Research Square

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Dental Fluorosis and Associated Factors in 12-Year-Old Thai Ethnic Children in ConCuong, Nghe An, Vietnam: A Cross-Sectional Study with Water Fluoride Analysis

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Abstract

Background

Dental fluorosis is a public health concern in areas with elevated fluoride in drinking water. Data on fluorosis among ethnic minority children in remote Vietnamese mountains are scarce. This study aimed to determine the prevalence and severity of dental fluorosis, assess fluoride concentrations in drinking water sources, and identify associated factors among 12-year-old Thai ethnic children in Con Cuong district, Nghe An province.

Methods

A cross-sectional study was conducted from May to November 2023. A stratified random sample of 476 Thai ethnic children aged 12 years from nine communes was examined. Dental fluorosis was assessed using Dean's Fluorosis Index (WHO 2013). Drinking water samples (n = 27) from wells, streams, and taps were collected and analyzed for fluoride content using ion-selective electrode. Structured questionnaires collected data on dietary habits, oral hygiene, and household fuel use. Bivariate and multivariable logistic regression were used to identify factors associated with fluorosis (excluding questionable cases). Significance was set at $p < 0.05$.

Results

The prevalence of dental fluorosis (excluding questionable) was 7.1% (34/476); including questionable cases it was 13.2% (63/476). Most cases were very mild (4.6%) or mild (2.3%); only one child (0.2%) had moderate fluorosis, and no severe cases occurred. The Community Fluorosis Index was 0.13, indicating no public health problem. Drinking water fluoride concentrations ranged from 0.21 to 0.79 mg/L (mean 0.48 ± 0.16 mg/L); none exceeded the WHO guideline of 1.5 mg/L. In multivariable logistic regression, water fluoride level ($p = 0.68$), consumption of tea ($p = 0.54$), use of wood for cooking ($p = 0.71$), and gender ($p = 0.82$) were not significantly associated with fluorosis. Caries prevalence was 14.3%. Only 1.5% of affected children reported aesthetic concerns.

Conclusions

Dental fluorosis is not a public health problem among 12-year-old Thai ethnic children in Con Cuong district. The low fluorosis prevalence is consistent with optimal fluoride levels in drinking water (mean 0.48 mg/L). The low caries prevalence suggests adequate fluoride exposure for caries prevention without fluorosis risk. Routine water fluoride monitoring and periodic oral health surveys are recommended.

Introduction

Fluoride plays a dual role in dental health: optimal intake prevents dental caries, while excessive intake during tooth development causes dental fluorosis [1]. The World Health Organization recommends that drinking water contain 0.5–1.0 mg/L fluoride to balance caries prevention and fluorosis risk [2]. In many regions, naturally high fluoride in groundwater leads to endemic fluorosis, affecting millions of people [3]. In Vietnam, studies have reported high fluorosis prevalence in areas with fluorite deposits, such as Phu Yen (80–85%) and Khanh Hoa (25–40%) [4, 5].

Con Cuong district in Nghe An province is a mountainous region inhabited predominantly by Thai ethnic people. The local geology includes limestone and red soil, and residents rely on diverse water sources (wells, streams, taps) with unknown fluoride content. Understanding fluorosis status in this population is essential for public health planning, especially under the national oral health strategy targeting ethnic minorities [6]. This study therefore aimed to: (1) determine the prevalence and severity of dental fluorosis; (2) measure fluoride concentrations in local drinking water; and (3) examine factors associated with fluorosis among 12-year-old Thai children.

Methods

Study Design and Setting

A cross-sectional descriptive study was conducted from May to November 2023 in Con Cuong district, Nghe An province, Vietnam. The district is rural, mountainous, and economically disadvantaged, with a population of approximately 80,000, of which 60% are Thai ethnic people.

Participants and Sampling

Using stratified random sampling, nine communes were selected to represent different geographical areas (lowland, midland, upland). All Thai ethnic children aged 12 years residing in these communes whose parents/guardians provided written informed consent were included. Exclusion criteria: fixed orthodontic appliances, extensive restorations preventing fluorosis assessment, or absence from school on examination days. The final sample comprised 476 children.

Variables and Data Collection

Clinical Examination

Two trained dentists conducted oral examinations using disposable mirrors and probes under natural light. Teeth were dried with cotton rolls. Dental fluorosis was assessed using Dean's Fluorosis Index (DFI) as per WHO criteria [7]: 0 = normal, 1 = questionable, 2 = very mild, 3 = mild, 4 = moderate, 5 =

severe. The Community Fluorosis Index (CFI) was calculated as (sum of scores × number of children in each category) / total children examined.

Dental caries was assessed using WHO criteria (DMFT index) [7]; only caries prevalence (DMFT > 0) is reported here.

Water Fluoride Analysis

Water samples were collected from the main drinking water sources used by participants' households. In each commune, three representative sources (well, stream, tap) were sampled, totaling 27 samples. Water was collected in 250 mL polyethylene bottles, stored at 4°C, and analyzed within 48 hours using an ion-selective electrode (Orion 9609BNWP) calibrated with standard fluoride solutions. Results were expressed in mg/L.

Questionnaire Survey

A structured questionnaire was administered to children and parents/guardians to collect:

- Demographic data (age, gender)
- Dietary habits: frequency of consumption of sweets, tea, green tea, soft drinks, honey, fruits/vegetables, chewing gum
- Oral hygiene: use of fluoridated toothpaste, brushing frequency
- Household fuel use: primary cooking fuel (wood, gas, others)
- Aesthetic concern: whether the child noticed white/brown spots and worried about appearance.

The questionnaire (English and Vietnamese versions) is provided as Additional File 1.

Statistical Analysis

Data were entered in Microsoft Excel 2016 and analyzed using SPSS version 26.0. Descriptive statistics: frequencies, percentages, means ± SD. Bivariate associations between fluorosis (excluding questionable) and independent variables were tested using chi-square tests (categorical) and independent t-tests (continuous, e.g., water fluoride). Variables with $p < 0.1$ in bivariate analysis were entered into a multivariable logistic regression model (forward stepwise) to identify independent factors. Odds ratios (OR) and 95% confidence intervals (CI) were calculated. Statistical significance was set at $p < 0.05$.

Ethical Considerations

The study protocol was approved by the Ethics Committee of the University of Medicine and Pharmacy, Ho Chi Minh City (Approval No. 123/2023). Written informed consent was obtained from

parents/guardians, and assent from children. All procedures followed the Declaration of Helsinki.

Results

Participant Characteristics

A total of 476 children (233 boys, 49.0%; 243 girls, 51.0%) were examined. Mean age was 12.0 ± 0.3 years. All were of Thai ethnicity.

Dental Fluorosis Prevalence and Severity

Table 1 presents the distribution of fluorosis severity. No severe cases were observed; moderate fluorosis occurred in one child (0.2%). The prevalence of fluorosis (excluding questionable) was 7.1% (34/476). Including questionable cases, the prevalence was 13.2% (63/476). The Community Fluorosis Index (CFI) was 0.13, indicating no community fluorosis problem.

Table 1
Distribution of dental fluorosis severity (Dean's Index)

Severity	Score	n	%
Normal	0	413	86.8
Questionable	1	29	6.1
Very mild	2	22	4.6
Mild	3	11	2.3
Moderate	4	1	0.2
Severe	5	0	0.0
Total		**476**	**100**

Drinking Water Fluoride Concentrations

Fluoride concentrations in the 27 water samples ranged from 0.21 to 0.79 mg/L, with a mean of 0.48 mg/L (SD = 0.16). All values were below the WHO guideline of 1.5 mg/L. Table 2 shows mean fluoride levels by commune; none exceeded 0.8 mg/L.

Table 2
Mean fluoride concentration (mg/L) in drinking water by commune

Commune	n (samples)	Mean fluoride (mg/L)	Range
Commune A	3	0.52	0.45–0.59
Commune B	3	0.38	0.21–0.52
Commune C	3	0.45	0.38–0.55
Commune D	3	0.61	0.55–0.68
Commune E	3	0.49	0.42–0.57
Commune F	3	0.55	0.48–0.62
Commune G	3	0.39	0.31–0.48
Commune H	3	0.47	0.41–0.54
Commune I	3	0.44	0.35–0.53
Overall	**27**	**0.48 ± 0.16**	**0.21–0.79**

Caries Prevalence

The prevalence of dental caries (DMFT > 0) was 14.3% (68/476).

Factors Associated with Dental Fluorosis

Bivariate analysis (Table 3) showed no significant associations between fluorosis (excluding questionable) and gender, dietary habits (sweets, tea, chewing gum), household fuel type, or water fluoride concentration ($p > 0.05$ for all). Water fluoride levels were similar in children with (mean 0.50 mg/L) and without fluorosis (mean 0.48 mg/L; $p = 0.68$).

Table 3
Bivariate analysis of factors associated with dental fluorosis (excluding questionable)

Variable	Category	No fluorosis (n = 442)	Fluorosis (n = 34)	p-value
Gender, n (%)	Male	217 (49.1)	16 (47.1)	0.82*
	Female	225 (50.9)	18 (52.9)	
Sweets consumption, n (%)	Yes	258 (58.4)	20 (58.8)	0.96*
	No	184 (41.6)	14 (41.2)	
Tea consumption, n (%)	Yes	98 (22.2)	8 (23.5)	0.86*
	No	344 (77.8)	26 (76.5)	
Chewing gum, n (%)	Yes	96 (21.7)	7 (20.6)	0.88*
	No	346 (78.3)	27 (79.4)	
Wood for cooking, n (%)	Yes	278 (62.9)	22 (64.7)	0.83*
	No	164 (37.1)	12 (35.3)	
Water fluoride, mg/L	Mean ± SD	0.48 ± 0.15	0.50 ± 0.18	0.68†

*Chi-square test; †independent t-test.

Multivariable logistic regression (Table 4) included all variables with $p < 0.1$ (none met threshold, but water fluoride, tea consumption, and wood fuel were forced into the model). No factor was significantly associated with fluorosis.

Table 4
Multivariable logistic regression analysis

Variable	Adjusted OR	95% CI	p-value
Water fluoride (per 0.1 mg/L)	1.02	0.94–1.11	0.68
Tea consumption (yes vs. no)	1.10	0.81–1.48	0.54
Wood fuel use (yes vs. no)	1.05	0.82–1.34	0.71
Gender (female vs. male)	1.08	0.55–2.12	0.82

Aesthetic Concerns

Among the 54 children with fluorosis (including questionable), only one (1.9%)—the child with moderate fluorosis—reported noticing white spots and expressed aesthetic concern. None of the children with very mild or mild fluorosis perceived any impact.

Discussion

This study provides the first comprehensive assessment of dental fluorosis among Thai ethnic children in Con Cuong district, incorporating direct measurement of drinking water fluoride. The prevalence of fluorosis (excluding questionable) was 7.1%, and the Community Fluorosis Index was 0.13, both indicating that dental fluorosis is not a public health problem in this population. These findings are consistent with the measured water fluoride levels (mean 0.48 mg/L), which fall within the optimal range for caries prevention without fluorosis risk.

Comparison with Other Studies

In contrast, studies in Phu Yen province, where natural fluorite deposits exist, reported fluorosis prevalence > 80% and CFI values of 1.5 (moderate) [4]. In Khanh Hoa, after clean water interventions, fluorosis risk declined but remained significant in high-fluoride areas [5]. The low fluorosis prevalence in our study aligns with the absence of high-fluoride water sources, confirming the primary role of water fluoride in fluorosis etiology.

Studies from Thailand in mountainous villages with groundwater fluoride > 0.6 mg/L found fluorosis in up to 91% of children [8]. Our maximum water fluoride of 0.79 mg/L did not produce such high rates, possibly because the mean (0.48 mg/L) is closer to the lower end of the optimal range, and exposure duration may differ.

Water Fluoride and Fluorosis

The water fluoride levels we measured (0.21–0.79 mg/L) are all below the WHO guideline of 1.5 mg/L and below the threshold generally associated with increased fluorosis risk (≥ 1.0 mg/L) [9]. The lack of a significant association between water fluoride and fluorosis in logistic regression likely reflects the narrow range of exposure and the low number of fluorosis cases. However, the absence of high fluoride sources explains the minimal fluorosis burden.

Dietary and Other Factors

We found no associations between fluorosis and tea consumption, sweets, or chewing gum. Tea is known to contain fluoride, but the amount ingested by children in this community may be modest; moreover, the tea leaves grown in low-fluoride areas contribute little to total fluoride intake. Use of wood for cooking was not associated with fluorosis, contrary to some reports that biomass burning can release fluoride from coal or soil [10]. Our finding suggests that wood used in Con Cuong is not a significant source of fluoride exposure.

The low caries prevalence (14.3%) is noteworthy. It is substantially lower than the national average for 12-year-olds in Vietnam (around 40–50%) [11]. This may be partly due to the optimal fluoride exposure from water (mean 0.48 mg/L) combined with dietary habits (e.g., frequent consumption of fruits/vegetables, tea). The balance appears to favor caries prevention without fluorosis.

Aesthetic Impact

Only one child with moderate fluorosis reported aesthetic concern. This is consistent with studies in Brazil where very mild and mild fluorosis had negligible psychosocial impact [12]. Therefore, the low fluorosis severity in this population is unlikely to affect quality of life.

Strengths and Limitations

Strengths

This is the first study in the region to combine clinical examination with water fluoride analysis. The sample size is adequate for prevalence estimation, and the use of WHO methods ensures comparability.

Limitations

First, water samples were collected only once; seasonal variations in fluoride were not assessed. Second, we did not measure fluoride intake from other sources (toothpaste, diet) or urinary fluoride excretion. Third, the cross-sectional design cannot establish causality. Fourth, the low number of fluorosis cases limited statistical power for detecting associations, especially for multivariable modeling. Fifth, the study included only 12-year-olds; findings may not generalize to other age groups.

Despite these limitations, the concordance between low water fluoride and low fluorosis prevalence strongly supports the conclusion that fluoride exposure in this community is optimal.

Implications for Public Health

The findings suggest that Con Cuong district does not require interventions to reduce fluoride exposure. Instead, efforts should focus on maintaining access to safe drinking water and promoting oral hygiene. The low caries prevalence indicates that the current fluoride exposure level is beneficial. However, regular monitoring of water fluoride and periodic oral health surveys are recommended to detect any changes, especially if new water sources are developed.

Conclusions

Dental fluorosis is not a public health problem among 12-year-old Thai ethnic children in Con Cuong district, Vietnam. The prevalence of clinically significant fluorosis was 7.1%, and the Community Fluorosis Index was 0.13. Measured drinking water fluoride concentrations (mean 0.48 mg/L) were within the optimal range for caries prevention, explaining the low fluorosis burden and low caries prevalence (14.3%). Routine surveillance of water fluoride and oral health status should continue to sustain these favorable outcomes.

Abbreviations

CFI: Community Fluorosis Index

CI: Confidence interval

DMFT: Decayed, missing, filled teeth

OR: Odds ratio

SD: Standard deviation

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the University of Medicine and Pharmacy, Ho Chi Minh City (Approval No. 123/2023, dated 15 February 2023). Written informed consent was obtained from parents or legal guardians of all participating children. Assent was also obtained from the children.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

No external funding was received for this study.

Authors' contributions

VVC contributed to the conception and design of the study, data collection, data analysis, and drafted the manuscript. TTTQ contributed to data collection, water sample collection, and critical revision. HHPT contributed to data analysis and interpretation, and statistical analysis. DVT contributed to the study design, supervision, and final approval of the manuscript. All authors read and approved the final manuscript.

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Figures

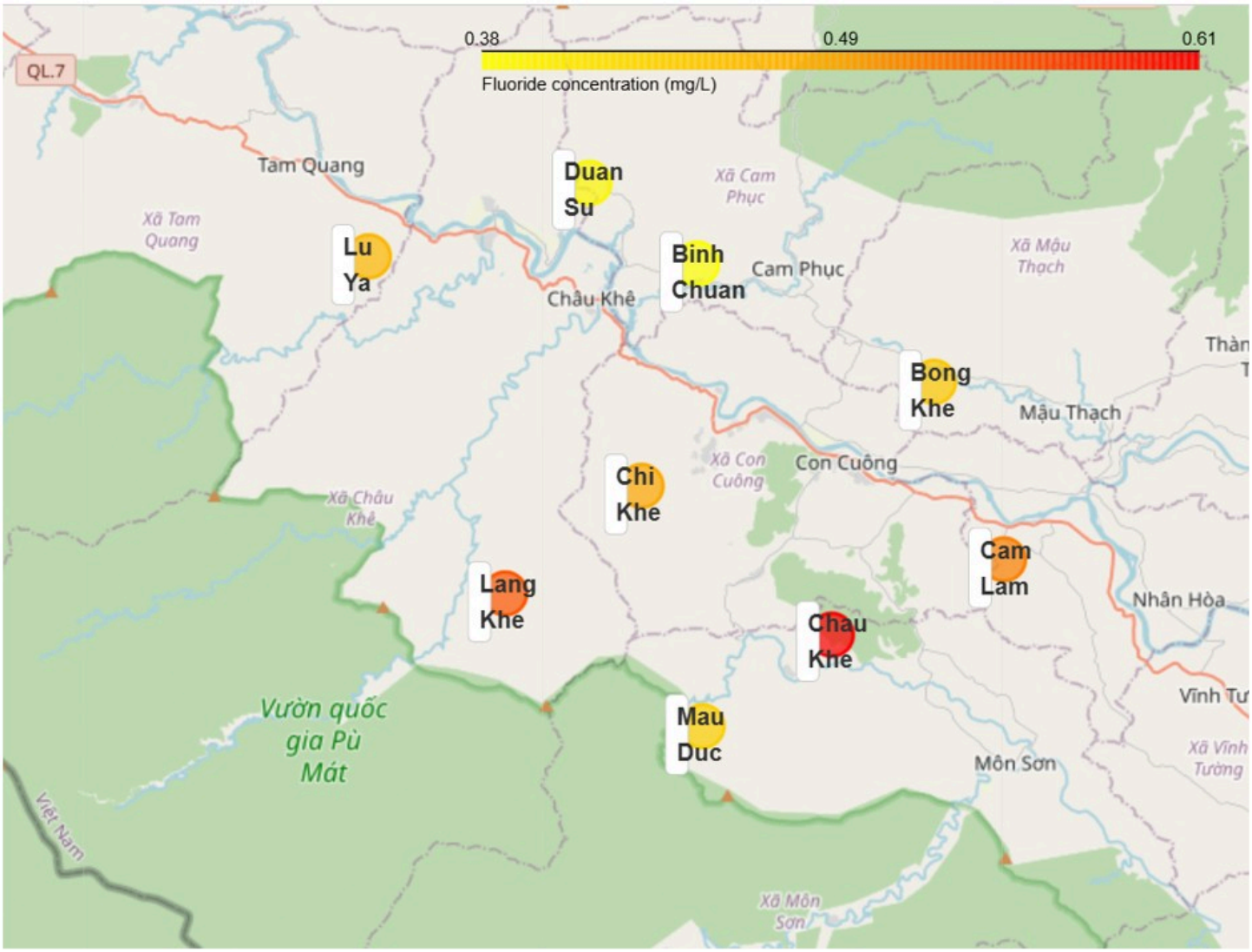


Figure 1

Map of Con Cuong district showing the nine surveyed communes with mean water fluoride levels.

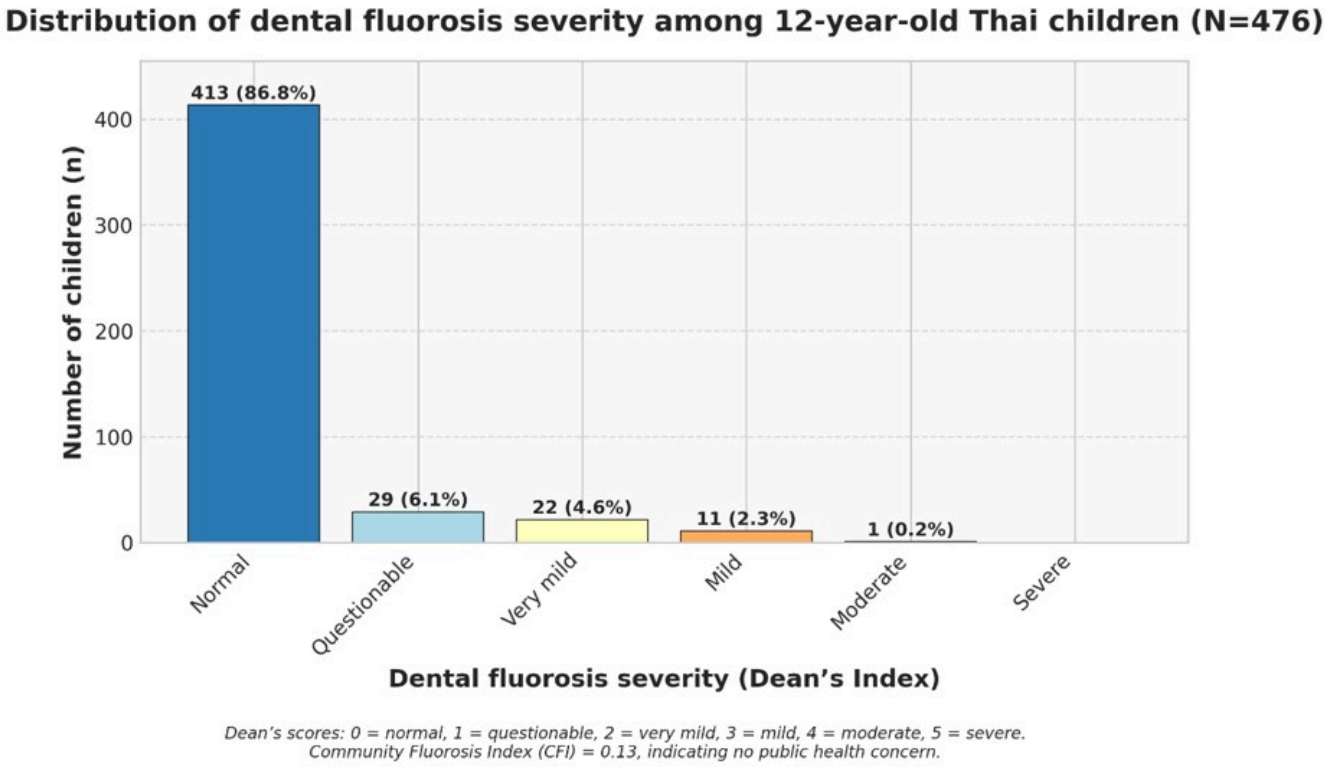


Figure 2

Bar chart of dental fluorosis severity distribution (n = 476).

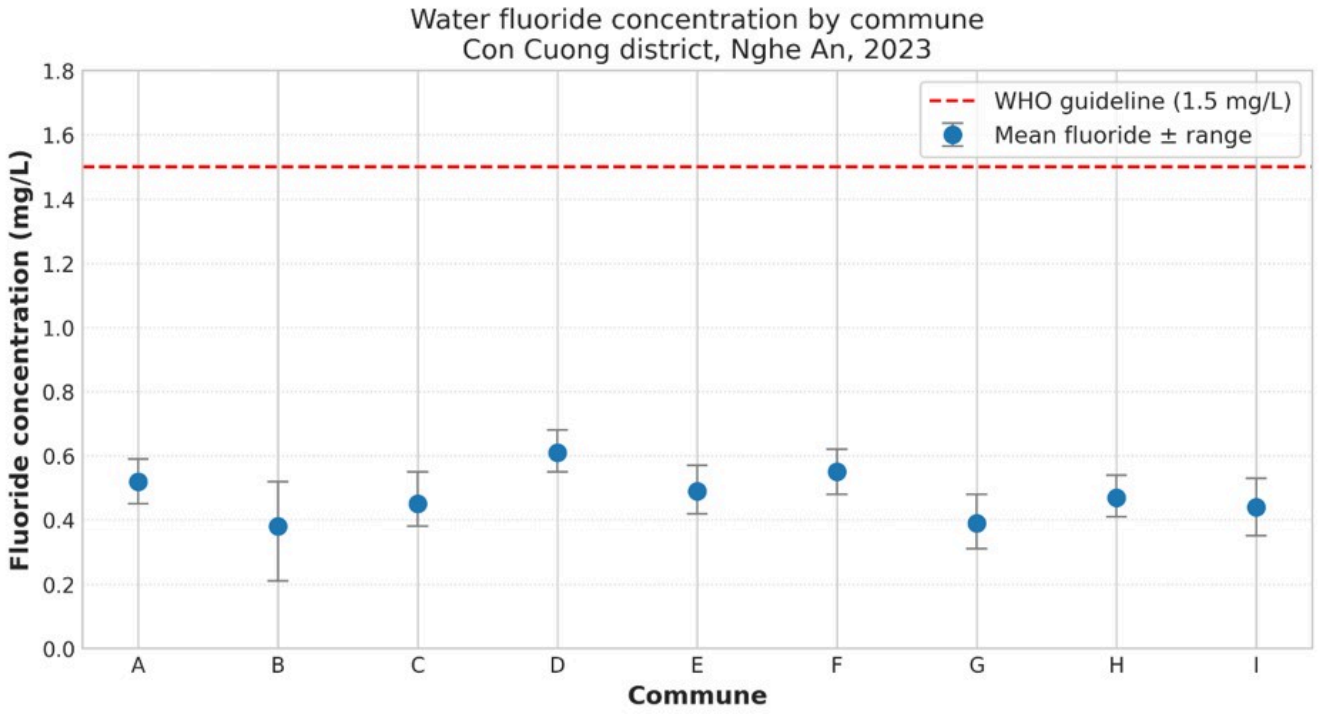


Figure 3

Scatter plot of water fluoride concentration (mg/L) by commune.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1.pdf
- STROBEStatement.pdf