Spatial Analysis of Fluoride concentration with respect to Lithology of the part of Chandrapur District

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ABSTRACT

Fluoride contamination is major issue in the Chandrapur area. Chandrapur district has a diverse geological set up, as all the lithologies are found here from Archean's to Recent Alluvium. Contamination of Fluoride is mainly from geogenic sources. From the chemical data collected from the observation wells, zonation of Fluoride contamination is carried out in the present study with the help of Inverse Distance Weight (IDW) interpolation technique of Arc GIS Map software. Geology map of the area is prepared with different lithounits and logs are also prepared existing Bore wells. Co-relation has been done with geology of the area and Fluoride contamination at various locations within the study area using the zonation map. With this study differential coefficient of co-relation is observed at different Formation/Lithounits. Study further concludes that the fluoride contamination varies spatially and with the depth aspect with the change in mineral composition with depth in different lithologies. The study also highlights the inevitability of representing the variation in pollution level in spatial domain to understand the pattern of contamination.

Keywords

Geology, Fluoride zonation, IDW tool, Coefficient correlation
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Introduction

Groundwater is main source for drinking water purpose, especially in rural areas. In this century, it is an challenging issue to provide good quality of water to the people. Anthropological interventions are causing deterioration in groundwater and surface water quality. Fluoride contamination in water is a worldwide problem.

In the world, around 200 million people from 25 nations have great health risks, with high fluoride in the drinking water (Ayoob and Gupta, 2006). In India alone, almost 60–65 million people drink fluoride-contaminated groundwater and the number affected by fluorosis is estimated at 2.5–3 million in many states (Athavale and Das 1999; Susheela 1999; Chakraborti et al., 2000; Muralidharan et al., 2002; Pillai and Stanley 2002). 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. Endemic fluorosis is prevalent in India since 1937 (Shortt et al., 1937).

To understand the mechanism of Fluoride contamination, it is very important to know the sources of fluoride in the water. The main sources of fluoride include fluorine-bearing minerals such as fluorite (CaF2), cryolite (Na3AlF6), topaz [Al2SiO4(F,OH2)], apatite [Ca5(Cl, F,OH)(PO4)3], amphiboles [A0–1B2C5T8-O22(OH, F, Cl)], micas [AB2–3(X, Si)4O10(O, F, OH)2] and sellaite (MgF2) (Hem, 1985; Pickering, 1985; Datta et al., 1996; Jadhav et al., 2015). Weathering of these fluorine rich minerals is the most important geogenic source of fluoride enrichment in water. Anthropogenic sources also contribute fluoride in the water. This includes activities such as mining, usage of pesticides and brick kilns (Datta et al., 1996).

High Fluoride concentration is noticed and reported in Vindhyan sediments in parts of Warora taluka followed by highly weathered granite gneisses of Chimur taluka. (CGWB district report, 2013).

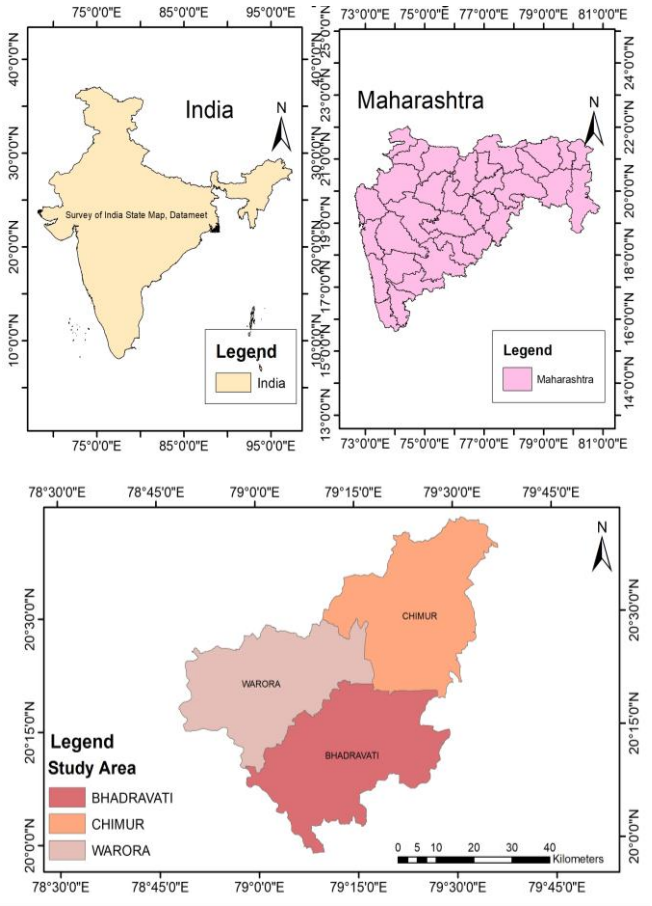


Figure 1. Location Map of the Study area

Study area

The study area is located in Chandrapur district of Maharashtra state. Study area is laying 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 Bhadravati, Chimur and Warora is 1165, 1142 and 1029 Sq. Km respectively. Total area for study is 3336 Sq km Bhadravati, 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 t0 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.

Geology

Geologically area comprises of oldest rock formation Archeans to youngest rock formation Alluvium and laterites. Archean rocks comprise of schist, gneisses quartzites, banded hematite quartzites, schists with basic intrusive like pyroxenites, amphibolites. The Achaeans are the oldest rock which are metamorphosed. They are comprised 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 tehsil.
- Lower Gondwana formation includes hard quartzite, Sandstones, Grits and Conglomerates and is called Mangli bed. The bed is located in Warora Tehsil.
- Lameta beds: These are infra-Trappe a beds are comprises sandstone often calcareous and charty 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 Tahsil.
- 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 comprises of sandy silt, gravel clays. In the study area, alluvium area is formed by Wardha, Irai and Uma River.

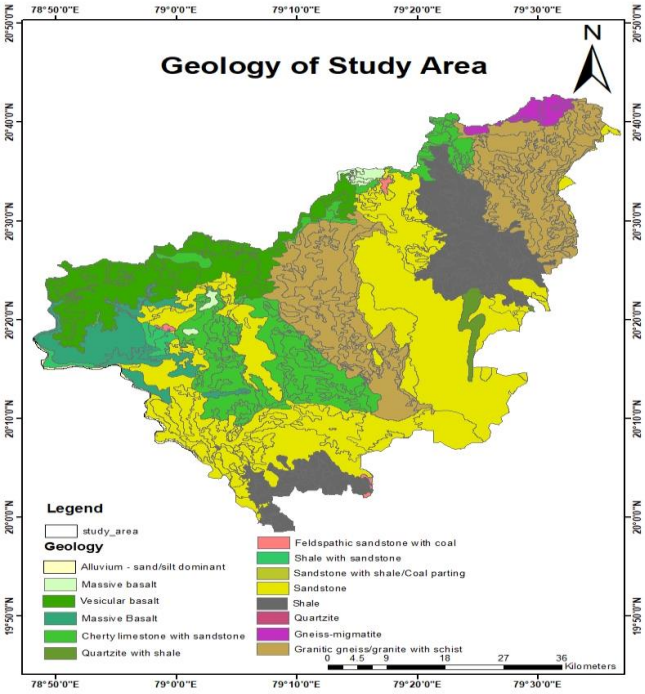


Figure 2. Geology Map of the Study Area

Methodology

In the study area, Chemical data is collected from the GSDA, Chandrapur. Here 2018-19 year data is considered for the study. For the year 2018-19, samples of 95 villages of Bhadravati, 126 villages of Chimur and 112 villages of Warora are analyzed. Iron (Fe), Nitrate (No3), Fluorite (F), Total Dissolved Soilds (IDS), Total Hardness (TH), Ph, Chloride (Cl) parameter wise values are procured. Water quality is very important and main issue for designing drinking water sources. Chemical data can be brought in GIS platform. GIS technology currently offers best accuracy and exceptional interpretation techniques, analysis and modeling of groundwater quality parameters in space and time. This technology provides a platform to build spatial information into a well-organized database and thus facilitates systematic handling of data to generate hydro-chemical information in a user desired format. (Kantharaja et al., 2012)

Fluoride affected villages are taken and Fluoride concentration maps are prepared by the Inverse Distance Weight (IDW) interpolation technique in Arc GIS Map software. Deterministic and Geo-statistical are two categories of interpolation techniques. Deterministic interpolation technique creates surfaces based on the measured points or mathematical formulas, such as inverse distance weighting (IDW), and kriging for spatial data sets. Inverse distance weighting (IDW) method is based on the extent of the similarity of the cells. The IDW function is used when the set of points is dense enough to capture the extent of local surface variation needed for analysis. IDW determines cell values using a linear-weighted combination set of sample points.

The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less influence the cell has on the output value. However, the geochemical data in the study area are non-stationary, because many of the closely located points have values drastically different from each other. Because of this reason, IDW method has been used for interpretation of data points instead of kriging to generate maps of continuous maps of geochemical parameters. (Mayuri Prajati et al., 2017)

To find out the relation between the Fluoride and some other parameters like TDS, Ph, Alkalinity and Chloride “correlation coefficient” a statistical method is used. For this, 2018 data is used for study area. Dug wells and Bore well samples of 347 villages of the study area are tested by GSDA, out of which Dug wells and Bore well samples of 303 villages are affected by Fluoride (ranges above 1 mg/l). From this affected villages Dug wells and Bore well samples of 82 villages have values 1- 1.499 mg/l and Dug wells and Bore well samples of 221 villages have values more than 1.5 mg/l. above information stated in the table. (GSDA Chemical Campaign data for Year 2018)

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	95	71	38	33	24
2	Chimur	126	120	28	92	6
3	Warora	126	112	16	96	14
Total		347	303	82	221	44

Calculated correlation coefficient of the other chemical parameters with respect to Fluoride is as follows,

Table 2 – Calculated Correlation Coefficient of the Parameters with Fluoride

Chemical Parameters	Correlation Coefficient (r) With Fluoride (n = 347)
Iron	-0.0204
TDS	0.3149
Alkalanity	0.3808
Ph	0.3446
Chloride	0.3075
Hardness	0.2047

Results and Discussion

Concentration of Fluoride in the study area is 0.1 mg/l to 4.2 mg/l with respect to geology of the study area. The minimum and maximum acceptable limit of fluoride concentration is 1.0 and 1.5 mg/L, respectively (WHO 2005).Fluoride concentration map is prepared by using IDW technique. Interpreting the map, North West side of the study area (Warora Taluka) has highest concentration of the Fluoride. In the study area, higher concentration of Fluoride occurs in depth means from the borewells than in the shallow area means from dug wells.

In general, fluoride is derived mainly from the lithological sources (Hem 1991). It may be noticed in Figure 3 that Fluoride concentration is higher in the eastern parts of study area and northwest parts of study area as well. In the wastern parts of study area which falls in Warora Taluka, the lithological formations are Deccan basalts of vesicular and massive nature. While in the estaern part which falls in Chimur taluka, the higher Fluoride concentration villages are also more where the rock types are metamorphics including gneisses, migmatites and schists. The Fluoride in the study area must be geogenic in nature as the derivation can be ascribed to the rock types present in the study area. The country rocks, containing apatite, besides replacement of hydroxyl by fluoride ions in amphibole and biotite, are the sources of fluoride in the groundwater (Hem 1991; Jacks et al. 2005).

Similarly, the present study also aimed at finding the relationship between the Chloride, Alkalanity, Iron, TDS Concentrations in the groundwater in the study area. For this, the Chloride, Alkalanity, Iron, TDS Concentrations in the study area were also interpolated using IDW method in GIS. It may be noticed in Figure 4 that the Fluoride concentrations are not highly correlated to these parameters. The regions where Fluoride concentrations are more do not match with the areas where the other parameters spatially modelled in the study.

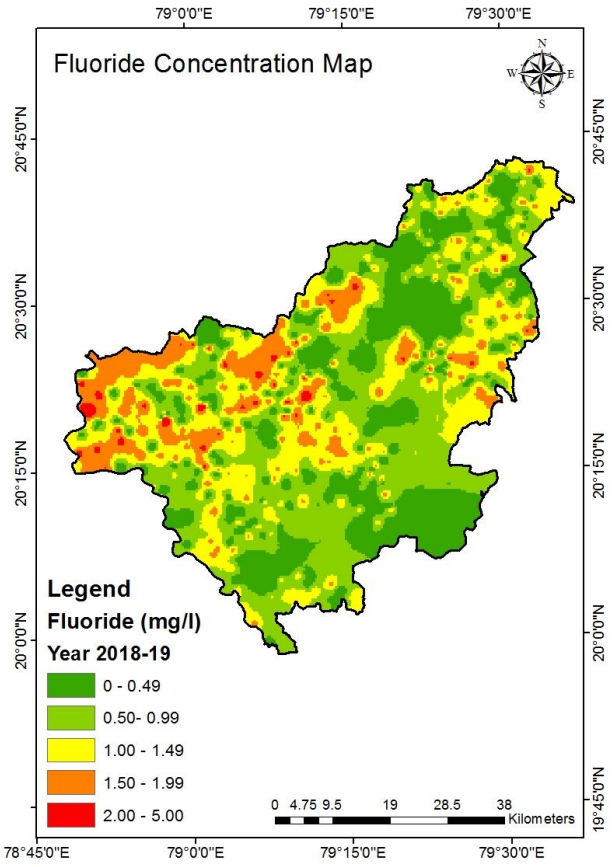
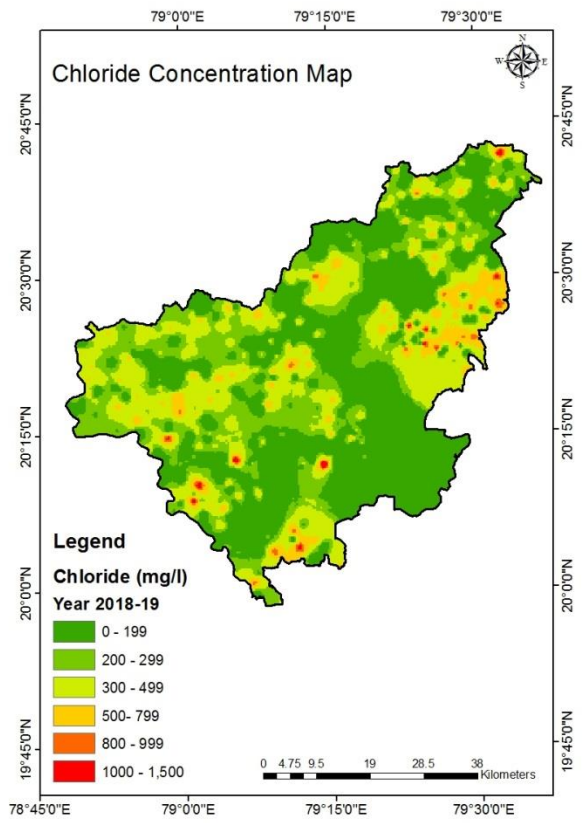
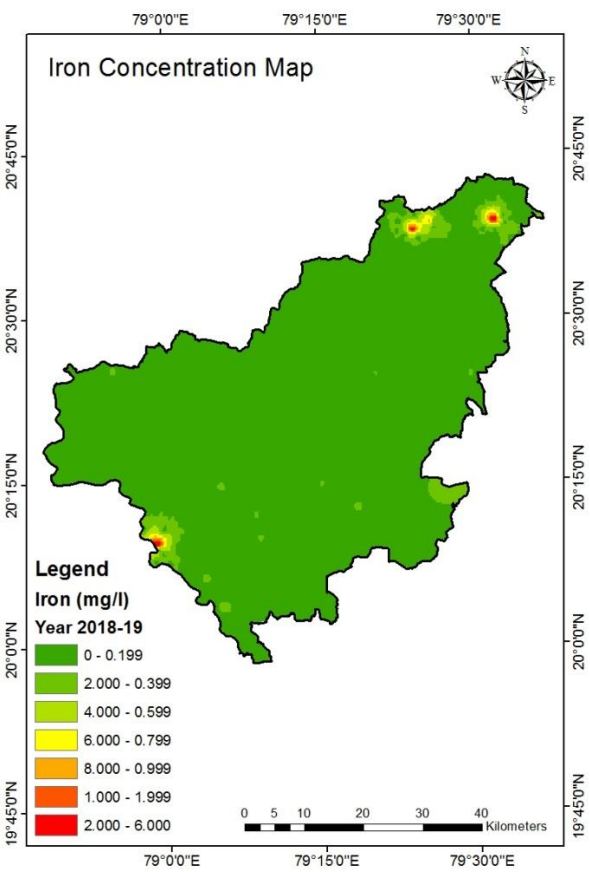
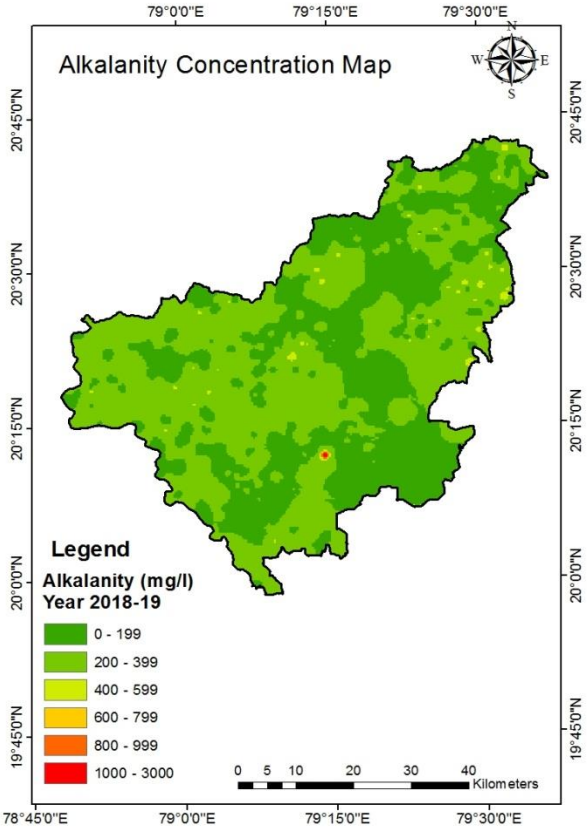


Figure 3. Fluoride Concentration map (Year 2018-19)







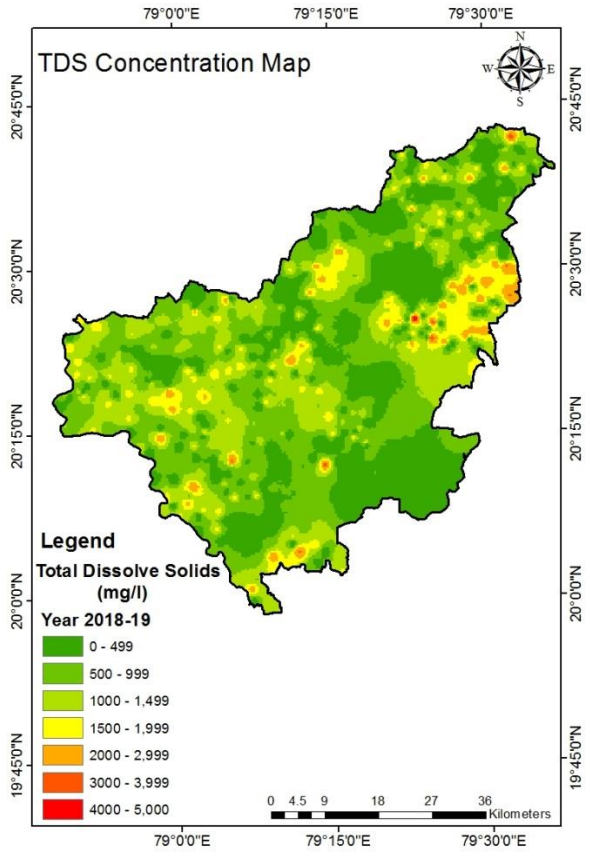


Figure 4. Chloride, Alkalanity, Iron, TDS Concentration maps (Year 2018-19)

Amphibole and biotite, are the sources of fluoride in the groundwater (Hem 1991; Jacks et al. 2005). The rocks, in which fluoride is strongly absorbed in the soils, consisting mostly of clays, are also the source of fluoride (Robinson and Edington, 1946; Subba Rao et al., 1998; Madhavan and Subramanian, 2002; Ayoob and Gupta, 2006). Highest concentration of the Fluoride (4.2 mg/l) is from the Gneisses and shales terrain. In the study area Fluoride is from geogenic origin. Sedimentary rocks formations (sandstone) and metamorphic formations (Gneisses and Schist) shows higher concentration of Fluoride.

In the study area, calculated Correlation coefficient is tabulated in the table no. 2. From this analysis, we can infer that there is negative correlation with the Iron (r=-0.204) parameter. Other parameters Total Dissolved Salts (r= 0.3149), Alkalinity(r= 0.3808), Ph (r= 0.3446), Chloride (r= 0.3075) and Hardness (r= 0.2047) shows very less correlation. From this analysis we can infer that no significant relationship between them.

Conclusion

Correlation analysis study shows the interrelationship of the Fluoride and other chemical parameters. Study brings out two major observations based on the spatial data generation and correlation analysis of the parameters like Chloride, Alkalanity, Iron, TDS Concentrations with Fluoride.

The study indicates that the Fluoride concentrations are spatially related to the lithological units i.e. the rock types present in the study area. These rock types are Basalts, gneisses, sandstones, migmatites and schists. The study also indicates that the parameters selected for comparison like Chloride, Alkalanity, Iron, TDS Concentrations are not spatially correlated in the study area.

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