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Original Research Article

PREVALENCE AND DETERMINANTS OF FLUOROSIS AMONG RURAL POPULATIONS IN THENI DISTRICT, TAMIL NADU: A COMMUNITY-BASED CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Endemic fluorosis has remained a significant public health concern in India due to prolonged exposure to elevated fluoride levels in drinking water, leading to dental, skeletal, and non-skeletal manifestations. Several districts of Tamil Nadu, including Theni district, have been identified as fluoride-endemic zones. Rural populations are particularly vulnerable due to dependence on groundwater sources. Identification of endemic areas and assessment of disease burden were considered essential for planning preventive and remedial public health interventions. This study was undertaken to estimate the prevalence of fluorosis and its determinants thereby estimating the fluoride levels in drinking water across villages of Aundipatti Community Development Block.

Materials and Methods: A community-based cross-sectional analytical study was conducted in all 18 villages of Aundipatti Community Development Block, Theni district, Tamil Nadu, over a two-year period from May 2018 to April 2020. A multistage clustered sampling technique was employed. In the first stage, villages were selected using Probability Proportional to Size (PPS) sampling, followed by systematic random sampling of households within each selected cluster. Data were collected after obtaining verbal consent using a pre-designed interviewer-administered questionnaire covering socio-demographic details, drinking water sources, dietary patterns, and clinical features suggestive of fluorosis. Clinical examination was performed to identify dental, skeletal, and non-skeletal fluorosis using standard case definitions. Drinking water samples were collected in pre-cleaned containers and analysed on the same day for fluoride concentration using the SPADNS spectrophotometric method at the MDRU laboratory, GTMCH, Theni. Data were entered in Microsoft Excel and analysed using Epi info version 7.2. Descriptive statistics and inferential analyses, including logistic regression, were performed, with a p-value <0.05 considered statistically significant.

Results: Fluorosis of at least one type was identified in 132 participants, yielding an overall prevalence of 22.6%. Dental fluorosis was observed in 15.6%, non-skeletal fluorosis in 14.5%, and skeletal fluorosis in 1.7% of participants. Fluoride levels between 1.5 and 3.0 mg/L were detected in 23.1% of drinking water samples. Multivariate analysis revealed that higher drinking water fluoride levels (OR = 3.27; 95% CI: 2.09–5.09), absence of water purification (OR = 3.85; 95% CI: 2.29–6.49), use of fluoridated toothpaste (OR = 3.59; 95% CI: 2.19–5.89), and higher socioeconomic status were independently associated with fluorosis.

Conclusion: The study findings emphasize the need for routine monitoring of drinking water fluoride levels, early detection of fluorosis, and implementation of preventive strategies such as provision of safe drinking water and community-based awareness programs.

Keywords: Fluorosis, Drinking water fluoride, Dental fluorosis, Skeletal Fluorosis, Rural population.

INTRODUCTION

Endemic fluorosis is a chronic condition resulting from prolonged ingestion or inhalation of fluoride at levels exceeding the body's tolerance. The World Health Organization has estimated that approximately 260 million people worldwide reside in areas where drinking-water fluoride concentrations exceed the recommended limit of 1.5 mg/L, placing them at increased risk of fluorosis.[1] It is a public health problem in India where approximately 25 million people including six million children suffer from fluorosis because of the consumption of water containing high fluoride concentrations.[2] Fluorosis was first described by Shortt et al. as a public health problem in different parts of India.[3] Due to its strong electronegativity, fluoride is attracted to positively charged calcium in teeth and bones, resulting in dental and skeletal fluorosis.[4]

In India, fluorosis has been recognized for more than eight decades, with early reports dating back to the British colonial period, when elevated fluoride concentrations in groundwater and associated fluorosis were identified in the Nellore district of present-day Andhra Pradesh and regions of the erstwhile Madras Presidency.[5,6] It is considered endemic in 20 states (230 districts) of India.[7] Subsequently, high fluoride levels in drinking water have been documented across several parts of the country. A large population residing in fluoride-endemic areas remains at risk of developing fluorosis. Although fluoride in optimal concentrations is known to confer protective benefits to dental and skeletal health, excessive exposure has been widely associated with toxicity.[8] High fluoride intake disrupts enzymatic functions, promotes oxidative stress, and leads to hormonal imbalances, thereby contributing to the clinical manifestations of fluorosis.[9]

Dental fluorosis primarily affects children and manifests as discoloration and structural changes of the teeth. Clinically, the enamel may appear chalky white, with varying degrees of white, yellow, brown, or black mottling and streaks on the tooth surface.[10] Skeletal fluorosis involves the bones and major joints, including the cervical spine, vertebral column, shoulders, hips, and knees, leading to symptoms such as chronic pain, stiffness, and restricted joint mobility. In advanced stages, skeletal fluorosis can result in significant functional impairment and disability.[11] Non-skeletal fluorosis represents an early and often overlooked manifestation of fluoride toxicity, commonly presenting with non-specific symptoms such as gastrointestinal disturbances. These features may overlap with other clinical conditions, increasing the risk of misdiagnosis and delayed recognition of fluorosis.[12]

Tamil Nadu is recognized as one of the endemic states for fluorosis, particularly in its rural and semi-arid regions where dependence on groundwater for drinking and domestic use is high. Studies and reports by the Central Ground Water Board (CGWB) have documented fluoride concentrations above permissible limits in several districts of Tamil Nadu, including Dharmapuri, Krishnagiri, Salem, Erode, Dindigul, and Theni.[13] In rural settings, limited access to treated water, inadequate awareness, and prolonged exposure further exacerbate the risk of fluorosis, especially among vulnerable populations such as children and agricultural workers.

Theni district, characterized by hard rock geology and heavy reliance on borewell water, has been identified as one of the fluoride-affected area in groundwater surveillance reports. However, despite evidence of elevated fluoride levels in drinking water sources, there is a paucity of community-based epidemiological data quantifying the burden of fluorosis and its associated determinants among rural populations in the district. Understanding the prevalence and determinants of fluorosis is essential for planning targeted public health interventions, including safe water supply, defluorination strategies, and community awareness programs. A community-based cross-sectional study design was conducted to determine the prevalence of Fluorosis and its determinants among rural populations in Theni district.

Objectives:

1. To find out the prevalence of Fluorosis among the study population.
2. To determine the Fluoride Level in Drinking water source of the study population.
3. To find the associated factors influencing the presence of Fluorosis among the study population.

MATERIALS AND METHODS

A Community based cross sectional analytical study was conducted among the adult populations residing in the Aundipatti Community Development Block comprising of 18 villages. The study was conducted over a two-year period from May 2018 to April 2020. A multistage clustered sampling approach was adopted for data collection across the villages. A two-stage sample design was followed. In the first stage, villages were selected using the Probability Proportional to Population Size (PPS) technique based on the village list obtained from the Primary Census Abstract 2011. In the second stage, households within the selected villages were selected using a systematic random sampling technique for the collection of the required data.

The sample size was calculated using Epi Info version.[7] The target household population was 29,827. Based on a reported prevalence of 63.1% from a previous study by Ramesh et al,[14] a confidence level of 95% and an absolute precision of ±5% were considered. A design effect of 1.5 was applied to account for the clustered sampling design. Using these parameters, the minimum required

sample size was estimated to be 531. After accounting for an anticipated non-response rate of 10%, the final sample size was adjusted to 584.1, which was rounded off to 585 households.

After selection of households, written consent was obtained from all respondents prior to data collection. Data were collected using a pre-designed and pre-tested interviewer-administered questionnaire. The questionnaire captured detailed information on socio-demographic characteristics, drinking water, dietary patterns, and relevant clinical symptoms. A systematic clinical examination was conducted to identify features of fluorosis. Dental fluorosis was assessed by inspection of teeth and gums for characteristic discoloration and mottling. Dental examination was performed using a mouth mirror and probe under natural daylight. The presence and severity of dental fluorosis were assessed using Dean's Fluorosis Index.[15] Skeletal fluorosis was evaluated by eliciting pain and stiffness in major joints, while non-skeletal fluorosis was assessed by examining gastro-intestinal, neurological, and muscular symptoms based on standard clinical criteria.

Drinking water samples were collected from household sources in 500-ml plastic bottles, which were thoroughly cleaned and doubly rinsed with distilled water prior to collection. The samples were appropriately labelled and coded and were transported to the laboratory on the same day for fluoride estimation. Fluoride analysis was carried out at the Multi-Disciplinary Research Unit (MDRU), Government Theni Medical College Hospital (GTMCH), using the SPADNS spectrophotometric method16 following standard operating procedures.

Statistical Analysis:

All data collected during the study were initially entered into Microsoft Excel 2010 and subsequently transferred to Epi Info software version 7.2 for Windows for statistical analysis. Descriptive statistics were used to summarize the data, with categorical variables presented as frequencies and percentages, and continuous variables summarized using mean with standard deviation or median with interquartile range, as appropriate. The distribution of continuous variables was assessed for normality using the Shapiro–Wilk test and the Kolmogorov–Smirnov test prior to inferential analysis.

The prevalence of fluorosis and its associated determinants constituted the primary outcome measures. Socio-demographic characteristics, housing and environmental factors, dietary practices, and clinical signs and symptoms were considered as explanatory variables. Bivariate analysis was performed to examine the association between the outcome variable and each explanatory variable. Variables demonstrating statistical significance were entered into a multivariable logistic regression model to identify independent determinants. Diagnostic tests were done after modelling to assess goodness-of-fit and assumptions pertaining to logistic regression. Effect estimates were presented with 95% confidence intervals, and a p-value of less than 0.05 was considered statistically significant.

Ethical considerations: The study protocol received approval from the Institutional Ethics Committee, Government Theni Medical College Hospital (GTMCH) with (IEC Certificate no: 5824/ MDRU/2018/01). The purpose, objectives, and procedures of the study were explained in detail to all eligible participants in a language understandable to them. Written informed consent was obtained from each participant before enrolment in the study. Participation was entirely voluntary, and participants were informed of their right to withdraw from the study at any stage without any consequences. Confidentiality of participant information was strictly maintained by anonymizing the data and restricting access to the research team only. No personal identifiers were used during data analysis or dissemination of results. Clinical examinations were conducted with due respect for privacy and dignity. Participants identified with signs of fluorosis or other health concerns were appropriately counselled and referred to the nearest health facility for further evaluation and management.

RESULTS

A total of 585 participants were included in the study. Regarding age distribution, most participants belonged to the 31–40 years age group accounting for 189 (32.3%), followed by those aged 41–50 years at 120 (20.5%) and 21–30 years at 115 (19.7%). Participants aged 18–20 years constituted 37 (6.3%), while 59 (10.1%) were in the 51–60 years age group. Individuals aged 61–70 years and ≥71 years accounted for 48 (8.2%) and 17 (2.9%), respectively. Female participants predominated the study population, with 370 (63.2%) females compared to 215 (36.8%) males. Most participants belonged to nuclear families, comprising 434 (74.2%), while 128 (21.9%) resided in joint families and 23 (3.9%) in three-generation families. Regarding duration of stay in the study area, 215 (36.8%) participants had been residing for ≥21 years, followed by 160 (27.4%) for ≤5 years and 102 (17.4%) for 6–10 years. Based on the Modified B.G. Prasad socioeconomic classification (2025), most participants belonged to Class IV, accounting for 222 (37.9%), followed by Class II at 135 (23.1%) and Class III at 122 (20.9%). Class I and Class V constituted 50 (8.5%) and 56 (9.6%), respectively. Regarding education of the head of the family, the highest proportion had primary school education at 208 (35.6%), followed by high school education at 140 (23.9%) and middle school education at 124 (21.2%). Illiteracy was observed among 53 (9.1%) heads of families. With respect to occupation, unskilled workers formed the majority at 256 (43.8%), followed by skilled workers at 190 (32.5%), while smaller proportions were engaged as semi-skilled workers, professionals, and clerical staff. [Table 1]

Table 1: Basic Socio Demographic Characteristics (n=585)

S. No.	Characteristics	Frequency (%)
1	Age	
	18 - 20 years	37 (6.3%)
	21 - 30 years	115 (19.7%)
	31 - 40 years	189 (32.3%)
	41 - 50 years	120 (20.5%)
	51 - 60 years	59 (10.1%)
	61 - 70 years	48 (8.2%)
	≥ 71 years	17 (2.9%)
2	Gender	
	Male	215 (36.8%)
	Female	370 (63.2%)
3	Family Type	
	Nuclear family	434 (74.2%)
	Joint family	128 (21.9%)
	Three Generation family	23 (3.9%)
4	Duration of stay	
	≤ 5 years	160 (27.4%)
	6 - 10 years	102 (17.4%)
	11 - 15 years	45 (7.7%)
	16 - 20 years	63 (10.8%)
	≥ 21 years	215 (36.8%)
5	Socioeconomic class [based on Modified B.G Prasad's scale 2025]	
	Class I (PCI ≥8592)	50 (8.5%)
	Class II (PCI 4296-8591)	135 (23.1%)
	Class III (PCI 2578-4295)	122 (20.9%)
	Class IV (PCI 1289- 2577)	222 (37.9%)
	Class V (PCI <1289)	56 (9.6%)
6	Education of Head of the Family (HOF)	
	Professional degree	12 (2.1%)
	Graduate	34 (5.8%)
	Intermediate/ diploma	14 (2.4%)
	High school	140 (23.9%)
	Middle school	124 (21.2%)
	Primary school	208 (35.6%)
	Illiterate	53 (9.1%)
7	Occupation of Head of the Family (HOF)	
	Professional	11 (1.9%)
	Technician/Associate Professional	27 (4.6%)
	Clerk	23 (3.9%)
	Skilled worker	190 (32.5%)
	Semi-skilled worker	61 (10.4%)
	Unskilled worker	256 (43.8%)
	Unemployed	17 (2.9%)

About drinking water purification practices, nearly half of the participants reported not using any purification method, accounting for 268 (45.8%), while 237 (40.5%) reported boiling water and 80 (13.7%) reported using reverse osmosis systems. Concerning oral hygiene practices, the use of non-fluorinated toothpaste or tooth powder was reported by 329 (56.2%) participants, whereas 256 (43.8%) reported using fluorinated products. Consumption of black tea was reported by 135 (23.1%) participants, while the majority, 450 (76.9%), did not consume black tea. The use of black rock salt was uncommon, with only 10 (1.7%) participants reporting its consumption. Soft drink consumption was reported by 82 (14.0%) participants, whereas 503 (86.0%) reported no such habit. Consumption of tinned food and processed food was reported by 4 (0.7%) and 12 (2.1%) participants, respectively. Consumption of jowar (sorghum or cholam) was reported by 4 (0.7%) participants, while 581 (99.3%) did not consume it. The history of abortion in the family was reported by 40 (6.8%) participants, whereas a history of stillbirth in the family was reported by 12 (2.1%). [Table 2]

Table 2: Determinants/ Risk Factors of Fluorosis (n=585)

S. No.	Characteristics	Frequency (%)
1	Drinking water Purification	
	Boiling	237 (40.5%)
	Reverse Osmosis (RO)	80 (13.7%)
	No purification method	268 (45.8%)
2	Toothpaste/Tooth powder type	
	Fluorinated	256 (43.8%)
	Non fluorinated	329 (56.2%)
3	Habit of Black Tea consumption	
	Yes	135 (23.1%)
	No	450 (76.9%)

4	Habit of Black Rock Salt consumption	
	Yes	10 (1.7%)
	No	575 (98.3%)
5	Habit of Soft drinks consumption	
	Yes	82 (14.0%)
	No	503 (86.0%)
6	Habit of Tinned food consumption	
	Yes	4 (0.7%)
	No	581 (99.3%)
7	Habit of Processed food consumption	
	Yes	12 (2.1%)
	No	573 (97.9%)
8	Habit of Jowar (Sorghum or Cholam) consumption	
	Yes	4 (0.7%)
	No	581 (99.3%)
9	History of Abortion in the family	
	Yes	40 (6.8%)
	No	545 (93.2%)
10	History of Stillbirth in the family	
	Yes	12 (2.1%)
	No	573 (97.9%)

Analysis of fluoride levels in drinking water sources revealed that nearly half of the households had fluoride concentrations between 0.5 and 1.0 mg/L, accounting for 284 (48.5%). Fluoride levels below 0.5 mg/L were observed in 62 (10.6%) households. Fluoride concentrations in the range of 1.0–1.5 mg/L were detected in 104 (17.8%) households, while higher concentrations between 1.5 and 3.0 mg/L were found in 135 (23.1%) households. None of the households had fluoride levels exceeding 3.0 mg/L. [Table 3]

Table 3: Level of Fluoride in Drinking Water (n=585)

S. No.	Characteristics	Frequency (%)
1	Fluoride level (mg/L)	
	< 0.5	62 (10.6%)
	0.5 – 1.0	284 (48.5%)
	1.0 – 1.5	104 (17.8%)
	1.5 -3.0	135 (23.1%)
	> 3.0	0 (0%)

Clinical assessments of fluorosis among the study participants showed that the majority had normal dentition as per Dean's Fluorosis Index, accounting for 494 (84.4%). Questionable fluorosis was observed in 8 (1.4%) participants, while very mild and mild fluorosis was noted in 20 (3.4%) and 24 (4.1%), respectively. Moderate fluorosis was present in 29 (5.0%) participants, and severe fluorosis was observed in 10 (1.7%). Symptoms suggestive of skeletal fluorosis in the form of pain or stiffness were commonly reported in the knee joint by 68 (11.6%) participants, followed by the neck in 65 (11.1%), lumbar region in 63 (10.8%), hip in 57 (9.7%), and shoulder in 38 (6.5%). Restricted mobility related to skeletal fluorosis was observed in 39 (6.7%) participants who reported inability to squat, followed by involvement of the cervical spine in 34 (5.8%) and lumbar spine in 24 (4.1%). No cases of knock knee or bowlegs were observed. Non-skeletal fluorosis symptoms involving the gastrointestinal system included intermittent constipation in 24 (4.1%) participants, intermittent diarrhoea in 18 (3.1%), bloated feeling in 16 (2.7%), loss of appetite in 12 (2.1%), nausea in 11 (1.9%), and consistent abdominal pain in 10 (1.7%). Neurological symptoms such as frequent urination were reported by 24 (4.1%) participants, followed by tingling sensations in fingers and toes and excessive thirst, each reported by 20 (3.4%), and nervousness or depression by 8 (1.4%). Muscular symptoms included muscle weakness and stiffness in 68 (11.6%) participants, pain or loss of muscle power in 12 (2.1%), and inability to walk or work in 6 (1.0%). As these symptoms were not mutually exclusive, multiple manifestations were reported by some participants. [Table 4]

Table 4: Clinical signs and symptoms (n=585)

S. No.	Characteristics	Frequency (%)
1	Dental Fluorosis using Dean's Index	
	Normal	494 (84.4%)
	Questionable	8 (1.4%)
	Very Mild	20 (3.4%)
	Mild	24 (4.1%)
	Moderate	29 (5.0%)
	Severe	10 (1.7%)
2	Skeletal Fluorosis symptoms (Pain/stiffness) *	
	Neck	65 (11.1%)
	Lumbar region	63 (10.8%)

	Shoulder	38 (6.5%)
	Knee	68 (11.6%)
	Hip	57 (9.7%)
3	Skeletal Fluorosis symptoms (Restricted mobility) *	
	Cervical Spine	34 (5.8%)
	Lumbar Spine	24 (4.1%)
	Presence of Knock Knee	0 (0%)
	Presence of Bowlegs	0 (0%)
	Inability to Squat	39 (6.7%)
4	Non - Skeletal Fluorosis symptoms (Gastrointestinal)*	
	Consistent Abdominal pain	10 (1.7%)
	Intermittent Diarrhoea	18 (3.1%)
	Intermittent Constipation	24 (4.1%)
	Bloated feeling	16 (2.7%)
	Nausea	11 (1.9%)
	Loss of appetite	12 (2.1%)
5	Non - Skeletal Fluorosis symptoms (Neurological)*	
	Nervousness/Depression	8 (1.4%)
	Tingling sensation in fingers & toes	20 (3.4%)
	Excessive thirst	20 (3.4%)
	Tendency to urinate frequently	24 (4.1%)
6	Non - Skeletal Fluorosis symptoms (Muscular)*	
	Muscle weakness & Stiffness	68 (11.6%)
	Pain in the muscle/loss of muscle power	12 (2.1%)
	Unable to walk or work	6 (1%)

* Not Mutually Exclusive

Overall, fluorosis of at least one type was identified in 132 (22.6%) participants, while the remaining 453 (77.4%) participants did not exhibit any form of fluorosis. [Table 5] Among the 132 participants with fluorosis, dental fluorosis was the most observed manifestation, present in 91 (15.6%) participants. Non-skeletal fluorosis was identified in 85 (14.5%) participants, while skeletal fluorosis was observed in 10 (1.7%) participants. As these categories were not mutually exclusive, some participants exhibited more than one type of fluorosis. [Table 6]

Table 5: Presence of Fluorosis (n=585)

S. No.	Characteristics	Frequency (%)
1	Presence of Fluorosis (At least one type)	
	Yes	132 (22.6%)
	No	453 (77.4%)

Table 6: Fluorosis type (n=132)

S. No.	Characteristics*	Frequency (%)
1	Dental Fluorosis	91 (15.6%)
	Skeletal Fluorosis	10 (1.7%)
	Non - Skeletal Fluorosis	85 (14.5%)

* Not Mutually Exclusive

Bivariate logistic regression analysis was performed to assess the association between fluorosis and selected socio-demographic, drinking water related, dietary factors and history of abortions and stillbirth. Age, analysed as a continuous variable, was not found to be significantly associated with fluorosis (OR = 1.013; 95% CI: 0.999–1.027; p = 0.066). Gender was also not significantly associated, with males having higher odds compared to females (OR = 1.362; 95% CI: 0.917–2.023; p = 0.125). Duration of stay was not significantly associated with fluorosis (OR = 0.991; 95% CI: 0.980–1.002; p = 0.111). Type of family showed a significant association, wherein participants from nuclear families had higher odds of fluorosis compared to those from three-generation families (OR = 7.560; 95% CI: 1.007–56.74; p = 0.049). Socioeconomic status demonstrated significant associations, with higher odds observed among Class I (OR = 3.937; 95% CI: 1.478–10.493; p = 0.006) and Class II participants (OR = 3.385; 95% CI: 1.418–8.078; p = 0.006), compared to Class V. Occupation of the head of the family was significantly associated only among clerical workers, who had higher odds of fluorosis compared to unemployed heads of households (OR = 14.66; 95% CI: 1.659–129.70; p = 0.016). Drinking water practices showed a significant association, with participants not using any purification method having higher odds of fluorosis (OR = 2.259; 95% CI: 1.519–3.361; p < 0.001). Use of fluorinated toothpaste or tooth powder was also significantly associated (OR = 3.112; 95% CI: 2.075–4.668; p < 0.001). Dietary habits such as black tea consumption (OR = 2.293; 95% CI: 1.499–3.510; p < 0.001), black rock salt consumption (OR = 3.528; 95% CI: 1.005–12.376; p = 0.049), soft drink consumption (OR = 2.579; 95% CI: 1.573–4.230; p < 0.001), and processed food consumption (OR = 5.018; 95% CI: 1.566–16.080; p

= 0.007) were significantly associated with fluorosis. Drinking water fluoride level, analysed as a continuous variable, showed a strong positive association with fluorosis (OR = 3.554; 95% CI: 2.372–5.326; p < 0.001). [Table 7]

Table 7: Bivariate logistic regression analysis of Fluorosis with various factors (N = 585)

Independent Variable	Fluorosis Present N (%)	OR (95% CI)	P value
AGE (continuous variable)	---------	1.013 (0.999-1.027)	0.066
GENDER			
Male (215)	56(26.0%)	1.362(0.917-2.023)	0.125
Female (Ref) (370)	76(20.5%)	1	
TYPE OF FAMILY			
Joint (128)	20(15.6%)	4.074(0.519-31.96)	0.181
Nuclear (434)	111(25.6%)	7.560(1.007-56.74)	0.049*
Three generation (Ref) (23)	1(4.3%)	1	
DURATION OF STAY (continuous variable)	----------	0.991 (0.980-1.002)	0.111
SOCIOECONOMIC STATUS			
Class I (PCI ≥8592) (50)	18(36.0%)	3.937(1.478-10.493)	0.006*
Class II (PCI 4296-8591) (135)	44(32.6%)	3.385(1.418-8.078)	0.006*
Class III (PCI 2578-4295) (122)	18(14.8%)	1.212(0.475-3.091)	0.688
Class IV (PCI 1289- 2577) (222)	45(20.3%)	1.780(0.755-4.193)	0.187
Class V (PCI <1289) (Ref) (56)	7(12.5%)	1	
EDUCATION OF HOF			
Illiterate (53)	8(15.1%)	1.067(0.200-5.696)	0.940
Primary school (208)	38(18.3%)	1.341(0.288-6.242)	0.708
Middle school (124)	37(29.8%)	2.552(0.544-11.969)	0.235
High school (140)	35(25.0%)	2.000(0.427-9.376)	0.379
Graduate (34)	11(32.4%)	2.870(0.545-15.099)	0.213
Professional degree (12)	1(8.3%)	0.545(0.043-6.889)	0.639
Intermediate/ diploma (Ref) (14)	2(14.3%)	1	
OCCUPATION OF HOF			
Professional (11)	1(9.1%)	1.600(0.090-28.566)	0.749
Technician/Associate Professional (27)	7(25.9%)	5.600(0.623-50.338)	0.124
Clerk (23)	11(47.8%)	14.66(1.659-129.70)	0.016*
Skilled worker (190)	35(18.4%)	3.613(0.464-28.158)	0.220
Semi-skilled worker (61)	12(19.7%)	3.918(0.472-32.534)	0.206
Unskilled worker (256)	65(25.4%)	5.445(0.708-41.867)	0.103
Unemployed (Ref) (17)	1(5.9%)	1	
DRINKING WATER PURIFICATION			
No purification done (268)	81(30.2%)	2.259(1.519-3.361)	0.000*
Purification done (Ref) (317)	51(16.1%)	1	
TOOTHPASTE/ TOOTHPOWDER TYPE			
Fluorinated (256)	86(33.6%)	3.112(2.075-4.668)	0.000*
Non-Fluorinated (Ref) (329)	46(14.0%)	1	
HABIT OF BLACK TEA CONSUMPTION			
Yes (135)	47(34.8%)	2.293(1.499-3.510)	0.000*
No (Ref) (450)	85(18.9%)	1	
HABIT OF BLACK ROCK SALT CONSUMPTION			
Yes (10)	5(50.0%)	3.528(1.005-12.376)	0.049*
No (Ref) (575)	127(22.1%)	1	
HABIT OF SOFT DRINKS CONSUMPTION			
Yes (82)	32(39.0%)	2.579(1.573-4.230)	0.000*
No (Ref) (503)	100(19.9%)	1	
HABIT OF TINNED FOOD CONSUMPTION			
Yes (4)	2(50.0%)	3.469(0.484-24.868)	0.216
No (Ref) (581)	130(22.4%)	1	
HABIT OF PROCESSED FOOD CONSUMPTION			
Yes (12)	7(58.3%)	5.018(1.566-16.080)	0.007*
No (Ref) (573)	125(21.8%)	1	
HABIT OF JOWAR (SORGHUM/CHOLAM) CONSUMPTION			
Yes (4)	1(25.0%)	1.145(0.118-11.100)	0.907
No (Ref) (581)	131(22.5%)	1	
HABIT OF ABORTION IN THE FAMILY			
Yes (40)	4(10.0%)	0.362(0.126-1.036)	0.058
No (Ref) (545)	128(23.5%)	1	
HABIT OF STILLBIRTH IN THE FAMILY			
Yes (12)	4(33.3%)	1.738(0.515-5.866)	0.373
No (Ref) (573)	128(22.3%)	1	
DRINKING WATER FLUORIDE LEVEL (continuous variable)	----------	3.554(2.372-5.326)	0.000*

*Statistically significant

Multivariate logistic regression analysis was performed to identify independent determinants of fluorosis after adjusting for potential confounders. Type of family was not found to be significantly associated with fluorosis in the adjusted model. Socioeconomic status showed a significant association with fluorosis. Participants belonging to Class I had markedly higher odds of fluorosis (OR = 21.37; 95% CI: 4.24–107.07; p < 0.001), followed by those in Class II (OR = 6.568; 95% CI: 2.36–18.269; p < 0.001) and Class IV (OR = 3.426; 95% CI: 1.250–9.395; p = 0.017), when compared to Class V. Occupation of the head of the family was not significantly associated with fluorosis after adjustment. Drinking water practices remained significantly associated, with participants not using any water purification method having higher odds of fluorosis (OR = 3.854; 95% CI: 2.288–6.492; p < 0.001). Use of fluorinated toothpaste or tooth powder was also independently associated with fluorosis (OR = 3.593; 95% CI: 2.194–5.886; p < 0.001). Dietary habits such as black tea consumption, black rock salt consumption, soft drink intake, and processed food consumption were not significantly associated with fluorosis in the multivariate analysis. Drinking water fluoride level, analysed as a continuous variable, demonstrated a strong independent association with fluorosis (OR = 3.268; 95% CI: 2.096–5.096; p < 0.001). [Table 8]

Table 8: Multivariate logistic regression analysis of Fluorosis with various factors (N = 585)

INDEPENDENT VARIABLE	Fluorosis Present N (%)	OR (95% CI)	P value
TYPE OF FAMILY			
Joint (128)	20(15.6%)	3.528(0.377-32.997)	0.269
Nuclear (434)	111(25.6%)	5.352(0.598-47.863)	0.133
Three generation (Ref) (23)	1(4.3%)	1	
SOCIOECONOMIC STATUS			
Class I (PCI ≥8592) (50)	18(36.0%)	21.37(4.24-107.07)	0.000*
Class II (PCI 4296-8591) (135)	44(32.6%)	6.568(2.36-18.269)	0.000*
Class III (PCI 2578-4295) (122)	18(14.8%)	1.702(0.578-5.008)	0.334
Class IV (PCI 1289- 2577) (222)	45(20.3%)	3.426(1.250-9.395)	0.017*
Class V (PCI <1289) (Ref) (56)	7(12.5%)	1	
OCCUPATION OF HOF			
Professional (11)	1(9.1%)	0.393(0.016-9.779)	0.569
Technician/Associate Professional (27)	7(25.9%)	0.358(0.023-5.587)	0.464
Clerk (23)	11(47.8%)	2.130(0.194-23.366)	0.536
Skilled worker (190)	35(18.4%)	1.426(0.152-13.398)	0.756
Semi-skilled worker (61)	12(19.7%)	0.981(0.094-10.208)	0.987
Unskilled worker (256)	65(25.4%)	1.826(0.200-16.627)	0.593
Unemployed (Ref) (17)	1(5.9%)	1	
DRINKING WATER PURIFICATION			
No purification done (268)	81(30.2%)	3.854(2.288-6.492)	0.000*
Purification done (Ref) (317)	51(16.1%)	1	
TOOTHPASTE/ TOOTHPOWDER TYPE			
Fluorinated (256)	86(33.6%)	3.593(2.194-5.886)	0.000*
Non-Fluorinated (Ref) (329)	46(14.0%)	1	
HABIT OF BLACK TEA CONSUMPTION			
Yes (135)	47(34.8%)	1.497(0.742-3.021)	0.260
No (Ref) (450)	85(18.9%)	1	
HABIT OF BLACK ROCK SALT CONSUMPTION			
Yes (10)	5(50.0%)	0.317(0.051-1.977)	0.219
No (Ref) (575)	127(22.1%)	1	
HABIT OF SOFT DRINKS CONSUMPTION			
Yes (82)	32(39.0%)	1.615(0.720-3.623)	0.245
No (Ref) (503)	100(19.9%)	1	
HABIT OF PROCESSED FOOD CONSUMPTION			
Yes (12)	7(58.3%)	1.147(0.194-6.765)	0.880
No (Ref) (573)	125(21.8%)	1	
DRINKING WATER FLUORIDE LEVEL (continuous variable)	----------	3.268(2.096-5.096)	0.000*

*Statistically significant

DISCUSSION

The present community-based cross-sectional study conducted in rural areas of Theni district revealed that 22.6% of the study population had fluorosis of at least one type. Dental fluorosis was the most common manifestation (15.6%), followed by non-skeletal fluorosis (14.5%) and skeletal fluorosis (1.7%). The overall prevalence of fluorosis observed in the present study was comparable to findings reported by Kumar et al,[17] and Punitha et al,[18] who documented prevalence ranging from 18% to 26% in rural South Indian settings with similar hydrogeological characteristics. In contrast, higher prevalence rates were reported by Suhirtha et al,[19] and Sirigala et al,[20] where fluorosis prevalence exceeded 30%, particularly in drought-prone regions. These differences may be attributed to variations in fluoride concentration, duration of exposure, climatic

conditions, and water consumption patterns. Dental fluorosis prevalence in the present study (15.6%) was slightly lower than that reported by Sharma et al,[21] who observed dental fluorosis in 19.1% in an endemic district, with prevalence exceeding 90% in areas where drinking water fluoride levels were above permissible limits. Similarly, Isaac et al,[22] reported dental fluorosis prevalence of approximately 20%, particularly among populations consuming untreated groundwater. The lower prevalence in the present study may be explained by partial adoption of water purification methods and lower exposure during early childhood in some households. Non-skeletal fluorosis manifestations, observed in 14.5% of participants, included gastrointestinal, neurological, and muscular symptoms. Comparable findings were reported by Ramesh et al,[14] and Gousalya et al,[23] who highlighted non-skeletal symptoms as early and often under-recognized indicators of chronic fluoride toxicity. These symptoms are frequently nonspecific and may lead to under-diagnosis unless actively screened, reinforcing the importance of comprehensive clinical evaluation in endemic areas.

Skeletal fluorosis was relatively uncommon in the present study (1.7%), which is consistent with observations by Duraiswami et al,[24] who reported skeletal fluorosis prevalence below 5% in community-based surveys. In contrast, Sirigala et al,[20] documented higher skeletal fluorosis prevalence among adults in YSR Kadapa district, attributed to prolonged exposure, high ambient temperatures, and increased daily water consumption. The lower prevalence of skeletal fluorosis in the present study may reflect earlier detection, lower cumulative exposure, or younger age distribution of the study population. A key finding of the present study was that 23.1% of drinking water samples had fluoride levels between 1.5 and 3.0 mg/L, exceeding WHO permissible limits. This finding aligns with groundwater surveillance reports and studies by Suhirtha et al,[19] and Kumar et al,[17] which documented fluoride concentrations above 1.5 mg/L in 15–30% of samples. Multivariate analysis demonstrated that drinking water fluoride level was a strong independent predictor of fluorosis (adjusted OR = 3.27; 95% CI: 2.09–5.09), corroborating evidence from Sharma et al.21 and Sirigala et al,[20] who consistently identified fluoride concentration as the most robust determinant of fluorosis.

Socioeconomic status emerged as an important determinant, with higher odds of fluorosis among participants belonging to higher socioeconomic classes. This finding is consistent with Sharma et al,[21] who reported higher fluorosis prevalence among children from higher socioeconomic groups, possibly due to increased use of fluoridated toothpaste, consumption of packaged foods, and beverages containing fluoride. Conversely, studies by Isaac et al,[22] reported no significant association between socioeconomic status and fluorosis, highlighting contextual and behavioural differences across study settings. Behavioural factors such as use of fluorinated toothpaste and lack of water purification remained independently associated with fluorosis in the present study, findings that are consistent with observations by Punitha et al,[18] and Ramesh et al.[14] However, dietary habits such as black tea, soft drinks, and processed food consumption, though significant in bivariate analysis, lost significance after adjustment, suggesting confounding by water fluoride exposure. Similar attenuation of dietary factors was reported by Duraiswami et al.[24]

CONCLUSION

The present study demonstrated that fluorosis continued to be a significant public health concern. Elevated fluoride levels in drinking water, lack of household water purification practices, and use of fluoridated dental products emerged as key independent determinants of fluorosis. These findings underscored the need for regular surveillance of drinking water fluoride concentrations, strengthening of safe drinking water initiatives, and implementation of community-based awareness programs focusing on fluorosis prevention and early identification. Future research should be directed towards objective measures such as bone density assessment and evaluation of functional disability providing a more comprehensive understanding of skeletal involvement. Additionally, intervention studies assessing the effectiveness of defluoridation strategies and mixed-methods research exploring community perceptions, health-seeking behaviour, and adherence to preventive measures are warranted to enhance sustainable fluorosis control programs.

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