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# Fluoride Contaminated Water and its Implications on Human Health in Vellore District, Tamil Nadu, India

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**Abstract:** Occurrence of fluorine in ground water has drawn worldwide attention due to its considerable impact on human physiology. In the present study the fluoride concentration in underground water was determined in four panchayats of Vellore district of Tamil Nadu State (India) where it is the only source of drinking water. The other water quality parameters such as pH, electrical conductivity, total dissolved salts, total hardness, total alkalinity as well as sodium, potassium, calcium, magnesium, chloride and sulphate concentrations were also measured. The analytical results indicated considerable variations among the analyzed samples with respect to their chemical composition. The fluoride concentration in the underground water of these villages varied from 0.43 to 4.59 mg $L^{-1}$, causing dental and skeletal fluorosis. Overall water quality was found unsatisfactory for drinking purposes without any prior treatment. The prevalence of dental and skeletal fluorosis was determined among the people of Narasingapuram panchayat of Alangayam block, Vellore district, where the fluoride concentration in drinking water ranges from 2.35 to 4.59 ppm. The study further revealed that male individuals are more prone to dental and skeletal fluorosis than the female individuals.

**Key words:** Fluoride, fluorosis, ground water, vellore district, India

## Introduction

The quality of groundwater is very important in evaluating its utility in various fields such as domestic public water supply and agriculture. The assessment of the dissolved constituents thus become very important for safe drinking water. Some ions dissolved in water and present in appropriate concentration are essential for human beings while higher concentration results in toxicity.

Fluorine is the most electronegative of all elements and is physiologically more active than any other ion. Fluorine is never found free in nature. Fluorine in drinking water is totally in an ionic form and hence it rapidly, totally and passively passes through the intestinal mucosa and interferes with major metabolic activities of the living system. Fluorine is often called a two-edge sword.

The occurrence of fluoride in ground water has attracted attention globally, since it has considerable impact on human health. The major sources of fluoride in groundwater are fluoride-bearing rocks such as fluorspar, cryolite, fluorapatite and hydroxylapatite (Agarwal *et al*., 1997). The fluoride content in the groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, etc. (Chandra *et al*., 1981). Excess fluoride affects plants and animals also. The permissible limit for fluoride in drinking water is 1.5 mg $L^{-1}$ (WHO, 1984).

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The major health problems caused by fluoride exposure are dental fluorosis, teeth mottling, skeletal fluorosis and deformation of bones in children as well as in adults (Susheela *et al*., 1993). An estimated 62 million people in India residing in 17 states are affected with fluorosis (Susheela, 1999). According to a recent report, 3555 habitations have been identified as fluoride affected settlements spreading over the Vellore, Dharmapuri, Trichy, Karur, Salem, Namakkal, Erode, Coimbatore and Virudhunagar Districts of Tamil Nadu, India (Mariappan *et al*., 1999). Dental fluorosis occurs during tooth formation and becomes apparent upon eruption of the teeth. It ranges from very mild symmetrical whitish areas on the teeth to pitting of the enamel, frequently associated with brownish discoloration (DHHS, 1991). Skeletal fluorosis, in turn, is caused by a complex dose-related action of fluoride on bone. Fluoride increases bone formation and simultaneously decreases bone resorption. As a result of these effects, bone changes observed in people heavily exposed to fluoride ranges from osteosclerosis to exostosis formation of varying degrees (ATSDR, 1993).

The study was undertaken to assess the quality of underground water in four Panchayats in Vellore district, Tamil Nadu, India and to identify the prevalence of dental and skeletal fluorosis in Narasingapuram panchayat of Vellore district, Tamil Nadu, India.

## Materials and Methods

*Study area-Vellore District, Tamil Nadu, India*

The Geographical area constituting the present Vellore District is the second most populous district in Tamil Nadu. It lies between 12° and 13° 15′ of the northern latitude and 78° 2′ and 79° 50′ of eastern longitude. It slopes from East to West and the land in eastern part is flat. Generally the region has a long spell of hot climate with a short spell of rainy season and winter, which is mild one. Temperature is low during the month of January and the lowest average mean daily temperature is 21°C. The mean maximum daily temperature recorded during the hot season in the month of May is 38°C. The district received intermittent rainfall from the month of June to December, with occasional rains in other months.

*Analysis of Ground Water Samples*

Seventy ground water samples covering the entire area of Poongulam and Sowedakuppam Panchayats of Tirupattur block and Marimanikuppam and Narasingapuram Panchayats of Alangayam blocks of Vellore district, Tamilnadu were collected in precleaned 500 mL polythene bottles with air tight lids.

Parameters like total dissolved solids, total hardness and total alkalinity, sodium, potassium, calcium, magnesium, chloride, sulphate and nitrate were analysed according to American Public Health Association (APHA) 1989 standard methods.

The pH and electrical conductivity of the water were determined on site. The pH was measured using pH meter (Model No.524, Systronics (P) Ltd., Chennai). The conductivity was determined using the direct reading conductivity meter (Model No.304, Systronics (P) Ltd., Chennai). The TDS were calculated using a formula from the United States Salinity Laboratory, 1954. Sodium, potassium and calcium concentrations were determined using (ELICO CL-220) flame photometer. Total alkalinity and total hardness were measured by titrimetric method using standard sulfuric acid and standard EDTA solutions, respectively. Fluoride was analysed using orion ion analyser (Orion, 720-ise-fluorimeter, USA) with fluoride ion selective electrode. Sulphate was determined nephalometrically using ELICO CL-52 Nephalometer. Chloride was determined by argentometric titration method. Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS).

*Analysis for the Prevalence of Dental and Skeletal Fluorosis*

The people living in Narasingapuram Panchayat of Alangayam block of Vellore district, Tamil Nadu were selected for the present study, since they have a relatively high fluoride concentration (2.35 to 4.59 ppm) in their drinking water. A cross-sectional survey was done and a total of 391 children and adults were examined as per norms of the WHO (1970) for dental and skeletal fluorosis. For the evidence of dental fluorosis, teeth of children and adults of both sexes were examined in day time and recorded and graded the degree of dental fluorosis using Dean's (1934) index. Adults residing in these villages for more than 15 years were examined clinically for skeletal fluorosis. Simultaneously, radiological examination was conducted for further evidence of skeletal fluorosis.

*Statistical Analysis*

All the grouped data were statistically evaluated with SPSS/10 software. Hypothesis testing methods included one-way analysis of variance (ANOVA) followed by Least Significant Difference (LSD) test. p-values of less than 0.05 were considered to indicate statistical significance. All the results were expressed as mean±SD for six animals in each group.

## Results

Analytical data for the groundwater samples from Poongulam and Sowedakuppam Panchayats of Tirupathur block and Marimanikuppam Panchayat and Narasingapuram Panchayat of Vellore district were presented in Table 1-4.

*Hydrogen Ion Concentration*

The pH values of groundwater samples ranges from 7.10 to 8.10 in Poongulam Panchayat, 7.05 to 8.05 in Sowedakuppam Panchayat, 7.50 to 8.30 in Marimanikuppam Panchayat and 7.60 to 8.50 in Narasingapuram Panchayat. All the water samples collected from the four panchayats are slightly saline and they are within the permissible limit (6.5-9.2) according to WHO standards.

*Electrical Conductivity*

There was a large variation in electrical conductivity even in the samples collected from the same panchayat.

Table 1 Physico-chemical properties of groundwater at Poongulam Panchayat of Thirupattur Block

| Sample No. | pH | EC | TDS | TH | TAlk | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | Cl | $SO_4$ | $NO_3$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.15 | 420 | 500 | 131 | 160 | 65 | 35 | 165 | 20 | 52 | 14 | 9 | 1.2 |
| 2 | 7.10 | 810 | 700 | 290 | 290 | 130 | 72 | 125 | 2 | 42 | 12 | 15 | 1.50 |
| 3 | 7.40 | 930 | 295 | 565 | 304 | 70 | 61 | 132 | 10 | 60 | 18 | 35 | 1.75 |
| 4 | 7.80 | 730 | 570 | 172 | 240 | 92 | 65 | 98 | 16 | 110 | 17 | 27 | 0.90 |
| 5 | 7.20 | 510 | 1390 | 320 | 328 | 80 | 95 | 128 | 32 | 125 | 10 | 20 | 2.10 |
| 6 | 7.65 | 1405 | 1075 | 230 | 240 | 133 | 149 | 153 | 9 | 104 | 23 | 9 | 1.05 |
| 7 | 7.55 | 940 | 1165 | 155 | 300 | 120 | 103 | 181 | 8 | 128 | 31 | 12 | 0.98 |
| 8 | 7.25 | 575 | 950 | 403 | 372 | 165 | 84 | 96 | 12 | 190 | 29 | 8 | 2.31 |
| 9 | 7.90 | 950 | 1050 | 175 | 245 | 147 | 60 | 85 | 4 | 145 | 38 | 23 | 1.25 |
| 10 | 8.05 | 1400 | 535 | 440 | 180 | 288 | 149 | 190 | 7 | 152 | 37 | 18 | 0.95 |
| 11 | 7.15 | 450 | 465 | 240 | 260 | 71 | 84 | 50 | 3 | 130 | 35 | 15 | 3.86 |
| 12 | 7.25 | 935 | 1445 | 515 | 192 | 154 | 48 | 95 | 1 | 75 | 27 | 37 | 2.50 |
| 13 | 7.45 | 960 | 1220 | 276 | 248 | 170 | 56 | 130 | 5 | 105 | 56 | 48 | 0.95 |
| 14 | 7.05 | 820 | 1024 | 525 | 148 | 208 | 101 | 120 | 7 | 118 | 90 | 73 | 1.60 |
| 15 | 8.10 | 562 | 580 | 330 | 320 | 85 | 83 | 170 | 12 | 131 | 24 | 54 | 1.75 |
| 16 | 7.10 | 944 | 2475 | 198 | 215 | 108 | 79 | 187 | 10 | 78 | 50 | 20 | 1.15 |
| 17 | 7.25 | 1749 | 970 | 454 | 248 | 204 | 58 | 105 | 6 | 195 | 79 | 16 | 0.43 |

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

Table 2: Physico-chemical properties of groundwater at Sowedakuppam Panchayat of Thirupattur Block

| Sample No. | pH | EC | TDS | TH | TAlk | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | Cl | $SO_4$ | $NO_3$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.40 | 275 | 495 | 170 | 180 | 75 | 40 | 170 | 22 | 50 | 12 | 10 | 0.97 |
| 2 | 7.20 | 320 | 570 | 380 | 240 | 140 | 81 | 130 | 3 | 38 | 11 | 16 | 1.30 |
| 3 | 7.55 | 130 | 200 | 260 | 290 | 80 | 73 | 140 | 11 | 65 | 19 | 37 | 1.25 |
| 4 | 7.15 | 310 | 650 | 190 | 210 | 90 | 61 | 100 | 18 | 115 | 16 | 24 | 0.98 |
| 5 | 7.90 | 1100 | 1280 | 420 | 350 | 85 | 93 | 130 | 39 | 135 | 11 | 20 | 2.15 |
| 6 | 7.25 | 960 | 1150 | 240 | 245 | 130 | 150 | 160 | 11 | 110 | 21 | 9 | 0.99 |
| 7 | 8.05 | 1085 | 1480 | 380 | 360 | 140 | 120 | 183 | 7 | 130 | 33 | 11 | 1.15 |
| 8 | 7.90 | 550 | 996 | 298 | 315 | 155 | 90 | 98 | 14 | 180 | 30 | 9 | 3.05 |
| 9 | 7.10 | 904 | 1090 | 460 | 245 | 148 | 70 | 87 | 6 | 155 | 35 | 21 | 2.50 |
| 10 | 7.25 | 1020 | 1650 | 240 | 150 | 280 | 150 | 195 | 9 | 150 | 29 | 19 | 1.50 |
| 11 | 7.15 | 650 | 880 | 380 | 280 | 81 | 89 | 55 | 5 | 120 | 36 | 17 | 1.30 |
| 12 | 7.45 | 185 | 560 | 250 | 160 | 156 | 50 | 98 | 2 | 80 | 28 | 35 | 1.50 |
| 13 | 7.85 | 470 | 890 | 320 | 170 | 180 | 54 | 140 | 7 | 115 | 51 | 41 | 1.30 |
| 14 | 7.10 | 490 | 885 | 178 | 255 | 210 | 121 | 130 | 11 | 117 | 93 | 72 | 2.25 |
| 15 | 7.15 | 140 | 460 | 221 | 260 | 90 | 80 | 180 | 9 | 139 | 21 | 58 | 0.98 |
| 16 | 7.30 | 1810 | 2130 | 340 | 290 | 110 | 75 | 90 | 8 | 80 | 55 | 21 | 1.31 |
| 17 | 7.05 | 580 | 930 | 290 | 250 | 201 | 60 | 110 | 7 | 75 | 74 | 19 | 1.20 |

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

Table 3 Physico-chemical properties of groundwater at Marimanikuppam Panchayat of Alangayam Block

| Sample No. | pH | EC | TDS | TH | TAlk | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | Cl | $SO_4$ | $NO_3$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.90 | 1420 | 550 | 120 | 190 | 50 | 28 | 190 | 32 | 55 | 14 | 12 | 1.04 |
| 2 | 8.10 | 350 | 780 | 310 | 250 | 110 | 68 | 150 | 5 | 42 | 13 | 18 | 2.56 |
| 3 | 7.80 | 1730 | 3240 | 215 | 310 | 40 | 42 | 160 | 16 | 71 | 21 | 40 | 3.24 |
| 4 | 8.15 | 330 | 780 | 160 | 280 | 60 | 38 | 120 | 20 | 120 | 18 | 26 | 2.31 |
| 5 | 8.20 | 1000 | 1310 | 380 | 400 | 50 | 75 | 150 | 45 | 140 | 13 | 22 | 3.10 |
| 6 | 7.80 | 1005 | 1460 | 210 | 290 | 110 | 130 | 180 | 15 | 112 | 24 | 10 | 1.75 |
| 7 | 8.30 | 1095 | 1590 | 280 | 410 | 105 | 98 | 195 | 9 | 135 | 36 | 13 | 1.10 |
| 8 | 8.10 | 980 | 1050 | 175 | 330 | 145 | 62 | 10 | 18 | 190 | 32 | 10 | 1.25 |
| 9 | 7.80 | 940 | 1120 | 360 | 280 | 128 | 40 | 99 | 9 | 170 | 40 | 23 | 1.56 |
| 10 | 8.20 | 360 | 780 | 110 | 180 | 190 | 125 | 205 | 12 | 160 | 35 | 21 | 2.27 |
| 11 | 8.10 | 1330 | 920 | 270 | 300 | 53 | 85 | 75 | 7 | 130 | 42 | 19 | 1.60 |
| 12 | 7.90 | 340 | 640 | 180 | 260 | 130 | 32 | 110 | 4 | 90 | 32 | 40 | 2.75 |
| 13 | 8.30 | 680 | 930 | 210 | 210 | 190 | 44 | 160 | 9 | 120 | 55 | 44 | 2.56 |
| 14 | 7.50 | 770 | 980 | 128 | 280 | 180 | 105 | 150 | 13 | 122 | 98 | 75 | 1.58 |
| 15 | 7.90 | 1240 | 1570 | 168 | 190 | 68 | 70 | 200 | 12 | 145 | 25 | 60 | 1.75 |
| 16 | 8.10 | 1110 | 2150 | 280 | 310 | 96 | 55 | 105 | 10 | 85 | 60 | 25 | 1.80 |
| 17 | 8.30 | 570 | 990 | 140 | 305 | 187 | 40 | 120 | 13 | 80 | 80 | 22 | 2.75 |
| 18 | 8.20 | 270 | 680 | 180 | 280 | 173 | 90 | 160 | 12 | 95 | 90 | 24 | 3.15 |

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

Table 4: Physico-chemical properties of groundwater at Narasingapuram Panchayat of Alangayam Block

| Sample No. | pH | EC | TDS | TH | TAlk | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | Cl | $SO_4$ | $NO_3$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.10 | 210 | 575 | 110 | 210 | 45 | 25 | 200 | 40 | 58 | 16 | 15 | 2.35 |
| 2 | 8.50 | 340 | 800 | 250 | 260 | 90 | 60 | 160 | 10 | 45 | 18 | 22 | 2.50 |
| 3 | 8.15 | 110 | 300 | 200 | 330 | 20 | 38 | 175 | 20 | 73 | 25 | 45 | 2.75 |
| 4 | 8.20 | 250 | 790 | 110 | 300 | 35 | 20 | 135 | 25 | 121 | 20 | 28 | 3.05 |
| 5 | 7.90 | 920 | 1400 | 300 | 450 | 25 | 60 | 160 | 50 | 141 | 19 | 26 | 3.15 |
| 6 | 8.20 | 930 | 1500 | 215 | 305 | 100 | 110 | 190 | 25 | 122 | 26 | 12 | 2.41 |
| 7 | 7.80 | 850 | 1150 | 210 | 420 | 140 | 78 | 210 | 12 | 136 | 38 | 16 | 2.60 |
| 8 | 8.10 | 870 | 1200 | 150 | 350 | 120 | 50 | 120 | 22 | 210 | 34 | 15 | 4.59 |
| 9 | 8.30 | 2100 | 3790 | 160 | 305 | 110 | 20 | 105 | 11 | 180 | 45 | 26 | 2.41 |
| 10 | 8.20 | 520 | 940 | 100 | 195 | 140 | 110 | 225 | 6 | 165 | 39 | 24 | 2.38 |
| 11 | 7.60 | 200 | 700 | 260 | 315 | 40 | 80 | 80 | 13 | 135 | 44 | 21 | 2.50 |
| 12 | 8.30 | 875 | 1080 | 160 | 270 | 120 | 30 | 120 | 6 | 105 | 35 | 45 | 4.31 |
| 13 | 8.10 | 810 | 1100 | 190 | 215 | 160 | 35 | 190 | 14 | 125 | 58 | 50 | 2.35 |
| 14 | 8.20 | 1001 | 1600 | 120 | 290 | 150 | 100 | 160 | 18 | 129 | 100 | 80 | 2.32 |
| 15 | 8.15 | 1300 | 2300 | 158 | 210 | 42 | 60 | 230 | 15 | 148 | 30 | 70 | 4.01 |
| 16 | 8.35 | 855 | 1150 | 170 | 340 | 80 | 40 | 108 | 11 | 89 | 70 | 28 | 3.15 |
| 17 | 8.10 | 2005 | 3300 | 120 | 325 | 162 | 30 | 130 | 16 | 90 | 90 | 30 | 2.20 |
| 18 | 8.40 | 1995 | 3150 | 135 | 295 | 154 | 70 | 180 | 18 | 98 | 95 | 35 | 2.80 |

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

*Total Dissolved Solids (TDS)*

The values of TDS of groundwater samples ranges from 295 to 2475 in Poongulam Panchayat, 200 to 2130 in Sowedakuppam Panchayat, 550 to 3240 in Marimanikuppam Panchayat and 300 to 3300 in Narasingapuram Panchayat. According to a salinity classification, groundwater was non-saline at 36 locations, slightly saline at 30 locations and moderately saline at 4 locations (Table 5).

*Total Hardness (TH)*

The total hardness of groundwater samples ranges from 131 to 565 in Poongulam Panchayat, 170 to 460 in Sowedakuppam Panchayat, 120 to 360 in Marimanikuppam Panchayat and 110 to 300 in Narasingapuram Panchayat. According to Durfor and Backers (1964) classification of total hardness, water was moderately hard at 7 locations, hard at 19 locations and very hard at 44 locations. Almost all the water samples are hard (Table 6).

*Total Alkalinity (Talk)*

The total alkalinity of groundwater samples ranges from 160 to 372 in Poongulam Panchayat, 180 to 360 in Sowedakuppam Panchayat, 190 to 410 in Marimanikuppam Panchayat and 210 to 450 in Narasingapuram Panchayat. The WHO acceptable limit for alkalinity in drinking water is 200 mg $L^{-1}$. In all the water samples from Narasingapuram panachayat, the total alkalinity was higher than acceptable limit.

*Calcium (Ca)*

The calcium content of groundwater samples ranges from 65 to 288 in Poongulam Panchayat, 75 to 280 in Sowedakuppam Panchayat, 50 to 190 in Marimanikuppam Panchayat and 45 to 162 in Narasingapuram Panchayat. The calcium content was found to be lower and inversely related to fluoride in the water samples collected from four panchayats. The calcium content was very low in Narasingapuram panchayat than in other panchayats.

*Magnesium (Mg)*

The magnesium content of groundwater samples ranges from 35 to 149 in Poongulam Panchayat, 40 to 150 in Sowedakuppam Panchayat, 28 to 130 in Marimanikuppam Panchayat and 25 to 110 in Narasingapuram Panchayat. The magnesium content was found to be lower and had negative correlation with fluoride in the water samples collected from four panchayats. Magnesium content was very low in Narasingapuram panchayat.

*Sodium (Na)*

The sodium content of groundwater samples ranges from 95 to 187 in Poongulam Panchayat, 55 to 183 in Sowedakuppam Panchayat, 75 to 205 in Marimanikuppam Panchayat and 80 to 230 in Narasingapuram Panchayat. Sodium was higher than the WHO acceptable limit of 50 mg $L^{-1}$ in all the water samples. There was a high sodium content in Narasingapuram panchayat.

Table 5: Classification of the water samples of Thirupattur and Alangayam Blocks on the basis of total dissolved salts

| Sample No. | Classification of ground water | Total dissolved salts (mg $L^{-1}$) | No. of Samples |
|---|---|---|---|
| 1 | Non saline | <1,000 | 36 |
| 2 | Slightly saline | 1,000-3,000 | 30 |
| 3 | Moderately saline | 3,000-10,000 | 4 |
| 4 | Very saline | > 10,000 | - |

Table 6: Classification of the water samples of Thirupattur and Alangayam Blocks of Vellore district on the basis of total hardness

| Sample No. | Description | Hardness s(mg L) | No. of Samples |
|---|---|---|---|
| 1 | Soft | 0-60 | - |
| 2 | Moderately hard | 61-120 | 7 |
| 3 | Hard | 121-180 | 19 |
| 4 | Very hard | > 180 | 44 |

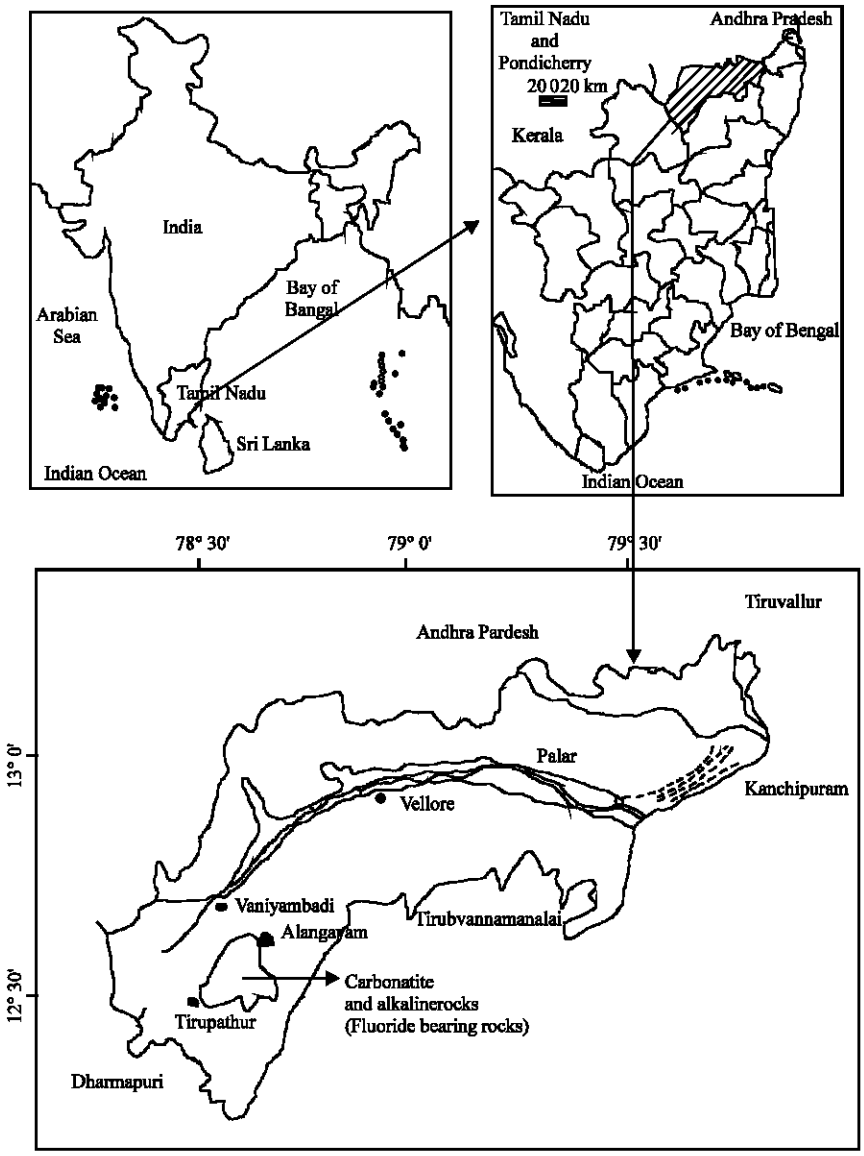


Fig. 1: Location map of the study area

*Potassium (K)*

The potassium level of ground water sample ranges from 1 to 32 in Poongulam Panchayat, 2 to 39 in Sowedakuppam Panchayat, 5 to 45 in Marimanikuppam Panchayat, 10 to 50 in Narasingapuram Panchayat. There was positive correlation between fluoride and potassium in all the four panchayats. High potassium level was found in Narasingapuram Panchayat.

*Chloride (Cl)*

The chloride concentration of groundwater samples ranges from 42 to 195 in Poongulam Panchayat, 38 to 180 in Sowedakuppam Panchayat, 42 to 190 in Marimanikuppam Panchayat and

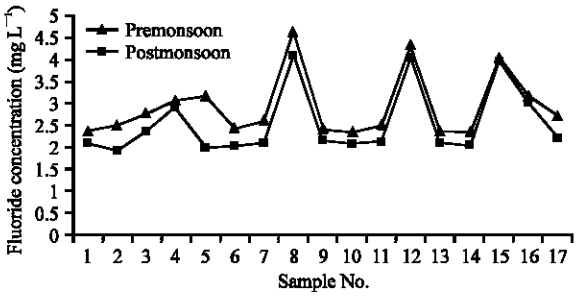


Fig. 2: Seasonal variation of fluoride concentration in Narasingapuram Panchayat

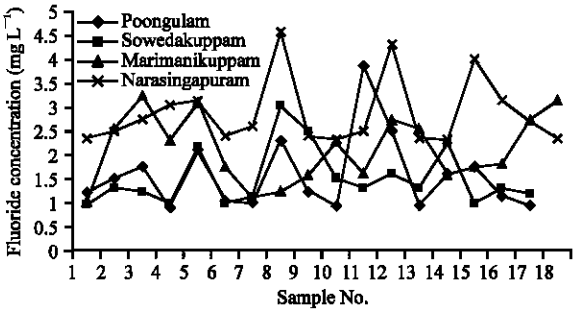


Fig. 3: Fluoride concentration of groundwater samples in the four panchayats as compared to the maximum allowable limit for drinking water in India

45 to 210 in Narasingapuram Panchayat. There was a positive correlation between fluoride and chloride in all the four panchayats. The level of chloride was found to be high in Narasingapuram Panchayat.

*Sulphate ($SO_4$)*

The sulphate concentration of groundwater samples ranges from 10 to 90 in Poongulam Panchayat, 11 to 93 in Sowedakuppam Panchayat, 13 to 98 in Marimanikuppam Panchayat and 16 to 95 in Narasingapuram Panchayat. High level of sulphate was found in Narasingapuram Panchayat.

*Nitrate ($NO_3$)*

The nitrate content of groundwater samples ranges from 8 to 73 in Poongulam Panchayat, 9 to 72 in Sowedakuppam Panchayat, 10 to 75 in Marimanikuppam Panchayat and 12 to 80 in Narasingapuram Panchayat. Nitrate content was found to be higher in Narasingapuram panchayat than the other panchayats.

*Fluoride ($F^-$)*

The location map of the study area (Fig. 1) shows that the groundwater fluoride content was higher in Tirupattur and Alangayam blocks of Vellore district, than others. At most of the locations, fluoride concentrations was higher than the permissible limit as evidenced in Fig. 2. The fluoride concentration of groundwater samples ranges from 0.90 to 3.86 in Poongulam Panchayat, 0.97 to 3.05 in Sowedakuppam Panchayat, 1.04 to 3.24 in Marimanikuppam Panchayat and 2.32 to 4.59 in Narasingapuram Panchayat. The fluoride concentration above the permissible limit (1.5 mg $mL^{-1}$ according to WHO standards) in all the samples from Narasingapuram panchayat. The seasonal comparison of fluoride concentration in water samples of Narasingapuram panchayat was indicated in Fig. 3. It is observed that the fluoride concentration is comparatively low in post monsoon than in pre monsoon.

Table 7: Incidence and severity of dental fluorosis in Narasingapuram panchayat of Alangayam Subdivision, Vellore district, Tamil Nadu, India

| Age group, (years) | No. of individuals examined | Total No. Affected | No. with dental fluorosis | | |
|---|---|---|---|---|---|
| | | | Mild | Moderate | Severe |
| Males | | (72.0)[a] | | | |
| 7 – 9 | 21 | 13 (61.9) | 8 (61.5) | 2 (15.3) | 3 (23.0) |
| 10-12 | 19 | 16 (84.2) | 8 (50.0) | 5 (31.3) | 3 (18.8) |
| 13-15 | 23 | 11 (47.8) | 7 (63.6) | 3 (27.3) | 1 (9.0) |
| 16-20 | 25 | 13 (52.0) | 6 (46.2) | 4 (30.8) | 3 (23.0) |
| 21-30 | 15 | 10 (66.7) | 6 (60.0) | 3 (30.0) | 1 (10.0) |
| 31-40 | 27 | 20 (74.0) | 10 (50.0) | 6 (30.0) | 4 (20.0) |
| 41-50 | 30 | 28(93.3) | 13 (46.4) | 8 (28.6) | 7 (25.0) |
| > 50 | 44 | 36 (81.8) | 20 (55.6) | 13 (36.1) | 3 (18.3) |
| Total | 204 | 147 | 78 | 44 | 25 |
| Females | | (50.8)[a] | | | |
| 7 – 9 | 18 | 7 (38.8) | 4 (57.1) | 2 (28.6) | 1 (14.2) |
| 10-12 | 16 | 8 (50.0) | 4 (50.0) | 3 (37.5) | 1 (12.5) |
| 13-15 | 20 | 9 (45.0) | 5 (55.6) | 3 (33.3) | 1 (11.1) |
| 16-20 | 21 | 11 (52.4) | 6 (54.5) | 4 (36.4) | 1 (9.0) |
| 21-30 | 19 | 8 (42.1) | 5 (62.5) | 2 (25.0) | 1 (12.5) |
| 31-40 | 24 | 10 (41.6) | 5 (50.0) | 4 (40.0) | 1 (10.0) |
| 41-50 | 30 | 16 (53.3) | 7 (43.7) | 6 (37.5) | 3 (18.7) |
| > 50 | 39 | 26 (66.6) | 15 (57.6) | 8 (30.7) | 3 (11.5) |
| Total | 187 | 95 | 51 | 32 | 12 |

[a]Figures in parenthesis indicate percentage

Table 8: Incidence and severity of skeletal fluorosis in Narasingapuram Panchayat of Alangayam Block, Vellore district

| Age Group (years) | No. of individuals examined | Total No. of individuals affected with skeletal fluorosis | Individuals affected | | |
|---|---|---|---|---|---|
| | | | Grade I | Grade II | Grade III |
| Male | | (4.4)[a] | | | |
| 7-9 | 21 | - | - | - | - |
| 10-12 | 19 | - | - | - | - |
| 13-15 | 23 | - | - | - | - |
| 16-20 | 25 | - | - | - | - |
| 21-30 | 15 | 2 (13.3) | 1 (50.0) | 1 (50.0) | - |
| 31-40 | 27 | 2 (13.3) | 1 (50.0) | 1 (50.0) | - |
| 41-50 | 30 | 2 (6.6) | 1 (50.5) | 1 (50.0) | - |
| > 50 | 44 | 5 | 2 (40.0) | 2 (40.0) | 1 (20.0) |
| Total | 204 | 9 | 4 | 4 | 1 |
| Female | | (3.2)[a] | | | |
| 7-9 | 18 | - | - | - | - |
| 10-12 | 16 | - | - | - | - |
| 13-15 | 20 | - | - | - | - |
| 16-20 | 21 | - | - | - | - |
| 21-30 | 19 | - | - | - | - |
| 31-40 | 24 | 1 (4.16) | 1 (100.0) | - | - |
| 41-50 | 30 | 2 (6.6) | 1 (50.0) | 1 (50.0) | - |
| > 50 | 39 | 3 (7.6) | 2 (66.7) | 1 (33.3) | - |
| Total | 187 | 6 | 4 | 2 | - |

[a]Figures in parenthesis indicate percentage

*Dental and Skeletal Fluorosis*

The incidence and severity of dental fluorosis among different age groups and sex groups of Narasingapuram Panchayat (Table 7) revealed that between the two sexes, 72.1% males were affected with dental fluorosis as compared to only about 50.8%, females which showed that males are more vulnerable as compared to females (Table 7). The incidence and severity of skeletal fluorosis among different age groups and sex groups of Narasingapuram panchayat (Table 8) revealed that between the

Table 9: Prevalence of symptoms and findings on physical examination of 240 patients with dental fluorosis in Narasingapuram panchayat of Alangayam block, Vellore district

| Symptoms | No. of patients (%) |
|---|---|
| White areas | 129 (32.9) |
| Brown spots | 78 (19.9) |
| White spread brown stains and pitting | 33 (8.4) |

Table 10: Prevalence of symptoms and findings on physical examination of 15 patients with skeletal fluorosis in Narasingapuram panchayat of Alangayam block, Vellore district

| Symptoms | No. of patients (%) |
|---|---|
| Low back pain | 14 (93.3) |
| Joint pains | 12 (80.0) |
| Pain in legs | 13 (86.6) |
| Loss of appetite | 9 (60.0) |
| Constipation/diarrhea | 7 (46.6) |
| Neurological manifestations | 1 (6.6) |

two sexes, 4.4% males were affected with skeletal fluorosis as compared to only about 3.2% females which showed that males are more vulnerable as compared to females. About 9.8% of the males and 6.4% of the females were affected with both dental and skeletal fluorosis.

Table 9 and 10 shows the prevalence of symptoms and findings on physical examination of patients with dental and skeletal fluorosis in Narasingapuram panchayat of Alangayam block, Vellore district.

## Discussion

Majority of the groundwater samples in the Alangayam block have high fluoride content which are characterized by high pH and this indicates that alkaline environment is more favoured for fluoride concentration. The calcium content in Alangayam block is very low. Calcium content of water in which alkalinity is in excess of hardness is kept low by early precipitation of calcite (Vergouwen, 1981). In such waters where calcium is virtually eliminated, the rise of fluoride content during evaporation is not checked by the formation of fluorite. In dry periods fluoride rich salts will temporarily precipitate in the top layers of soil. These salts are re-dissolved by rains and thus constitute a semi permanent reservoir of easily dissolvable fluorine (Prem Babu, 2004). When groundwater reacts with the silicate minerals like labradorite, a major mineral in basalt, during percolation, sodium ion is released. Dominant sodium ion and basicity of water provide favourable condition for migration of fluorine from rocks and its concentration in water. The water samples in Alangayam block have high concentration of sodium. When concentration of sodium in water increases, its solubility increases correspondingly and it diverts more fluorine into water. Basicity of water, control leaching of fluorine from rocks on one side and promote precipitation of Ca as $CaCO_3$ on the other hand. The lack of calcium in water thus decrease chance of calcium fluoride ($CaF_2$) precipitation and create sodium fluoride salts in soil, which has high solubility and gets dissolved in the next rainy season releasing fluorine. Alternate dry and rainy seasons results in frequent transfer and exchange of soluble salts between soil and groundwater (Ramamohana Rao *et al*., 1993).

The greatest contribution of nitrate in groundwater is decaying organic matter, sewage and fertilizer. As such high concentration of nitrate is found in Alangayam block. The high value of nitrate in study area might be due to excessive use of nitrogen rich fertilizers in the area. The high salinity as well as high conductivity might be on account of precipitation of salt in groundwater. The precipitation of salt to a great extent is being caused by over-saturation of the top soil on account of availability of water in plenty. The fluoride concentration in Narasingapuram panchayat is comparatively low in post-monsoon than premonsoon which is due to dilution from rain water. The high fluoride groundwater in many parts of India is formed through evapotranspiration of groundwater with residual alkalinity.

In India, dental fluorosis has been previously described in human beings ingesting 0.5 ppm and 0.9-1.0 ppm fluoride in drinking water (Ray *et al*., 1981), while at concentration of 3.4 to 3.8 ppm, 100% dental fluorosis has been reported (Choubisa *et al*., 1996). From Rajasthan, 89.3% with dental fluorosis at 7.6 ppm and 100% at 3.8-50 ppm fluoride concentrations have been observed (Choubisa and Sompura, 1996). In the present study 72.1% of children and adult males revealed enamel mottling at 4.59 ppm. This suggests that the prevalence and occurrence of fluoride toxicity can vary widely between different geographical locations having almost the same fluoride concentration in drinking water. Besides water fluoride concentration and duration of exposure, other factors, such as dissolved salts in drinking waters, nutrition and habits (WHO, 1970), also affect the prevalence of dental fluorosis. In addition to these factors, age, health, stress factors, biological response of individuals, local environment factor (humidity and temperature), involvement of number of fluoridated food chains and frequency of intake of fluoride may also accelerate the prevalence and severeness of fluoride toxicity.

Several workers have reported skeletal and crippling fluorosis at fluoride levels above 1 and 3 ppm, respectively (Choubisa *et al*., 2001). Moreover, other deformities have also been observed in endemic areas of fluorosis. In India, southern states (Andhra Pradesh, Karnataka and Tamil Nadu) and middle region (Madhya Pradesh), where skeletal fluorosis is hyperendemic, cases of genu-valgum deformity along with oseteoporosis of long bone have been reported (Chakama *et al*., 1997).

As fluoride concentration in drinking water increase, the prevalence of skeletal fluorosis affecting lower age group increase also. However, there are varying prevalence of skeletal fluorosis in those villages where fluoride level is almost identical due to sex, age and occupation (WHO, 1970). The proportion of males affected by fluorosis was slightly but significantly higher than the proportion of females. One possible explanation for this might be that men drink more water than women to compensate for fluid loss during field work. They also drink relatively more local wine and tea, both of which can increase fluoride intake. The lower prevalence or proportion of women with fluorosis may result, in part, from an influx of women into the villages on marriage, from areas where fluorosis is not endemic. A high prevalence and severity of skeletal fluorosis in higher age group is almost certainly due to longer exposure to F.

## Conclusions

The high fluoride concentration in groundwater of Narasingapuram panchayat is mainly from leaching from rocks and soils. The favourable factors which contributed to rise of fluoride in groundwater are the presence of fluoride bearing minerals in rocks and soil, low calcium and magnesium and high sodium and potassium of groundwater. The risk to the health of people living in the high fluoride area needs to be checked by conducting regular health check up and necessary remedial measures have to be provided to them.

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