Spatial Analyses of Fluoride Co-Related with Influencing Parameters to Demarcate Contamination Zones in Chandrapur District

Shilpa Janak[1],Yashwant B Katpatal[2] D K Agrawal[3]
[1]Ph.D. Scholar, RTMNU, Nagpur, India,
[2]Professor, Department of Civil Engineering, VNIT, Nagpur, India,
[3] Additional director research, KIMSDU, Karad

***Abstract*:- Groundwater is the main source for the drinking water purpose. To assure the groundwater for the drinking water purpose good quantity as well as good quality of groundwater is also necessary. Fluoride is a serious issue in Chimur, Bhadrawati and Warora taluka of Chandrapur district. Present study focuses on relation of fluoride with drainage density, lineament density, lithology and groundwater fluctuation. GIS is very important tool to develop a correlation of fluoride with different parameters. To study the combined analysis of multiclass data weighted Overlay Analysis method is used in ARCGIS. From this analysis, fluoride contaminated zones are identified whereas this analysis shows a relationship between fluoride concentration with lithology, drainage and lineament density and groundwater level fluctuation maps.**

Key words: Fluoride, GIS, Spatial variation, Weighted Overlay analysis,drainage density and Potential Fluoride Contamination Zone

1. INTRODUCTION

Groundwater has played important role in the maintenance of economy, environment and standard of living. This is true for Maharashtra as well, as it has been the primary source of water supply for domestic, agriculture and many industrial uses. It is the single largest and most productive source of irrigation and more than 60% of the total area under irrigation depends on groundwater sources. The rural water supplies are basically based on groundwater (GSDA report, 1992).

The quality of groundwater is governed by various factors of hydrogeology, hydro morphology and agro-climatic environment which are classified as natural factors (Pophare et al., 2014). However, it is further modified by man-made factors like urbanization, solid waste disposal and agro-industrial development (Devalla and Katpatal, 2019).

If once the aquifer is polluted then it cannot be regained with respect to quality. The source of pollution may be anthropogenicor many times it is geogenic. Excessive use of insecticides and pesticides in the fields, industrial discharges from factories and increasing urbanization leads the groundwater pollution. But when it is geogenic then the geology of the particular area decides the nature and extent of the pollution. In India, Fluoride and Arsenic contamination is mainly because of geogenic origin.

Fluoride contamination in the groundwater has been the major emerging challenge and concern across the world. Many researches and studies have reported fluoride related health problems in human beings which has serious implications on mankind. The concentration of fluoride in natural water depends on many factors like temperature, pH (Genzu and Guadong, 2001), solubility of fluorine bearing minerals, anion exchange between hydroxyl and fluoride ions, water residence time and geological formations (Apambire et al., 1997).

Fluoride in groundwater shows both spatial and temporal variation. Most countries in the world have controlled fluoride related health problems though some cases of dental fluorosis have been reported. In countries such as India, China, Ethiopia, Kenya and Argentina, contamination of fluoride in groundwater is a serious issue, while Mexico is the least affected country (Khan et al., 2016).

High fluoride in groundwater has been reported from 19 states in India (CGWB, 2010) with fluoride contamination in groundwater resources being widespread, intense, and alarming.

As per the CGWB report (2018-19), according to chemical quality analysis reports, parts of Nagpur, Bhandara, Gondia and Chandrapur districts have fluoride contamination at shallow depths and over extraction of groundwater from the deeper aquifer results in the fluoride contamination in Yawatmal, Latur, Osmanabad, Solapur, Nanded, Buldhana, Pune, Hingoli and Parbhani districts.

Geographic Information System (GIS) is a system for capture, storage, retrieval, analysis and display of spatial data. GIS is general purpose technology for handling geographic data in digital form. GIS has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields. GIS is used as an effective tool for developing solutions for water resources problems for assessing and mapping of ground water quality, understanding the natural environment and managing water resources on a required scale, assessing groundwater vulnerability to pollution (Singha et al., 2015).

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2. STUDY AREA

The study area is located in Chandrapur district of Maharashtra state. Study area is lying in the NW corner (78^0 40’ E to 79 37’ E and 19^0 59’ N to 20^0 43’ N) of district headquarter. Area of the talukas Bhadrawati, Chimur and Warora is 1165, 1142 and 1029 Sq. Km respectively.

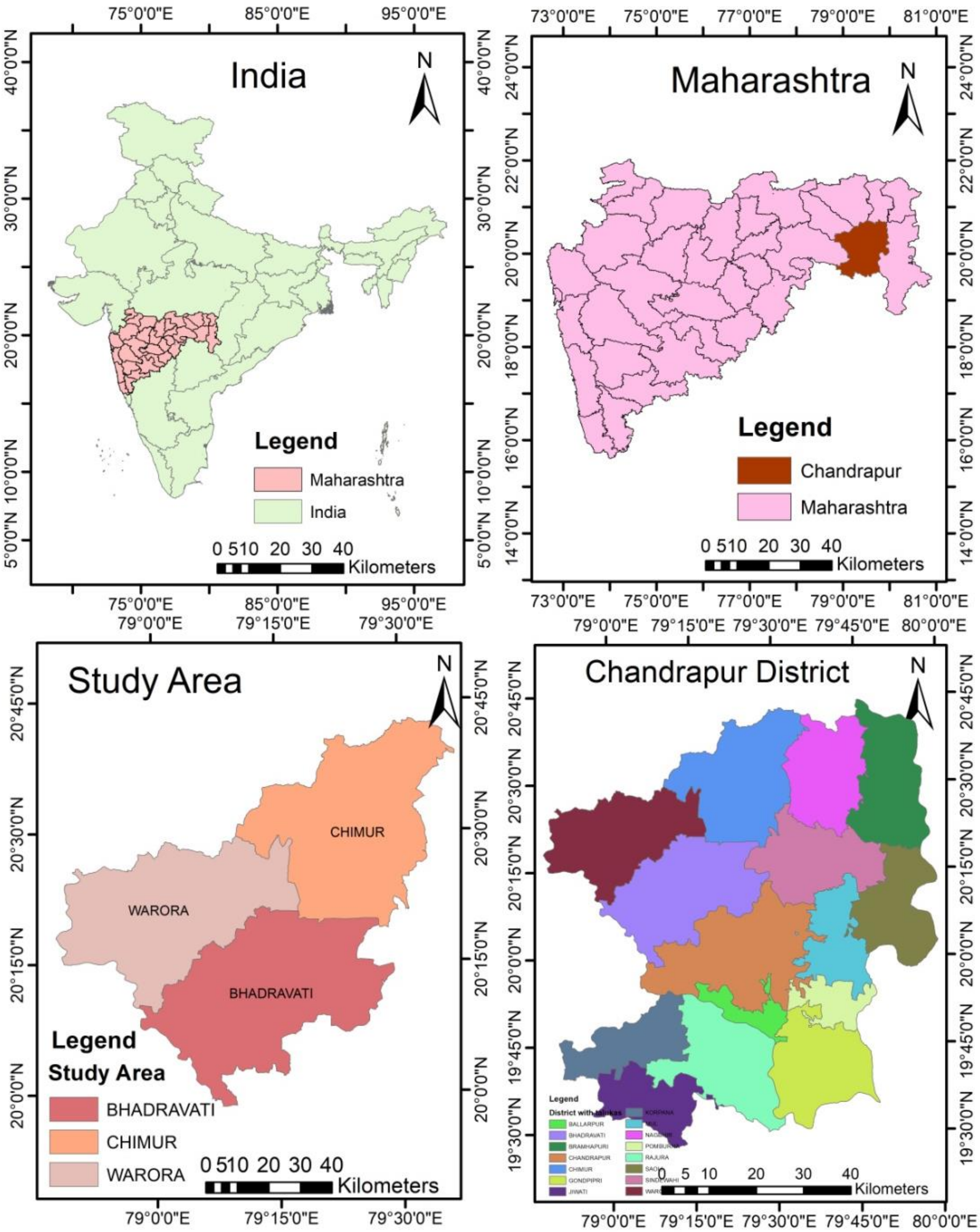

Figure 1: Location map of the study area

Total area selected for the study is 3336 Sq km. Bhadrawati, Warora and Chimur taluka are affected by the high fluoride concentration in ground water (CGWB district report, 2013). Due to this issue, these talukas are selected for study. Rainfall of the area ranges from 1200 to 1450 mm. Temperature of study area maximum temperature ranges to 42.8^0C in April- may season and minimum temperature in December is 12.2 ^{0}C. The relative humidity is 70% during monsoon season (GSDA, 2005). Study area is drained by southwards flowing Wardha, Erai and Uma River and its tributaries.

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3. GEOLOGY

Geologically the area comprises of oldest rock formation Archaean to youngest rock formation Alluvium and laterites. Archaean rocks comprise of schist, gneisses quartzites, banded hematite quartzites, schists with basic intrusive like pyroxenites, amphibolites. The Achaeans are the oldest rocks which are metamorphosed. They comprise of rocks called the older schist or unclassified crystalline which are overlain by the metamorphosed sedimentary rocks of Dharwar System and intrusive rocks of the Dharwar such as granites etc. The sedimentary Dharwarian rocks are further divided into three groups namely, Sausar series, Sakoli Series, Iron Ore Series. Iron Ore series: Iron Ore series and Sakoli Series are equivalent in age (GSI report, 1985).

- The Vindhyans overlie Achaeans basement with well-defined unconformity. They are represented mainly by flaggy and massive limestones, shale's and sandstones. The limestones occupy an extensive area in Chimur taluka.
- Lower Gondwana formation includes hard quartzite, Sandstones, Grits and Conglomerates and is called Mangli bed. The bed is located in Warora Taluka.
- Lameta beds: These are infra-Trappean beds comprising sandstone often calcareous and cherty lime stones and clays. The Lameta beds are located at various places along fringes of Deccan trap. Index fossils of Lametas are Dinosaurs and fishes, are found in Pisdura and Dongargaon villages of Warora Taluka.
- Deccan Basalt: Deccan basalts occur as a horizontal flow, which is massive and compact in nature.
- Alluvial Deposits: The alluvial deposits are generally occurring along the bank of nallahas and rivers. It is mostly fluviatile origin comprising of sandy silt, gravel clays. In the study area, alluvium area is formed by Wardha, Irai and Uma River.

4. METHOD AND MATERIALS

In this study, different thematic maps are generated using ARC GIS software. Study area boundary map is generated using taluka map. Geology thematic map is generated with the help of map published by the GSI. Geomorphology Map is prepared from the information gathered combined from satellite image, toposheets and observations from the field studies.Satellite data used for extraction of the geomorphological units in the study area are the LISS III images with 23.8 m spatial resolution.

Drainage map is generated from the SRTM data and toposheets. From the satellite data and GIS report, lineaments and faults are marked in the study area.

Chemical composition information was collected for the Year 2017-18 from the GSDA organization. For this, 2018 data is used for study area. Dug wells and Bore well samples of 280 villages of the study area are tested by GSDA, out of which Dug wells and Bore well samples of 228 villages are affected by Fluoride (ranges above 1 mg/l). From this affected villages Dug wells and Bore well samples of 90 villages have values 1- 1.499 mg/l and Dug wells and Bore well samples of 138 villages have values more than 1.5 mg/l. above information stated in the table. (GSDA, Chemical Campaign data for Year 2017). Different parameterwise maps are prepared. For this study we considered only Fluoride and Alkalinity concentration map by the IDW method (Janak and Katpatal 2021).

Table No. 1 Fluoride Values

Sr. No.	Taluka	Total number of Villages	Total Villages affected by Fluoride	Villages Values F : 1-1.499	Villages Values F > 1.5	Villages Values F : 0-0.99
1	Bhadravati	88	63	38	25	25
2	Chimur	79	62	23	39	17
3	Warora	113	103	29	74	10
	Total	280	228	90	138	52

Groundwater Surveys and Development Agency is taking pre and post monsoon ground water levels from fixed dug wells. 5 years data was collected from year 2014 to 2018. In the study area, there are total 33 wells. Fluctuation of water level is calculated from the pre and post water level from year 2014 to 2018. 5 years pre and post monsoon groundwater level graphs Fluctuation map is generated with by IDW method.

Some more thematic layers are generated to locate the spatial relationship with Fluoride affected villages with the lithology and lithology with the observation well fixed by GSDA. Concentration of Fluoride, Alkalinity layer and Groundwater Fluctuation layer are converted to raster form. With the help of ArcGIS spatial analyst raster based spatial analysis is done. Functions such as map algebra, combinational operators, data conversion and overlay tools of spatial analyst extension allowed integration to obtain the final Potential Fluoride Contamination zones map. In order to understand the influence and importance of geology in the spatial distribution of fluoride, the GIS-based analytical hierarchy process (AHP) proposed by Saaty (1980) and the weighted overlay analysis method (WOAM) are used. According to this concept weightages are given to the each field of the considered layer.

4.1 Weighted Overlay Analysis

Weighted Overlay Analysis (WOAM) is a method for the combined analysis of multi-class maps. Input layers used in this study have different numbering systems with different ranges. In order to perform an overlay analysis, each cell for each criterion must be reclassified into a common numerical scale with the least to the most favourable (Katpatal et al., 2010; Thapa et al. 2017).

After the successful assignment of appropriate ranks and weights to different input factors and their respective sub-classes using the AHP technique (table 2), WOAM was adopted to delineate the final PFC zone using the following equation:

$$PFC = {}^{n,m}\sum_{i=1} (AxBy),$$

Where, A represents the rank of the factor class, B represents the weight of the factor sub-class, x (x = 1, 2, 3,...,m) represents the factor maps and y (y = 1, 2, 3,...,n) represents the factor class.

Table 2 Factors and related Co-variables, for demarcating the potential Fluoride contamination zone with ranks and weightages

Sr. No.	Factors	Weights	Variables	Rank
1	Fluoride	20 %	2.00-2.50	9
			1.50-1.99	8
			1.00-1.49	7
			0.50-0.99	5
			0.00-0.49	4
2	Geology	20%	Amgaon Gneiss Complex, Gneiss Migmatite and schist	9
			Lameta Group	8
			Talchir Formation, Shale	7
			Vindhyan Formation, Shale with sandstone	6
			Deccan Trap, Karanja Formation, Basalt	5
			Deccan Trap, Chikhali Formation, Basalt	5
			Deccan Trap, Ajanta Formation, Basalt	5
			Deccan Trap, Unclassified, Basalt	5
			VidhyanSupergroup, shales and sandstone	4
			GondwanaSupergroup, Barakar Formation, Sandstone	4
			Pakhal Group	4
			Penganga Group	4
			Gondwana, Sandstone/ Shale and ferruginous sandstone	3
			Bailadila Group, Quartzites	2
			Alluvium - sand/silt	1
3	Groundwater Fluctuation	15%	8.00-10.00	9
			7.99-6.00	8
			5.99-4.00	7
			3.99-2.00	6
			1.99-0.00	5
4	Geomorphology	15%	Pediplains	8
			Plateau	5
			Structural Hills	3
			Denudational Hill	1
			Flood Plain	1
			Alluvium Plain	1
			Water body mask	1
			Habitation mask	1
			Pediplains	8
			Plateau	5
			Structural Hills	3
			Denudational Hill	1
			Flood Plain	1
5	Drainage density	10%	0.00-1.00	2
			1.10-2.10	3
			2.20-3.10	6
			3.20-4.10	7
			4.20-5.20	8
6	Lineament density	10%	0.00 - 0.19	3
			0.20 - 0.39	4
			0.40 - 0.59	6
			0.60 - 0.79	7
			0.80 - 0.99	5
7	Alkalinity	10%	1000-2000	9
			999-800	8
			799-600	7
			599-400	3
			399-0	2

5. RESULT AND DISCUSSION

5.1 Chemical Results

Concentration of Fluoride in the study year 2017-18 ranges from 0.1 mg/l to 2.2 mg/l. The desirable value of Fluoride is 1.00 mg/l and maximum value is 1.50 mg/l. From the Fig No 3 Fluoride concentration map we can infer that maximum value of Fluoride is seen in the North-East side (ChimurTaluka), in central portion (Bhadrawati and WaroraTaluka) and North-West side (WaroraTaluka) of the study area. For the weighted overlay analysis ranking is given as per the table no. 2.

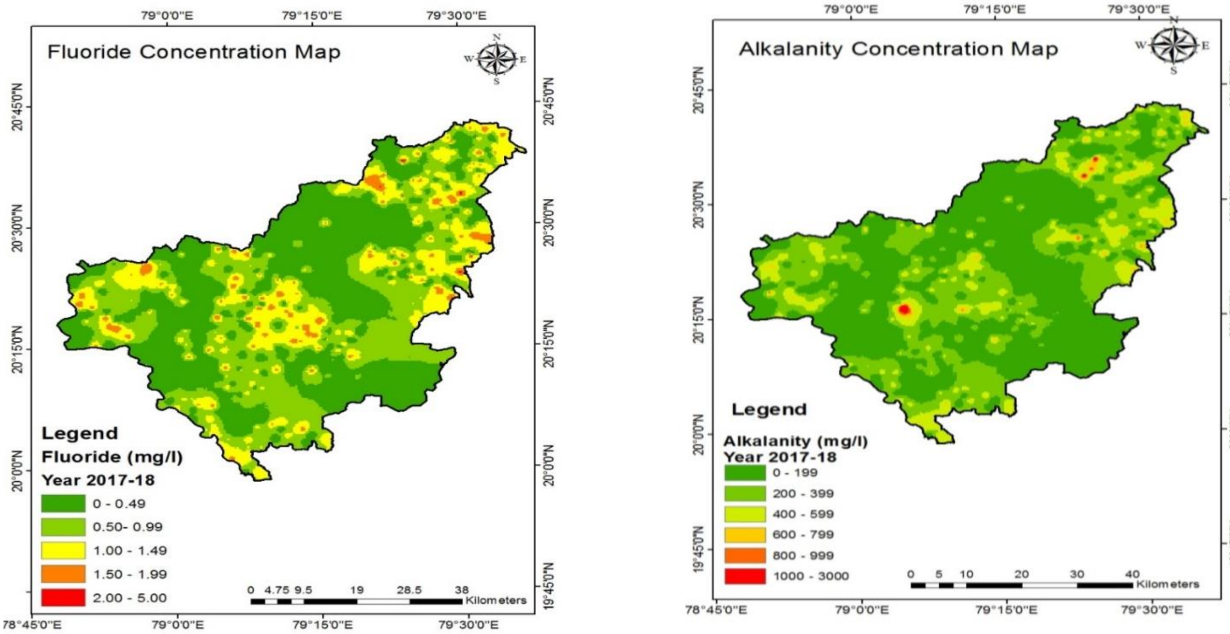
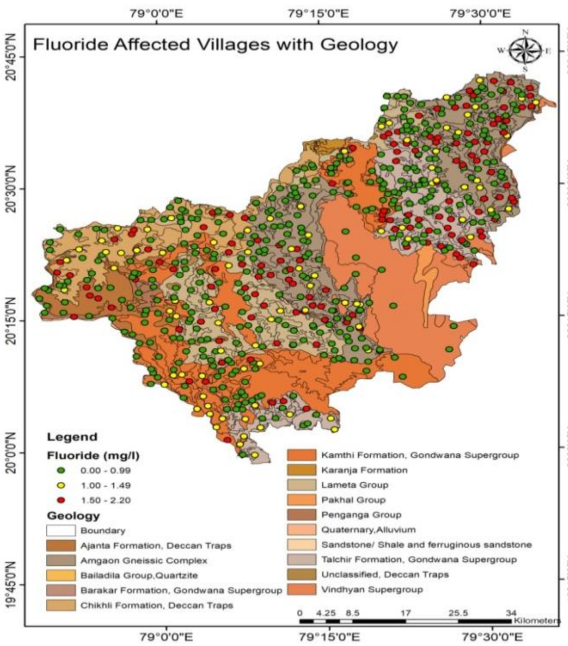


Figure 2: Fluoride Concentration Map of Fluoride and Alkalinity

5.2 Geological Analysis

From Figure 5, we can get the location of dugwells and borewells with category of Fluoride concentration. Fluoride concentration is divided in three categories – 0to 1.00 mg/l, 1.00-1.50 mg/l and above 1.50 mg/l. We can correlate the location of dugwells and borewells and lithology. Wells and borewells above 1.50 mg/l are located in the NE portion with lithology of gneiss with schist of Amagaon Gneiss Complex. In the central portion, higher F borewells are in the Talchir Formation, Lameta Group, KamthiFormationand some borewells are from basalts of Deccan Traps in the NW side.

Ranks have been assigned to each geological class. Archaean gneissic complex comprises of gneisses and schist which have minerals like biotite, hornblende which is responsible for Fluoride contamination, for which the highest ranking given is 9. Water samples from Talchir shales also show high Fluoride contamination, so, 8 no. ranks is given. Likewise other geological formations ranks are given (Janak and Katpatal, 2021).



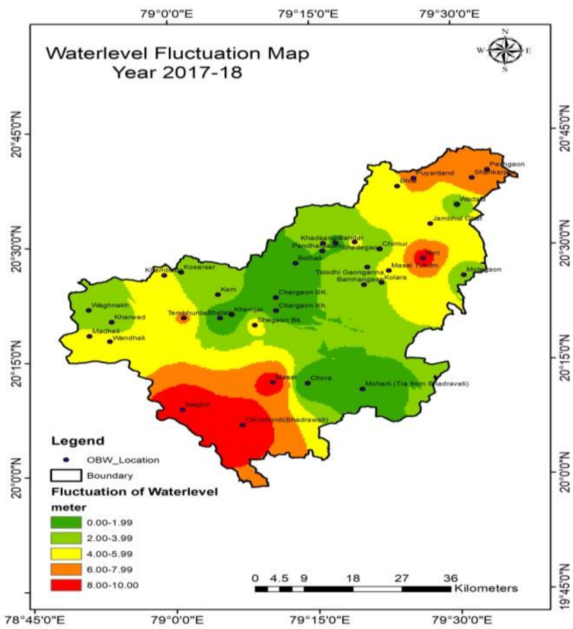


Figure 3: Dug well and Borewells Location Figure 4: Fluctuation Map of Pre and Post with Geology Monsoon Waterlevel for Year 2017-18

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5.3 Groundwater level Fluctuation analysis

In the **year 2017-18** (Figure 4)**,** Naglon, Masal, and Chinchordi of Bhadrawati taluka; Neri, Pachgaon, Shankarpur, Puyardand and Motegaon of Chimur taluka and Khambada of Warora taluka have fluctuations more than 8.00 m. Chora and Moharli of Bhadrawati taluka and other area has groundwater level fluctuation less than 8.00 m.

5.4 Drainage analysis

Drainages in the study area have been generated through DEM (Figure 5), whereas the drainage density map is generated by IDW method of interpolation. A total of 6 classes are generated to know the drainage density. Higher drainage density is observed in the north-east, west and south-west side of the study area while lower drainage density is observed in the north and central part of the study area. As per the Figure 6, drainage density ranges from 0 to 6 Sq.Km. In the study area drainage density is in the range 1 to 4 Sq. Km.

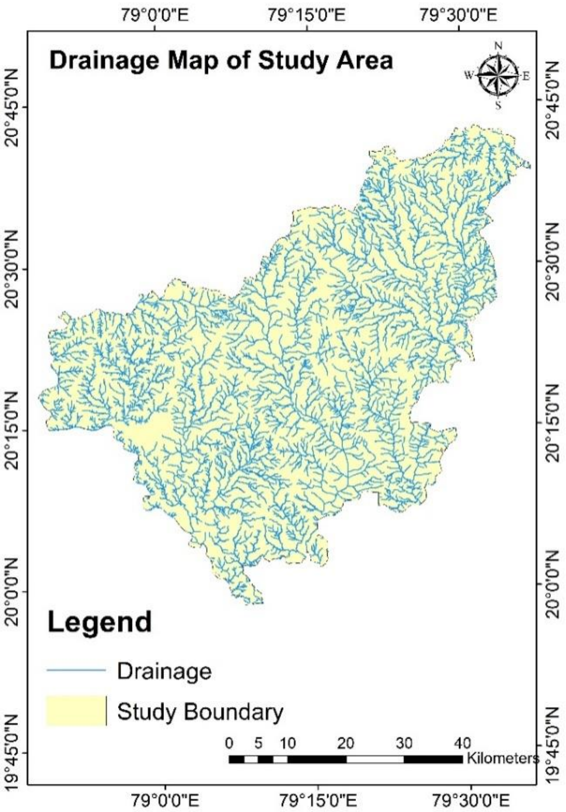

Figure 5: Drainage map of the study area

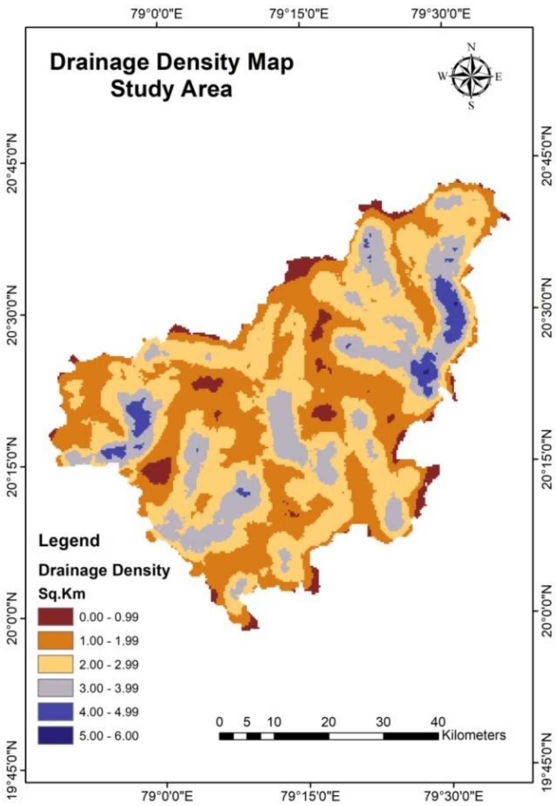

Figure 6: Drainage density map of the study area

5.5 Lineament analysis

From the satellite data and GIS report, lineaments and faults are marked in the study area. There are sets of lineaments in the direction of NE-SW, NNE-SSW, NW-SE and two faults in the study area. From this we can infer that area has undergone many phases of structural deformation (Figure 7).

In hard rock and metamorphic terrain, the movement and occurrence of groundwater is mainly depending upon secondary porosity which is developed due to folding, faulting and fracturing. All these process leads to develop lineaments in the area. Lineaments may be carrier or barrier with respect to groundwater movement. With the groundwater movement, quality affecting components may pass through one place to another. This will lead more area to be contamination. Due to which lineament is also plays an important role in the groundwater quality. LISS-III image is used of the delineation of lineament. The lineament analysis gives a synoptic view about groundwater movement in the area. Lineament density is calculated and map is generated in the ARCGIS.

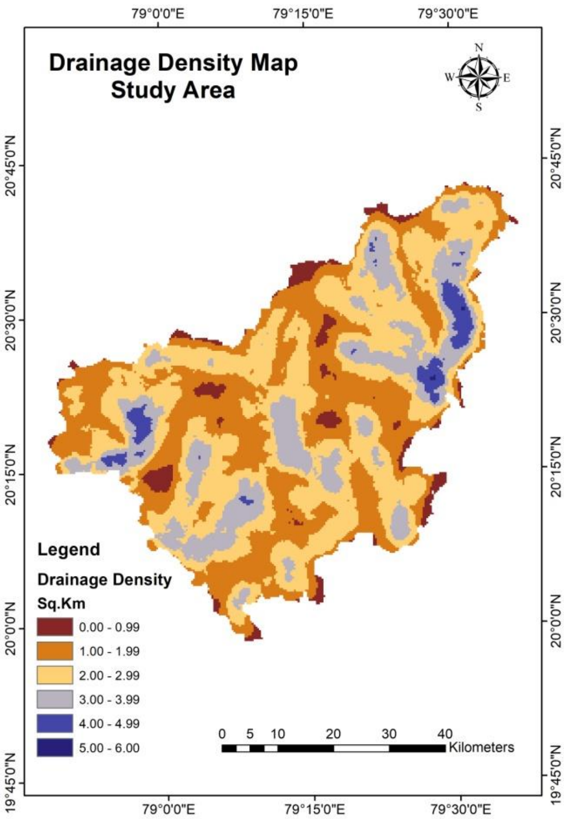

Figure 7: Lineament map of study area

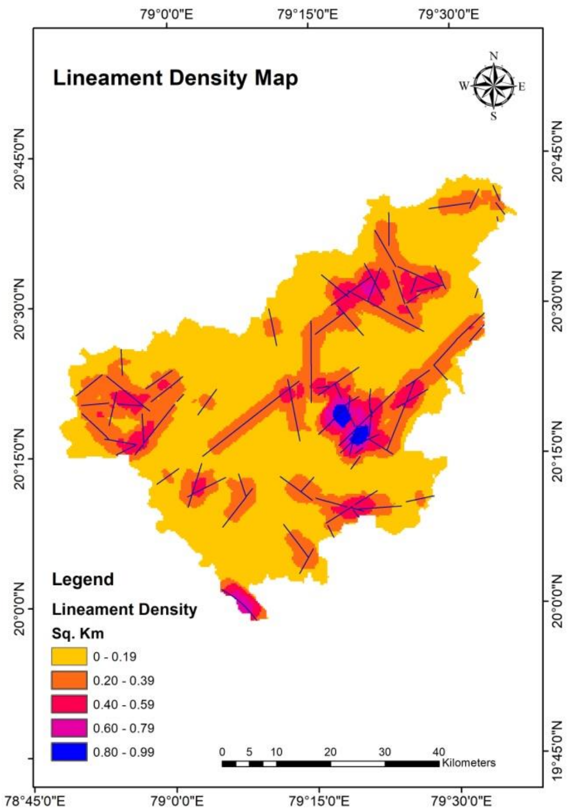

Figure 8: Lineament density map of the study area

Figure 8 shows the density of lineament. It ranges from 0 to 0.99 sq. Km. Highest lineament can be seen in the eastern part of the study area. Medium density i.e. 0.40-0.59 sq.km range show in the patches in western, central, eastern, southern and northeast part and rest area is in low density.

The Weighted Overlay analyses had been performed. For the analysis, seven factors are considered. These factors are Fluoride, Geology, Water level fluctuations of pre and post monsoon water level of 5 years (2014-2018), Geomorphology, drainage density, lineament density and Alkalinity. For this analysis only 2017 year's data was considered. From this analysis we can get the relationship between fluoride with other parameters and we get the Potential Contaminated Fluoride zone.

a) Assigning ranking to variables

Based on the field data and from inferences, ranking is to be assigning to the each variables.Fluoride concentration is classified in the 5 category. High concentration values given the higher rank and low concentration values for the analysis. Two different overlay analyses were performed in the study to evaluate weather using more parameters which are contributing in the Fluoride concentration changes the identification of the zones of Fluoride occurrence or in some way indicate its relationship with these parameters.

Weighted overlay analysis is done considering the following seven layers:

- Fluoride contamination layer
- Geology layer
- Groundwater level fluctuation (pre and post monsoon) layer
- Geomorphology layer
- Drainage density
- Alkalinity layer
- Lineament density

All layers are transferred in raster. Ranking is given. Also, weightage are given as fluoride and geology layer has given 20%; groundwater fluctuation and geomorphology has given15% and drainage density, alkalinity and lineament density has given 10%.

After integration of all layers, a map is generated showing Potential Fluoride contamination zone map (Figure 9). Five categories are formed in the potential fluoride contamination zone map. They are safe, Low, Medium, High and Very High.

- In ***Safe category***, F values are between 0 to 0.49 mg/l and also lithology is alluvium or quartzite. Water level fluctuation is mostly in 0-1.99 m and alkalinity value is between 0-399 mg/l. Geomorphology is alluvium or flood plains. Drainage density is in the range 0 -1.00 sq. km. Lineament density is between 0 – 0.19 sq. km.

- In ***Low zone***, F values are between 0.50 to 0.99 mg/l and having lithology preferably shale and sandstone from Vindhyans. Water level fluctuation is mostly in 2.00 -3.99 m and alkalinity value is between 400-599 mg/l. Geomorphology is denudational hills. Drainage density is in the range 1.1 -2.00 sq. km. Lineament density is between 0.20 – 0.39 sq. km.

- In ***Medium zone***, F values are between 1.00 to 1.49 mg/l and having lithology preferably shale and sandstone from Kamthi formation and some part from Talchir Formation. Water level fluctuation is mostly in 4.00 -5.99 m and alkalinity value is between 600-799 mg/l. Geomorphology is structural hills. Drainage density is in the range 2.20 – 3.10 sq. km. Lineament density is between 0.20 – 0.39 sq. km.

- In ***High contamination zone***, the F values range from 1.50 to 2.00 mg/l and lithology consisting of basalts, Talchir shales, Gneisses from Archaean complex gneisses. Water level fluctuation is mostly in 6.00 -7.99 m and alkalinity value is between 800-999 mg/l. Geomorphology is mostly plateau. Drainage density is in the range 3.20 – 4.10 sq. km. Lineament density is between 0.60 – 0.99 sq. km.

- ***Very high contamination zone,*** has the F values more than 2.00 mg/l and the lithology is Gneisses from Archaean Complex. Water level fluctuation is mostly in 8.00 -10.00 m and alkalinity value is between 1000-2000 mg/l. Geomorphology is mostly pediplain. Drainage density is in the range 4.20 – 5.20 sq. km. Lineament density is between 0.80 – 0.99 sq. km.

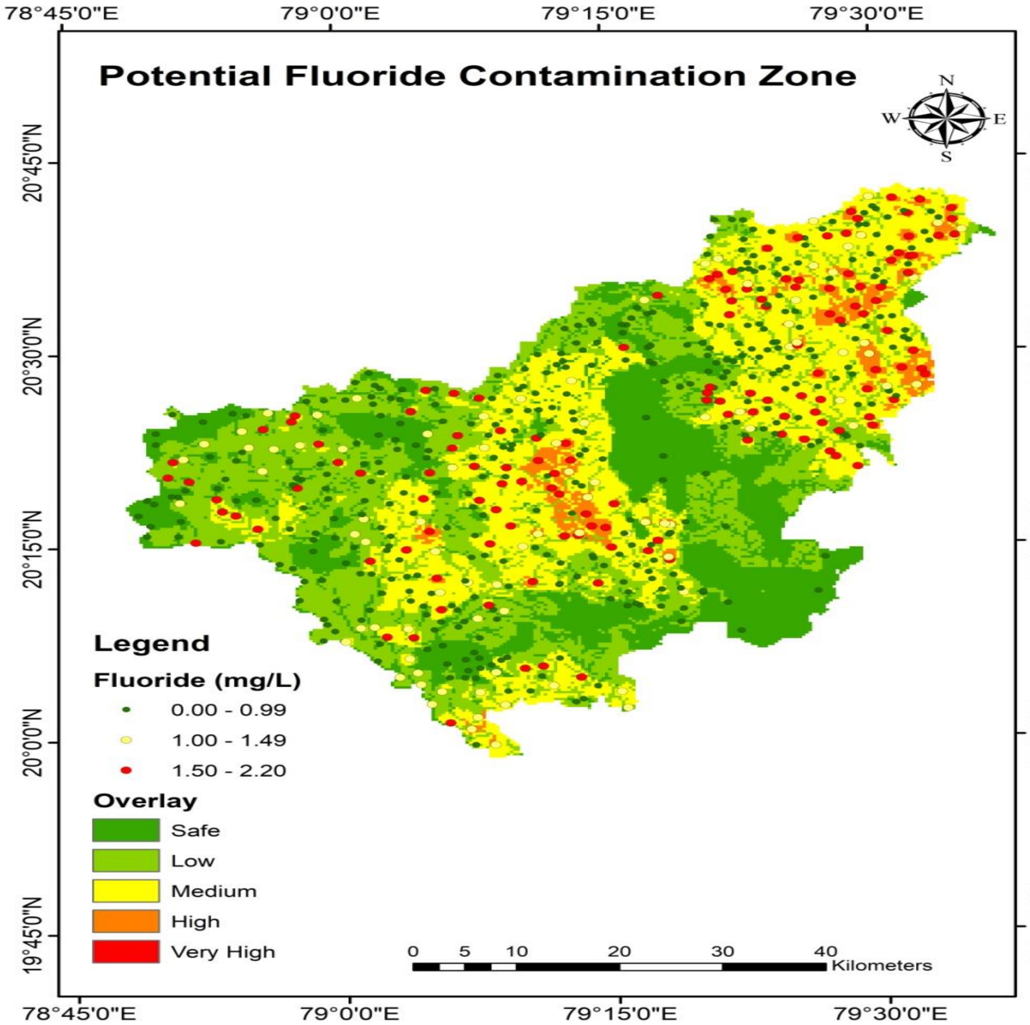

Figure 9: Potential Fluoride Contamination Map Overlay analysis

5. CONCLUSIONS

Applications of RS-driven data and GIS-based overlay techniques prove to be a useful combination for providing a **Potential Fluoride Contamination zone**. Integrating the seven different thematic maps using weighted overlay analysis, fluoride contamination map is generated. A final map with 5 zones of contamination is generated. The map shows contamination zone of the study area with respect to lithology of the area and groundwater fluctuation of the study area. We can infer that gneiss and sandstone from the Archeans and Gondwanas are the main source of fluoride contamination. In this area water level fluctuation is also high. High drainage and lineament density shows higher fluoride values. This is very useful for planning the public water schemes or drinking water measures in the study area.

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