Asian Journal of Dental Sciences

Volume 7, Issue 1, Page 75-83, 2024; Article no.AJDS.115315

Determination of Fluoride Concentration in Drinking Water Resource at Lao P.D.R.

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Authors' contributions

This work was carried out in collaboration among all authors. Author Phimfalee Sayaxang contributed to design data acquisition analysis interpretation, drafted and critically revised the manuscript. Authors Phetmany Sihavong, AP, VI, MS, AH, TV, Phetlamphy Sidanoumonh, VB, KL, MK contributed to data acquisition and analysis, critically revised the manuscript; and author HV contributed to conception, design, and data interpretation, drafted and critically revised the manuscript. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/115315

Original Research Article

Received: 28/01/2024
Accepted: 01/04/2024
Published: 04/04/2024

ABSTRACT

Introduction: Consuming water from different sources might lead to different fluoride intake levels for human health. High or low-concentration contamination can cause risk factors for human health, such as dental cavities, dental fluorosis, and skeletal tissues. Accordingly, there is limited evidence of fluoride contamination in drinking water among Lao people.

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Aims: To estimate the level of fluoride concentration in drinking water sources and describe fluoride water drinking knowledge and behavior among Lao people.
Place and Duration of Study: The study was conducted in two areas of Laos, the northern and the southern, from May to December 2023.
Methodology: A cross-section was performed. The questionnaires were used in face-to-face interviews to gather information about participants, such as demographics, fluoride knowledge, and drinking water behavior. Testing for fluoride content was conducted using an ExStik FL700 fluoride meter from Extech Instrument. The data analysis was done using SPSS for descriptive analysis.
Results: A total of 496 samples (36% male and 63.10% female; range ages 16–85 years). The study involved contributing fluoride to 118 samples of drinking water that were collected for a criterion. The study found low fluoride concentration levels, a mean of 0.124 ppm, 82.3% of bottled water consumed by drinking more than 2 liters per day, and 91.30% don't know about fluoride.
Conclusion: To prevent dental caries and the risk of dental fluorosis, fluoride concentration levels in drinking water are essential for detection to ensure compliance with recommended fluoride arrangements for routine protocol.

Keywords: Fluoride concertation; drinking water; oral health risk factor; fluoride knowledge; drinking behavior; Lao PDR.

1. INTRODUCTION

Fluoride is a naturally occurring element widely distributed in the earth's crust [1]. and its presence in drinking water has been a subject of significant public health concern, as studies in India, Central Africa, and China reported that a high level of fluoride concentration in drinking water consumption can cause dental fluorosis, skeletal fluorosis and other health issue [2-6]. A systemic review from Akuno found an association between a high prevalence of dental fluorosis and long-term consumption of drinking water with fluoride levels above 1.5 mg/l [7], including Veneri et al.'s researcher indicator consumption of fluoride in drinking water, there was a significant relationship between fluoride exposure and IQ [8]. The benefits of fluoride in preventing dental caries are well documented because fluoride ions interact with tooth enamel, which is made up of calcium and phosphate compounds and is susceptible to decay induced by acid-producing bacteria [9]. Thus, populations residing in areas with optimal fluoride levels in drinking water experience lower dental decay rates, particularly among children, adolescents, and adults. The report in Austria shows that 89% of Australians have accessed fluoridated drinking water, which reduces dental caries in children, teenagers, and adults by 26-44% [10,11]. Studies in Lithuania have shown that the high levels of fluoride in drinking water are associated with lower dental caries experiences in adults [12]. Although the established benefits of water fluoridation exist, the optimal fluoride concentration in drinking water remains a subject of ongoing discussion and investigation. The optimal concentration is typically influenced by factors such as climate, diet, oral hygiene practice, and socioeconomic status [7]. The World Health Organization recommended that the standard fluoride concentration in community water supplies be 0.5-1.0 mg/L to prevent dental health without causing adverse health effects [13]. Furthermore, natural geological sources, artificial fluoridation programs, or environmental factors may all contribute to changes in fluoride content within and between locations because the rock and mineral containing fluoride in there composition [14].Consequently, in order to guide public health policies and interventions aimed at optimizing fluoride exposure while mitigating negative effects, it is imperative to understand the relationship between fluoride content in drinking water and dental health outcomes.

In Lao PDR, exploring the relationship between fluoride in drinking water and oral health outcomes is essential, particularly important where water fluoride programs are still evolving and oral health disparities groups. Thus, the Lao National Community Report on Nutrition revealed that 90.15% of the country's population can access water supplies despite the limited levels of fluoride concentration in drinking water [15]. By elucidating this, an association, policymaker, and public health authorities can make informed decisions regarding fluoride supplement programs and prevention of dental care initiatives tailored to the needs of the Lao population. Therefore, we conducted the study focusing on determining fluoride concentration levels in drinking water. Through rigorous data collection and analysis, we seek to contribute to promoting oral health in Laos.

2. MATERIALS AND METHODS

A descriptive cross-sectional study was conducted. It was performed at 4 villages: 2 villages in Luangprabang province (Northern part) and 2 villages in Champasck province (Southern part) of Lao PDR. In each province, there was 1 village representative in the rural and 1 village representative in the city. The sample size was calculated using the following formula [16].

$$n=\frac{p\times q\times z_{\propto}^{2}\times N}{\Delta^{2}\times N+p\times q\times z_{\propto}^{2}}$$

Where;

n = the required sample size.
p and q = a part and its inverse value in each class of the general total (p=0.5; q=0.5)
z_{α} =Standard error division =95%=1.96.
Δ = Difference in the effect of two interventions which is required (estimates effect size) Δ=5%
N = General total amount (N_1=128; N_2=181, N_3=210, N_4=120 (Local administration authority according to annual reported, 2023); N_1= Rural village, N_2 =City village of Lungprabang province; N_3= Rural village, N_4= City village of Champasack province.

$$n1=\frac{50\times50\times1.96^{2}\times128}{5^{2}\times128+50\times50\times1.96^{2}}=96\ ;$$

$$n2=\frac{50\times50\times1.96^{2}\times181}{5^{2}\times181+50\times50\times1.96^{2}}=123$$

$$n3=\frac{50\times50\times1.96^{2}\times210}{5^{2}\times210+50\times50\times1.96^{2}}=135;$$

$$n4=\frac{50\times50\times1.96^{2}\times120}{5^{2}\times120+50\times50\times1.96^{2}}=97$$

Provided inevitable loss amongst the participants in the course of the study for various reasons, the calculated sample size was increased by 10%:

n_1=96+ (10%×n1) =106;
n_2=123+(10%×n2) =135;
n_3=135+(10%×n3) =148;
n_4=97+(10%×n4) =107.

A tally simple size =106+148+135+107= 496

Inclusion Criteria: all available drinking water sources such as rivers, wells, springs, boreholes, and bottled water in household samples during the study.

Exclusion criteria: The same source of drinking water in each household sample participant was not collected, and the drinking water source was unclean and contaminated with chemicals from factories or other sites.

Question Interview: Fourth dentists from the faculty of dentistry were interviewed face-to-face with an open-ended questionnaire to gather information such as demographics, fluoride knowledge, and drinking water behavior. Before the interview, the questionnaires were completed using the pilot test. We administered the questionnaire to 30 respondents from a similar geographic group for data collection to evaluate its effectiveness and identify potential issues. The participants were asked to provide feedback on the questionnaire's clarity, the content's relevance, and the overall flow. After analyzing the responses, we made revisions to improve the questionnaire's clarity and coherence.

Drinking Water Resource Sample Collection: A 500 ml sample of each participant's drinking water source was collected in a disabled plastic bottle and labeled with a unique identifier, date, time, and area was collected a sample.

Fluoride Concentration Analysis: Two dentists from the faculty of dentistry evaluated the fluoride concentration. The first dentist developed a sample water solution, and the last performed a fluoride concertation calculation. The detected fluoride concentration was at room temperature or at least 25°C [17]. The ExStik FL700 fluoride meter from Extech Instrument has been conducted on the study site for the fluoride test of water. The total ionic strength adjustment buffer (TISAB) table was used as a reagent. For values exceeding the meter's operating arrangement of 0.00-9.99, deionized water was used for dilution. Based on the instrument's user guide, the fluoride meter was calibrated between 1 and 10 ppm fluoride standard and other tablets in 20ml to 10 ppm fluoride standard, respectively [18] [19]. The fluoride concentration evaluation process followed the following steps: First, the instrument for fluoride concentration was calibrated before tests. The positive control contained 20 ml of a 1 ppm fluoride standard solution. In comparison, the negative control added 20 ml of distilled water with one tablet reagent of the Total Ionic Strength adjustment buffer (TISAB). Second, add one tablet of the Total Ionic Strength Adjustment Buffer (TISAB) reagent to 20 ml of sample water from the collection in the simple cup. Please wait for the table to dissolve, mix well, and then thoroughly rinse the instrument's end with distilled water before wiping it dry with a clean tissue. The instrument was immersed in the simple preparation. Last, after 35 seconds, the instrument will display the fluoride concertation value numerically from 0 to 9.99 ppm [19].

Data Analysis Management: The final data was collected using the Microsoft Excel version 2017 for data cleansing. The statistical analysis was performed using descriptive statistics, frequency, percentage, mean, and standard deviation (SD) by SPSS (Statistical Package for Social Sciences) version 27 to characterize the sample.

3. RESULTS

Of a total of 496 patriciates in the study, the number of gender groups of participants was more Female (63.1%), while age groups were more 25 to 49 years old (70.2%), and more education level at primary school (27.6%). 72.60% had drinking water more than 2 liters per day, and 86.70% had to pay for water drinking and they didn't have knowledge of fluoride (91.30%), including never tested fluoride concertation level in the past. As a Table 1.

Table 2. Describes the etiology of fluoride concentration levels in different drinking water resources. A total of 496 householders participated in the study; water consumption was collected from 188 samples, and in the criteria for the study, the study found 0.124 ppm of mean fluoride concentration in the range of 0.01 ppm to 0.7 ppm. The highest in borehole water was 0.15 ppm of mean, and the lowest in spring water was 0.22 ppm of mean.

Table 1. Demographic characteristics, drinking water consuming behavior, fluoride knowledge

Variable	Number	Percentage
Gender		
Male	183	36.90
Female	313	63.10
Age		
>25	23	4.60
25-49	348	70.20
50-74	117	23.60
<75	8	1.60
Education		
No education	95	19.20
Primary school	137	27.60
Middle school	122	24.60
Secondary school	108	21.80
Higher	34	6.90
Drinking water in liters per day		
2 liters>	136	27.40
< 2 liters	360	72.60
Cost of drinking water		
No pay	66	13.30
Pay	430	86.70
Payment per year for drinking water		
1-396.000 kip	107	24.90
397.000-900.000 kip	112	26.00
900.100-1.326.000 kip	104	24.20
<1.326.000 kip	107	24.90
Fluoride knowledge		
Don't know	453	91.30
Know	43	8.70

Variable	Number	Percentage
Drinking water fluoride concentration levels evaluation in the past		
Never	496	100
Ever	0	0.00

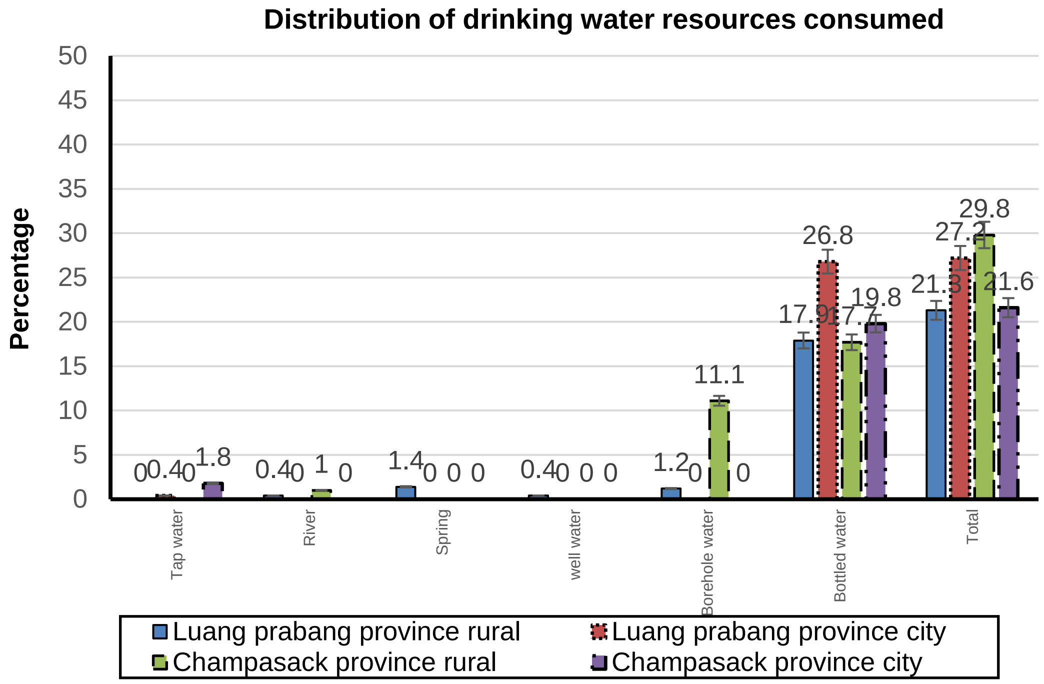

Fig. 1. A graph shows the distribution of drinking water resources consumed in Luang Prabang and Champasack provinces. The higher percentage of water resources consumed came from bottled water in Luang prabang province in rural (17.9%), city (26.8%), and Champasack provinces in rural (17.7%), city (19.8%)

Table 2. Fluoride concentration levels

Type of drinking water resources	n. sample householder	n. sample drinking water	F-conc** Rang	F-conc** Mean (ppm*)	SD
Tap water	11	3	0.02-0.3	0.101	0.103
River	7	7	0.03-0.1	0.082	0.298
Spring	7	7	0.01-0.02	0.015	0.005
Well water	2	2	0.03-0.04	0.035	0.007
Borehole water	61	61	0.02-0.7	0.22	0.169
Bottled water	408	43	0.01-0.5	0.11	0.114
Total	**496**	**118**	**0.01-0.7**	**0.124**	**0.126**

1 part per million (ppm)=1mg/L
*** Fluoride concentration*

4. DISCUSSION

The study found that the average fluoride concentration in drinking water resources was low, 0.124 mg/L, compared to WHO recommendations [14]. The average fluoride was highest in groundwater drinking resources, such as borehole water, while the lowest was in drinking water from the surface, such as river and spring water resources. The resulting study was similar to GT. Tayanin noted that the lowest value for fluoride concentration in drinking water in Laos from stream water was 0.013 ppm, and the average fluoride concentration in drinking water in Luagpraban was 0.512 ppm [20]. In the 2003 study by Hoque et al. published in

Bangladesh, the average concentration of fluoride was found to range from 0.02 to 2.32 mg/L; the lowest concentration was found in surface water, with a mean of 0.14±0.10 mg/L, while the highest concentration was found in groundwater, with a mean of 0.33±0.21 mg/L [21]. In comparison, a study in Cambodia showed that the Southern coastal area was exospore to fluoride concentration >50mg/L [22]. E. Shaji et al. recommend investigating the high fluoride in groundwater by exploiting rich rocks, including minerals such as biotite and amphiboles, especially in metamorphic basement rocks [23]. Furthermore, the findings indicated that the distribution concentration of fluoride is contingent upon the various sources identified in each region.

Conversely, the study found that drinking more than 2 liters of water per day does not make the body receive more fluoride concentration. Sawka, MN notes that the net body water balance is astonishingly well-regulated day-to-day (loss = gain) [24]. The body of an individual requires water due to a variety of components that affect the intake of water, for instance, dietary habits, physical activity, and climate [25]. This finding suggests that the low amount of fluoride in their drinking water did not affect fluoride concentration in the human body. Therefore, consuming more liters of drinking water daily does not always mean the water is contaminated with fluoride at high concentrations.

In the study, drinking water resources were bottled in over 80% of cases. There was a distinction from the research by GT. Tayanin showed that the main drinking water resource for the Lao people in Vientiane was the Mekhonge River [20]. As a result, the current situation of water-drinking consumers has changed their behavior when compared to the past, which is in line with C. ferrite-AMBIO, who said that bottled water consumption is a global trend and that many residents believe that bottled water drinking provided by factories is good taste, safe for health concerns and more accessible to carry. Overall, bottled water was a more popular choice for consumers [26,27]. In contrast, bottled water may contain chemicals from plastic bottles, such as bisphenol A (BPA) or microplastic, which can harm human health through hormone-like properties, body weight, tumorigenesis, metabolism, cancer progression, and male reproductive function. Transcription factors, epigenetic changes, changes in DNA methylation, histone modification, and microRNA expression influence BPA's effects [28]. Doppong et al. studied bottled water quality based on the drinking water quality index and the heavy mental index. The results showed that the water was of poor quality and had a potential risk of aluminum, chloride, and nitride for the inhabitants who were drinking simple water [29]. Similarly Mizaei et al. showed that bottled water had numerous potential lifelong carcinogenicities because of the heavy metals in plastic bottled water [30]. Besides that, water bottles, in particular, can impact the environment because of the plastic bottles used for packing water. Orest, Barret, and Lemaire's study showed that 62.8% of plastic bottles were environmentally harmful [31]. The significant relationship between plastic bottles and the environment has an impact for several reasons, such as plastic pollution, resource depletion, energy consumption, waste management issues, and microplastics [32-34]. Geyer et al., Between 1950 and 2015, the world's plastic production expanded from 2 to 380 megatons, with 9% of plastic waste being recycled, 12% being burned, and 79% being accumulated in landfills [35]. Currently, plastic has been entering the oceans at least 8 million tons per year, creating concerns regarding their toxicity on marine biota as they end up in the food chain and ultimately affect human health [34]. However, the different fluoride concentration levels in bottled water depended on the water resource and processing method used by various brands. Natural spring water, for instance, naturally contains fluoride due to the geological characteristics of the area where the water originates. On the other hand, purified or distilled waters typically have low levels of fluoride because they undergo processes that remove impurities, including fluoride. Additionally, some bottled water brands may add fluoride to their water bands to achieve a certain level of dental health. Therefore, the study's results found a range of fluoride concentration levels in bottled water drinking between 0.01 ppm - 0.5 ppm.

Knowledge about fluoride is crucial for understanding the prevention of dental caries and fluorosis. Fluoride health prevents tooth decay by strengthening tooth enamel and making teeth more resistant to acid attacks from plaque, bacteria, and sugar in the oral cavity. Sajji et al. showed that 78% of the representatives studied didn't know the fluoride concentration in drinking water or toothpaste, and a yellow discoloration of the tooth surface caused embarrassment when speaking and smiling [36]. Like Duguma and Fasil Kenea, 89.5% of respondents don't know if fluoride in toothpaste has been provided, while there is a high prevalence of dental fluorosis of teeth (91%) [37]. As a result, we found that 91.3% were not aware of the knowledge concentration of fluoride. Excessive fluoride intake during tooth development in childhood can lead to dental fluorosis, which manifests as white spots or steaks on the teeth therefore, understanding the appropriate use of fluoride, including optimal levels in drinking water, is essential for maintaining oral health and prevention.

Although the study also had some limitations due to human health issues, such as the prevalence of dental caries or dental fluorosis, all the results have shown that a primary database level of fluoride concentration in drinking water is accuracy by obtaining a precise understanding of the current state relevant to a particular community in Laos. The data can be used to assess the population's fluoride intake, monitor changes over time, and inform public health policies related to fluoridation and dental health promotion.

5. CONCLUSION

Understanding the contamination relationship between the levels of fluoride concentration and drinking water resources is important for monitoring fluoride levels in the drinking water supplied and consistently demonstrates that optimal fluoride levels contribute to improved dental health outcomes, including a reduction in dental caries and cavities. Therefore, maintaining appropriate fluoride levels in drinking water remains a crucial aspect of public health policy to promote oral health and prevent oral disease within communities and oral health issues.

CONSENT

Each participant obtained full details about the study and signed a consent form.

ETHICAL APPROVAL

Ethical Approval was approved by the Ethics Committee of the University of Health Sciences Lao PDR No. 502/IREC.

ACKNOWLEDGEMENTS

We would like to thank the Asian Development Bank for its support to this CRF initiative. We are grateful to Dr. Alexo Esperato and the TA TA9397-REG organization team for their support research financially, and the CRF community for providing us with research opportunities. Finally, thanks to our research team, who worked hard to complete the study. Epically, participants in our household sample cooperated during the survey.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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