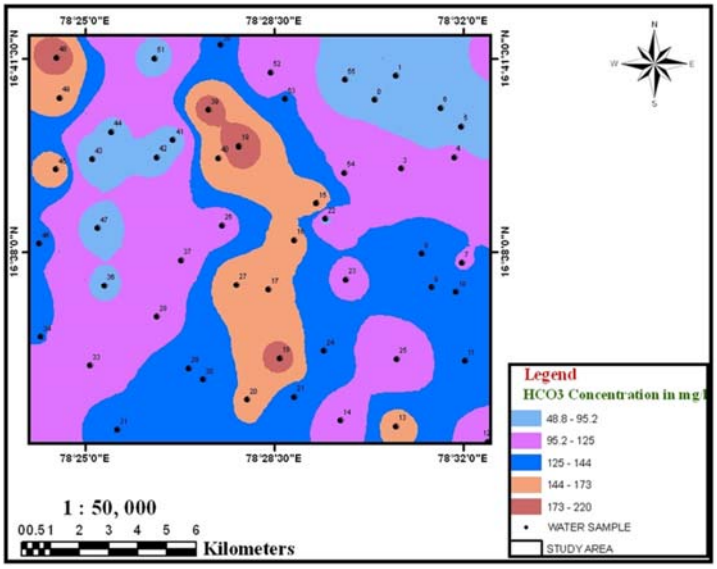

Fig 12: Map Showing Concentration Pattern of HCO_3^-

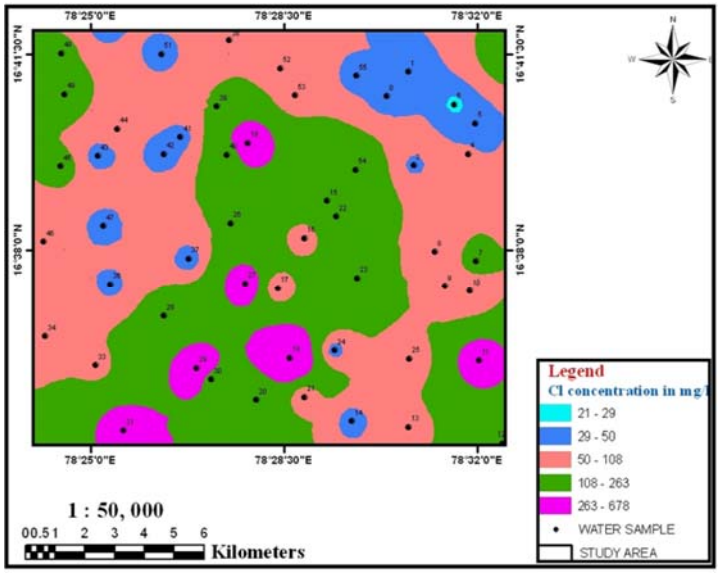

Fig 13: Map Showing Concentration Pattern of Cl^-

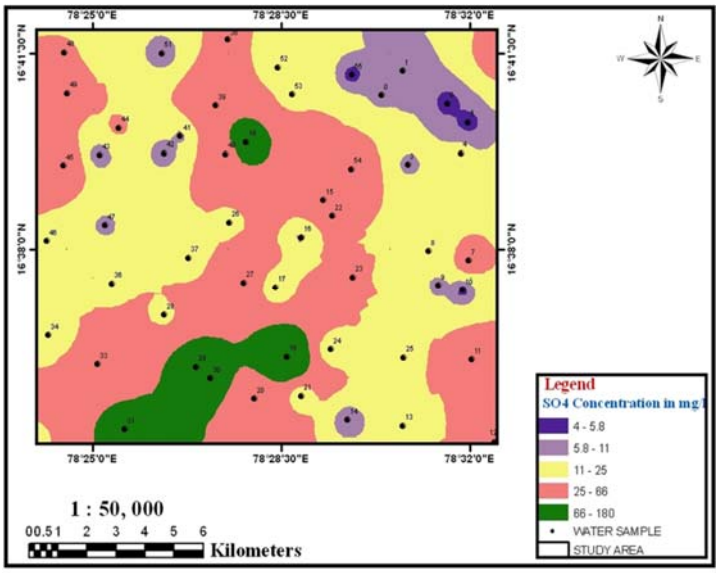

Fig 14: Map showing Concentration pattern of SO_4^-

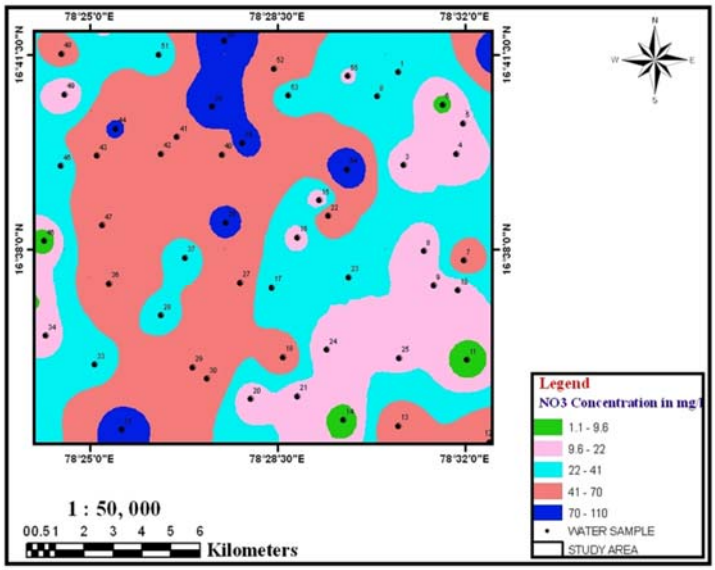

Fig 15: Map Showing Concentration Pattern of NO_3^-

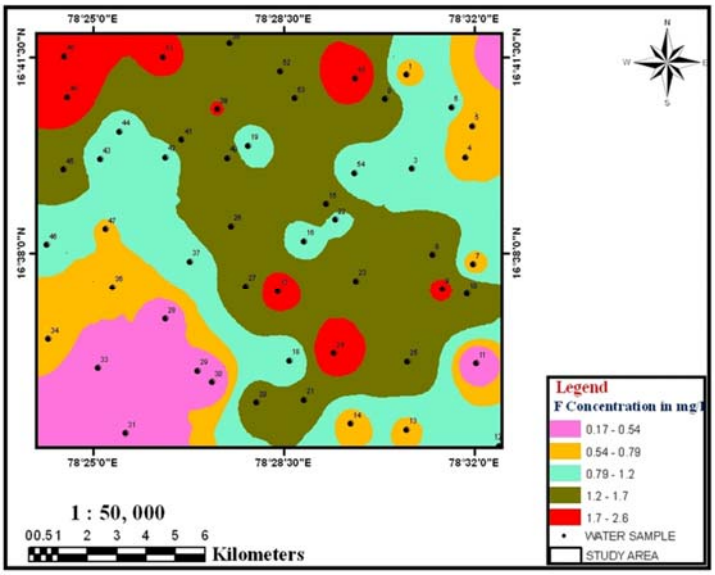

Fig 16: Map showing Concentration pattern of F

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