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Groundwater Quality Assessment in Northeastern Bundelkhand Granitic Complex, Central India: Especial Emphasis on Fluoride (F-) Pollution/Contamination

Sourabh Tiwari[1], P. K. Kathal[1]*, Jemini Khatik[1], and Navneet Ranjan[2]

[1]Department of Applied Geology, Dr. Harisingh Gour Vishwavidyalaya, Sagar-470003, India
[2]Bhuvigyan Bhawan, Geological Survey of India, Eastern Region, Patna, 800 020, India
Corresponding author email: kathalpk@rediffmail.com

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Abstract

Water plays a crucial role in nourishing ecosystems on the earth. Groundwater is an essential source of potable is a key component in the earth's water cycle. The 'hydrogeochemical characterization'of groundwater in parts of Mahoba and Chhatarpur districts, Bundelkhand region of central India, in the pre-monsoon season (May, 2019) attempted in the study hasrevealed elevated fluoride (F^-) levels in 12 locations.

The analysis carried out in the present study incorporated parameters like 'major cations and anions' and 'their impacts on the quality of groundwater' in the region. Some localities show F^- values beyond the standard upper/lower limitsas defined the World Health Organisation (WHO). Besides,the study includes identification of 'hydrogeochemical facies' to comprehend the 'release of F^- ions' from rocks, along with an analysis of the 'Sodium Adsorption Ratio' (SAR) useful in classification of waters based on its utilities. The incidences of 'high/low' F^- necessitate a need to monitor the 'quality' as well as 'management of groundwater'in the region, to ensure the availability of potable water to the habitants.

Keywords: Hydrogeochemical Facies, Sodium Adsorption Ratio (SAR)

Introduction

Groundwater, an indispensable part of the earth's water cycle and a pivotal reservoir of freshwater, occurs in permeable rock formations called 'aquifer'. It accumulates over time through processes like precipitation and run in and, therefore, the chemical composition of groundwater exhibits variations from place to place due to its differential interactions with rocks that causes release of diverse chemical compounds. The issue of F^- pollution/contamination in groundwater is a cause for concern, given its association with dental and skeletal fluorosis. Groundwater generally contains more fluoride than surface water due to its prolonged contact and long 'residence time' with fluoride-bearing minerals during rock-water interactions (Edmunds and Smedley, 2012). Consequently, a comprehensive assessment of all physico- and geochemical parameters governing its quality becomes imperative to ensure the availability of safe and uncontaminated potable water.

Sixty groundwater samples, collected from the parts of Mahoba and Chhatarpur districts of Bundelkhand, central Indiain pre-monsoon (May, 2019) period were analysed. The quality of the water sampled has been assessed by analyzing major cations and anions (Ca^{+2}, Mg^{+2}, Na^+, K^+, Cl^-, F^-, HCO_3^-, and SO_4^{-2}) besides evaluating pH, EC, TDS, H_T. Hydrogeochemical facies determined through the plotting on data on the 'Trilinear Piper Diagram' to delineate the rock water interaction and its causes.

Study Area

The area falls in parts of Mahoba (Uttar Pradesh) and Chatarpur (Madhya Pradesh) sub-humid regions of the Bundelkhand, central India (Figure 1), covering over 2500 km^2 (250'00" N - 2530'00" N and 7945'00" E - 8015'00" E), in 53O/15, 53O/16, 63C/3 and 63C/4 Toposheets of the Survey of India (Figure 1).

Geographically, the elevated terrain represent north-eastern slopes of the granitoids of the Bunelkhand Gneissic Complex (BGC, Archaean to Proterozoic), overlain with Holocene alluvium (sand, silt, and clays, Holocene). The rocksshow a general diversity (coarse-grained granites to migmatites), which also encompasses quartz reefs and dykes (Figure 2).

Materials and Methodology

Sixty groundwater samples, collected from tube/bore-wells during pre-monsoon season in 'high-density polypropylene' bottles, properly rinsed with the water being sampled. GPS co-ordinates of each location were recorded. Major ions were chemically analysed in the Laboratory of the District Pollution Control Board, Sagar, Madhya Pradesh using Flame Photometer for Na^+ and K^+; Spectrophotometer for SO_4^{2-}; Colorimetric Titrations for 'Total Hardness' (TH), Ca^{+2}, Mg^{+2}, and HCO^{3-}; and Soil/Water Analyzer for pH, 'Electrical Conductivity,' (EC), and 'Total Dissolved Solids' (TDS). The stated standard procedures were followed throughout the analysis of these samples (American Public Health Association APHA, 2005).

Result and Discussion

The values of F^- contents along with the other major ions vary from the standards (Bureau of India, BIS, 2015) in all samples analysed.

Results show that pH varies from 6.9 to 5.8 (within the permissible limits); EC varies from 2780 to 1.4µS/cm (permissible limit, 300 µS/cm); TDS varies from 40.46 to 1328 mg/l(permissible limit, 2000 µS/cm; Ca^{+2}varies from 487.5 to 12.8mg/l(permissible limit, 200 mg/l; Mg^{+2}varies from 0.1602to 120 mg/l (permissible limit, 30 mg/l); Na^+ varies from 40 to 540.8mg/l(permissible limit of 200 mg/l); while K^+ goes up to 180.7 mg/l (permissible limit, 12 mg/l); HCO_3^-varies from 140to 890.0 mg/l; Cl^-varies from 1.25 to 345.9mg/l (permissible limit, 250-1000 mg/l); and SO_4^{-2}varies from 7.87 to 180 mg/l(within the permissible limit). Table 1 shows 'Maximum', 'Minimum', 'Mean' and 'Standard Deviation' values of all the physicochemical parameters determined in the study. Table 2 show that F^- ranges from 0.05 to 2.43 mg/l (above the upper tolerance limits of 1.5 mg/l) at 12 localities, while Table 3 shows values of F^-contentin all samples collected from the area.

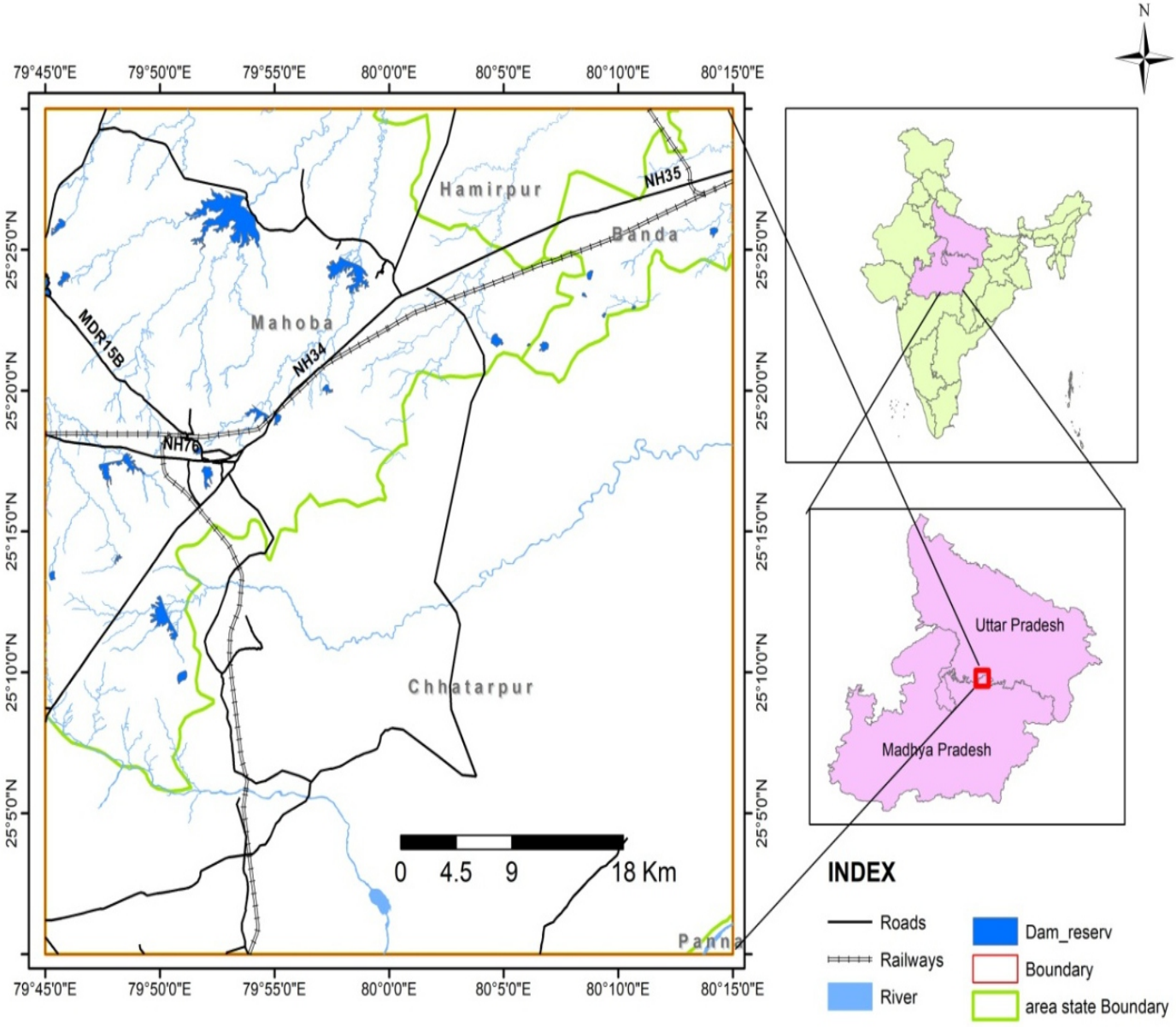
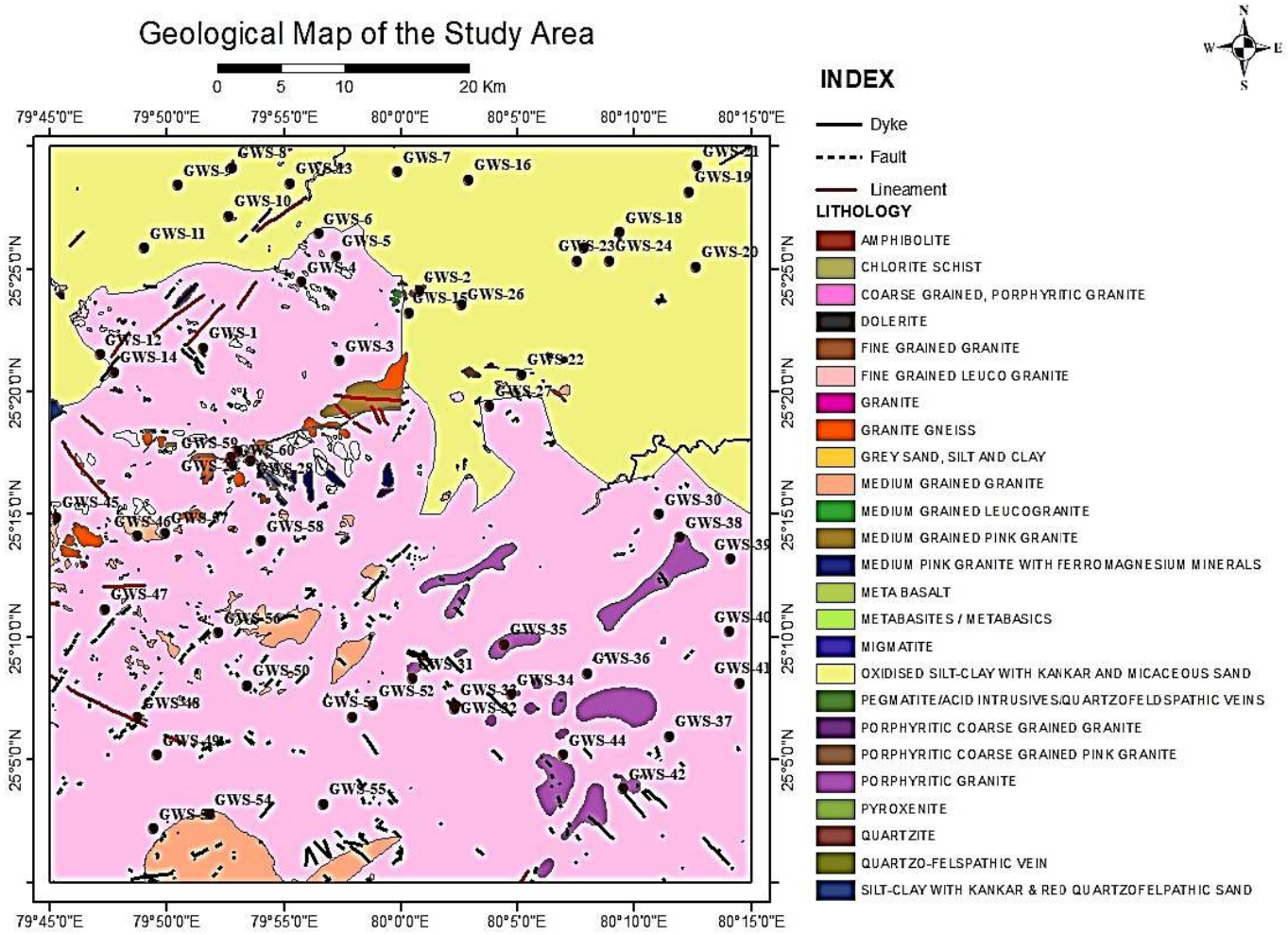


Figure 1: Location Map of the Study



(Modified after: BHUKOSH, Geological Survey of India Portal)

Figure. 2 Rock types and sample locations

GWS-1: Chikhara; GWS-2: Bilbai; GWS-3: Jijhar; GWS-4: Ganj; GWS-5: Dharaun; GWS-6: Gahra; GWS-7: Singhanpur Bagri; GWS-8: Patha; GWS-9: Kakun; GWS-10: Matiyai; GWS-11: Bamrara; GWS-12: Imaliya; GWS-13: Madarin Mata; GWS-14: Karahra Kala; GWS-15: Kabrai; GWS-16: BarbaiPahar; GWS-17: SirsiKala; GWS-18: Mataund; GWS-19: Chandpura; GWS-20: PahraKhadi; GWS-21: Khaddi; GWS-22: Palta; GWS-23: BadhauraKala; GWS-24: Abhau; GWS-25: Chandwara; GWS-26: Mudawra; GWS-27: Pargas;Bamori; GWS-28: Ratauli; GWS-29: Paswara; GWS-30: Joraha; GWS-31: Lauri; GWS-32: Katahra; GWS-33: Marwa; GWS-34: Nagroli; GWS-35: Gadhaura; GWS-36: Maniyari; GWS-37: Baraha; GWS-38: Gahabra; GWS-39: Churyari; GWS-40: Ghatra; GWS-41: Singhpur; GWS-42: Chandla; GWS-43: Sarai; GWS-44: Hiraurabari; GWS-45: Mureri; GWS-46: Sijahri; GWS-47: Srinagar; GWS-48: Dikhwaha; GWS-49: Digaria; GWS-50: Ragoli; GWS-51: Akhton; GWS-52: Bagmau; GWS-53: Phulari; GWS-54: Tattam; GWS-55: Dumra; GWS-56: Bhadar; GWS-57: Patha; GWS-58: Chitahri; GWS-59: Shah Pahari; GWS-60: Mahoba.

Figure. 3 shows 'spatial distribution map, prepared with the help of Arc-GIS (Arvindan *et al*.,2010, Maghesh *et al*., 2019, Shankar *et al*, 2010) shows undesirable values of F^- in some localities namely Ganj, Karahra Kala, Chandpura, Pahra, Khaddi, Ratauli, Paswara, Lauri, Katahra, Maniyari, Mureri, Digaria, and Bagmau. It shows 'low meteoric precipitation' as the foremost reason for increase in salinity in groundwater, which in turn dissolves more 'undesirable solids' and affects its drinking quality. In the samples, the ionic dominancy trend is:

$Na^+ > Ca^{+2} > Mg^{+2} > K^+$ and $HCO_3^- > Cl^- > SO_4^{-2}$.

Table 1: Statistical summary of groundwater quality parameters

S. No.	Parameters (in mg/l except pH and EC)	Minimum	Maximum	Mean	Standard Deviation
1	pH	5.80	6.90	6.41	0.25
2	EC	1.40	**2780.0**	**896.65**	514.98
3	TDS	40.46	1328.0	476.58	246.55
4	TH	68.00	570.0	242.28	66.44
5	Ca^{2+}	12.80	**487.50**	89.50	58.13
6	Mg^{2+}	0.17	**120.0**	9.92	18.43
7	Na^{+}	40.00	**540.8**	163.23	91.60
8	K^{+}	2.70	**180.7**	14.88	30.42
9	HCO_3^{-}	140.00	**890.0**	473.10	170.91
10	Cl^{-}	11.25	345.9	58.42	58.13
11	F^{-}	0.05	**2.43**	**1.90**	0.59
12	SO_4^{2-}	7.87	180	82.5	55.01

Note: Values above permissible limits are shown in **bold** letters.

Table 2: F^- values exceeding maximum permissible limit (>1.5 ppm)

S. No.	Localities	F^- values (>1.5 mg/l)
1	Ganj	1.62
2	KarahraKala	2.13
3	Chandpura	1.71
4	PahraKhadi	1.80
5	Ratauli	1.73
6	Paswara	2.03
7	Lauri	1.74
8	Katahra	1.92
9	Maniyari	2.28
10	Mureri	1.98
11	Digaria	2.13
12	Bagmau [21]	2.43

Figure 4 shows Piper's diagram (Piper, 1944), the 'quality indicating parameters' and the 'correlation of analytical data, based on the hydrogeochemical data.' It reveals a connection between 'high F^- values' and hydrogeochemical facies of 'Na-K-HCO_3^-,' 'Ca-Na-HCO_3^-,' "Ca-Mg-HCO_3^-," and 'Mixed type' under an 'alkaline medium' (pH >7.5, as indicated by Khatik *et al*., 2012 and 2015). This association leads to the continuous release of F^- from minerals like apatite, biotite, muscovite, hornblende, sericite, kaolinite, and chlorite (which host F^-) into subsurface water through processes such as 'ion-exchange processes' and 'rock-water interaction.' The predominant occurrences of 'Ca-Mg-HCO_3' and 'Ca-Na-HCO_3' type waters indicate a substantial 'water-rock relationship', which involves 'dissolution of plagioclase-feldspar', 'ferromagnesian minerals', and 'carbonates' within the country rock. This dissolution takes place as the recharging water, potentially carrying other reactive ions, infiltrates the groundwater from various sources, including irrigation, rainfall, or other surface inputs.

Conclusion

The hydrogeochemical analysis of the samples of the pre-monsoon period shows incidences of 'high F^-' contents in all the 12 localities, attributable to several factors like 'dissolution of F^- bearing minerals' into the groundwater, under 'high alkaline condition'. The hydrogeochemical facies in the 'high F^- zones'has been dominated by 'Na-K-HCO_3', 'Na-HCO_3', and 'Ca-Mg-HCO_3', suggesting a specific geochemical environment conducive to F^-enrichment.

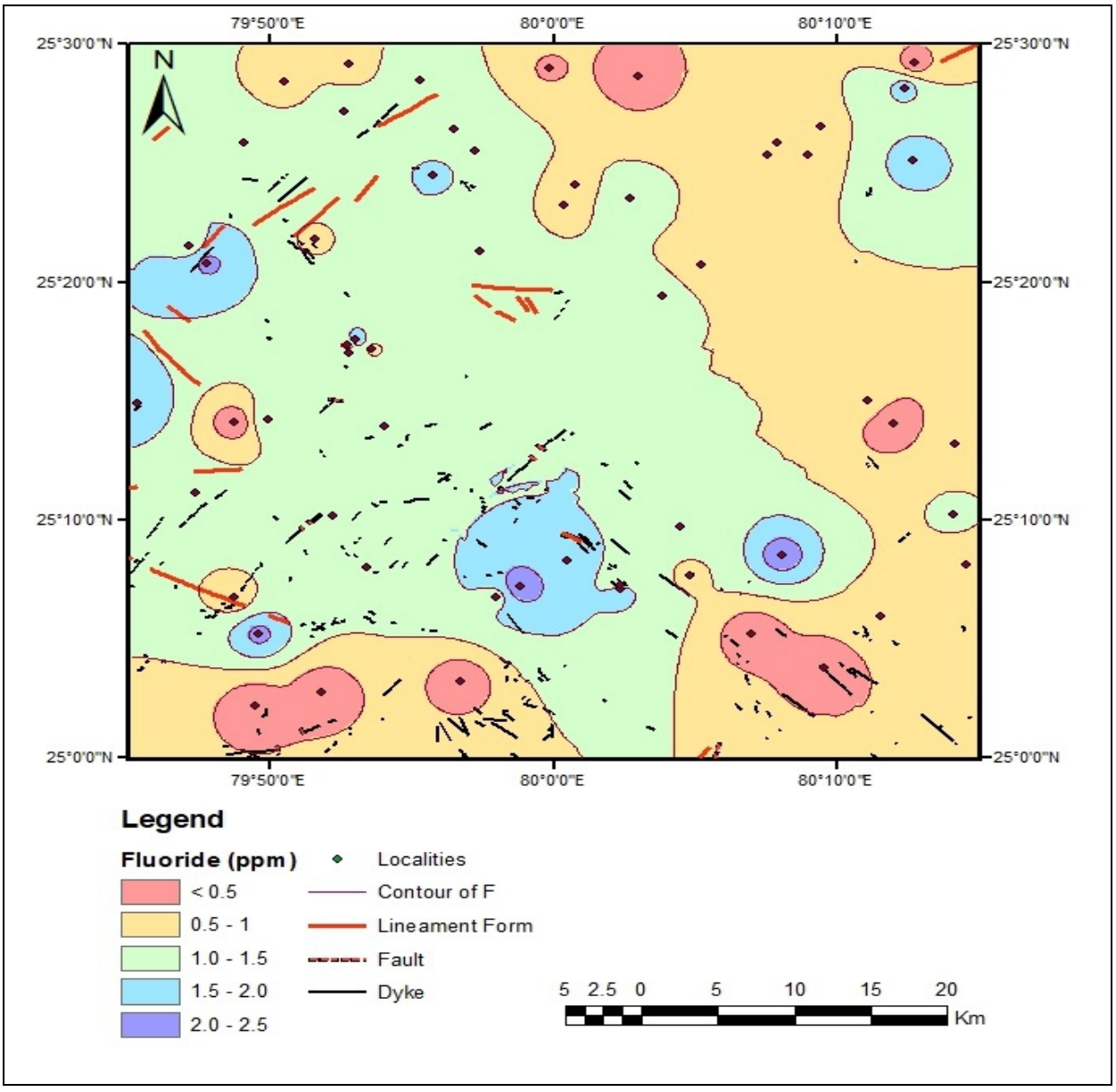


Figure 3: Spatial Distribution of F^- in Study Area

Table 3. Classification of groundwater based on F^- concentrations

Sr. No.	Sample Id	Locality	F^- (ppm)
1	GWS-1	Chikhara	0.91
2	GWS-2	Bilbai	0.87
3	GWS-3	Jijhar	1.26
4	GWS-4	Ganj	1.62
5	GWS-5	Dharaun	1.50
6	GWS-6	Gahra	1.22
7	GWS-7	SinghanpurBagri	0.44
8	GWS-8	Patha	0.72
9	GWS-9	Kakun	0.75
10	GWS-10	Matiyai	1.39
11	GWS-11	Bamrara	1.32
12	GWS-12	Imaliya	1.30
13	GWS-13	Madarin Mata	1.36
14	GWS-14	KarahraKala	2.13
15	GWS-15	Kabrai	0.88
16	GWS-16	Barbai Pahar	0.12
17	GWS-17	Sirsi kala	0.94
18	GWS-18	Mataund	0.90
19	GWS-19	Chandpura	1.71
20	GWS-20	PahraKhaddi	1.80
21	GWS-21	Khaddi	0.24
22	GWS-22	Palta	0.58
23	GWS-23	BadhauraKala	0.74
24	GWS-24	Abhau	0.83
25	GWS-25	Chandwara	0.85
26	GWS-26	Mudawra	1.35
27	GWS-27	Pargas Bamori	1.36
28	GWS-28	Ratauli	1.73
29	GWS-29	Paswara	2.03
30	GWS-30	Joraha	0.80
31	GWS-31	Lauri	1.74
32	GWS-32	Katahra	1.92
33	GWS-33	Marwa	1.04
34	GWS-34	Nagroli	0.88
35	GWS-35	Gadhaura	1.05
36	GWS-36	Maniyari	2.28
37	GWS-37	Baraha	0.95
38	GWS-38	Gahabra	0.07
39	GWS-39	Churyari	1.00
40	GWS-40	Ghatra	1.10
41	GWS-41	Singhpur	0.75
42	GWS-42	Chandla	0.09
43	GWS-43	Sarai	0.85
44	GWS-44	HirauraBari	0.05
45	GWS-45	Mureri	1.98
46	GWS-46	Sijahri	0.10
47	GWS-47	Srinagar	1.30
48	GWS-48	Dikhwaha	0.80
49	GWS-49	Digaria	2.13
50	GWS-50	Ragoli	1.30
51	GWS-51	Akhton	1.36
52	GWS-52	Bagmau	2.431
53	GWS-53	Phulari	0.16
54	GWS-54	Tattam	0.14
55	GWS-55	Dumra	0.17
56	GWS-56	Bhadar	1.10
57	GWS-57	Patha	1.50
58	GWS-58	Chitahri	1.20
59	GWS-59	Shah Pahari	0.67
60	GWS-60	Mahoba	1.45

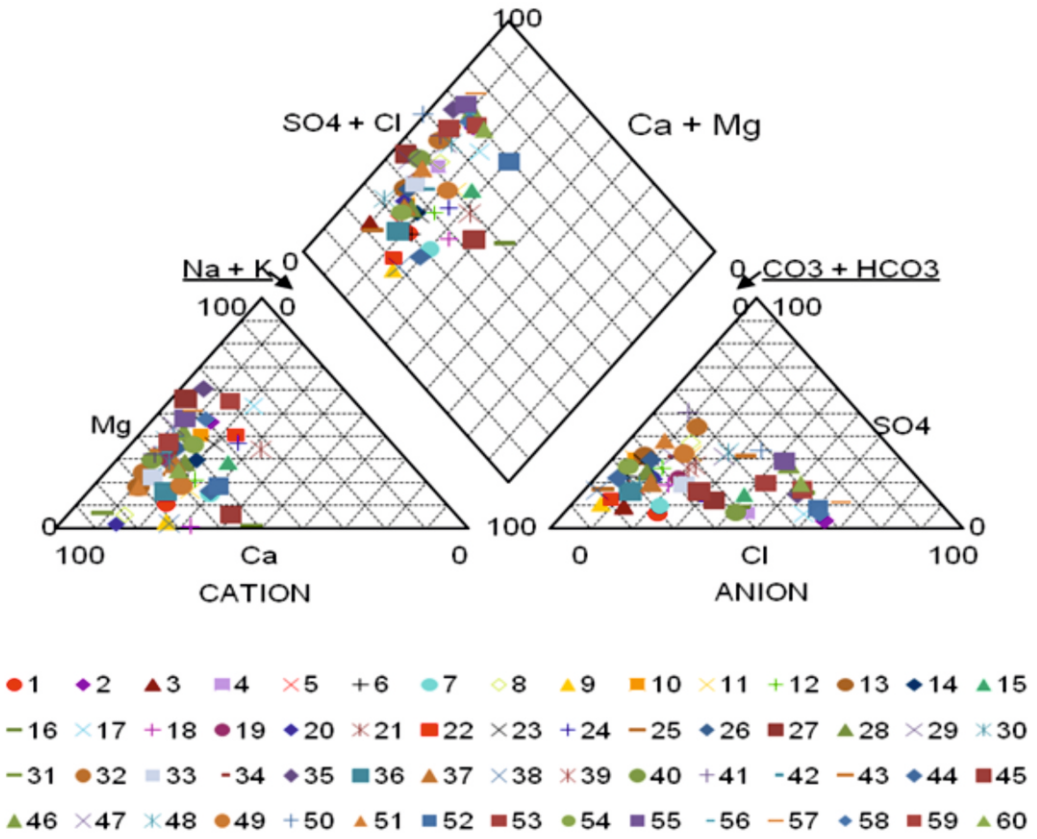


Figure 4: Trileniar Piper (1944) diagram based on the pre-monsoon data

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