A Case Study From Ramannapeta Mandal, Nalgonda, Telangana, India: Fluoride Contamination of Ground Water

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Abstract

The groundwater quality evaluation for fluoride element was studied in Ramannapeta Mandal, Nalgonda District, and Telangana State, India. The water samples were collected in pre and post monsoon seasons in the year of 2015-2016 from hand pumps bore wells or dug wells in the villages of Ramannapeta Mandal. The collected water samples were analyzed within a week. The Spatial distributions of fluoride maps were prepared with the help of the Remote Sensing Imaginary (RSI) and Geographical Information System (GIS) techniques. The range of fluoride in the study area varied from 0.6 to 5.6 ppm whereas the maximum permissible limit in drinking water is 1.5 ppm (As per Bureau of Indian Standard (BIS) guideline-IS: 10500: 1991). The high contamination 4.0-5.5 ppm of fluoride in drinking water was observed in Siripuram, Dubbaka villages. During the study, it was found that the most of villages in Ramannapeta Mandal are affected with high fluoride content in drinking water in the range of 1.5-3.0 ppm. Nalgonda district including Ramannapeta Mandal is underlain by different rocks such as granites (80%), gneisses, dolerite, dykes (10%), older metamorphic and intrusive (10%). The lock of freshwater exchange due to periodical drought conditions, the granitic rocks and the arid climate of the region are the factors for the higher incidence of fluoride in the groundwater resources. The constructions of rain water harvesting structures are proposed to minimize fluoride content in drinking water.

Introduction

Groundwater is the major source for drinking in most parts of the world, as it is available cheaply near to door step and free from pathogenic bacteria. Good quality of drinking water is essential for human life. The goal of Government is to provide every person with adequate safe water for drinking, cooking and other domestic uses. The spatio-temporal variations in rainfall, regional distribution in geological formations and geomorphic composition of various units have led to uneven occurrence and distribution of groundwater resources.

There are few chemical contaminations of drinking water that can lead to severe health problems. Especially fluoride is a major concern; the recommended concentration of fluoride in drinking water is 1.5 mg/l (WHO; 1984). Seawater typically contains about 1 mg/l of F^- where rivers and lakes generally exhibit less than 0.5 mg/l. Low or high concentrations of fluoride is possible in groundwater, depending on the existence of nature of the rocks and fluoride-bearing minerals. The high fluoride containing water occurs in large and extensive geographical belts associated with sediments of marine origin in mountainous areas, volcanic rocks, granitic and gneissic rocks.

In India, high groundwater fluoride content associated with igneous and metamorphic rocks such as granites and gneisses have been reported. Endemic fluorosis is still a challenging and extensively studied national health problem. The most seriously affected areas in India are Telangana, Andhra Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Tamil Nadu, Orissa, Punjab and Uttar Pradesh etc (Kumaran, *et al.*, 1971; Teotia*et al.*, 1984). The high concentration of fluoride in drinking water was reported in 19 states and territories which include 177 districts. The highest concentration observed to date in India is 48 mg/l in Rewari District of Haryana.

Groundwater is the primary source of potable water supply in rural India. It is not possible to estimate the number of people at risk with high fluoride in drinking water. This is because of the difficulty of sampling groundwater from India's many millions of hand pumps. In these states, 10 to 25% of the rural population has been estimated to be at risk, and approximately 60–70 million people are influenced by fluoride contaminated groundwater. About 60% of land comes under irrigation of groundwater; this is also other main reason of producing high fluoride food. The rainfall is the source of recharge of groundwater, geomorphology plays a vital role in controlling distribution of precipitation, runoff, and infiltration contributing to recharge.

Fluorosis is an endemic disease. An endemic disease found in a certain geographic region or in a specific race of people. The fluoride in potable water not exceed to1 mg/L. High F^- concentration in drinking water is main concern, because of its negative impact on human health. The fluoride arises into the water from the geological crust. The main potential health risks from fluoride are considered to be fluorosis or bone disease. Based on body tissues influenced by fluoride, fluorosis is categorized into Dental, Skeletal and Non-Skeletal fluorosis. Irrespective of age and gender, anybody can become victims of Fluorosis. Fluoride content range in drinking water and how it effects on human health is listed in Table 1.

Table 1
Fluorosis Hazards chart.

	F^- in drinking water (mg/L)	Effects on human health
1	0.6	Dental caries
2	0.6–1.2	Development of normal bones & teeth
3	1.2-2.0	Mottled enamel
4	2.0–4.0	Dental fluorosis
5	4.0–8.0	Skeletal fluorosis
6	8.0–10.0	Mild crippling Skeletal
7	Above 10.0	Cripping Skeletal Fluorosis

In the present study, groundwater quality evaluation was carried out in the villages of Ramannapeta Mandal, Telangana State, India. In order to evaluate the spatial distribution of fluoride concentration, 72 water samples were collected from 36 places before and after monsoon season. The Spatial distributions of fluoride maps were prepared with the help of the Remote Sensing Imaginary (RSI) and Geography Information System (GIS) techniques. The relations between fluoride distribution and physiology, hydrogeology were correlated.

Description of Study Area

The study area is located in northern part of the district of Nalgonda, Telangana State, India. It lies in between 78. 59°- 79.15° of East-longitudes and 17.14°-17. 22° of North- latitude with an average elevation of 322 meters. It falls in the SOI Toposheets No. 56 O/3. The location of the study area is shown in Fig. 1. As per 2011 census, the population of the area is 51,534 while the urban population is 10,202. The area experiences semi-arid climate, the average temperature varies from 17°C in winter (December-January) to 45°C in summer (March-May).

The average annual rainfall is 649 mm both by northeast and southwest monsoons. 80% of the people from the study area use bore and dug wells water for drinking, cooking and other domestic uses. The depth of the bore wells varied between 90 and 300 feet. The area around228 sq.km was covered and 36 water samples were collected in cleaned and sterilized glass bottles. All the collected samples were analyzed within week in the laboratory.

Remote Sensing and GIS

The Remote Sensing imagery with its synoptic coverage acts as a tool for finding suitable solution when combined with conventional data. Hydro-geomorphic maps were prepared by integrating the lithology, landforms, and structural fabric and hydrology layers using Remote Sensing and GIS techniques, the scale range of 1:10,000. The satellite data has been used for updating of drainage and surface water bodies. The IRS P6 LISS-IV is a multi-spectral high resolution camera with a spatial resolution of 5.8m at nadir. Satellite image of the study area is shown in Fig. 2.

Physiography of the study area

Ramannapeta Mandal is located in the northern of the District. The study area is surrounded by Mothkur, Valigonda, Narketpalli, Chityala and Choutuppal Mandals. The elevation of the study area varies from 225 to 370m to mean sea level (MSL). A major part of the Mandal is covered by the Musi river basin which rises in Dubbaka and Nidanpalle Hills. The river flows from South to North of the Mandal. The river passes through Valigonda, Ramannapeta towards Nakrekal Mandal; it joins the Krishna River near Wadapalli.

From the satellite imaginary studies, it was observed that 76% of the study area covered by major landforms in granitic rocks which are pediplains. About 14% of the area covered by pediment and Inselberg zone, 4% of the area covered by valley zones and the remaining area covered by highly weathered hills and water bodies.

Drainage & Rainfall

The drainage pattern of the study area is mainly dendritic drainage, all the water streams flow from Southwest to Northeast direction. Nalgonda district has an average rainfall of 649 mm during years of 2004–2015.The most rainfall is received through the Southwest monsoon during the period of June-September. An average annual temperature of the study area varies from 17°C in winter (December-January) to 45°C in summer (March-May).

Geology of the study area

The study area underlined by the variety of granite and gneisses rocks which are intruded by dolerite dykes/quartz veins. Granite, old and hard rocks, are widely distributed throughout the area. The nature of granite varies in the study area, grey to pink, medium to coarse granite, porphyritic or non-porphyritic and massive. The granitoid rocks are complex which associated with profuse injections of aplite, fine grained quartzo-feldspathic veins and pegmatite, quartz veins and reefs.

From the stratigraphical studies, the study area predominantly exposes rocks of Peninsular Gneissic Complex (PGC) along with enclaves of basic dykes (Proterozoic). The PGC includes mainly two varieties of granitoid rocks i.e. older granite gneiss and younger granite (alkali feldspar). The most of the lineaments/faults identified are aligned in the direction of Northeast to Southwest and North-northeast to South-southwest. Generally dolerite dykes appear to be very hard and compact and poorly devoid of fractures, whereas the Pegmatite veins / Quartz reefs are highly fractured.

Hydrogeology

The majority of the area occupies with hard rock like gneissic complex which includes granite/gneisses, dolerite dykes. Very little area covered with other formations. Even though, the absence of primary porosity in hard rock formations, the aquifer system developed because of secondary porosity due to various tectonic disturbances and weathering activity. The deeper aquifer system developed due to major faults, joints, fractures, crevices, shear zones etc. It was observed that the groundwater prospect of the study area is in the range of 100–200 lpm in moderately weathered granite gneiss/granitoid rocks and valleys whereas the range is 50–100 lpm in shallow weathered granite gneiss/granitoid rocks and valleys. The availability of groundwater is in the range of 10–50 lpm and low to poor (0 to 10 lpm) in the pediment zones of granitic rocks and highly dissected hills/plateaus respectively.

Materials And Methods

Groundwater samples were collected in polyethylene bottles from pre-identified places of the villages of Ramannapeta Mandal. All the samples were collected in pre and post monsoon season, 2015–2016.The collected samples were analyzed within a week. Fluoride was analyzed using Lovibond PC Spectrophotometer (SN 100537, Germany) following the method of SPANDS colorimetric method. Various other water quality parameters such as pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity, sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, and sulfate concentrations were measured. The techniques and methods followed for the collection, preservation, analysis, and interpretation are those given by (Rainwater and Thatcher 1960), (Brown et al. 1970), (Karanth, 1989), (Hem,1991), (APHA,1992), and (BIS, 2003).

Results And Discussions

The data is segregated into pre and post monsoon seasons based on date of collection of samples and these results are listed in Table 2 and Table 3 respectively.

Table 2
Chemical Analysis of water samples collected during pre-monsoon season

S.N.	S_No	Village	DMV_Code	LAT	LONG	SourceType	pH	EC	TDS	Ca +2	Mg +2	Na+	K+	TH	CO3$^{-}_{2}$	H
1	RP_01	Dubbaka	2320014	17.31	79.14	BW	7.1	3600	2304	110	65	198	2.0	543	0	1
2	RP_02	Dubbaka	2320014	17.32	79.14	BW	7.9	3800	2432	96	53	182	1.0	457	12	9
3	RP_03	Munipampula	2320004	17.32	79.15	TANK	8.2	2200	1408	74	40	176	3.0	351	9	6
4	RP_04	Munipampula	2320004	17.32	79.17	DW	7.8	2300	1472	88	44	161	4.0	401	12	5
5	RP_05	Palliwada	2320005	17.35	79.17	RIVER	7.9	2800	1792	112	28	242	2.0	395	9	1
6	RP_06	Palliwada	2320005	17.33	79.17	BW(HP)	7.1	2000	1280	110	26	99	4.0	382	0	9
7	RP_07	Bachuppala	2320006	17.34	79.21	DW	7.3	2500	1600	163	38	168	1.0	563	0	8
8	RP_08	Suraram	2320007	17.35	79.23	DW	7.8	3100	1984	74	48	176	2.0	382	6	1
9	RP_09	B.Thurkapalle	2320008	17.36	79.23	BW(HP)	7.3	4400	2816	99	52	231	6.0	460	0	1
10	RP_10	Peddabaigudem	2320010	17.34	79.23	BW	7.2	2700	1728	122	66	134	5.0	575	0	1
11	RP_11	Yennaram	2320010	17.32	79.21	DW	7.7	1200	768	118	74	268	4.0	601	0	9
12	RP_12	Kakkireni	2320011	17.32	79.21	BW	7.0	3500	2240	143	76	221	2.0	669	0	1
13	RP_13	Kakkireni	2320011	17.30	79.20	BW	7.0	2200	1408	112	16	176	8.0	348	0	7
14	RP_14	Iskilla	2320013	17.29	79.05	BW	7.1	1300	832	41	16	65	4.0	169	9	5
15	RP_15	Iskilla	2320013	17.29	79.14	BW	7.6	700	448	116	42	13	6.0	461	0	1
16	RP_16	Janampalli	2320021	17.29	79.12	BW	7.3	800	512	147	57	12	2.0	600	0	2
17	RP_17	Neernemla	2320015	17.32	79.09	DW	7.5	3300	2112	161	134	38	2.0	952	0	1
18	RP_18	Shobhanadripur	2320002	17.35	79.10	DW	7.6	3600	2304	121	48	186	4.0	499	33	7
19	RP_19	Laxmapur	2320003	17.35	79.11	DW	7.2	5700	3648	186	76	221	2.0	777	0	6
20	RP_20	Laxmapur	2320003	17.34	79.10	BW	7.2	3100	1984	184	26	186	1.0	565	0	5
21	RP_21	Neernemla	2320015	17.31	79.09	DW	7.4	4800	3072	161	28	198	8.0	517	0	1
22	RP_22	Kommaigudem	2320020	17.27	79.09	BW(HP)	7.2	2100	1344	116	65	242	4.0	558	0	8
23	RP_23	Ramannapet	2320020	17.30	79.10	BW	7.7	1500	960	47	19	162	2.0	195	9	7
24	RP_24	Bogaram	2320017	17.30	79.08	BW	7.2	900	576	86	21	14	1.0	302	0	6
25	RP_25	Bogaram	2320017	17.30	79.07	BW(HP)	7.5	600	384	39	5	12	3.0	118	0	6
26	RP_26	Bogaram	2320017	17.31	79.07	BW	8.7	1500	960	55	14	102	4.0	195	9	6
27	RP_27	Nidanpalli	2320016	17.32	79.08	BW	7.3	3200	2048	129	56	198	6.0	551	0	9
28	RP_28	Thummalagudem	2320001	17.34	79.05	TANK	8.5	2100	1344	49	42	176	2.0	293	6	7
29	RP_29	Thummalagudem	2320001	17.33	79.05	DW	7.2	1900	1216	112	13	145	1.0	332	0	8
30	RP_30	Yellanki	2320018	17.30	79.04	DW	7.3	1600	1024	67	26	158	2.0	275	0	9
31	RP_31	Yellanki	2320018	17.30	79.02	BW	7.6	1000	640	51	9	86	4.0	164	6	1
32	RP_32	Siripuram	2320019	17.29	79.04	BW	7.2	1400	896	63	15	76	2.0	220	0	8
33	RP_33	Siripuram	2320017	17.29	79.08	BW	7.4	1600	1024	98	8	162	4.0	276	0	9
34	RP_34	Siripuram	2320019	17.27	79.06	BW	7.4	1100	704	41	24	22	6.0	200	0	6
35	RP_35	Thummalagudem	2320001	17.33	79.04	BW	8.8	2100	1344	74	28	162	2.0	300	24	7
36	RP_36	Uthatoor	2320012	17.28	79.17	BW	7.5	810	520	104	38	16	5.0	442	0	7

Table 3
Chemical analysis of water samples collected during post-monsoon season

S.N.	S_No	Village	DMV_Code	LAT	LONG	Type of Source	pH	EC	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	TH	CO_3^{-2}	HCO
1	RP_01	Dubbaka	2320014	17.31	79.14	BW	7.5	2813	1800	114	76	156	2.0	597	0	156
2	RP_02	Dubbaka	2320014	17.32	79.14	BW	7.8	3072	1966	116	66	186	4.0	561	0	201
3	RP_03	Munipampula	2320004	17.32	79.15	TANK	8.1	1992	1275	68	45	181	2.0	355	13	162
4	RP_04	Munipampula	2320004	17.32	79.17	DW	7.7	2189	1401	76	56	176	6.0	420	0	98
5	RP_05	Palliwada	2320005	17.35	79.17	RIVER	7.7	2563	1640	102	22	221	2.0	345	0	77
6	RP_06	Palliwada	2320005	17.33	79.17	BW(HP)	6.9	1859	1190	86	42	102	4.0	388	0	77
7	RP_07	Bachuppala	2320006	17.34	79.21	DW	7.3	2203	1410	126	34	148	4.0	455	0	178
8	RP_08	Suraram	2320007	17.35	79.23	DW	7.8	2906	1860	86	40	167	2.0	379	0	99
9	RP_09	B.Thurkapalle	2320008	17.36	79.23	BW(HP)	7.2	3828	2450	98	41	201	6.0	413	0	221
10	RP_10	P. Gudem	2320010	17.34	79.23	BW	7.2	2516	1610	126	58	146	2.0	553	0	121
11	RP_11	Yennaram	2320010	17.32	79.21	DW	7.7	1063	680	102	67	232	1.0	530	0	98
12	RP_12	Kakkireni	2320011	17.32	79.21	BW	6.8	3313	2120	122	72	209	4.0	601	0	126
13	RP_13	Kakkireni	2320011	17.30	79.20	BW	7.0	2158	1381	106	22	168	6.0	355	12	186
14	RP_14	Iskilla	2320013	17.29	79.05	BW	7.5	1047	670	56	28	98	4.0	255	14	88
15	RP_15	Iskilla	2320013	17.29	79.14	BW	7.2	3344	2140	86	38	66	4.0	371	0	76
16	RP_16	Janampalli	2320021	17.29	79.12	BW	7.3	2156	1380	121	38	22	2.0	459	21	222
17	RP_17	Neernemla	2320015	17.32	79.09	DW	7.5	1231	788	146	77	52	6.0	681	0	88
18	RP_18	Shobhanadripuram	2320002	17.35	79.10	DW	7.1	559	358	119	44	178	4.0	478	0	82
19	RP_19	Laxmapur	2320003	17.35	79.11	DW	7.1	753	482	151	71	186	6.0	669	0	121
20	RP_20	Laxmapur	2320003	17.34	79.10	BW	7.3	3266	2090	144	22	171	4.0	450	0	128
21	RP_21	Neernemla	2320015	17.31	79.09	DW	7.1	3444	2204	148	26	201	6.0	477	0	256
22	RP_22	Kommaigudem	2320020	17.27	79.09	BW(HP)	7.1	3922	2510	94	46	228	2.0	424	0	151
23	RP_23	Ramannapet	2320020	17.30	79.10	BW	7.5	2828	1810	56	26	152	4.0	247	0	128
24	RP_24	Bogaram	2320017	17.30	79.08	BW	7.2	4047	2590	98	18	26	6.0	319	0	146
25	RP_25	Bogaram	2320017	17.30	79.07	BW(HP)	7.3	1938	1240	42	16	32	2.0	171	0	58
26	RP_26	Bogaram	2320017	17.31	79.07	BW	8.4	1219	780	66	18	121	4.0	239	26	52
27	RP_27	Nidanpalli	2320016	17.32	79.08	BW	7.2	775	496	108	69	178	6.0	554	0	168
28	RP_28	Thummalagudem	2320001	17.34	79.05	TANK	8.3	534	342	52	56	168	2.0	360	22	88
29	RP_29	Thummalagudem	2320001	17.33	79.05	DW	7.1	1525	976	108	18	152	6.0	344	0	88
30	RP_30	Yellanki	2320018	17.30	79.04	DW	7.2	763	488	68	33	144	2.0	306	0	76
31	RP_31	Yellanki	2320018	17.30	79.02	BW	7.5	531	340	69	12	99	6.0	222	0	98
32	RP_32	Siripuram	2320019	17.29	79.04	BW	7.2	1281	820	58	24	71	4.0	244	0	76
33	RP_33	Siripuram	2320017	17.29	79.08	BW	7.4	3094	1980	79	18	156	4.0	271	0	72
34	RP_34	Siripuram	2320019	17.27	79.06	BW	7.3	2047	1310	38	26	28	2.0	202	0	66
35	RP_35	Thummalagudem	2320001	17.33	79.04	BW	8.2	1733	1109	78	56	158	6.0	425	18	129
36	RP_36	Uthatoor	2320012	17.28	79.17	BW	7.5	801	512	103	40	14	3.0	438	0	72

Fluoride

As per WHO and BIS guidelines, Allowable fluoride concentrations in potable waters is 1.5 mg/l. Consumption of high fluoride water can cause dental, mild skeletal, and crippling skeletal fluorosis (WHO; 2004). Fluoride in the water ranged from 0.30 to 3.00 mg/Lin the study area with an average of 1.42 mg/L was found. An average value of fluoride for all the sources is calculated for each habitation. From the collected data, the fluoride distribution maps were prepared using Spatial Analyst Tools (SAT)adopting Inverse Distance Weightage (IDW) method. Based on fluoride content in drinking water, the map is divided into three zones. That are Desirable (< 1.00 mg/L), Permissible (1.50-3.00 mg/L) and Non Potable (> 3.00 mg/L).

Figures 4 and 5 shows spatial fluoride distribution of the study area based on the collected water samples in pre and post monsoon seasons respectively. The elevated level (3–5 mg/L) of fluoride was observed at isolated places like in Dubbaka and Siripuram villages in central and south region of the Mandal. The people from these villages are at risk of dental/skeletal fluorosis.

Even, Ramannapet, Kommaigudem and Nidanpalli showed marginally high concentration of fluoride (1.5-3.0 mg/L). From Figs. 4 and 5, the spatial distribution of fluoride is lower during post-monsoon in some places when compared with pre monsoon collections. The dilution of fluoride with recharged rain water might be the reason. The fluoride concentration in groundwater can be diluted with surface water and its infiltration into downstream.

The fluoride content in groundwater varied in the study area due to the accessibility of fluorine-bearing minerals to the circulating water, the leaching and weathering activities. The fluoride concentration is more in shallow or moderately weathered Pediplains, Alkali Feldspar Granite, and Grey Biotite Granite which located in western part and around the mandal. Even, high concentration of fluoride was observed at isolated places in granite and dolerite, the west side of the mandal. Fluoride in the exogenic cycle of the fluorosis belt is almost contributed by the granitic and pegmatitic rocks. Above discussed fluoride bearing minerals of these rocks are the acid soluble minerals such as fluorite, fluorapatite, hornblende, mica, epidote etc. These minerals are responsible for high concentration of fluoride in natural waters, as they release fluoride under normal temperature pressure conditions. Furthermore, pH of water increases the releasing of fluorides from fluoride-bearing minerals during the weathering processes within the aquifers (Saxena and Ahmed 2001).

The fluoride minerals are abundant in the granite and gneiss rocks present in the mandal. Hence, the concentration of fluoride in groundwater is the highest in those villages present on the northern and southern parts and in isolated patches of the study area. The distribution of fluoride in groundwater depends on the amount of fluoride in the rocks or soils, the contact time of the water with the rocks, temperature, rainfall, vegetation and oxidation and reduction reactions. The percolating water dissolves the salts from soils, the fluoride concentration of groundwater may be higher than that during dry periods. The other factor is the amount of fluoride in the water depends on the degree of granitic rock weathering of the area (APSRAC, 1997).

Hydrogen Ion Concentration (pH)

pH is a measure of the relative acidity or alkalinity of a sample. It is equal to the negative logarithm of the hydrogen ion activity in moles per liter (–log aH+). The pH scale ranges from 1 to 14, with 1 being the most acidic and 14 being the most alkaline. Solutions with a pH less than 7.0 are typically classified as acidic; those greater than 7.0 as alkaline

The pH values in the Study area varied from 6.92 to 8.78 with an average of 7.51. pH of all the analyzed samples were within the permissible limiting value of 6.5–8.5 given by the BIS (2003).

Total Hardness

Water total hardness [TH] is caused by various dissolved salts of calcium, magnesium or iron and expressed as mg/l of CaCO¬3. The total hardness (TH) in ppm was determined by following equation (Todd 1980):

TH = 2:497 Ca2 + + 4:115Mg2+

According to Durfor and Becker's (1964) classification of TH (i.e. 0–60, soft; 61–120, moderately hard; 121–180, hard; and > 180 very hard). In the present study area the hardness levels measured were in the range of 118 mg/l 8 to 952 mg/l with a mean value of 418 mg/l.

Electrical conductivity

Electrical Conductivity [EC] is one of the important indices of water quality, which gives the measure of the dissolved salts and salinity, the parameters imparting unpalatable taste to groundwater (Langengger, 1990). This has a significant impact on the user's acceptance of such water resources (EdetAe, 1993). Conductivity is the measure of a solution's ability to transfer electric current. The higher the conductivity of a solution, greater the potential to transfer electrical current. The conductance of a solution is dependent on three parameters: temperature (temperature increases the conductivity of a solution), nature of ions present, and quantity of ions present. Multivalent ions (i.e, those with valency greater than one) contribute more to conductivity than monovalent (valency one) charged ions. Most often, equipment for measuring conductivity gives results based on a temperature of 25°C. Such measurements can be adjusted to correct for other ambient temperatures (Peavy, et al., 1985). Because hydrogen ions (H+) and hydroxyl ions (OH–) exhibit higher conductance, due to their increased mobility, extreme pH levels are an important consideration when measuring conductance (Sawyer, et. al., 1994). The higher EC of the water samples is the result of ion exchange and dissolution of the aquifer material (Sanchez-Perez and Tremolieres, 2003).

The study area groundwater samples have EC in the range 600 to 5700 with an average of 2348 µS/cm. The maximum limit of EC in drinking water is prescribed as 1,500 µs/cm as per WHO standard. About half of the samples collected showed EC values more than permissible limit. EC distribution is found to be similar to that of Cl-, SO42-, HCO3- and K + distribution patterns, indicating it is positively correlated with these ions.

Total dissolved Solids (TDS)

TDS refers to the total dissolved solids present in the water. Measurement of conductivity is often used as an indirect method of estimating the dissolved solids content of a solution. (Chapra, 1997) reports a relationship between total dissolved solids and conductivity.

TDS (mg/L) = 0.64 x Conductivity (µmhos/cm)

As per the (BIS, 2003) specification for drinking water, 500 mg/l is treated as desired limit and 2000 mg/l of TDS is treated as maximum permissible limit. Higher concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits. It is a well-known fact that the recharging water during its downward movement through the zone of aeration dissolves mineral matter thus enriching itself in total dissolved solids. This dissolution continues even in the zone of saturation due to rock-water interaction during the residence time of groundwater in the host rock. The enrichment of TDS is also governed by evaporation of water. In this study area all the samples have TDS between 384 and 3648 mg/l with an average value of 1503 mg/l.

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. (Doneen, 1964) 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. The PI of the area varied from 53.81 to 122.32 and the average value is 72.10.

Piper Classification:

The trilinear diagrams of Piper are very useful in determining chemical relationships in groundwater in more definite terms than is possible with other plotting methods (Piper, 1953). 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 (Fig. 6). The chemical subdivisions 1, 2, 3, 4, 5, 6, 7, 8 and 9 indicate that the alkaline (Ca + and Mg+) and strong acids mainly dominate the chemical characteristic of the groundwater. Based on Piper classification all samples are fall in the IV category (Strong acids exceeds weak acids) in pre and post-monsoon periods.

US salinity Laboratory diagram:

The US Salinity Laboratory Staff, 1954) proposed a diagram for studying the suitability of groundwater for irrigation purposes by using the SAR values on vertical axis and electrical conductivity on horizontal axis.

The diagram is divided into four distinct classifications both horizontally and vertically. On horizontal axis the salinity hazard classification is divided into low salinity (C1), medium salinity (C2), high salinity (C3) and very high salinity (C4). Likewise on vertical axis sodium hazard classification is divided into low sodium water (S1), medium sodium water (S2), high sodium water (S3) and very high sodium water (S4). Figure 7 shows Richards Diagrams classification of irrigation water during pre and post monsoon period respectively.

It is clear from the Fig. 7 that the groundwater samples of the study area out of 36samples fall under Majority of samples are fall in the S1C3 and S2C4 category in pre and post-monsoon periods.

Recommendations & observations

It is important to educate every citizen about the fluoride toxicity and the necessity of avoiding fluoride consumption. The intake of fluoride above the permissible limit in drinking water is the major reason for fluorosis disease in some parts of the study area. It is encouraged that Taking safe drinking water with sufficient dietary food in order to avoid fluorosis disease. It should be identified the fluoride affected areas with the help of scientific mapping and watersheds are proposed in the area. It is important to look for holistic and people-centred approaches for water management.

The occurrence groundwater in the study area is completely controlled by rainfall and canal whereas the quality of the water controlled by the terrain features like landforms, lithology, soil, drainage, topography, etc. The information provided in the groundwater prospect zones helps in identifying the areas suitable for artificial recharge. Tremendous pressure on groundwater for domestic, agriculture and industrial uses results in pollution of groundwater resources. In the future, the limited resources will not be able to meet out the water demand qualitatively and quantitatively for next generation. With scientific guidelines, watersheds to be constructed on Fast Track basis. Groundwater management and artificial recharge structures will be helpful for recharging of groundwater to make the existing bore wells and dug wells sustainable.
Table 4. Number of Samples falling in different Areas of Diamond shaped field of Piper Diagram

Sl. No.	Description	Number of Samples Pre mon	Number of Samples Post mon
1.	Alkaline earths exceeding Alkalies	20	23
2.	Alkalies exceeds Alkaline earths	16	13
3.	Weak acids exceeds strong acids	-	-
4.	Strong acids exceeds weak acids	36	36
5.	Carbonate hardness exceeds 50%	-	-
6.	Non-carbonate– hardness exceeds 50%	8	6
7.	Non carbonate Alkali	16	13
8.	Carbonate Alkali	-	-
9.	No on Cation– Anion pair exceeds 50%	12	17

Conclusions

The Spatial distributions of fluoride maps were prepared with the help of the Remote Sensing Imaginary (RSI) and Geographical Information System (GIS) techniques. The techniques are very useful in identifying of groundwater prospect zones in various hydro-geomorphic units. The range of fluoride in the study area varied from 0.6 to 5.6 ppm. Based on fluoride levels, the well water is unsuitable for drinking. The main factors that control the quality of water are associated with lithology and soil. The arid climate with high evaporation and insignificant natural recharge might have accelerated the increase in fluoride concentration in the groundwater of this area. The main sources of fluoride in natural waters are fluorite and fluor-apatite, as well as micas and hornblende in which the fluoride ion replaces the hydroxyl group.

Based on fluoride content in groundwater the map is divided into three zones. The high fluoride content in the groundwater is correlated with the fluoride bearing rocks of the study area.It was observed that fluoride contamination in the water is more in high yielding Hydrogeomorphic units as compared to low yielding Hydrogeomorphic units. The periodical drought and arid climate of the region increases incidence of fluoride in the groundwater resources. The constructions of rain water harvesting structures are proposed to minimize fluoride content in drinking water.

Declarations

Acknowledgments

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Figures

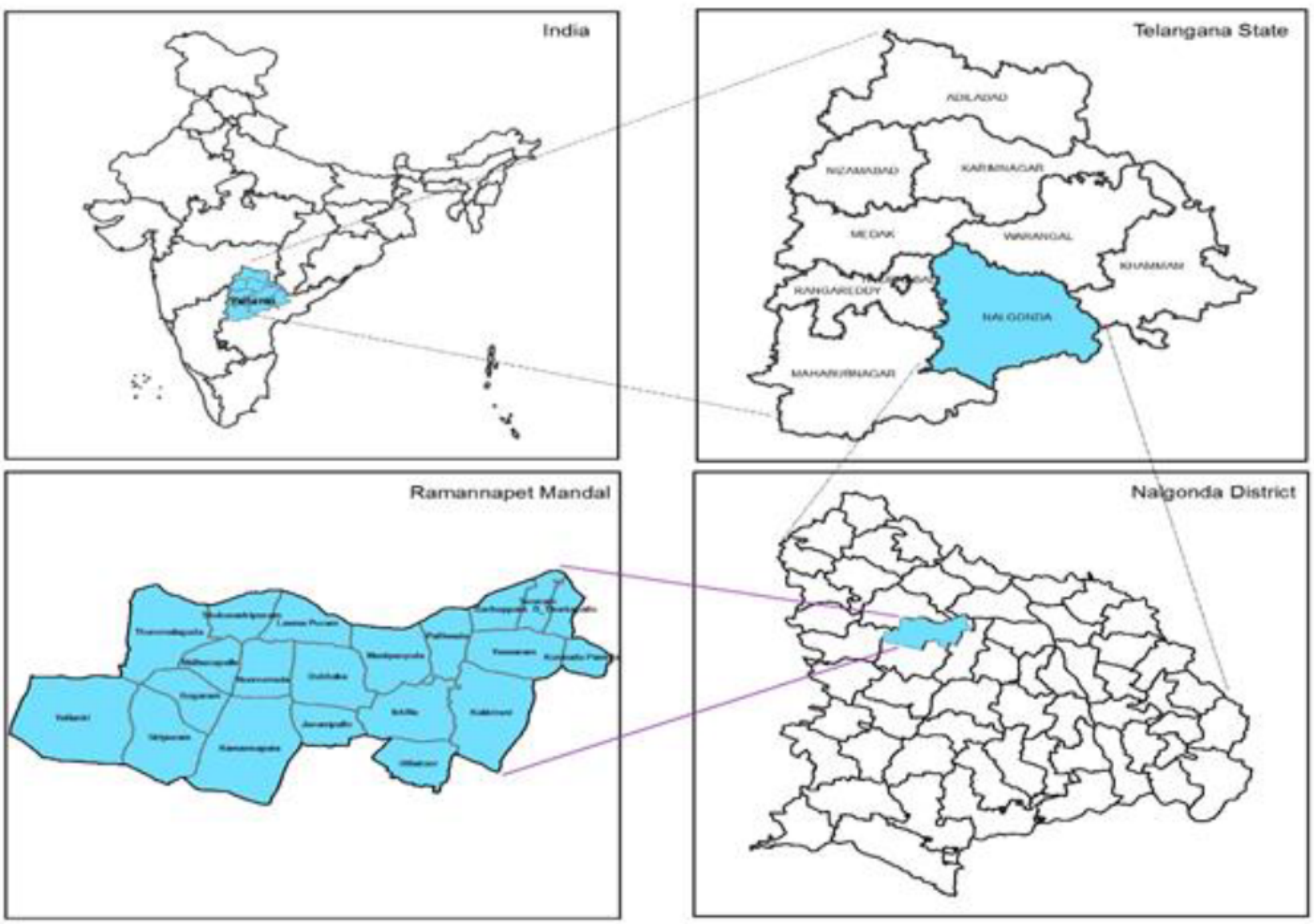

Figure 1

The location map of the present study area

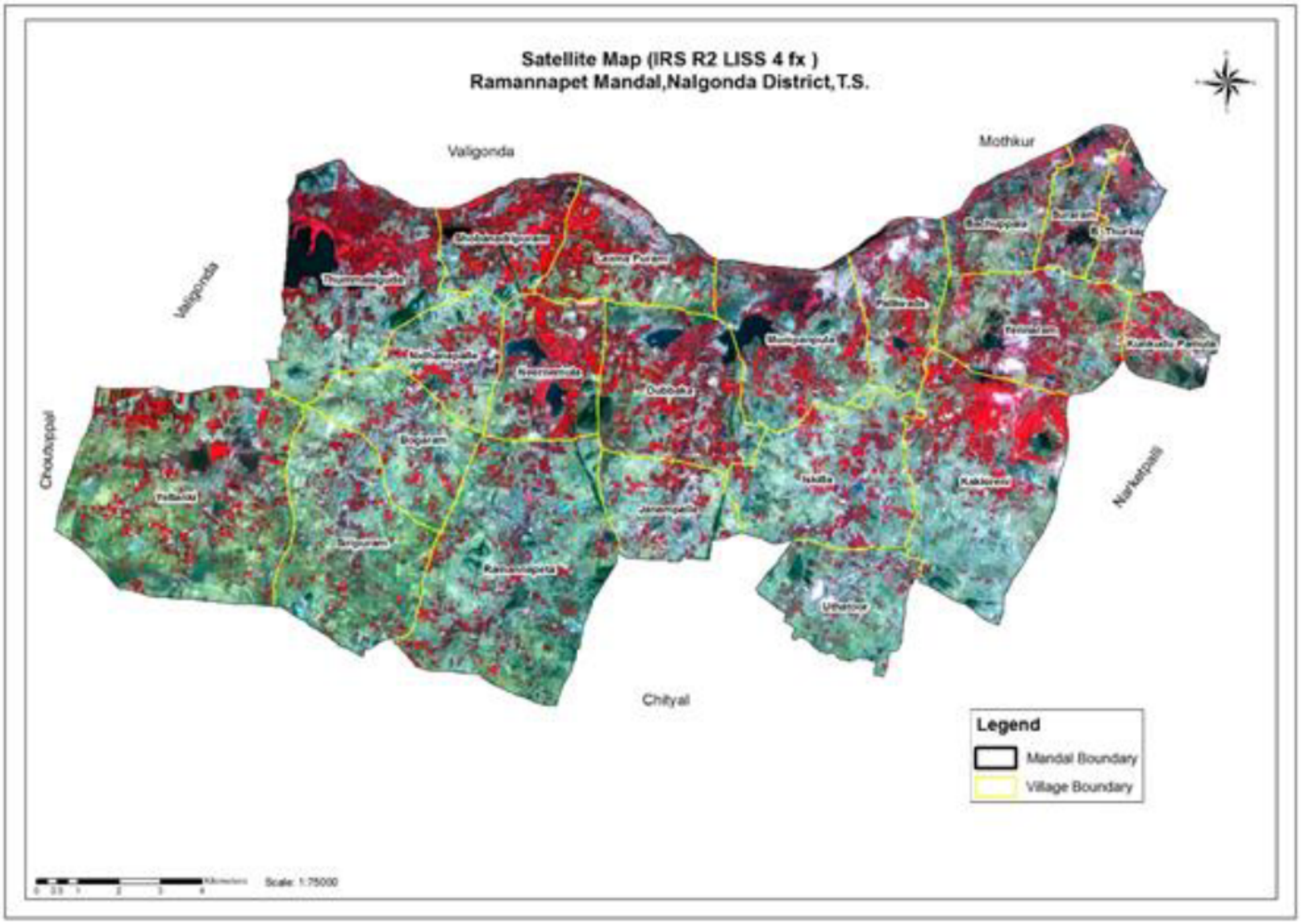

Figure 2

Satellite Map of the Study Area

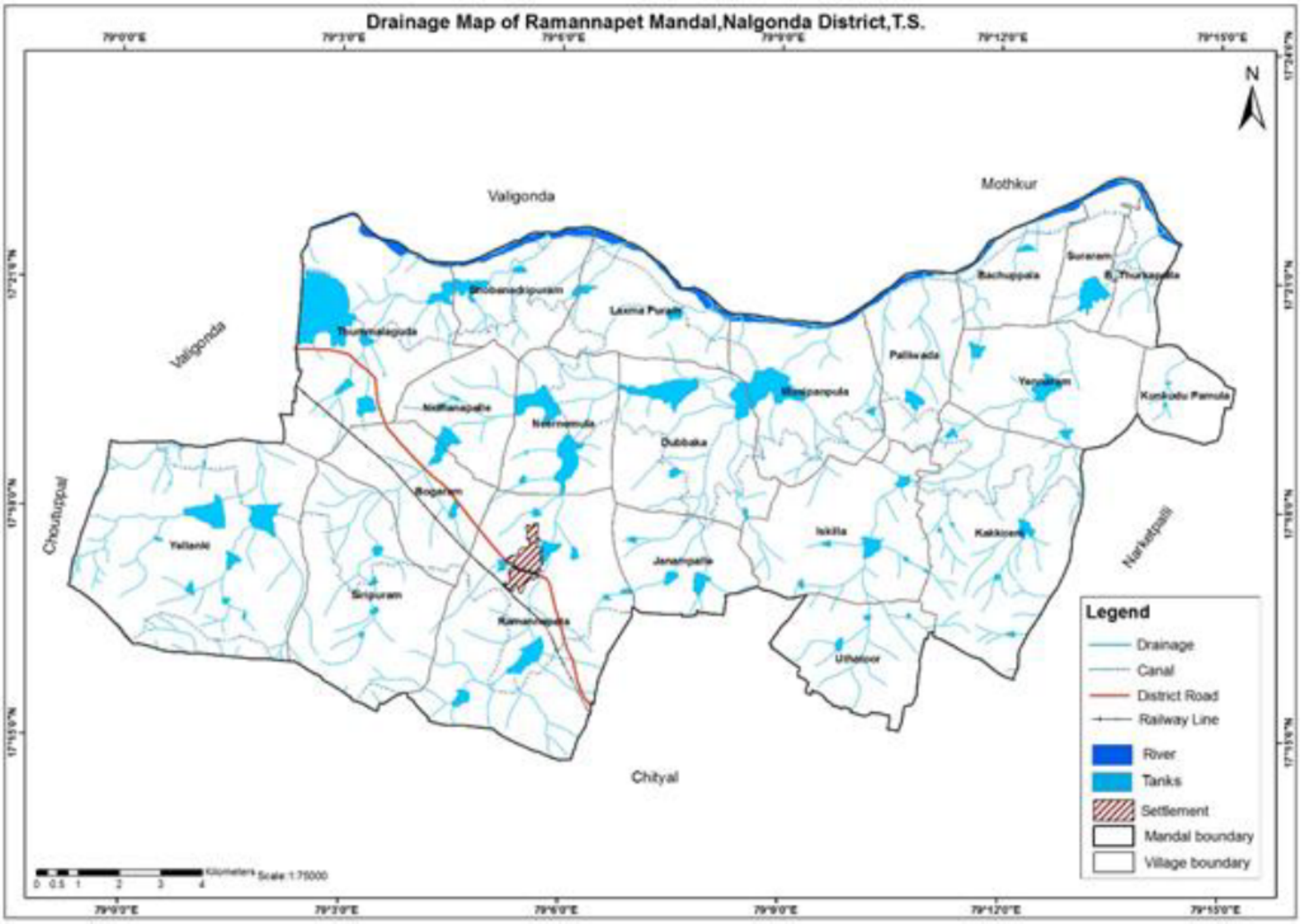

Figure 3

Drainage Map of the Study Area

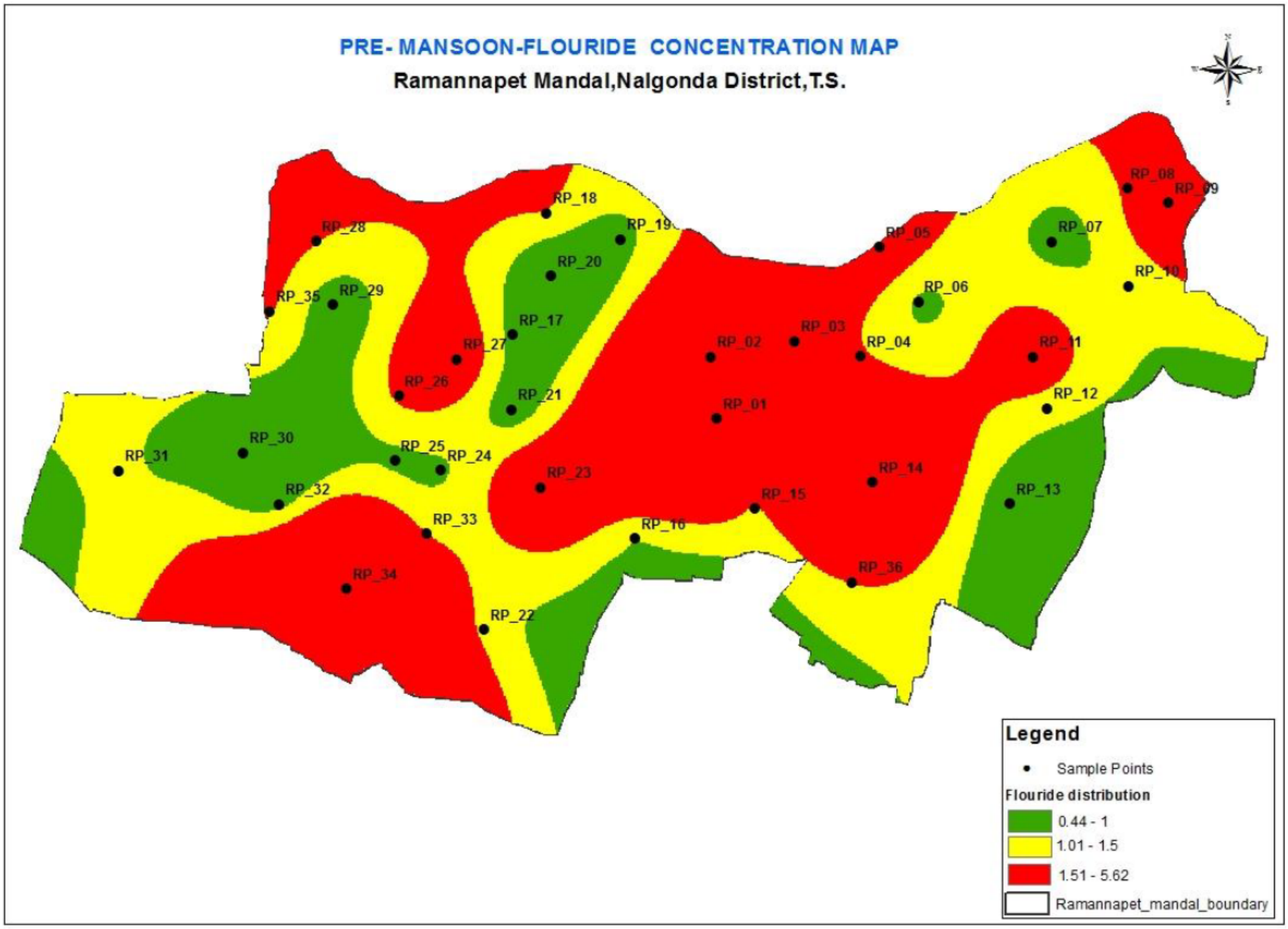

Figure 4

Spatial distribution of fluoride during pre-monsoon season.

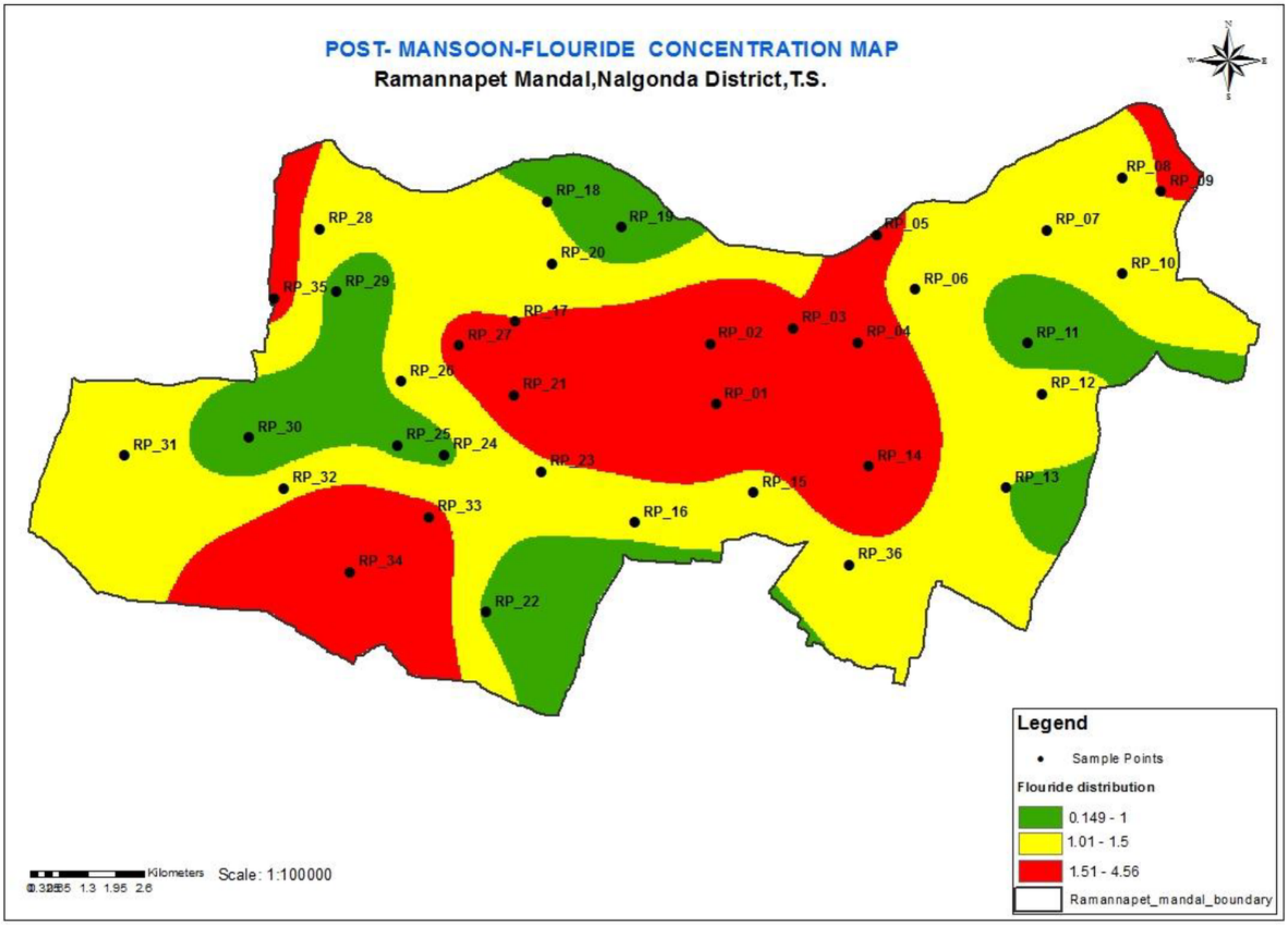

Figure 5

Spatial distribution of fluoride during post monsoon season

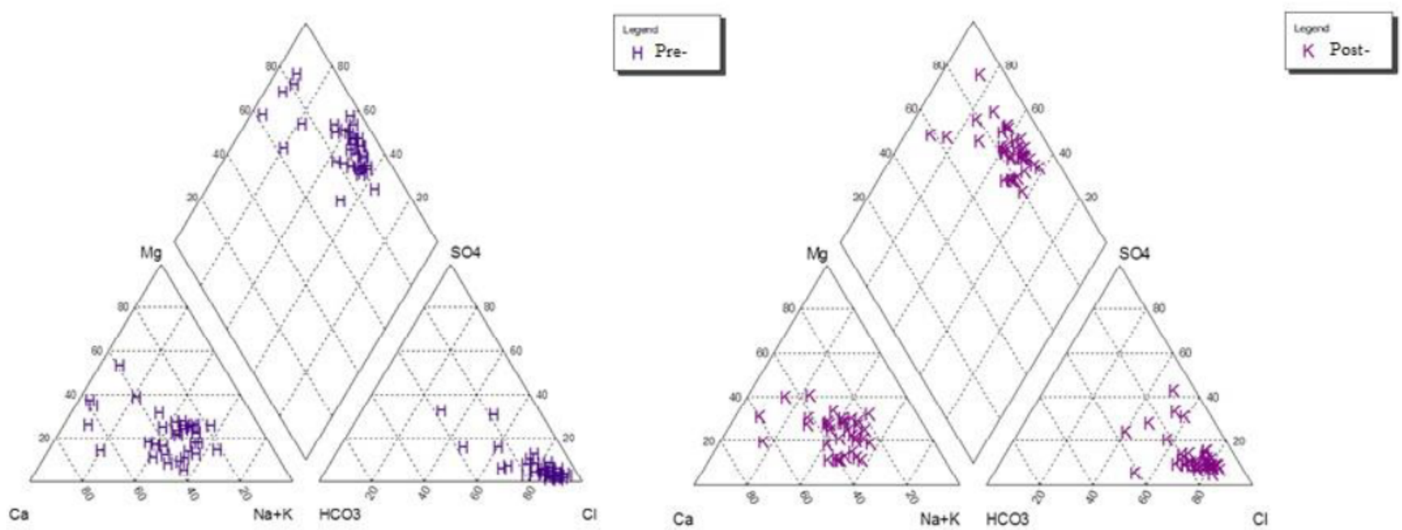

Figure 6

Piper classification of the study area

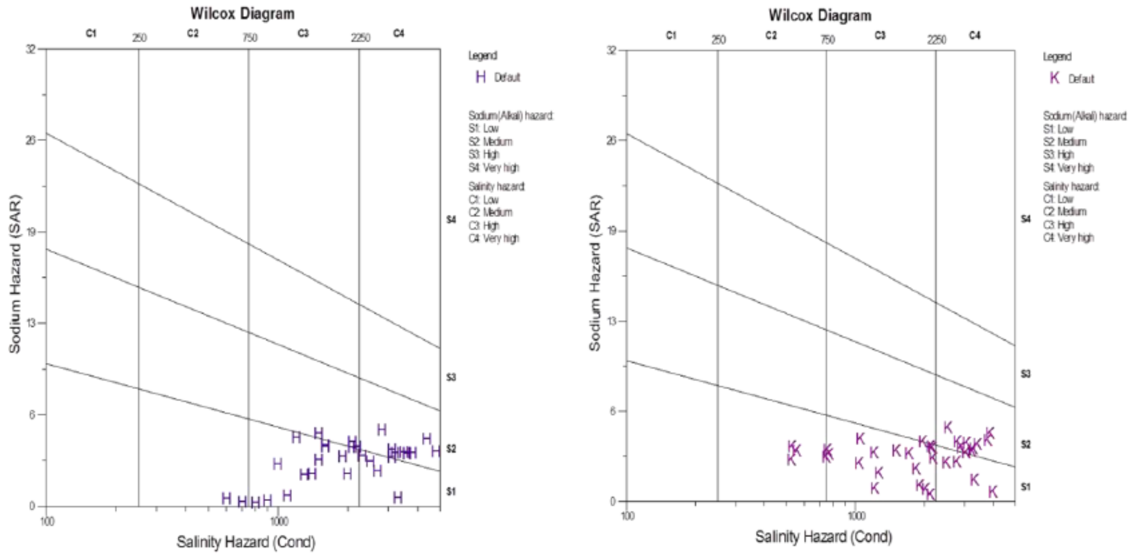

Figure 7

US salinity Laboratory diagram