RELATIONSHIP BETWEEN FLUORIDE CONTENTS IN GROUNDWATER AND PREVALENCE OF FLUOROSIS IN TAY SON DISTRICT, BINH DINH PROVINCE, VIETNAM

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ABSTRACT  

The communities within Binh Dinh province in the Central Vietnam are reliant on groundwater as their primary supply of domestic and potable water. Meanwhile, it is seriously contaminated with fluoride that causing fluorosis problem for people. This study aims to investigate the link between severity of dental fluorosis rate in a population and fluoride concentration in drinking water in Tay Son area. A total of 50 well-water samples were collected and 220 people were surveyed by questionnaire from 50 households at 3 villages: Tay Phu, Binh Tuong, Tay Giang of Tay Son district, Binh Dinh province, Vietnam. The quantitative assessment of severity of dental fluorosis was done by calculating the Community Fluorosis Index (CFI) using Dean’s classification. Result of this study showed that fluoride concentration in well-water varied from 0.31 mg/L to 7.69 mg/L (mean 2.66 mg/L, SD: 2.18 mg/L) with 70 % of well-water samples above the maximum permissible limit of 1.5 mg/L of World Health Organization (WHO) drinking water standard. 100 % people surveyed was suffered from dental fluorosis and Dean scale of dental fluorosis ranged from level 2 to level 5. CFI varied from 3.45 to 4.13 above limit value (0.6). The community seriously suffered from dental fluorosis. The fluoride concentrations and Dean Index have high correlation ($r = 0.580$, $p < 0.0001$). Based upon results of this study, it is recommended that the government should supply drinking water with appropriate fluoride content for this community.  

Keywords: fluoride, dental fluorosis, groundwater, Dean’s classification.
1. INTRODUCTION

Water is considered as a vital substance in the environment, and its contamination with fluoride has become a worldwide environmental problem. Estimated to be 13th most abundant element in the earth’s crust [1, 2], fluoride is widely dispersed in nature, and the amount of fluoride presented naturally in groundwater is highly dependent upon the individual geological environment from which the water is obtained [3, 4]. Fluoride occurs in a combined form in rocks and soils in a wide variety of minerals such as fluorspar (fluorite) (CaF$_2$), cryolite (Na$_3$AlF$_6$), apatite (Ca$_5$(PO$_4$)$_3$F), topaz (Al$_2$SiO$_4$(F,OH)$_2$), amphiboles and micas [5].

Fluoride is an element of major health concern and it is absorbed into the organism as a result of environmental or industrial exposure [6]. In fact, fluoride in drinking water is known for both beneficial and detrimental effects on health [7]. Especially, fluoride intake plays an essential role in the development of teeth and bones. The World Health Organization specified the drinking water quality guideline value for fluoride is 1.5 mg/L [8]. Besides, studies have shown that fluoride concentrations below 0.5 mg/L in drinking water leads to dental carries [6] while fluoride content of between 0.5 and 1.5 mg/L promotes dental health [9] while fluoride concentrations exceed 4 mg/L leads to dental and skeletal fluorosis [12]. Dental fluorosis is a tooth malformation related to excessive fluoride ingestion during tooth development [13]. It gives unsightly marks on the teeth.

Many of previous studies from various part of the world reported that the high fluoride concentrations in local well-water cause the fluorosis problem for people. Fluoride has caused significant contamination of groundwater in many regions worldwide including India [14, 15], Korea [16, 17], Malawi [11], Pakistan [18], Sri Lanka, West Indies, Spain, Holland, Italy, Mexico countries... Especially, India, East Africa and China have been identified as the countries with the most seriously fluoride-contaminated aquifers [19, 20].

In some areas of Vietnam, people have been exposed to fluoride that occurs naturally in groundwater. The well water used for drinking, domestic as well as agriculture has resulted in a variety of serious health risks, including dental fluorosis. The prevalence of dental fluorosis has been affecting both the health and the beauty of local resident from elder generation to younger generation. However, in Vietnam in general, Binh Dinh province in particular, the study of fluoride in groundwater and other related issues is scarce.

To determine the severity of dental fluorosis as a public health problem, Dean (1935) devised a method of calculating the prevalence and severity of fluorosis in a group or community. The prevalence of fluorosis was determined through clinical survey and expressed as percentage of fluorosis incidence and the quantitative assessment of severity of dental fluorosis incidence which was done by calculating the Community Fluorosis Index (CFI) using Dean’s classification [21, 22]. Many of the previous studies expressed the degree of fluorosis prevalence using CFI measurement [23].
This study was conducted at Tay Son district which is a midland area situated in Southwest of Binh Dinh province in the central region of Vietnam (Figure 1). This study area is located from the latitude 13°56'5"N to the longtitude 108°54'36"E. It covers an area of 678.99 km² and has a population of about 123,199 within 1% of ethnic minority. Although total area is extensive, springs and rivers as well as mountain are mainly. Therefore, most of residents are distributed along the main roads. Because groundwater is used as a main water source for drinking and other life supporting activities, it can directly affect human health. In the study area, local residents are suffered from unsightly marks and brown stains on their teeth. However, community awareness about fluoride and its effects are limited. Dental fluorosis problem has not been adequate attention. Up to now, the Community Fluorosis Index in study area has not been assessed. Therefore, it is vital to assess the fluoride level in groundwater and fluorosis problem in this area.

The objectives of this study are to determine the fluoride concentration in groundwater and to investigate the dental fluorosis rate in a population through drinking water in Tay Son area. Relying on that, the link between severity of dental fluorosis rate in a population and fluoride concentration in drinking water in study area are assessed. The results of this research become a premise for following researches.

2. MATERIALS AND METHODS

2.1. Sampling collection and chemical analysis

A total of 50 well water samples were collected from 50 households at 3 villages: Tay Phu, Binh Tuong, Tay Giang of Tay Son district in July, 2009 and July, 2010. The sampling collection depend on the 1 × 1 km and 0.5 × 0.5 km grid cells which have been split on the map to ensuring that the sampling position is random, the sampling density is uniform and the number of selected samples is representative of study area (Figure 1). Out of 50 collected sampling wells, there are 48 dig-wells and 2 drill-wells. The average depth of the wells is 8.2 m. All samples were filtered over a 0.45 µm filter, stored in polyethylene bottles that were previously washed with deionized water at 4 °C before being analyzed.

Fluoride level was determined using ion chromatography with conductivity detection. The column used was Allsep Anion (4.6 mm i.d. × 100 mm) and eluent solution was 1.8 mM HCO₃⁻ / 1.7 mM CO₃²⁻. Blank sample was also included and fluoride concentrations were below the detection limit of 0.1 mg/L.

As a matter of fact, the local groundwater not only affects the human’s health but also impacts on the daily life. Thus, beside fluoride concentration, total hardness in water samples was also analyzed to find out the relationship between total hardness and fluoride concentration in the groundwater in study area.
2.2. Clinical survey and Community Fluorosis Index (CFI)

Dental fluorosis was assessed on all partly or fully erupted teeth surfaces except for third molars. The dental fluorosis score for each individual was determined based on the median of the highest dental fluorosis score on each permanent tooth and confirmed by digital images. Participants were classified as having normal, questionable, very mild, mild, moderate and severe fluorosis if the median dental fluorosis score was 0, 1, 2, 3, 4 and 5, respectively. Dental examinations were conducted in the daytime, under natural light, by visual inspection, using dental mirrors, tongue depressors and gauze to dry teeth by the help of a dentist, according to the guideline established by the World Health Organization (WHO) [24].

A total of 220 randomly selected inhabitants consuming well water from 50 households in the study area were interviewed during the field visits. The Community Fluorosis Index was calculated by using Dean’s classification and assessed on the basis of dental fluorosis symptoms, which are classified into six categories according to Dean’s classification [18, 19] viz normal, questionable, very mild, mild, moderate, and severe. Each of these six criteria was given a numerical statistical value (weights) viz 0, 0.5, 1, 2, 3 and 4 respectively as described in Table 1. From these results, the relationship between dental fluorosis and fluoride concentration were determined.

People with symptoms of dental fluorosis were identified and classified in each category and the number of people in each category was multiplied by the corresponding numerical weight. The Community Fluorosis Index (CFI) is calculated by the sum of various categories divided by the total number of people surveyed. Only when the community fluorosis index value exceeds 0.6, fluorosis is considered to be a public health problem in that area [4]. CFI is calculated with formula 1.

\[
CFI = \sum_{i=0}^{5} \frac{n_i \times w_i}{N}
\]

where, \(n_i\) – number of people, \(w_i\) – Dean’s numerical weight, \(N\) – total number of people examined.
The percentage incidence of fluorosis was calculated from the number of people affected by fluorosis from the study area with total number of people surveyed. A total 115 males and 105 females were examined for this study.

### Table 1. Criteria for Dean's Fluorosis Index.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>The enamel represents the usual translucent semivitriform type of structure. The surface is smooth, glossy, and usually of a pale creamy white color.</td>
<td>0</td>
</tr>
<tr>
<td>(level 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questionable</td>
<td>The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is utilized in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of &quot;normal&quot; is not justified.</td>
<td>0.5</td>
</tr>
<tr>
<td>(level 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Mild</td>
<td>Small opaque, paper white areas scattered irregularly over the tooth but not involving as much as 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1-2 mm of white opacity at the tip of the summit of the cusps of the bicuspids or second molars.</td>
<td>1</td>
</tr>
<tr>
<td>(level 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth.</td>
<td>2</td>
</tr>
<tr>
<td>(level 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>All enamel surfaces of the teeth are affected, and the surfaces subject to attrition show wear. Brown stain is frequently a disfiguring feature.</td>
<td>3</td>
</tr>
<tr>
<td>(level 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is discrete or confluent pitting. Brown stains are widespread and teeth often present a corroded-like appearance.</td>
<td>4</td>
</tr>
<tr>
<td>(level 5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


### 3. RESULTS AND DISCUSSION

#### 3.1. Fluoride contamination in groundwater

The fluoride concentrations for 50 well-water samples collected in study area ranged from 0.31 mg/L to 7.69 mg/L, mean 2.66 mg/L ± 2.18 mg/L. The number of samples with
Relationship between fluoride contents in groundwater and prevalence of fluorosis in Tay Son

Concentrations from 1.5 mg/L to 3.5 mg/L is dominant. Results indicate that 70% of water samples give fluoride concentration above WHO maximum permissible limit of 1.5 mg/L. The mean fluoride levels in well water in 3 villages, Tay Phu, Binh Tuong, Tay Giang, and study area in general are shown in Figure 2. Excessive concentrations of fluoride were found principally in Binh Tuong commune with 100% samples collected in this commune above the limit value of 1.5 mg/L (WHO), whereas low fluoride concentrations were found in well water samples in Tay Phu and Tay Giang commune. It is calculated that 55% and 40% of groundwater samples collected from Tay Phu and Tay Giang, respectively, had fluoride content below WHO guideline level (1.5 mg/L).

![Figure 2. The mean fluoride levels in well water in 3 villages and study area.](image)

Water fluoride contents in Tay Phu, Binh Tuong and Tay Giang regions reach the values of 6.28 ppm, 7.69 ppm and 4.88, respectively, slight difference between these three regions with respect to natural resources of fluoride. The percentage of samples from three communes of study area exceeding the guidelines for drinking water was displayed in Table 2. Among three regions included in the study, fluoride levels in water in Binh Tuong were the highest fluoride concentration with the value more than 5 times higher than WHO limited value.

<table>
<thead>
<tr>
<th>Commune</th>
<th>Tay Phu</th>
<th>Binh Tuong</th>
<th>Tay Giang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
<td>20</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Mean of fluoride concentration (mg/L)</td>
<td>2.08</td>
<td>3.55</td>
<td>2.04</td>
</tr>
<tr>
<td>Percentage above the guideline (%)</td>
<td>45</td>
<td>100</td>
<td>60</td>
</tr>
</tbody>
</table>

Analyzing of the regression correlation between fluoride concentration and the total hardness of well water, the results showed that two factors are high correlation (the correlation coefficient $r = 0.610$, significance level $p < 0.0001$). From Figure 3, it is evident that an inverse relationship occurred in the ranges of fluoride and total hardness. Similar trend was also
observed by Viswanathan [14].

![Image](image1)  
*Figure 3. The correlation between fluoride concentration and total hardness.*

### 3.2. Community fluorosis effects

![Image](image2)  
*Figure 4. The dental fluorosis level in residents who lives in study area according to Dean’s classification.*

![Image](image3)  
*Figure 5. The percentage of people was suffered from dental fluorosis according to Dean’s classification.*

220 questionnaires were validly completed. The results show that 100% of 220 people surveyed was suffered from chronic dental fluorosis and Dean scale of dental fluorosis ranged
from level 2 to level 5 (from very mild to severe). It was mainly at level 4 and level 5 (Figure 4). Among them, 37 people is suffered from dental fluorosis in level 2, 26 people is in level 3, 66 people is in level 4 and a total of 91 people is in level 5. The percentages of fluorosis prevalence among these levels are 16.82%, 11.82%, 30 % and 41.36%, respectively. Figure 5 shows the percentage of people suffered from dental fluorosis according to Dean’s classification.

The classification results also showed that the number of people suffered from dental fluorosis in Binh Tuong is the highest and lowest in Tay Giang. In fact, Binh Tuong village is contaminated with the highest fluoride concentration. The relationship between fluoride concentration and the Dean index were also analyzed and presented in Figure 6.

![Figure 6. The relationship between fluoride concentration and the Dean index.](image)

The CFI of three villages Tay Phu, Binh Tuong and Tay Giang are higher than limited level for fluorosis community (0.6). Therefore, it proves that the community-based fluorosis condition is at all three villages: Tay Phu, Binh Tuong and Tay Giang. Through the dental fluorosis classification and CFI calculation results, it is found that the community in study area in general is affected by dental fluorosis at high levels and the dental fluorosis is highest at Binh Tuong village in particular. The CFI of study area and each of village are many times higher than limited level. It means the community who lives on research place is suffered from fluorosis at serious level. In there, CFI is lowest at Tay Phu village (CFI = 2.45) and highest at Binh Tuong village (CFI = 4.13). The CFI score of 2.96 found in this fluoride area represents public health problem (Table 3). Moreover, correlation analysis between fluoride in all samples and dental fluorosis level among residents showed statistical significance.

Thus, with the fluoride concentration in drinking water several times higher than normal, many generations in study area has been affecting by fluorosis and they will be suffered from fluorosis problem if there are not an opportune solution. Based upon the studies conducted by Dean (1942) the optimum level of fluoride in drinking water, associated with the maximum level of dental caries protection and minimum level of dental fluorosis, was considered to be
approximately 1ppm [25]. WHO (2002) also recommends levels of fluoride in drinking water that are considered useful for the prevention of dental caries, in a range from 0.5 to 1.2 ppm. However, in this area, all people had evidence of dental fluorosis even though their low fluoride concentration intake. It means that people may expose with fluoride from other sources beside drinking water. In general, the occurrence of dental fluorosis (score of 1 and higher) was essentially related primarily to the fluoride level in the water.

Table 3. The CFI calculation result in study area.

<table>
<thead>
<tr>
<th>Dean’s classification</th>
<th>Tay Phu</th>
<th>Binh Tuong</th>
<th>Tay Giang</th>
<th>Study area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2 (%)</td>
<td>36.04</td>
<td>3.16</td>
<td>7.69</td>
<td>16.82</td>
</tr>
<tr>
<td>Level 3 (%)</td>
<td>11.63</td>
<td>7.37</td>
<td>23.07</td>
<td>11.82</td>
</tr>
<tr>
<td>Level 4 (%)</td>
<td>23.26</td>
<td>36.84</td>
<td>28.21</td>
<td>30.00</td>
</tr>
<tr>
<td>Level 5 (%)</td>
<td>29.07</td>
<td>52.63</td>
<td>41.03</td>
<td>41.36</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>CFI</td>
<td>2.45</td>
<td>4.13</td>
<td>3.03</td>
<td>2.96</td>
</tr>
</tbody>
</table>

In conclusion, the studied results provide evidence that there is positive and statistically significant correlation between daily intake of fluoride in drinking water and dental fluorosis level in study area. Based on assessment of fluoride intake and its impact on dental health, it is obvious that study area has high fluoride content in well-water. It may be the main reason why endemic fluorosis is a major public health concern in Tay Son district, Binh Dinh province due to the excessive consumption of fluoride in drinking water.

3. CONCLUSIONS

Groundwater in the Tay Son area is high in fluoride, with 70 % of the samples contained fluoride concentrations that exceed the drinking water standard of 1.5 mg/L set by WHO. Groundwater in the study area is also high in hardness. This study has shown that fluoride is a serious contaminant of most groundwater in this area. It is a high correlation between fluoride concentration and the total hardness of well water ($r = 0.610$, $p < 0.0001$). 100 % of residents in community were suffered from chronic dental fluorosis and Dean’s scale of dental fluorosis ranged very mild to severe. The fluoride concentrations and Dean Index have high correlation ($r = 0.580$, $p < 0.0001$). That means the higher Dean Index is the higher concentration. The CFI for this study area is 2.96. The community who lives on research place is suffered from fluorosis at serious level.

Based upon results of this study, it is recommended that the government have to supply drinking water with appropriate fluoride content for this community. Therefore, comprehensive studies should be carried out to map out all areas for fluoride content in water and create a database of fluoride content in ground water in this area and in the whole of Vietnam.
Even though the fluoride in water may be the main source of fluoride in groundwater in Tay Son district, additional sources of fluorides such as fluoride in food, fluoride in beverage, and fluoride dentifrices should be studied because exposure to all sources of fluoride is important for the estimation of daily intake and consequently for the assessment of its adverse health effects. This information may be important especially with respect to the issue of topical versus systemic effects of fluoride on caries.

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