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Research paper

A Study on Spatial Variability of Groundwater Quality From a Fluoride Infested Aquifer of Nalgonda District of Telangana State, India.

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Abstract

The manuscript should contain an abstract. The abstract should be self-contained and citation-free and should not exceed 200 words. The abstract should state the purpose, approach, results and conclusions of the work. The author should assume that the reader has some knowledge of the subject but has not read the paper. Thus, the abstract should be intelligible and complete in it-self (no numerical references); it should not cite figures, tables, or sections of the paper. The abstract should be written using third person instead of first person.

Keywords: *Groundwater; G.I.S and Remote sensing; Hydrogeochemistry; Fluoride;*

1. Introduction

The Nalgonda district of Telangana State covers around 2880 km^2 and stretches along the Northern bank of the river Krishna of Telangana state in India. This district is known for high fluoride contamination and a number of investigations conducted earlier reported the incidence of skeletal fluorosis due to the fluoride occurrence in the Ground Water. Due to severity of the problem Government has taken many initiatives to ensure safe drinking water to the community after necessary treatment, however with limited success. Many attempts were made [1], [2] and [3] to evaluate groundwater quality in this area however, no detailed work was attempted in recent times. Under this situation this work is planned to cover the whole district for total quality determination of groundwater with an attempt to evaluate the present situation in the context of Government's initiative to undertake a cleanup programme more seriously. The area under investigation lies in between the longitudes 79^0 0' to 79^0 30' E and latitudes 16$^{\mathbf{0}}$ 45' to 17^0 15' N (Figure 1)

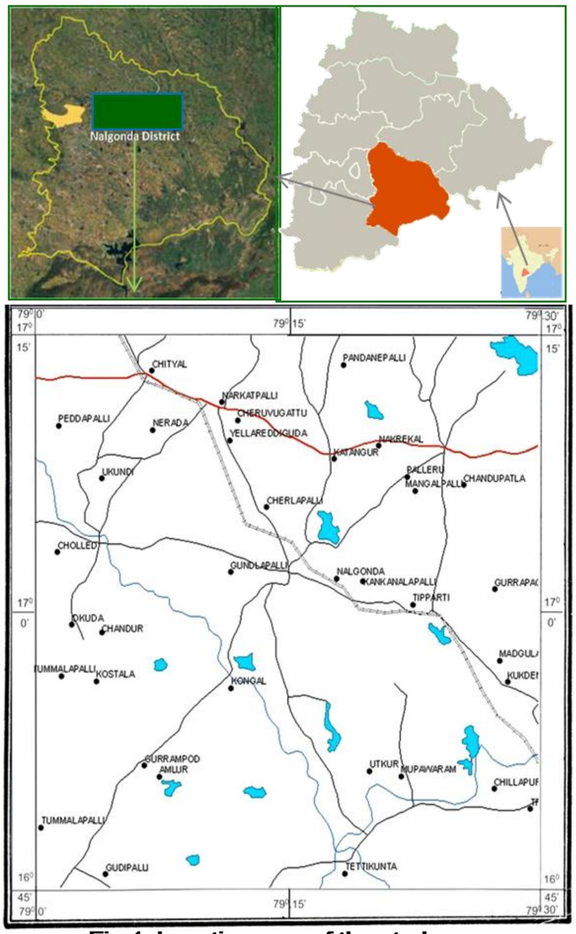

Fig.1: Location map of the study area

2. Materials and methods

A total of 122 samples from 33 villages covering the entire district were collected from bore wells from the study area (Figure 2). The samples were collected in the month of May, 2016 in 500 ml plastic containers for chemical analyses. Standard methods were used for the determination of the chemistry of the water [4]. The parameters analyzed are TDS, TH, Ca, Mg, Na, K, Cl, SO4, NO3 and F. All the constituents except pH are expressed in mg/l (Milligram/Litre)

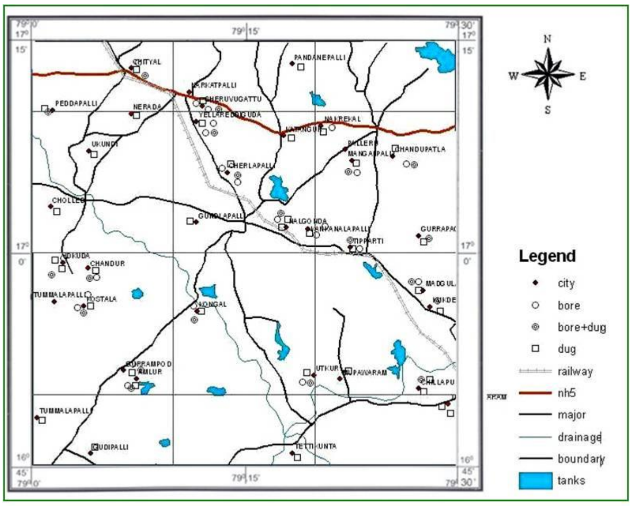

Fig.2: Well location map

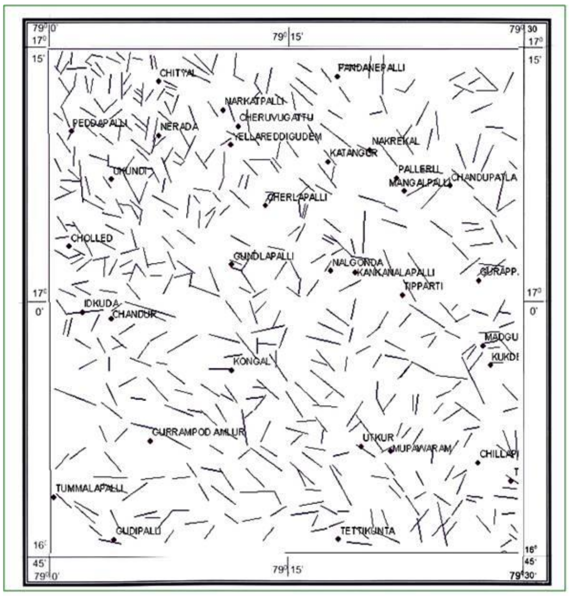

Fig. 3: Lineaments of the study area

2.1. Aquifer Conditions

Table 1 General geological succession of Nalgonda district

Age	Super group	Group	Lithology
Recent to Sub recent			Soil and Alluvium
Proterozoic	Kurnool	Jammalamadugu Banaganapalli	Nargi limestones and shales Quartzites and conglomerates
		Unconformity	
	Cuddapah	Krishna	Srisailam quartzites and shales
		Unconformity	
Archaeans	Younger intrusives		Quartz reefs, dolerites, pegmatites, quartz veins, pink granites and other ultra basics
	Dharwar		Chlorite, hornblende schists and granulites
	Peninsular Gneissic complex		Grey granites, gneisses and migmatites
	Older metamorphics		Biotite schists Pyroxenites and amphibolites

The area under study forms the part and parcel of Indian peninsular gneissic complex, characterized by the prominent geological formations mainly gneisses and granites, which were later, intruded by dolerite dykes and pegmatite bodies. Subsequently the formation of inland basins resulted the sedimentary formations like sandstones and limestones. The rocks of gneissic complex generally lack the primary porosity, however secondary porosity developed by fractures, joints by deformation and by weathering is common. The sedimentary formations though minor in aerial extension found to poses excellent aquifer conditions. The water table is observed to occur moderately deep to deep and the general direction of groundwater movement follows the topographic slope of the area. (Table 1).

2.2. Lineaments in the Study Area

The lineaments are present in different directions with different lengths in the study area. Figure 3 shows that the majority of lineaments having the trend N 20^0 W to E-W, with 52.94% of lineaments are occupied in this direction. In the north eastern direction the major set of lineament trend N20^0E to E-W with 43.05% of lineaments are occupied in this direction. Apart from this some of the lineaments trends N-S direction i.e., 3% and E-W direction with 2%. Based on these studies on lineament density map of the entire study area has been prepared indicating areas of high, moderate and low density lineaments (Figure 3).

3. Results

The results of the present study are shown in the Table 2, which provides a comprehensive picture of the quality of groundwater in different villages in the district. The pH of the study area, which varies from a maximum of 8.65 (Kanagal) to a minimum of 7.43 (Gurrapagudem). Majority of the villages are in the range of 7.50 – 8.20. (Figure 4A). The Total Dissolved Solids in the study area ranges from200 mg/l (Cholled) to 2359.66 mg/l (Amlur). Maximum villages have TDS values 499 mg/l-1212 mg/l. The data suggest that 100% samples exceed the desirable limits of TDS (Figure 5A). The Total Hardness is ranging from 236 mg/l – 1308 mg/l in the study area. Maximum villages of study area having TH values between 240 mg/l-650 mg/l. The data infers that about 88% of samples exceed desirable limits (Figure 6A). In the study area Calcium varies from a minimum of 29.2 mg/l (Yellareddyguda) to maximum of 120.7 mg/l (Pandenapalli). Maximum villages having the Calcium in the range 49 mg/l-84 mg/l. Only about 25% samples indicated calcium concentration exceeding the desirable limits (Figure 7A).

The Magnesium of the study area varies from 25.33 mg/l (Tipparthi) to 143.25 mg/l (Cheruvugattu). Majority of the villages having values 26 mg/l—50 mg/l. The study indicates that about 88% of samples registered magnesium concentration exceeding the desirable limits (Figure 8A). Sodium recorded values varying from 28 mg/l (Gundlapalli) to 279.33 mg/l (Tipparthi) in the study area. Maximum villages having sodium values from 31 mg/l to 90 mg/l. Only about 12% of samples have indicated excess sodium than the desirable limits (Figure 9A).

The Potassium of the study area having values varying from 1.3 mg/l (Kanagal) to a maximum of 103.75 mg/l (Yellareddyguda). Maximum villages having potassium values from 1.4 mg/l –25 mg/l. The villages from the Northern part of the study area registered higher potassium values. The Chloride varies from 56.4 mg/l (Tetikunta) to 390.33 mg/l (Mangalapalli). Most of the villages in the study are having chloride values from 51 mg/l –79 mg/l . About 18% of samples recorded chloride concentration exceeding the desirable limits (Figure 10A). The Sulphate concentration of the ground waters of the study area having values from 1 mg/l (Kubagudem) to 67.5 mg/l (Cheruvugattu). Maximum villages having sulphate values ranging from 0.4 mg/l to 15 mg/l. Total of the study area having below permissible levels of sulphate values (Figure 12 A). Nitrate in the study area varies from 0.6 mg/l to 4.775 mg/l. Majority of the villages having values from 0.4 mg/l—2 mg/l. The entire study area is having below permissible levels of nitrate (Figure 13 A). The fluoride in the study area having values from 0.3 mg/l (Muppavaram) to 9.8 mg/l (Yellareddyguda). Maximum villages having fluoride values from 3 mg/l to 6 mg/l. About 91 % of the samples analysed in this study indicated fluoride concentration exceeding the desirable limits (Figure 14 A).

Table 2: Quality of the groundwater in the study area

S.NO.	No. samples	Name of the village	Avg pH	Avg TDS	Avg TH	Avg Ca	Avg Mg	Avg Na	Avg K	Avg Cl	Avg SO_4	Avg NO_3	Avg F
1	3	Chityala	7.9	667.66	264.3	106.6	49.33	140.33	30.33	261.33	12.62	1.6	2.3
2	5	Cheruvugattu	7.5	1868.5	727.5	87.75	143.2	315	92.5	763	67.5	2.07	5.02
3	6	Yellareddigudа	7.5	1283.5	615	29.2	42	280	103.75	159.5	11.5	1.4	9.8
4	5	Nalgunda	7.6	606.5	261.5	35.5	28.25	31.5	3.15	78.5	14.5	4.25	1.26
5	3	Cherlapalli	7.52	615.75	275	45	26.25	92.5	2.375	79	10	1.2	1.5
6	4	Gundlapalli	7.85	1194	569	57.5	39	28	4.65	70.5	7.5	0.8	2.54
7	3	Idukuri	8.52	1440.25	618	38.25	64.25	164.25	11.17	72	62.5	2.6	3.61
8	4	Chandur	7.54	991	991	35.33	67	104.3	2.73	59.66	51.67	1.53	6.03
9	3	Kastala	8.23	829.25	297.2	38.75	39	137.5	1.22	135.5	34	0.9	3.09
10	4	Kanagal	8.65	975	440.6	38.33	30.66	68.33	1.3	99.33	41.33	0.76	1.33
11	3	Gurrampod	7.47	1844.75	341.2	65.5	60.75	82	2.87	51.75	27.5	4.77	3.62
12	4	Amlur	7.45	2359.66	1308.3	74.66	34.93	97.3	3.6	57.33	60	0.8	3.13
13	3	Nakrekal	7.55	500.5	866.5	71	49	147.5	3.25	175	5	0.7	5.7
14	4	Mangalapalli	8.0	2011.37	750	67.33	50.67	202	2.5	390.33	4.2	1.03	0.86
15	3	Chandupatla	8.26	1554.66	643.3	76	55.33	82.33	15.3	136.67	4	0.76	0.4
16	3	Kankandlapalli	7.96	1187.33	550	38	38.33	280	56.67	224	27.33	1.0	5.3
17	5	Tipparthi	7.96	1049.66	432.6	35.33	25.33	279.33	20.96	100	21.33	1.16	1.42
18	3	Madugulapalli	7.98	1181.33	333.6	64.33	55.67	107.33	29.33	242.67	0.133	0.66	1.22
19	4	Kubagudem	7.78	634.5	268.5	39	70	96.2	6.4	138	1	0.9	2.35
20	3	Utkur	7.45	887.33	423.6	102.66	61.33	88.33	2.53	76	1.4	3.03	5.3
21	3	Chillapur	7.83	1001.75	417	80.5	60.75	82	2.87	51.73	27.5	4.77	5.2
22	4	Muppavaram	7.85	488.5	236	56	31	86	32.7	71	25	2.8	0.3
23	5	Tripuravaram	763	1279.33	558.3	47.33	26	57.67	2.36	59.33	11.67	4.73	3.02
24	5	gurrapagudem	7.43	1177.66	464	65.66	54.33	198.33	41.66	280.67	-	0.6	2.5
25	3	Tummalapalli	7.6	1768.5	780.8	68.9	34	110.5	4.8	64.8	34.6	3.2	4.8
26	4	Gudipalli	7.5	1678.9	650	59.75	52.3	98.6	2.6	59.4	28.4	1.8	2.8
27	3	Peddapalli	8	873	350	67	48.9	192.4	24.5	56.8	8.9	1.8	3.2
28	3	Ukindi	7.8	1000	286.6	78	36.4	148	16.6	86.4	12.5	1.6	4.2
29	3	Cholled	8.2	200	450.8	89	38.4	174.7	12.6	78.2	26.4	2.1	5.6
30	3	Nereda	8	974	420.6	78.89	52.6	164	28.9	198.6	10.4	1.8	2.6
31	4	Kattangur	8	1678.7	632.4	82.8	62.8	166.2	84.5	292.8	13.4	2.1	4.2
32	5	pandenapalli	7.6	1345.6	780.9	120.7	54.33	193	58.6	286	18.8	1.9	5.6
33	5	Tetikunta	8	798.6	480.8	68.7	68.8	64.6	26.4	56.4		2.4	1.8

Table 3. Groundwater quality compared with WHO (1984) and BIS (1991) Standards

Parameters	WHO (1984)	BIS (1991)	% of sample exceeds desirable limits	Adverse effects beyond the desirable limits
pH	6.5-8.5	7.0-8.5	Within the range	The mucous membrane and/or water supply system
TDS	1000.0	500	100.0	Palatability decreases and may cause gastrointestinal irritation
TH	-	300	87.87	Encrustation in water supply structure and adverse effects on domestic use
Ca2+	500.0	75	24.24	Encrustation in water supply structure and adverse effects on domestic use
Mg2+	-	30	87.87	Encrustation in water supply structure and adverse effects on domestic use
Na+	200.0	-	12.12	Hypertension or heart diseases
Cl-	250.0	250	18.18	Taste, corrosion and palatability are affected-
SO42-	400.0	150	All are within the limits	-
NO3-	45.0	45	All are within the limits	-
F	1.5	0.6-1.2	90.90	High levels of Fluoride came skeletal fluorosis

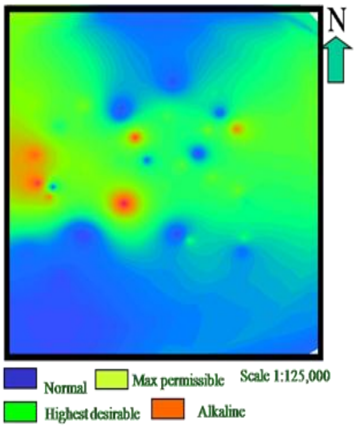

Fig. 4 A Spatial variability of p^H concentration

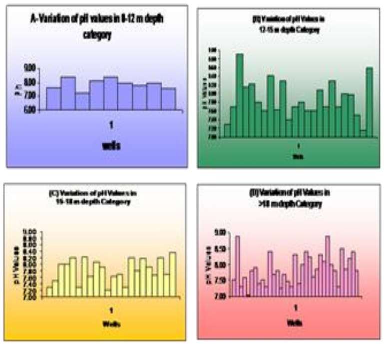

Fig. 4 B Variation of p^H values in different depth categories(A,B,C,D)

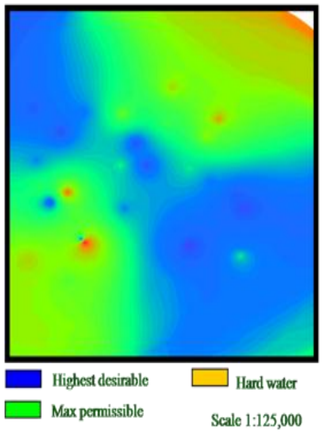

Fig. 6A Spatial variability of TH concentration

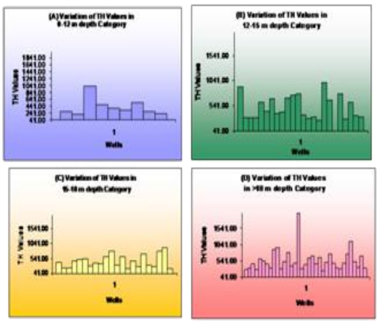

Fig. 6B Variation of TH values in different depth categories (A,B,C,D)

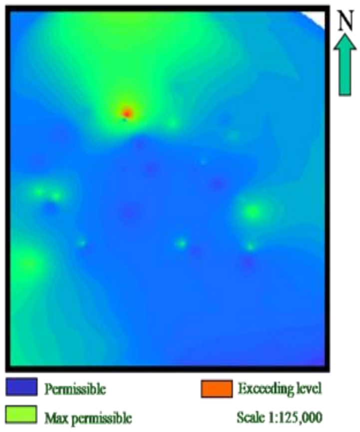

Fig. 8A Spatial variability of Magnesium concentration

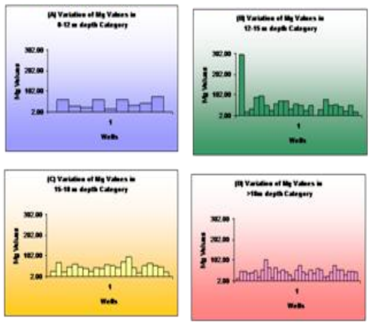

Fig. 8B Variation of Mg values in different depth categories (A,B,C,D)

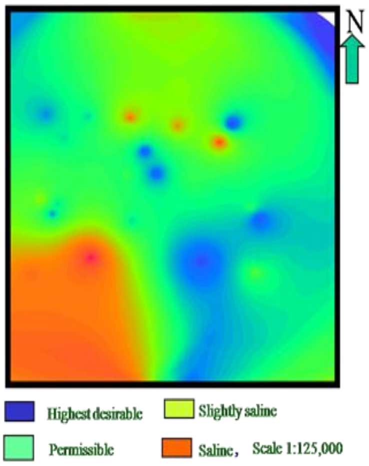

Fig. 5A Spatial variability of TDS concentration

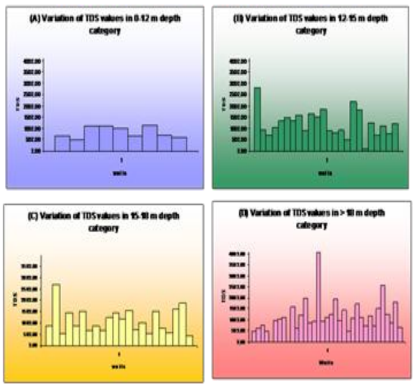

Fig. 5 B Variation of TDS values in different depth categories (A,B,C,D)

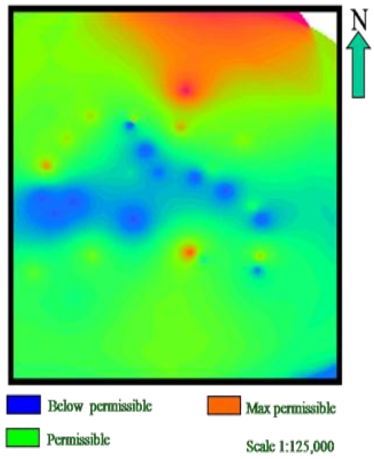

Fig. 7A Spatial variability of Calcium concentration

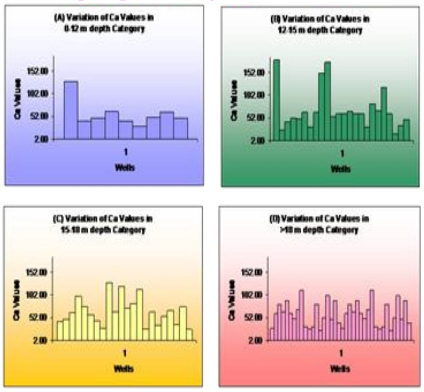

Fig. 7B Variation of Ca values in different depth categories (A,B,C,D)

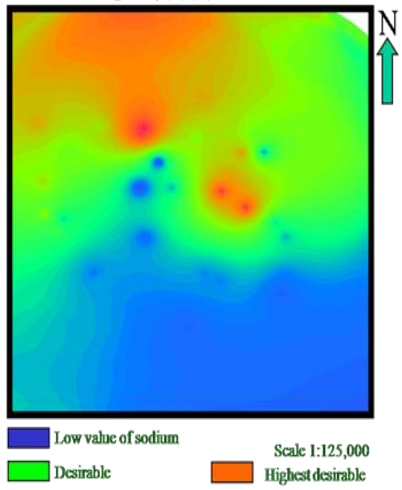

Fig. 9A Spatial variability of Sodium concentration

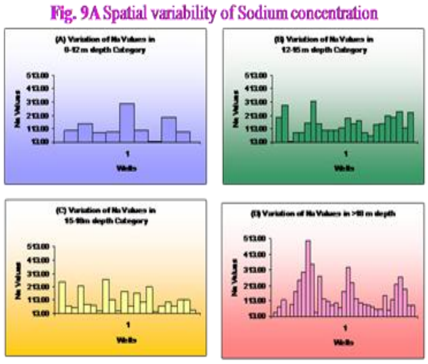

Fig. 9B Variation of Na values in different depth categories (A,B,C,D)

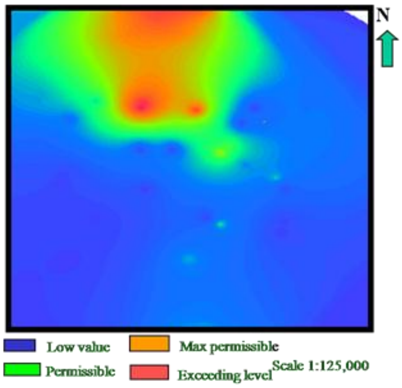

Fig. 10A Spatial variability of Potassium concentration

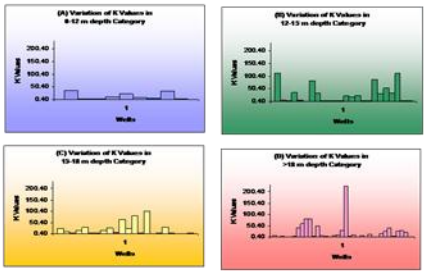

Fig. 10B Variation of K values in different depth categories (A,B,C,D)

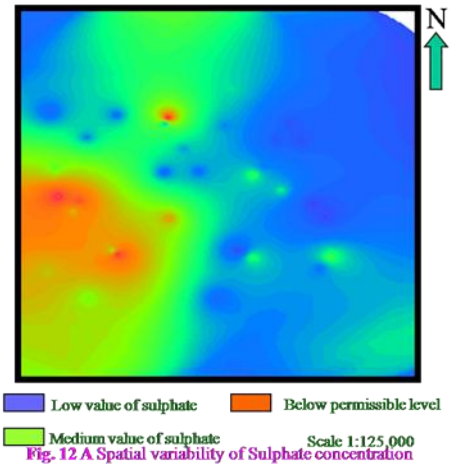

Fig. 12 A Spatial variability of Sulphate concentration

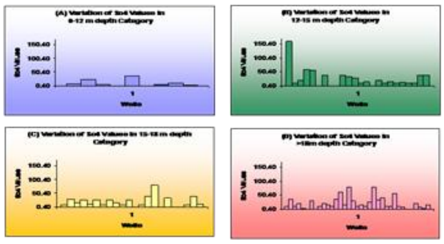

Fig. 12 B Variation of SO_4 values in different depth categories (A,B,C,D)

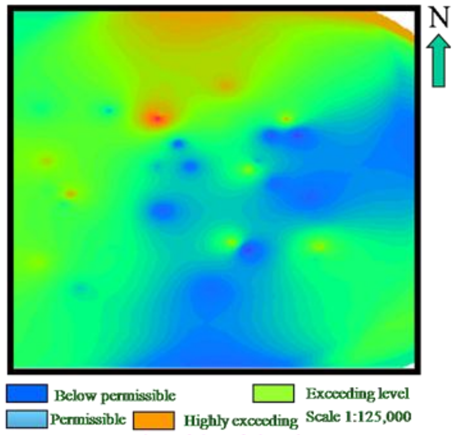

Fig. 14A Spatial variability of Fluoride concentration

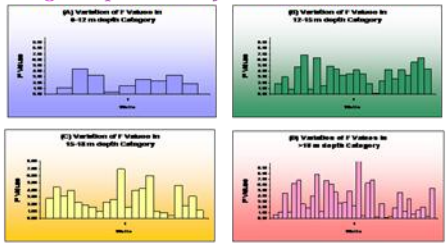

Fig. 14 B Variation of F values in different depth categories (A,B,C,D)

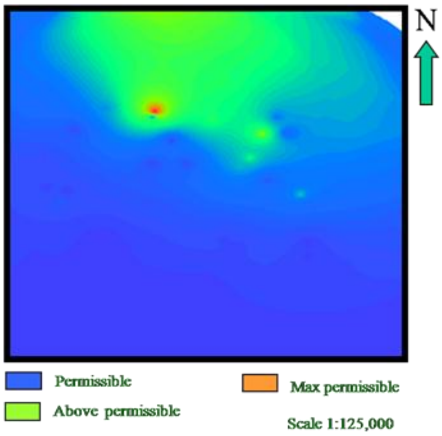

Fig. 11A Spatial variability of Chloride concentration

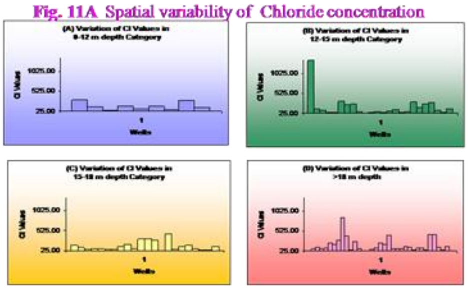

Fig. 11B Variation of Cl values in different depth categories (A,B,C,D)

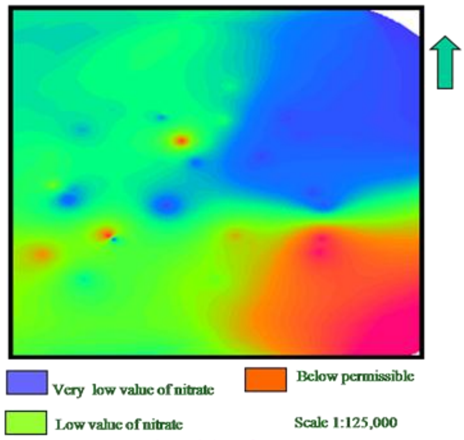

Fig. 13 A Spatial variability of Nitrate concentration

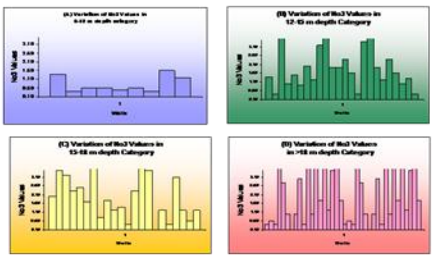

Fig. 13 B Variation of NO_3 values in different depth categories (A,B,C,D)

This confirms that almost the entire study area is polluted with fluoride. The distribution different chemical parametes in this study area indicated that the village namely Cheruvugattu, Yellareddyguda, Amlur, Kattangur, Chandupatla, and Gudipalli have indicated the highest concentrations of the parameters namely fluoride. Total dissolved solids and Total hardness. Hence these villages can be termed as the villages of high to very high levels of pollution. Similarly the villages of Chityala, Gurrapagudem, Tummalapalli, Madugulapalli and Kanagal have shown moderate levels of pollution. However the villages Nalgonda, Cherlapalli, Tetikunta, Tiparthi and Mappuvaram have recorded less pollution and hence can to be considered having relatively safe drinking water quality.

4. Discussion

The results of the study indicate severe deterioration of groundwater quality in major part of the district. The concentration of various quality parameters in the groundwater of study area are alarmingly high making it totally unsuitable for human consumption. Geologically speaking the quality deterioration must be attributed to the weathering of rocks and also subsequent contribution from soils [5] and [6]. The contamination of fluoride in the study area can be attributed to the fluoride bearing minerals in rocks and soils [7].

It is to be noted that a number of conspicuous dolerite dykes in the area may be acting as barriers to the ground water flow, there-by enabling a longer contact time of the water with the fluoride bearing minerals. The dry weather and hot climate further favours the concentration of fluoride in soils and river sediments, which is available for reprecpitation.

It is observed that the subsurface geology has shown more influence on the fluoride occurrence. Wells existing close proximity have been found to differ in fluoride concentration significantly. The comparisons of quality parameters with the incidence of fluoride reveal that there is a positive relationship between the fluoride occurrence and the concentration of Ca, K and Na. This indirectly suggest that the sources of fluoride derivation must be related to a mineral or minerals rich in the Ca, K and Na.

5. Conclusion

The study indicated with the villages namely Cheruvugattu, Yellareddyguda, Amlur, Katangur, Chandupatla and Gudipalli are highly polluted. In general the pattern of pollution indicates that the Northern part of the district is characterized by high-level contamination of groundwater, which can be attributed to geology of the terrain. The ground water quality interms of TDS, TH, Ca, Mg, Na, K, Cl, $S0_4$, $N0_3$ and F have been found to occur in excess amounts when compared to the values recommended [8], [9] and [10]. The consumption may lead to severe health hazards, which are already found to occur in the community (Table 3).

The high incidence of fluoride over the study area in the ranges of 3 mg/l to 6 mg/l, can cause skeletal fluorosis, which is a chronic high bone refraction results due to long term exposure to high levels of fluoride from the consumption of the fluoride rich waters. The other health hazards include impairing immune system, permanent disfigurent of teeth, suppression of thyroid functions and disruption of enzyme activity besides many other hazards. Corrective measures should be taken by the government to ensure safe drinking water to the people residing in the area.

The spatial variability of pH is concerned that the northeastern and south western parts indicated higher pH values and the pH is controlled by shallow wells and less number of lineaments (Figure 4 A).

The TDS concentration has been established in southwestern parts of the study area and the quality reaches saline water (Figure 5 A).

The TH indicate that the TH concentration in the study area is characteristically indicate that TH distribution has been high in the north east and southwest regions. The villages in this area having total hardness from maximum permissible to hard water. This concentration is marked by moderate to low lineament density with wells having high to moderate depth. The TH is not having any meaningful relationship with water table fluctuation (Figure 6 A).

The Ca concentration indicated that higher values are reported in north and northeastern parts of the study area and in the wells with low water table fluctuations (Figure 7 A).

The Mg concentration also recorded in higher amounts in north and northwestern parts of the study area reaching up to maximum permissible limits. The Mg concentration indicated a relationship with high density lineaments and high water fluctuations (Figure 8 A).

The Na concentration also indicated similar trend with Mg showing higher values in northern and northwestern parts of the study area showing relationship with high density lineaments and high water fluctuations (Figure 9 A).

The K concentration in the study area also in tune with Mg and Na concentrations which is an important observation indicating northern and northwestern parts recording maximum permissible to exceeding levels of K. The wells also located in high density lineaments indicating higher water table fluctuations (Figure 10 A).

The Cl concentration is also indicating similar distribution with that of K, Mg and Na. The relationship strongly points out a source mineral or minerals which contributed these parameters to the groundwater (Figure 11 A).

The SO_4 concentration is abnormally higher in the southwestern part of the study area which perhaps influenced by man made reasons such as habitation and farming besides utilisation of fertilizers (Figure 12 A).

The NO_3 concentration has been report to occur in exceeding levels in the southeastern part which may be having influence from habitation farming and fertiliser utilization (Figure 13 A).

The fluoride concentration indicates that exceeding and highly exceeding levels of fluoride occur in northern and northwestern parts of the study area. The striking observation is the F concentration is also showing exact distribution pattern with parameters like K, Mg, Na and Cl. This indirectly suggests the F derivation from the source mineral or minerals rich in K, Na, Mg and Cl. The extensive granitisation of the area might have contributed minerals of metasomatic origin rich in chlorine, fluorine besides potassium, sodium etc. which might have contributed the source minerals of these variables. However more detailed petrographic work may be needed to establish this (Figure 14 A).

The fluoride concentration has shown no difference in wells when studied with reference to time, in other words the fluoride concentration has no temporal variation.

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