

Fluoride concentrations and pH levels of bottled mineral water commercially available in Bangkok, Thailand

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Objectives: To assess the fluoride concentrations and pH levels of commercially available bottled mineral water in Bangkok, Thailand.

Materials and Methods: Between April and June 2025, 41 brands of bottled mineral water were randomly purchased from retailers across Bangkok. Three bottles with different batch numbers were collected for each brand. Fluoride concentrations were analyzed using a fluoride ion-selective electrode with TISAB II, and pH levels were measured using a calibrated digital pH meter. Fluoride concentrations were compared among brands and among production batches within each brand using the Kruskal–Wallis test with Bonferroni-adjusted post hoc comparisons ($\alpha = 0.05$).

Results: Fluoride concentrations varied widely among brands, ranging from 0.02 to 1.69 mg/L ($p < 0.001$). No significant differences were observed among batches within any brand ($p > 0.05$). Thai-sourced mineral waters demonstrated the highest fluoride levels and the greatest variability, with four brands containing approximately 1.0 mg/L or higher. pH values ranged from 5.65 to 8.86, with most products falling within the recommended range of 6.5–8.5. Only one of the 41 brands reported fluoride content on its label.

Conclusions: Fluoride concentrations in bottled mineral waters sold in Bangkok show substantial variation, with several Thai-sourced brands exceeding recommended levels for tropical climates. The absence of fluoride labelling limits consumer awareness and complicates clinical assessment of total fluoride intake. Regular monitoring and improved labelling regulations are recommended to reduce the risk of excessive fluoride exposure, particularly in young children.

Keywords: dental fluorosis, drinking water, fluorides, mineral water, pH

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Introduction

Mineral water has gained popularity due to its perceived health benefits and its contribution to dietary mineral intake, particularly calcium and magnesium, which play important roles in bone development, metabolism, and overall systemic health [1,2]. With increasing public awareness of nutrition and wellness, bottled mineral water has become a preferred drinking option among urban populations in Bangkok. The rapid expansion of

the bottled water market has introduced a wide variety of brands sourced from different geological formations, resulting in substantial variability in mineral composition.

Fluoride is a naturally occurring ion in groundwater-derived bottled waters, and its concentration varies according to geological strata, aquifer depth, and hydrological characteristics [3, 4]. Fluoride is well recognized for its caries-preventive effect, and community water fluoridation remains an effective public health measure [5].

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However, fluoride has a narrow therapeutic window. Excessive systemic intake during tooth development can lead to dental fluorosis, and a clear dose–response relationship between fluoride concentration in drinking water and fluorosis prevalence has been widely reported [5,6]. Young children are particularly vulnerable because of higher systemic fluoride absorption and the unintentional ingestion of fluoridated toothpaste during routine oral hygiene practices [6].

Climate is an additional determinant of fluoride exposure. In tropical countries such as Thailand, higher ambient temperatures are associated with increased daily water consumption, which may elevate systemic fluoride intake even when fluoride concentrations in drinking water are moderate [7]. Therefore, accurate information on the fluoride content of bottled water is essential for estimating total fluoride exposure during critical periods of enamel formation in children.

Despite the clinical and public health relevance of fluoride intake, bottled water manufacturers in Thailand are not required to disclose fluoride concentrations on product labels. This lack of transparency limits informed consumer choice and complicates clinical assessment of fluoride exposure in dental practice. Previous surveys of fluoride concentrations in bottled water available in Bangkok were published more than a decade ago [8,9]. Since then, substantial changes in the bottled water market—including the introduction of new brands, discontinuation of existing products, and potential changes in water sources—highlight the need for updated and comprehensive data.

In Thailand, the fluoride content of drinking water is regulated by the Ministry of Public Health. According to the Notification on Drinking Water Quality Standards (B.E. 2524), the maximum permissible fluoride concentration in drinking water is set at 1.5 mg/L [10]. In addition, the Ministry

of Public Health Notification No. 454 B.E. 2567 requires that food and beverage products containing fluoride as an ingredient provide appropriate labelling information to ensure consumer awareness [11]. However, bottled mineral water products are not consistently required to disclose fluoride concentrations on product labels, despite their potential contribution to total fluoride intake, particularly in young children.

Previous studies conducted in Bangkok have reported considerable variation in fluoride concentrations among commercially available bottled waters. Dhanuthai and Thangpitsityotin reported fluoride concentrations ranging from very low to moderately high levels among bottled water brands available in Bangkok in 2011, highlighting the influence of water source and geological characteristics [8]. Similarly, Rirattanapong and Rirattanapong later demonstrated wide variability in fluoride content among bottled drinking water products, with several brands containing fluoride levels that may be clinically relevant for children [9]. However, these studies were conducted more than a decade ago, and the bottled mineral water market in Thailand has since undergone substantial changes, including the introduction of new brands, modifications in production sources, and evolving consumer preferences. Therefore, updated and comprehensive data on fluoride concentrations and pH levels of bottled mineral water currently available in Bangkok are necessary to support accurate fluoride exposure assessment, inform clinical decision-making in pediatric dental practice, and provide evidence to guide public health and regulatory considerations.

Therefore, this study aimed to assess current fluoride concentrations and pH levels in commercially available bottled mineral water in Bangkok, Thailand. The findings are expected to provide updated evidence to support clinical counselling,

guide parental education, and inform public health and regulatory considerations regarding fluoride exposure.

The null hypothesis of this study was that there would be no significant differences in fluoride concentrations among bottled mineral water brands or among different production batches within the same brand.

Materials and Methods

Sampling Procedure

Between April and June 2025, 41 brands of commercially available bottled mineral water were randomly purchased from hypermarkets and grocery stores across Bangkok, Thailand. For each brand, three bottles with different batch numbers and bottling dates were collected to represent independent production lots. All bottles were stored unopened in their original containers at room temperature and protected from light until analysis. Prior to measurement, each bottle was gently shaken to ensure sample homogeneity.

Fluoride Analysis

For fluoride determination, 1 mL of each water sample was mixed with 0.1 mL of Total Ionic Strength Adjusting Buffer (TISAB II; Thermo Fisher Scientific, Cambridge, MA, USA) to stabilise ionic strength and pH. Fluoride concentrations were measured using a fluoride ion-selective electrode (Orion Model 96-09; Thermo Fisher Scientific, Beverly, MA, USA) connected to an ion analyser (Orion EA 940; Thermo Fisher Scientific, Waltham, MA, USA).

The electrode was calibrated using fluoride standard solutions of 0.01, 0.10, 1.00, and 10.00 mg/L. A calibration curve (mV versus log fluoride concentration) was constructed for each calibration cycle, and sample readings were

converted to fluoride concentrations expressed in mg/L. To ensure analytical accuracy and minimize potential electrode drift during extended measurement sessions, recalibration was performed after every 20 samples. Periodic recalibration of fluoride ion-selective electrodes is recommended, as changes in electrode response may occur over time due to membrane aging, temperature variation, or prolonged sample analysis. This approach is consistent with standard analytical practice and manufacturer recommendations for maintaining measurement reliability when analyzing large numbers of samples.

pH Measurement

The pH of each water sample was measured using a digital pH meter (Orion 3-Star; Thermo Fisher Scientific, Waltham, MA, USA) equipped with a combination glass electrode (Mettler Toledo 405-S7/120; Mettler-Toledo, Greifensee, Switzerland). The pH meter was calibrated before each measurement session using standard buffer solutions at pH 4.00, 7.00, and 10.00.

Replication and Data Recording

Fluoride concentration and pH measurements were performed in triplicate for each bottle, and the mean value was recorded. As each batch represented an independent production lot, the three batches per brand were analyzed as separate samples. The mean of the batch values was reported as the final fluoride concentration and pH for each brand.

Statistical Analysis

All statistical analyses were performed using IBM® SPSS® Statistics version 13.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated and reported as mean $\pm$ standard deviation. Because batches originated from

different production lots and were treated as independent samples, the Kruskal–Wallis test was used to compare fluoride concentrations among brands and across batches within each brand. When statistically significant differences were detected, Bonferroni-adjusted post hoc pairwise comparisons were applied. Statistical significance was set at $p < 0.05$.

Results

Fluoride concentrations and pH values of all bottled mineral water samples are summarized in Table 1, and fluoride concentrations categorized by country of origin are presented in Table 2.

Table 1 Fluoride concentrations and pH of commercially available bottled mineral waters in Bangkok, Thailand

Brand	Country of origin	Batch 1	Batch 2	Batch 3	Fluoride concentration (mean $\pm$ SD), mg F/L	Labelled fluoride (mg F/L)	pH (mean $\pm$ SD)
DM Berg Iceberg ^a	Canada	0.02	0.02	0.02	0.02 $\pm$ 0.000	NL	7.72 $\pm$ 0.02
Fiji	Fiji	0.30	0.32	0.30	0.30 $\pm$ 0.004	NL	7.53 $\pm$ 0.01
Evian	France	0.08	0.08	0.08	0.08 $\pm$ 0.003	NL	7.60 $\pm$ 0.02
Perrier	France	0.14	0.14	0.14	0.14 $\pm$ 0.005	NL	5.65 $\pm$ 0.07
Volvic	France	0.25	0.25	0.25	0.25 $\pm$ 0.004	NL	7.43 $\pm$ 0.01
Vittel	France	0.33	0.33	0.33	0.33 $\pm$ 0.003	NL	7.46 $\pm$ 0.06
Borjomi	Georgia	0.28	0.28	0.28	0.28 $\pm$ 0.002	NL	6.16 $\pm$ 0.03
Iceland Spring	Iceland	0.07	0.07	0.07	0.07 $\pm$ 0.001	NL	8.43 $\pm$ 0.05
Icelandic Glacial	Iceland	0.07	0.08	0.07	0.07 $\pm$ 0.006	NL	7.98 $\pm$ 0.05
Aqua Panna	Italy	0.07	0.07	0.07	0.07 $\pm$ 0.001	NL	8.01 $\pm$ 0.07
Saint Anne	Italy	0.08	0.08	0.08	0.08 $\pm$ 0.001	NL	7.46 $\pm$ 0.05
San Benedetto	Italy	0.10	0.10	0.10	0.10 $\pm$ 0.002	NL	8.43 $\pm$ 0.04
Goccia Blu	Italy	0.25	0.25	0.25	0.25 $\pm$ 0.002	NL	7.58 $\pm$ 0.04
Santa Victoria	Italy	0.63	0.63	0.63	0.63 $\pm$ 0.006	NL	7.57 $\pm$ 0.01
Yuki no Mizu ^b	Japan	0.03	0.03	0.02	0.03 $\pm$ 0.008	NL	6.72 $\pm$ 0.05
Mt. Fuji	Japan	0.04	0.04	0.04	0.04 $\pm$ 0.001	NL	7.92 $\pm$ 0.02
Suisai No Mori	Japan	0.22	0.23	0.22	0.22 $\pm$ 0.004	NL	7.91 $\pm$ 0.01
Okuna Koukasui	Japan	0.26	0.26	0.26	0.26 $\pm$ 0.003	NL	7.20 $\pm$ 0.01
Voss	Norway	0.14	0.14	0.14	0.14 $\pm$ 0.001	NL	6.56 $\pm$ 0.05

Table 1 Fluoride concentrations and pH of commercially available bottled mineral waters in Bangkok, Thailand (continued)

Brand	Country of origin	Batch 1	Batch 2	Batch 3	Fluoride concentration (mean $\pm$ SD), mg F/L	Labelled fluoride (mg F/L)	pH (mean $\pm$ SD)
Highland Spring	Scotland	0.07	0.07	0.07	0.07 $\pm$ 0.001	NL	7.99 $\pm$ 0.02
Solán de Cabras	Spain	0.11	0.10	0.10	0.10 $\pm$ 0.001	NL	7.77 $\pm$ 0.06
Waitrose Essential	United Kingdom	0.05	0.05	0.05	0.05 $\pm$ 0.003	NL	8.04 $\pm$ 0.01
Aquafina Minerale	United States	0.40	0.40	0.41	0.40 $\pm$ 0.005	NL	8.13 $\pm$ 0.01
Chang	Thailand	0.05	0.04	0.05	0.05 $\pm$ 0.001	NL	7.48 $\pm$ 0.05
ManNature	Thailand	0.08	0.08	0.08	0.08 $\pm$ 0.002	NL	8.82 $\pm$ 0.12
Mont Fleur	Thailand	0.08	0.09	0.09	0.09 $\pm$ 0.001	NL	7.48 $\pm$ 0.06
Monte Fleur Elite	Thailand	0.10	0.10	0.10	0.10 $\pm$ 0.001	NL	8.36 $\pm$ 0.03
VAVA	Thailand	0.11	0.11	0.11	0.11 $\pm$ 0.002	NL	8.06 $\pm$ 0.05
Eto	Thailand	0.12	0.12	0.12	0.12 $\pm$ 0.001	NL	6.93 $\pm$ 0.05
Welle	Thailand	0.16	0.16	0.15	0.16 $\pm$ 0.002	NL	8.40 $\pm$ 0.07
7-Select Mineral Water	Thailand	0.20	0.20	0.19	0.20 $\pm$ 0.005	NL	7.13 $\pm$ 0.05
Aura	Thailand	0.35	0.35	0.35	0.35 $\pm$ 0.001	0.39	7.39 $\pm$ 0.03
Monte	Thailand	0.46	0.46	0.46	0.46 $\pm$ 0.002	NL	8.14 $\pm$ 0.04
Vivalka	Thailand	0.47	0.47	0.47	0.47 $\pm$ 0.003	NL	8.00 $\pm$ 0.02
Minere	Thailand	0.50	0.50	0.51	0.50 $\pm$ 0.003	NL	7.96 $\pm$ 0.03
Singha	Thailand	0.62	0.62	0.62	0.62 $\pm$ 0.003	NL	7.87 $\pm$ 0.03
Eight Plus	Thailand	0.73	0.73	0.74	0.73 $\pm$ 0.010	NL	8.86 $\pm$ 0.14
6ty Degrees	Thailand	0.93	0.93	0.93	0.93 $\pm$ 0.002	NL	8.12 $\pm$ 0.07
Purra	Thailand	1.05	1.05	1.05	1.05 $\pm$ 0.000	NL	7.98 $\pm$ 0.02
Rene ^a	Thailand	1.25	1.24	1.25	1.25 $\pm$ 0.006	NL	7.99 $\pm$ 0.06
AllSpring ^{a,b}	Thailand	1.69	1.69	1.70	1.69 $\pm$ 0.012	NL	8.46 $\pm$ 0.05

Table 2 Fluoride concentration of bottled mineral waters by country of origin

Country of origin	Number of brands (n)	Average fluoride concentration (mean $\pm$ SD), mg F/L
Canada	1	0.02
Fiji	1	0.30
France	4	0.20 $\pm$ 0.112
Georgia	1	0.28
Iceland	2	0.07 $\pm$ 0.000
Italy	5	0.23 $\pm$ 0.237
Japan	4	0.14 $\pm$ 0.120
Norway	1	0.14
Scotland	1	0.07
Spain	1	0.10
United Kingdom	1	0.05
United States	1	0.40
Thailand	18	0.50 $\pm$ 0.470

Table 1 presents fluoride concentrations and pH values of 41 bottled mineral water brands. Superscript letters indicate significant differences ($p < 0.05$). NL = not labelled.

- NL indicates that fluoride concentration was not specified on the product label.
- Superscript letters (a, b) indicate statistically significant differences in mean fluoride concentration between brands based on Bonferroni-adjusted post hoc comparisons ($p < 0.05$). Brands sharing at least one letter are not significantly different from each other.

Table 2 summarizes fluoride concentrations of 41 bottled mineral water brands by country of origin; standard deviations are reported only for countries with more than one brand.

Fluoride concentrations among the 41 brands ranged from 0.02 to 1.69 mg/L. No statistically significant differences were observed among the three batches within any brand ($p > 0.05$), indicating consistent fluoride content across production lots. In contrast, significant differences

in fluoride concentrations were detected among brands ($p < 0.001$).

The highest fluoride concentration was observed in AllSpring (1.69 $\pm$ 0.012 mg/L). Four Thai-sourced brands—AllSpring, Rene, Purra, and 6ty Degrees—contained fluoride concentrations of approximately 1.0 mg/L or higher. Brands with the lowest fluoride concentrations (≤ 0.07 mg/L) originated from Canada, the United Kingdom, Scotland, Iceland, and Japan.

Post hoc pairwise comparisons with Bonferroni adjustment demonstrated that DM Berg Iceberg contained significantly lower fluoride concentrations than Rene ($p = 0.048$) and AllSpring ($p = 0.031$). In addition, Yuki no Mizu showed significantly lower fluoride concentration than AllSpring ($p = 0.048$). When grouped by country of origin, Thai-sourced mineral waters exhibited the highest mean fluoride concentration and the widest variability (0.50 $\pm$ 0.470 mg/L), whereas imported mineral waters generally demonstrated lower and more uniform fluoride levels (Table 2).

The pH values of the bottled mineral waters ranged from 5.65 to 8.86. Most brands fell within the recommended drinking-water pH range of 6.5–8.5. The lowest pH was recorded in Perrier (5.65 ± 0.07), while the highest pH values were observed in Eight Plus (8.86 ± 0.14) and ManNature (8.82 ± 0.12).

Regarding product labelling, only one of the 41 bottled mineral water brands reported fluoride concentration on its label. The remaining 40 brands did not provide any information on fluoride content.

Discussion

This study provides updated data on fluoride concentrations and pH levels in bottled mineral waters commercially available in Bangkok, addressing a gap of more than a decade since previous surveys were conducted [8,9]. The findings demonstrate substantial variability in fluoride concentrations among brands, particularly those sourced from Thailand, while imported mineral waters generally exhibited lower and more consistent fluoride levels.

The wide range of fluoride concentrations observed in Thai-sourced mineral waters likely reflects the geological and hydrogeochemical diversity of groundwater sources across Thailand. Variations in rock composition, aquifer depth, and seasonal hydrological changes have been shown to influence groundwater fluoride levels in different regions of the country [8, 9, 12]. These factors may also explain the greater variability observed among Thai brands compared with imported mineral waters. In contrast, mineral waters from Europe and other regions showed relatively stable fluoride concentrations, consistent with the use of protected natural springs and stricter regulatory controls governing natural mineral water composition [8,9].

In the present study, fluoride concentrations ranged from 0.02 to 1.69 mg/L, with substantial variability among brands and notably higher values in several Thai-sourced products.

Compared with earlier Bangkok surveys [8, 9], the current findings suggest that variability in fluoride concentrations remains a persistent issue; however, the contemporary market appears to include a broader range of brands and a greater diversity of product origins, reflecting changes in product availability, distribution, and potentially water sourcing over time. Several factors may explain differences between the present and prior findings, including the introduction of new brands and discontinuation of older brands, changes in declared or actual water sources, geological heterogeneity of groundwater sources in Thailand, and possible differences in sampling frame and analytical time points [8,9,12]. From a consumer and public health perspective, the key implication is that bottled mineral water cannot be assumed to have uniformly low fluoride concentrations.

Thai-sourced bottled mineral waters with higher fluoride concentrations observed in the present study are likely derived from groundwater sources influenced by local geological and hydrogeochemical characteristics. Groundwater fluoride levels are known to vary according to rock composition, aquifer depth, and geochemical conditions, particularly in areas containing fluoride-rich minerals [9,12]. Previous hydrogeological studies in Thailand have demonstrated substantial regional variation in groundwater fluoride concentrations, which may contribute to the elevated fluoride levels detected in some Thai brands [8,9,12]. In contrast, Thai bottled mineral water brands with lower fluoride concentrations may originate from groundwater sources with lower fluoride-bearing mineral content or from surface water sources subjected to treatment processes that reduce fluoride levels.

Beyond dental fluorosis, excessive systemic fluoride intake has been associated with a range of potential health effects. Chronic exposure to high fluoride concentrations may affect skeletal health, potentially leading to alterations in bone mineralization and, in severe cases, skeletal fluorosis [6]. Young children are particularly vulnerable to systemic fluoride exposure because of higher absorption rates relative to body mass and immature renal clearance mechanisms [6]. In tropical climates such as Thailand, increased water consumption driven by higher ambient temperatures may further elevate total fluoride intake when drinking water contains moderate to high fluoride concentrations [7].

From a preventive dentistry perspective, fluoride is effective in reducing dental caries when present within an optimal concentration range. For community drinking water, an optimal fluoride concentration of approximately 0.6–0.8 mg/L has been recommended for warm and tropical climates to balance caries prevention while minimizing the risk of dental fluorosis, taking into account increased water consumption associated with higher ambient temperatures [7]. In contrast, higher fluoride concentrations increase the risk of adverse effects, particularly during tooth development. International guidelines generally indicate that fluoride concentrations exceeding 1.5 mg/L in drinking water are associated with an increased risk of dental fluorosis and are therefore not recommended for routine consumption, especially by infants and young children [6]. Infants and young children are particularly vulnerable to excessive fluoride intake because early-life exposure coincides with critical periods of enamel formation, higher fluoride absorption relative to body weight, and limited renal excretion, potentially increasing the risk of enamel fluorosis when drinking water with elevated fluoride concentrations is used for infant formula preparation or as a primary drinking source [6].

Epidemiological studies have consistently documented a positive association between fluoride exposure and the prevalence of dental fluorosis in children, with a clear dose–response relationship between fluoride concentration in drinking water and fluorosis prevalence and severity [5,6]. Studies conducted in Thailand have demonstrated that in areas where drinking water fluoride concentrations are below 0.5 mg/L, the prevalence of dental fluorosis among children is generally low, whereas communities exposed to fluoride concentrations around 1.0 mg/L or higher show a markedly increased prevalence of fluorosis [13]. In high-fluoride areas of Thailand, fluorosis prevalence among school-aged children has been reported to exceed 30–40%, with severity increasing as fluoride concentrations rise further [13].

In the context of the present study, the identification of bottled mineral water brands containing fluoride concentrations approaching or exceeding 1.0 mg/L is therefore clinically relevant. Although such concentrations may still confer caries-preventive benefits, regular consumption by infants and young children could contribute to cumulative fluoride exposure beyond optimal levels. These findings highlight the importance of fluoride concentration disclosure and informed selection of drinking water sources for young children, particularly in settings where bottled mineral water is frequently used as a substitute for tap water.

A strength of this study is the inclusion of three production batches for each brand, enabling an assessment of within-brand consistency. No statistically significant differences were found among batches within any brand ($p > 0.05$), indicating that fluoride concentrations were stable across the sampled production lots during the study period. However, ongoing surveillance remains warranted, particularly for brands sourced from regions known to have higher groundwater fluoride levels [9, 12].

From a clinical perspective, these results emphasize the need for dental practitioners to routinely assess the type and brand of bottled water consumed in households when estimating fluoride exposure in children, particularly those under six years of age. The cumulative fluoride intake from drinking water and dental products may increase the risk of enamel fluorosis during critical periods of tooth development, underscoring the importance of individualized fluoride exposure assessment in pediatric dental care [6].

In addition, the Notification of the Ministry of Public Health (No. 454) B.E. 2567 on natural mineral waters specifies explicit labelling requirements related to fluoride. In particular, products containing fluoride greater than 1 mg/L must display a warning statement indicating the presence of fluoride, while those containing fluoride concentrations exceeding 1.5 mg/L must additionally state that the product is not suitable for infants and children under seven years of age [12]. In the present study, several Thai-sourced brands contained fluoride concentrations around or above 1 mg/L, with the highest value reaching 1.69 mg/L. These findings underscore the importance of clear disclosure and warning information to support informed consumer choices. Enhanced labelling requirements may also assist dental professionals in estimating total fluoride exposure in children and in providing evidence-based guidance to caregivers [6,12].

The pH values of bottled mineral waters analyzed in this study ranged from mildly acidic to alkaline, with most products falling within the WHO-recommended drinking-water pH range of 6.5–8.5 [14]. Two sparkling mineral waters exhibited mildly acidic pH values below this range. Although sparkling mineral waters are generally considered to have low erosive potential due to buffering by dissolved minerals, primary enamel is thinner and less mineralized than

permanent enamel and may be more susceptible to demineralization [1,15]. Therefore, frequent consumption of acidic beverages, including certain mineral waters, should be moderated in young children.

An important finding of this study is that only one of the 41 bottled mineral water brands disclosed fluoride concentration on its product label. The absence of fluoride labelling limits consumer awareness and complicates clinical assessment of total fluoride intake. Similar concerns have been reported in previous studies conducted in Thailand [8, 9]. In several countries, including members of the European Union, bottled waters containing fluoride concentrations above 1 mg/L are subject to mandatory labelling and health warnings for young children. Implementing comparable labelling regulations in Thailand could support informed consumer choices and enhance preventive oral health strategies.

Overall, the findings underscore the need for regular monitoring of fluoride concentrations in bottled mineral waters sold in Thailand. Clear fluoride labelling, ongoing surveillance of groundwater sources, and targeted parental education are essential to minimize the risk of excessive fluoride exposure while maintaining the caries-preventive benefits of fluoride.

Conclusion

Fluoride concentrations in bottled mineral waters sold in Bangkok varied widely, particularly among Thai-sourced brands, with several exceeding recommended fluoride levels for tropical climates. Although most products had acceptable pH values, the absence of fluoride labelling limits accurate assessment of total fluoride intake. Regular monitoring of bottled mineral waters and clearer labelling regulations are recommended to support

informed consumer choices and protect vulnerable populations, especially young children, from excessive fluoride exposure.

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Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

Not applicable. This study involved the analysis of commercially available products and did not include human or animal subjects.

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