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Research Article

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Evaluation of Fluoride Contamination in Groundwater Using Remote Sensing and GIS Techniques in Virudhunagar District, India

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Abstract The prevalence of fluoride is mainly due to the consumption of more fluoride through drinking water. It is necessary to find out the fluoride contamination areas to adopt remedial measures to the people on the risk of fluorosis. The groundwater fluoride causes by rock water interaction. The occurrence of dental fluorosis among the people in the Virudhunagar district provides the motivation to investigate occurrence of fluoride in groundwater. The objective of the study is to find out the spatial distribution of fluoride in pre-monsoon and post-monsoon period using GIS and remote sensing. The fluoride concentration in groundwater varies from 0.2 mg/l to 1.6mg/l in pre-monsoon and 0.1mg/l to 1.9mg/l in post-monsoon. The overall distribution of fluoride concentration in the study area during the pre-monsoon and post-monsoon periods indicates slight dilution effect owing to fresh water recharge on account of rain fall. Exposure of fluoride among different age group was calculated in this study area. From the results, the fluoride concentration was identified to be 33% in pre-monsoon period and 25% in post-monsoon period in Virudunagar district, Kavalur, Rajapalayam, Srivilliputtur, Vembakottai, and Watrap blocks were highly affected, but the neighboring blocks are free from excess fluoride contamination in drinking water. It has been recommended to the government authorities to take serious steps to supply drinking water with low fluoride concern for the fluorosis affected areas.

Keywords GIS, Remote Sensing, Fluoride

1. Introduction

Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps preventing and even reverse the early stages of tooth decay. The weathering of primary rocks and leaching of fluoride-containing minerals in soils yield fluoride rich groundwater in India which is generally associated with low calcium content and high bicarbonate ions (1). The unfettered groundwater tapping exacerbates the failure of drinking

water sources and accelerates the entry of fluoride into groundwater. Dental fluorosis, which is characterized by discolored, blackened, mottled or chalky-white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing. These effects are not apparent if the teeth were already fully grown prior to the fluoride overexposure; therefore, the fact that an adult may show no signs of dental fluorosis does not necessarily mean that his or her fluoride intake is within the safety limit. Chronic intake of excessive fluoride can lead to the severe and permanent bone and joint deformations of skeletal fluorosis. The only remedy is prevention by keeping fluoride intake within safe limits.

1.1. Description of the Study Area

The study area Virudhunagar is located in southern part of Tamil Nadu state. It is spread across of 4243 sq.kms. It lies between $9^0$15'0"N to $9^0$44'0"N latitudes and $77^0$27'00"E to $78^0$17'0"E longitudes, in the state of Tamil Nadu (Figure 1.1). It is bounded by Madurai district on the north, Sivagangai district on the northeast, Ramanathapuram district on the southeast, Thoothukudi district to the south, Tirunelveli district to the southwest, Kerala state to the west, and Theni district to the northwest. The normal annual rainfall over the district varies from about 757 mm to 987 mm.

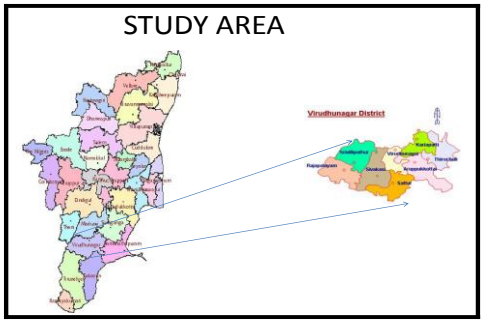

Figure 1.1: Study Area Location

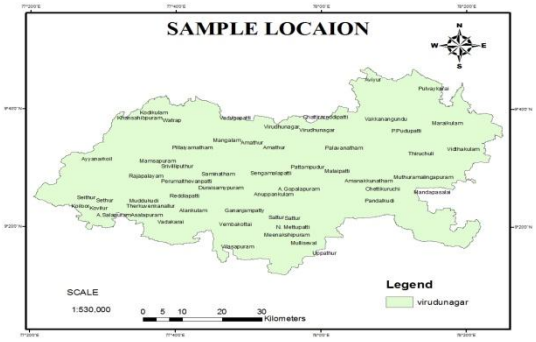

Figure 1.1a: Sample Location

2. Materials and Methods

The fluoride map was created for Virudhunagar district by using GIS software. Bore well and dug well water quality data are used to evaluate the fluoride level in pre-monsoon and post-monsoon period. Data acquisition involves with the collection of toposheet, water quality data, rainfall data and population census data for the study area. The spatial data of study area such as base map, land use, fluoride, and population were derived in the form of maps in the same scale using ArcGIS 9.3 land use map, fluoride map and population map. A total of 63 groundwater samples were collected from CGWB bore wells, dug wells etc (2). The geographical information of dug well and bore well has been changed degree minute to decimal degree. The amount of fluoride in drinking water in Virudunagar district was used as resource data to create the fluoride database by using Microsoft excel and access programs.

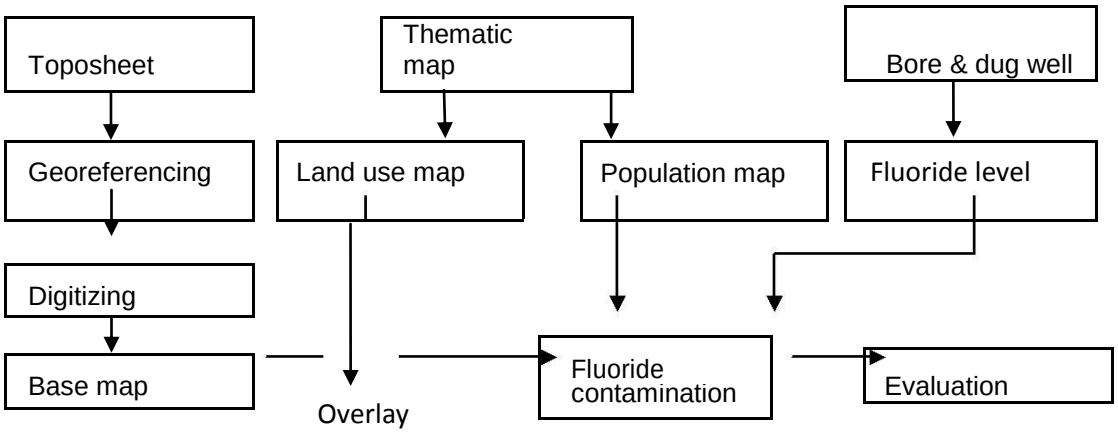

Figure 2.1: Methodology of the Study

The fluoride database was redesigned as relational database so that it can be linked to another database such as spatial data. GIS is a tool to define risk areas that require planning for fluorosis prevention program because of GIS's features and capability in model and data processing with attribute and spatial data (3). ARCGIS provides a broad range of powerful spatial modeling and analysis feature. GIS analysis perform integrate raster data and vector data analysis (4).Using the tools of spatial analysis, geo statistical analyses, & 3d analyst. Fluoride database is used and classified into 4 classes, it is linked together with spatial data to create map layout in GIS (5). According to WHO, 1971, permissible limit for fluoride in drinking water is 1.0 mg/l, whereas USPHS, 1962 has set a range of allowable concentrations for fluoride in drinking water for a region depending on its climatic conditions because the amount of water consumed and consequently the amount of fluoride ingested being influenced primarily by the air temperature.

Annual Average of Maximum Daily Air Temperature (◦C)	Recommended Fluoride Concentration (mg/l)			Maximum Allowable Fluoride Concentration (mg/l)
	Lower	Optimum	Upper	
10 – 12	0.9	1.2	1.7	2.4
12.1 – 14.6	0.8	1.1	1.5	2.2
14.7 – 17.7	0.8	1.0	1.3	2.0
17.8 – 21.4	0.7	0.9	1.2	1.8
21.5 – 26.2	0.7	0.8	1.0	1.6
6.3 – 32.5	0.6	0.7	0.8	1.4

Table 2.1: Fluoride Concentration Specified by WHO

Villages	TDS	NO3	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3	F	pH	EC	TH
N. Mettupatti	1982	68	184	199	196	17	748	221	0	226	0.2	8.0	3390	1280
A.Gopalapuram	642	29	110	27	78	2	106	24	0	329	0.5	8.0	1080	385
A.Salapuram	711	1	92	61	94	7	199	24	0	458	0.7	8.0	1340	480

All values are in mg/l, except pH and EC. Units of EC are mmho/cm

Table 2.2: Concentration of Chemical and Physical Parameters in Ground Water Pre-Monsoon Period

Villages	TDS	NO3	CA	MG	NA	K	CL	SO4	CO3	HCO3	F	PH	EC	TH
N. Mettupatti	1057	22	120	49	189	10	298	106	0	372	0.6	7.8	1800	500
A.Gopalapuram	487	17	98	10	64	1	60	27	6	244	0.6	8.4	810	285
A.Salapuram	659	1	66	51	115	5	195	27	0	390	0.7	7.7	1230	375

All values are in mg/l, except pH and EC. Units of EC are mmho/cm

Table 2.3: Concentration of Chemical and Physical Parameters in Ground Water Post-Monsoon Period

2.1. Study Area Population

Total population is 1,943,309 male and female were 967,437 and 975,872 respectively. Total area of Virudhunagar district was 4,283 with average density of 454 per sq.km. Virudhunagar population constituted 2.69 percent of total Tamil Nadu population. Average literacy rate of Virudhunagar in 2011 were 80.75. If things are looked out at gender wise, male and female literacy were 88.46 and 73.14 respectively. The sex ratio in Virudhunagar is at 1009 per 1000 male.

3. Results and Discussion

3.1. Fluoride Exposure Dose

The fluoride exposure doses were calculated by the following generic equation:

Exposure Dose = (C * WI) / BW Where, C — fluoride concentration (mg/l), WI — water intake (l/d), and BW — body weight (kg). For the calculation, it was assumed chronic exposure and total bioavailability of fluoride in water. The water intake of different age group was estimated to infants in their budding life drank 250 ml of boiled water per day, used in the reconstitution of milk formulas. In boiled water, fluoride level increases proportionally to the loss of volume, so the concentration of fluoride in tap water was doubled (6). The estimated water intake for children and adult was 1.5 and 3.0 l per day respectively. For the calculation, body weight of infants in the age group of 0 to 6 months was kept as 6 kg. Children between 7 year to adulthood as 20 kg body weight and that of adults above 19 years as 70 kg. The mean of minimum and maximum range of water fluoride level in each well was used for minimum and maximum exposure dose calculation.

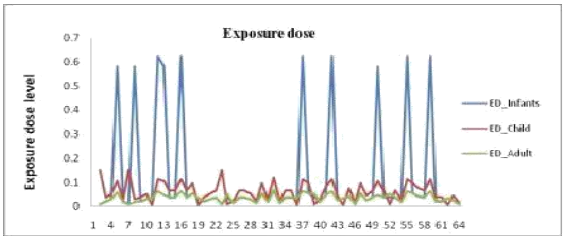

Figure 3.1: Pre-monsoon Exposure Dose

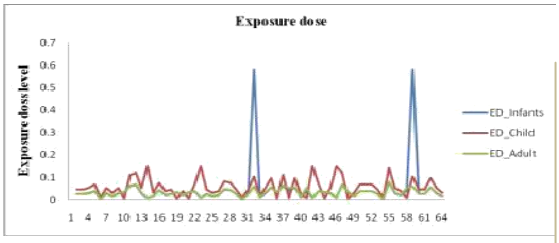

Figure 3.2: Post-monsoon Exposure Dose

3.2. Correlation

The correlation is one of the most common and most useful statistics. A correlation is a single number that describes the degree of relationship between two variables. Let's work through an example to show you how this statistic is computed.

Correlation Matrix: This is about to compute a correlation between two variables. In most studies we have considerably more than two variables. Let's say we have a study with 10 interval-level variables and we want to estimate the relationships among all of them (i.e., between all possible pairs of variables (7). A simple statistics program to generate random data for 10 variables with 20 cases for each variable. Then, to compute the correlations among these variables.

	TDS	*NO3*	*Ca*	*Mg*	*Na*	*K*	*Cl*	*SO4*	*CO3*	*HCO3*	*F*	*pH*	*EC*	*TH*
TDS	1													
NO3	0.7153	1												
Ca	0.838993	0.671852	1											
Mg	0.474055	0.65076	0.354648	1										
Na	0.959903	0.563747	0.707269	0.28872	1									
K	0.110596	0.311049	0.201041	0.101992	0.00855	1								
Cl	0.986678	0.690952	0.864342	0.491081	0.932928	0.08761	1							
SO4	0.954246	0.650816	0.76743	0.441786	0.924165	0.114121	0.910534	1						
CO3	0.71397	0.250354	0.599766	0.044265	0.771288	-0.07686	0.726026	0.654131	1					
HCO3	0.601155	0.311666	0.275447	0.178401	0.692272	-0.03409	0.514491	0.572054	0.397598	1				
F	0.170676	-0.05752	-0.03986	-0.03733	0.264137	-0.22779	0.107491	0.241433	0.060116	0.470379	1			
Ph	0.615423	0.20275	0.539317	0.189849	0.62881	-0.06082	0.648951	0.544188	0.784528	0.308242	0.035319	1		
EC	0.999059	0.717178	0.840206	0.501595	0.952863	0.101779	0.988346	0.950405	0.703158	0.600867	0.169137	0.615023	1	
TH	0.829178	0.80055	0.8825	0.752714	0.643197	0.192712	0.855581	0.762525	0.444334	0.283753	-0.04663	0.474915	0.843882	1

Table 3.1: Correlation Matrix for the Study Area Pre-monsoon

3.3. Fluoride Level

The concentration of fluoride above 1 mgl was observed in 13 wells and remaining wells in safe limit. The higher concentration is due to the over exploitation of the groundwater and the geological formation. The concentration of fluoride is mainly due to the rock water interaction. Recharging the groundwater in the higher concentration area may improve the groundwater quality.

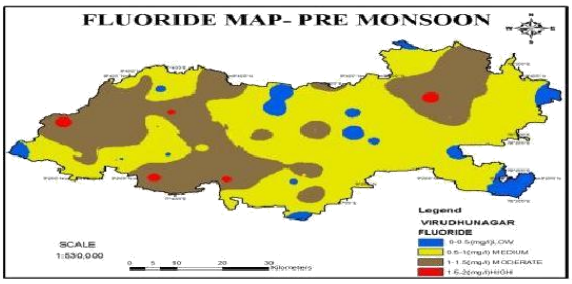

Figure 3.3: Pre-monsoon Fluoride Map

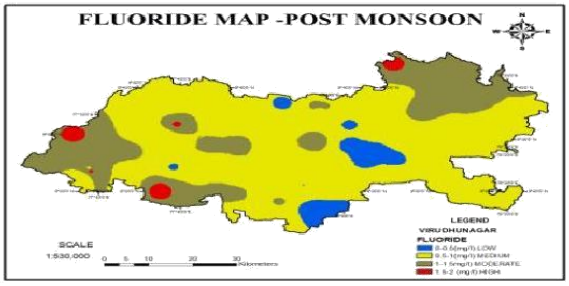

Figure 3.4: Post-monsoon Fluoride Map

3.4. Land Use

Major land use in the study area is covered by agriculture and forest. The different land use patterns identified were agriculture, forest, built-up area, water bodies and waste land. Samples were collected from the entire land use pattern in the pre-monsoon and the post-monsoon period (8). The table shows the samples of the land use the pattern.

3.5. Overlay

Overlays are another common cartographic modeling operation. An overlay is the primary way to combine information from two separate themes. Overlays are most common for polygonal data, and perform a geometric intersection, which results in a new layer with the combined attributes of both initial layers. The ArcGIS overlay analysis performed intersect between land use map and fluoride levels. These Alangulam, Chattirareddipatti, Khansahibpuram, Mamsapuram, Sattur, Srivilliputhur, and Subramaniyapuram have 0.5 range of low fluoride level in post-monsoon compare to pre-monsoon period.

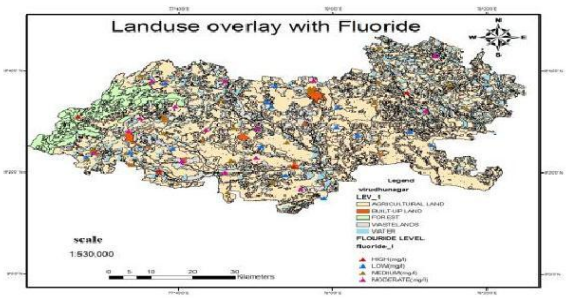

Figure 3.5 Land use pre-monsoon

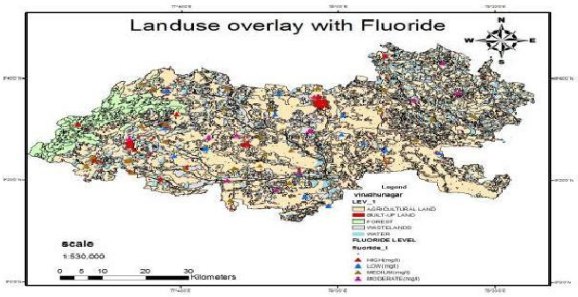

Figure 3.6 Land use post-monsoon

Period	Agriculture	Water Bodies	Forest	Waste Land	Built-up Land
Population percentage	52.2	0	0.44	0.16	46.6
Pre- monsoon samples	31	0	1	5	22
Pre-monsoon fluoride average	0.8	0	1.5	1.28	0.75
Post-monsoon samples	31	0	1	5	22
Post -monsoon fluoride average	0.8	0	1.6	0.8	0.609

Table 3.2: Land Use with Pre-monsoon and Post-monsoon Fluoride Level

4. Conclusion

The present geohydrological investigation was carried out with appropriate and state-of-the-art methodologies to meet the declared objectives. The work also integrates rainfall, land use, identifying the fluoride contamination region in the study area.

From the data interpretation very low rainfall in the winter season and high rainfall in the Northeast monsoon is observed. The study area samples chemical analysis shown fluoride is highly negative correlated with potassium and highly positive correlated with hydrogen carbonate. The correlation matrix shown the pre-monsoon period fluoride is correlated with potassium -0.222 and hydrogen carbonate correlate 0.47003 then post monsoon periods fluoride is correlated with potassium is -0.35206 and hydrogen carbonate is 0.238883.

The study was carryout in accordance with the declared methodology. The analysis was made in GIS for identifying the evaluation fluoride contamination region in the study area. The concentration of fluoride above 1 mg/l was observed in 21 samples in pre-monsoon 16 samples in post-monsoon and remaining samples in safe limit. The higher concentration is due to the over exploitation of the groundwater and the geological formation. The concentration of fluoride is mainly due to the rock water interaction. Recharging the groundwater in the higher concentration area may improve the groundwater quality. This study identified that 33% in pre-monsoon and 25% in post-monsoon in Virudhunagar district. Kavalur, Rajapalayam, Srivilliputtur, Vembakottai, Watrap blocks were highly affected, but the neighboring blocks are free from excess fluoride contamination in drinking water. People of all age groups are faced with higher risk of fluorosis in Virudhunagar district and infant's child and adults were highly affected in pre-monsoon period. In pre-monsoon period built-up areas are highly affected compare to post-monsoon period. Mapping of high fluoride areas are useful to plan and to bring safe drinking water from low fluoride areas.

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