

ISOPLETH MAPPING AND IN-SITU FLUORIDE DEPENDENCE ON WATER QUALITY IN THE KRISHNAGIRI BLOCK OF TAMIL NADU IN SOUTH INDIA

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SUMMARY: Drinking water samples from 255 villages in the Krishnagiri revenue block of Tamil Nadu in South India were analysed for fluoride and other water quality parameters. Fluoride endemic areas of the region were identified from the fluoride data and the prevalence of dental fluorosis. The high and low fluoride containing areas were located using the isopleth mapping technique. The dependence of fluoride on other drinking water quality parameters was assessed by simple and multiple correlation analysis.

Keywords: Dental fluorosis, Fluoride dependence, Fluoride water, India, Isopleth mapping, Krishnagiri block, Regression analysis, Tamil Nadu, Water quality.

INTRODUCTION

Dharmapuri district of Tamil Nadu in South India is reported to have drinking water containing high levels of fluoride as confirmed by the prevalence of dental fluorosis among the people of the villages in this region. It is of course well known that fluorosis is caused by the consumption of drinking water containing high fluoride.^{1,2} The prevalence of dental fluorosis in the villages of the Krishnagiri block of Dharmapuri district prompted us to determine the fluoride levels of all available drinking water sources in order to identify the fluoride endemic areas that require immediate adoption of remedial measures to prevent the problem of fluoride toxicity.

A total of 255 villages belonging to the 29 panchayats of Krishnagiri block of Dharmapuri district of Tamil Nadu in South India were included in this study. Drinking water samples from the 255 locations were analysed. The quality parameters tested include pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), chloride, sulphate, and fluoride. The water sources were generally found to be polluted. Nearly 50% of them have some quality parameters exceeding their rejection limits rendering them unfit for drinking and cooking.

Based on the fluoride content of water samples, the fluoride endemic villages in Krishnagiri block were identified. A survey with the help of qualified medical personnel was conducted among the people for physical verification of dental fluorosis. From the preliminary investigation, 58 villages of five panchayats were found to be fluoride endemic. This fact was supported by the prevalence of a high percentage of dental fluorosis in these villages. Mapping of these fluoride endemic villages was done using the isopleth technique, a statistical method. The dependence of each quality parameter with respect to one another was examined to understand the magnitude of pollution by correlation analysis of the experimental data. The results are explained in this paper.

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MATERIALS AND METHODS

Identification of fluoride endemic panchayats: A door-to-door survey was conducted among the primary and middle school children in the areas of study to determine the prevalence of dental fluorosis.³ Drinking water samples from all available sources of the study area were collected in precleaned, high density polyethylene bottles and were tested in the laboratory for the following quality parameters: pH, EC, TDS, TA, TH, Cl^- , SO_4^{2-} and fluoride (F^-). The fluoride content of these samples was determined using a fluoride ion selective electrode 9409, a reference electrode and an expandable ion analyser, EA 940 (Orion, USA make).⁴ The pH of the samples was determined using a pH electrode 9107 and an expandable ion analyser EA 940 (also Orion, USA). Electrical conductivity was measured using an Elico CM-180 conductivity meter, sulphate by the turbidimetric method⁵ using a Spectronic 20 (Bosch and Lomb, USA). The chloride, total alkalinity and total hardness were estimated by the Standard Methods for the examination of water and wastewater.⁵ Those panchayats having water sources containing high fluoride levels were classified as fluoride endemic.

Mapping of fluorotic areas: Based on the results of the fluoride levels of the water samples, a fluoride isopleth map of the region was prepared which is shown in Figure 1. Fluoride zones – regions containing high fluoride levels in their drinking water – were identified and distinguished by different shades depicting the fluoride levels.

Correlation studies: The fluoride data were correlated with those of other quality parameters of water from the five fluoride endemic areas. This correlation was limited to the five panchayats which showed maximum levels of fluoride in their water sources (above 4 mg/L). Simple and multiple regression analysis was done to determine the nature of correlation and significance of the quality parameters on fluoride content.

RESULTS AND DISCUSSION

Dental fluorosis and fluoride levels as indices of fluoride endemicity: The results of chemical analysis show that 39 villages of only 3 panchayats, namely, Mallinayanapalli, Periyamuthur, and Kallukuruki, contained water sources having fluoride within the tolerance limits. The remaining 216 villages, constituting 84.7%, had their drinking water sources contaminated with excessive fluoride. The door-to-door survey indicated the prevalence rate of dental fluorosis among the school going children of these villages to be between 65 and 70%. The water sources of these five panchayats contained exceedingly high fluoride levels, ranging up to 4.3 and 5.6 mg/L. Five ranges of fluoride levels in the water sources of the 29 panchayats are presented in Table 1.

Only 3 panchayats recorded fluoride levels within the tolerance limit of 0 - 1 mg/L. Eleven panchayats had fluoride in the range between 1 - 2 mg/L, seven 2 - 3 mg/L, three 3 - 4 mg/L, and five more than 4 mg/L. The five panchayats containing the highest fluoride levels are Kammampalli (1.00 - 5.1 mg/L),

Agasipalli (1.6 - 4.4 mg/L), Kattiganapalli (1.3 - 5.6 mg/L), Sökkadi (0.98 - 4.4 mg/L) and Jungipalli (2.3 - 4.3 mg/L). The rejection limit of fluoride according to the Bureau of Indian Standards is 1.5 mg/L.

Table 1. Water fluoride range in 29 panchayats

Sample grouping	Fluoride levels mg/L	Number of panchayats
1	0 - 1	3
2	1 - 2	11
3	2 - 3	7
4	3 - 4	3
5	> 4	5

While most of the chemical parameters were found to be within their respective rejection limits, the total alkalinity of nearly 57% of samples was above the rejection limit. About 20% of water sources contained hard waters with total hardness above 600 mg/L. Nearly 22% of samples have fluoride above 1.5 mg/L. The chemical parameters and the percentage of samples exceeding their rejection limits are given in Table 2. The fact that 22% of the samples contained fluoride above the rejection limit of 1.5 mg/L with a high prevalence of dental fluorosis among the children made it important to identify and map the fluoride endemic areas of Krishnagiri block by the isopleth technique.

Table 2. Quality parameters of water within and above the tolerance limits with percentage of samples

Parameter ^a	Tolerance limit (TL)	Rejection limit (RL)	Percent of samples		
			within TL	Below RL	Above RL
EC in S/cm	10 ³	-	72	-	-
TDS	500	1500	49	48	3
pH	7 - 8.5	6.5 - 9.2	100	-	-
TA	200	600	1	42	57
TH	200	600	2	78	20
Cl ⁻	200	1000	60	39	1
SO ₄ ²⁻	200	400	100	-	-
F ⁻	1.00	1.5	17	61	22

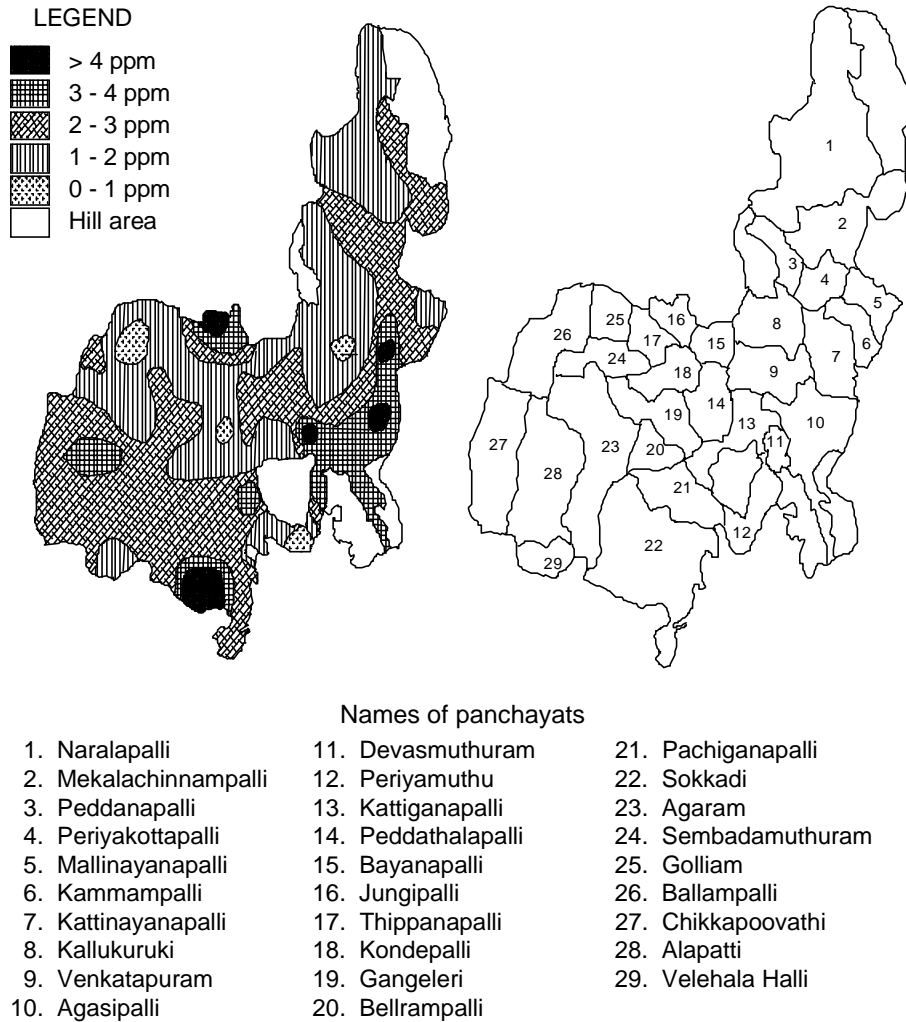
^aExcept pH all parameters are in mg/L.

Mapping of fluorotic areas: Fluoride endemic villages are located from the fluoride content of the water sources with 84.7% of samples containing fluoride above the tolerance limit. The areas with high fluoride are identified, and a map of the region distinguishing the relatively low and high fluoride endemic areas is drawn by the isopleth technique frequently used by geographers.⁶ This technique helps to interpolate lines of equal fluoride levels. Normally natural

data sets are represented by using this technique. The pre-requisite for employing this method is that the data should be natural and contiguous. The water samples are considered to be representative data points of the natural underground water table, and of course the reliability of the isopleth map increases with the number of data points. The areas of intensity can then be easily identified, thereby highlighting the details about the places for which data are neither collected nor generated.

Figure 1 represents the isopleth map showing the fluorotic zones of Krishnagiri block. The picture on the right shows the geographical demarcation of the 29 panchayats of the block. The isopleth map on the left divides the region into the different fluoride levels of the drinking water sources.

Figure 1. Fluorotic zones of Krishnagiri revenue block



The five priority panchayat areas are identified as the ones containing the maximum fluoride pollution. Such mapping of fluorotic areas helps in locating the regions that require immediate attention by the Government for remedial measures to minimize fluoride intoxication.

Influence of other quality parameters on fluoride: The interdependence of the quality parameters of the water samples was studied using linear regression analysis. The results are presented in Table 3.

Table 3. Correlation coefficient values of water quality parameters^a

Parameter	EC	TDS	pH	TA	TH	Cl ⁻	SO ₄ ²⁻	F ⁻
EC	i.	1.00	0.05	0.61	0.78	0.73	0.89	-0.28
	ii.	0.99	0.17	0.35	0.93	0.33	0.76	-0.45
	iii.	0.99	-0.33	0.06	0.97	0.97	0.86	-0.25
	iv.	1.00	0.11	0.59	0.93	0.92	0.52	0.10
	v.	0.99	-0.07	0.01	0.93	0.38	0.29	-0.86
TDS	i.		0.05	0.61	0.78	0.73	0.89	-0.28
	ii.		0.18	0.36	0.93	0.35	0.77	-0.43
	iii.		-0.33	0.06	0.97	0.97	0.87	-0.25
	iv.		0.11	0.59	0.93	0.92	0.52	0.10
	v.		-0.07	0.01	0.93	0.38	0.28	-0.86
pH	i.			0.63	-0.24	-0.17	0.25	-0.28
	ii.			0.12	0.10	0.43	0.33	0.04
	iii.			0.78	-0.46	-0.46	-0.54	0.50
	iv.			0.15	-0.02	0.12	-0.23	-0.19
	v.			-0.68	0.14	-0.20	0.66	0.29
TA	i.				0.20	0.18	0.65	0.19
	ii.				0.22	0.71	0.44	0.17
	iii.				-0.08	-0.08	-0.12	0.44
	iv.				0.46	0.47	0.41	0.11
	v.				0.05	0.07	-0.54	-0.37
TH	i.					0.62	0.65	-0.68
	ii.					0.20	0.69	-0.35
	iii.					0.96	0.85	-0.26
	iv.					0.91	0.62	0.09
	v.					0.17	0.29	-0.87
Cl ⁻	i.						0.59	-0.22
	ii.						0.48	0.12
	iii.						0.87	0.19
	iv.						0.66	0.19
	v.						0.60	-0.02
SO ₄ ²⁻	i.							-0.21
	ii.							-0.23
	iii.							-0.16
	iv.							0.05
	v.							0.18

^aThe small Roman numerals represent the five highest fluoride panchayats, viz., Kammampalli, Agasipalli, Kattiganapalli, Sökkadi, and Jungilpalli, respectively.

An overall positive correlation is evident in almost all cases between the concentration of fluoride ion with pH, Cl^- and total alkalinity. However, EC, TDS, TH, and SO_4^{2-} correlated negatively with fluoride concentration. A similar trend was observed by Garg *et al*⁷ in their study of fluoride in the ground waters of Haryana. Because the fluoride concentration in water depends on several contributing factors, we decided to apply multiple regression analysis to correlate the behaviour of the dependent factors of fluoride in the five fluoride endemic areas. The multiple regression analysis was done using the following relationships:

$$Y = C + m_1X_1 + m_2X_2 + m_3X_3 + \dots m_nX_n$$

$$F = C + m_1\text{TA} + m_2\text{TH} \quad (1)$$

$$F = C + m_1\text{TA} + m_2\text{TH} + m_3\text{pH} \quad (2)$$

Where:

F = fluoride ion concentration; TA = total alkalinity;

R^2 = Coefficient of determination (Regression constant);

TH = total hardness; C = constant; m_1 , m_2 and m_3 = co-efficients.

Using equations 1 and 2 separately the following results were obtained as indicated in Table 4.

Table 4. Results of multiple correlation analysis^a

Panchayat		No. of data	R^2	SE	m_1	m_2	m_3
Kammampalli	I	11	0.5780	0.81	0.0030	-0.0039	-
	II		0.5770	0.87	0.0029	-0.0039	0.1717
Agasiplli	I	10	0.1870	0.84	0.0013	-0.0021	-
	II		0.1890	0.88	0.0013	-0.0021	0.1710
Kattiganapalli	I	17	0.2460	1.18	0.0040	-0.0011	-
	II		0.2660	1.26	0.0019	-0.0006	1.3560
Sokkadi	I	15	0.0130	0.97	0.0004	0.0002	-
	II		0.0550	0.99	0.0007	0.0001	-1.1100
Jungilpalli	I	5	0.8730	0.39	-0.0020	-0.0041	-
	II		0.9450	0.37	-0.0007	-0.0044	-1.0680

^aI - Results obtained using equation 1. II - Results obtained using equation 2.

SE = Standard error.

The following conclusions are drawn from the multiple regression analysis:

- The positive sign of most of the coefficients of TA, Cl^- and pH suggest that they all have a direct influence on fluoride ion concentration.
- The magnitude of the coefficient of pH indicates that the contribution of pH on fluoride ions is high to the order of about 96%.

- The negative sign of all but one of the coefficient of TH indicates that TH has only an indirect impact on fluoride ion concentration.
- A slightly improved correlation of the contributing factors on fluoride was observed in multiple regression analysis compared to simple regression analysis (Table 3). This is attributed to the overall dependence of the concentration of fluoride ions on pH, TA, and TH of the water besides other environmental factors.

ACKNOWLEDGEMENT

This work was supported by a research grant from the Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, Government of India, New Delhi. The authors are grateful to Dr N D Mani and Mr C Sivaprakasam, Faculty of Rural Development, Gandhigram Rural Institute for the helpful discussions.

REFERENCES

- 1 Teotia SPS, Teotia, M. Endemic fluoride: bones and teeth - update. *Ind J Environ Toxicol* 1991;1:1-16.
- 2 Susheela AK, Kumar A, Bhatnagar M, Bahadur R. Prevalence of endemic fluorosis with gastrointestinal manifestation in people living in some north-Indian villages. *Fluoride* 1993;26:97-104.
- 3 Karthikeyan G, Anitha P, Apparao BV. Contribution of fluoride in water and food to the prevalence of fluorosis in areas of Tamil Nadu in South India. *Fluoride* 1996;29:151-5.
- 4 Fluoride electrode instruction manual, Orion Res. Inc., USA 1991.
- 5 Standard methods for the examination of water and wastewater, APHA, AWWA, WEF, 19th Edn. American Public Health Association, Washington, DC 20005, 1995.
- 6 Monkhouse FJ, Wilkinson HR. Maps and diagrams - their compilation and construction. B I Publications, New Delhi 1980, p. 39.
- 7 Garg VK, Sharma IS, Bishnoi MS. Fluoride in underground waters of Uklana town District Hisar, Haryana. *Pollution Research* 1998;17:149-52.