Determining the Optimal Concentration of Fluoride in Drinking Water from the Republic of Macedonia

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Abstract

Aim: The aim of this study was to determine the optimal concentration of fluoride in drinking water from 11 cities located on different sites throughout the Republic of Macedonia.

Method: The optimal level of fluoride in drinking water is universally calculated by applying the equation of Galagan and Vermillion, which permits the calculation of water as a function of temperature.

Results: The annual mean maximum temperatures (AMMT) recorded during the last 5 years were collected from the meteorological centres of the 11 divisional headquarter stations. The optimal fluoride concentration in drinking water from different cities in Macedonia was calculated to be 0.84 mgF/L in Gevgelija, 0.83 mgF/L in Demir Kapija, 0.88 mgF/L in Strumica, 0.89 mgF/L in Shipoj, 0.9 mgF/L in Skopje (Zajcev Rid), 0.92 mgF/L in Bitola, 0.94 mgF/L in Prilep and Ohrid, 0.95 mgF/L in Kriva Palanka, 1.00 mgF/L in Berovo and 1.09 mgF/L in Lazaropole.

Conclusion: Determining the most appropriate concentration of fluoride in drinking water is crucial for communities. The optimal fluoride concentration in drinking water from different cities from the Republic of Macedonia was calculated to be between 0.84 - 1.09 mg F/L.

Keywords: Drinking water fluoride levels; Optimal fluoride level; Macedonia

Background

The greatest achievement of dentistry achieved by these modern times is certainly the discovery of the protective capacity of fluoride against caries made in 1930. The researchers conducted in this area have shown that fluoridated water, natural or by means of artificial adding (fluorination) reduces the manifestation of caries for around 40-50% in the case of deciduous teeth and 50%-60% in the case of permanent teeth [1-5]. The information that different fluoride concentrations in potable water largely influence the manifestation of caries has encouraged great challenge for researchers in the area of fluoride content in the world [1,2,6,7].

As our country is going to be a member of the EU, it is obliged to determine the values of a set of microbiological parameters and of chemical compounds, among which is the fluoride, within the great program of the control of the drinking water quality, which is used by people, the water from the rivers and the lakes. Actually, European Union countries develop their own regulations about the quality of drinking water based on the European directive for water quality from 1983 [8]. This directive provides permissible concentrations for many substances, among which is fluoride.

In 2006 the European Commission adopted a regulation with the aim to harmonize divergent national views which refer to addition of vitamins, minerals and other substances in the food. Fluoride is included as a mineral which may be added in the food in form of sodium fluoride and potassium fluoride [9].

For the dentistry, the information about the concentration of fluoride in drinking water is still most important and popular information. The various committees of specialists from the WHO repeatedly re-examined all the data, as epidemiological data of dental fluorosis, caries prevalence and climatic conditions, which resulted in the issuance of more guidance over the last 40 years [10-14] (Table 1).

Minimal deviations which appear in these guidelines are consequence of the difficulties that exist around the determination of a value acceptable for each geographical area, which could provide at the same way anti-caries effects of fluoride and minimizes the risk of dental fluorosis [15].

Climate in the Republic of Macedonia

Climate in the Republic of Macedonia depends on many climatic factors. The most significant of them are the following: geographic position, closeness of the surrounding seas and the relief. As a result of the climatic and other natural factors, three basic climatic types have been represented in the territory of the Republic of Macedonia. They are as it follows: alternated Mediterranean, temperate continental and mountainous climate.

Our country expand between 40°30’ and 42°20’ north geographic latitude and 20°27’ and 23°05’ east geographic length. That means our country is not very close to the equator, where reign to the end of time summer, nor very close to the North Pole where reign everlasting winter. Republic of Macedonia is situated approximately on the middle between them, in the north temperate thermal zone.

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The vicinity of the surrounding seas is the second important factor on which the climate in our country depends. The Aegean Sea in the north is most closely to the Republic of Macedonia and in the west the Adriatic Sea. The warm influences of the Aegean Sea get in through the valleys of the Vardar and Strumica rivers. The warm influences of the Adriatic Sea enter through the valley of the Black Drim river. Also, the influences of the Atlantic Ocean, from where the west winds bring rainfalls in the spring and the autumn months penetrate from the west.

The orography is as well the important factor for the climate in our country. The Kozuv, Nidje and Belasica mountains, as well and Jablanica, Desat and Korab mountains with their heights and direction of stretch prevent warm influences from the south and the west. The Skopska Crna Gora and the Shar Mountains prevent the cold continental influences from the north.

The temperature of the air in the Republic of Macedonia is affected by the orography, vicinity of the seas, vegetables and other things. The correlation existing between dental fluorosis and fluoride concentration in water is based on average water consumption, a condition that depends directly from air temperature and local climate conditions. As a result of its geographic position and topography, our country is at the crossroads of continental and Mediterranean climates (Figure 1). Temperatures, rainfall, atmospheric pressure, wind and moisture vary significantly and influence the overall water regime. Dry and hot periods predominate (summer-autumn) while cold periods are short (winter). Rainfall is irregular, sporadic and in small quantity throughout the country (average annual precipitation is 733 mm).

Fluoride uptake is increasing proportionally with the increasing of the concentration of fluoride in water, as well as with air temperature in the area, since summer temperatures are higher than winter temperatures [5]. Drinking-water is typically the largest single contributor to daily fluoride intake [16]. For a given individual, fluoride exposure via drinking-water is determined by the fluoride level in the water and the daily water consumption. More recently national figures can be obtained or computed from various compendia of environmental and water supply statistics such as World Bank (1994) and World Resources Institute (1996). However, national consumption figures, especially for developing countries, may be of limited use for this purpose because there are likely to be major differences between urban and rural communities using wells and boreholes with hand pumps.

For a given individual, water consumption increases with temperature, humidity, exercise and state of health, and is modified by other factors including diet. Roughly, the closer to the Equator the higher is the water consumption [16]. From the perspective of public health, drinking water should be the main source of fluoride for humans. The entire population of every region of the world drink equal quantity of water and fluoride intake [16]. For a given individual, fluoride exposure via drinking-water is determined by the fluoride level in the water and the daily water consumption. More recently national figures can be obtained or computed from various compendia of environmental and water supply statistics such as World Bank (1994) and World Resources Institute (1996). However, national consumption figures, especially for developing countries, may be of limited use for this purpose because there are likely to be major differences between urban and rural communities using wells and boreholes with hand pumps.

### Material and Method

Based on average maximum temperature of various climates in 1957 Galagan DJ and Vermillion JR proposed this formula to calculate the optimal amount of fluoride in drinking water, which is widely accepted:

$$
\text{Optimal concentration} = \frac{\text{Max. temperature}}{20} \times 0.1
$$

where Max. temperature is the maximal daily temperature in degree Celsius.
Optimal concentration within the water supply network depends on the highest, lowest and optimal values [15].

Fluoride in drinking water considerably contributes to the daily fluoride intake, but more than 50% of the fluoride in total fluoride intake per day is derived from food and beverages such as tea and coffee.

Because water consumption, and therefore the amount of imported fluoride is proportional to the average outdoor temperature, it would be desirable to calculate the optimal amount of fluoride based on average seasonal temperature (winter, summer and average years Table 4).

In the USA, the authorities established the rule there is no need of changing the water for areas with less than 200 inhabitants and with water which contains to 4 mg F/l. The decision is supported by the fact that the above mentioned concentration of fluoride does not cause any problems for the general health and is related only to the dental fluorosis. For the USA, the prevention of dental fluorosis is not a cause for neglecting the cost-benefit analysis.

Instead of changing the water which requires many expenses, it is suggested to inform the families who have babies and small children, in order to avoid drinking and using this water for preparing meals, until the children are six years old.

The content of fluoride in the drinking water has an effect upon the dental health of the population of the Republic of Macedonia. So far in our country there were some information about existence of areas with abundance of fluoride in the drinking water that attracted the interest of dentists due to teeth aesthetic damage (dental fluorosis) [18-21].

In the Progress Report 2008 for the Republic of Macedonia, prepared by the Commission of the EU it is stated that little progress has been made in the field of water quality. The new Law on water was enacted. The monitoring system has improved but still lacks sufficient coverage and data collection. The first annual report on water quality and quantity was submitted to the European Environment Agency. The new Law on water has not yet been adopted by parliament. The new Law on water came in to force. The monitoring system was improved (upgraded), but there is still insufficient scope of work and collecting of data. Some investments were made for project preparation and implementation of small infrastructure projects. The substantial investments required for compliance with the acquis have not yet been planned. Preparations in the area of water quality are moderately advanced.

Within their work the dentists are obliged to prescribe individual a mass preventive programs. It is necessary for the dentist to know the fluoride concentration of drinking water of the area where the patients live, before any mass or individual fluoride program (local or systemic F-supplements) is applied.

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On the Table 5 are presented the calculated optimal concentrations of fluoride in water according to average annual temperatures of 11 meteorological stations.

<table>
<thead>
<tr>
<th>Fluorides concentration (ppm)</th>
<th>Average annual temperature (°C)</th>
<th>minimal</th>
<th>optimal</th>
<th>maximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-12</td>
<td>0.9</td>
<td>1.2</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>12-14.5</td>
<td>0.8</td>
<td>1.1</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>14.6-17.5</td>
<td>0.8</td>
<td>1.0</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>17.6-21.4</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>21.5-26.2</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>26.3-32.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Optimal fluorine concentrations in drinking water


Fluoride in drinking water considerably contributes to the daily fluoride intake, but more than 50% of the fluoride in total fluoride intake per day is derived from food and beverages such as tea and coffee.

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Table 3: Average monthly and annual maximum air temperature in °C
Source: Hydrometeorological Service, in May 2013

<table>
<thead>
<tr>
<th>Hydro-meteorological stations</th>
<th>Average annual air temperature (°C)</th>
<th>Op (mg F/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEVGELIJA</td>
<td>22.1</td>
<td>0.84</td>
</tr>
<tr>
<td>DEMIR KAPIJA</td>
<td>21.1</td>
<td>0.83</td>
</tr>
<tr>
<td>STRUMICA</td>
<td>20.4</td>
<td>0.88</td>
</tr>
<tr>
<td>ŠTIP</td>
<td>20.0</td>
<td>0.89</td>
</tr>
<tr>
<td>BITOLA</td>
<td>18.6</td>
<td>0.92</td>
</tr>
<tr>
<td>PRILEP</td>
<td>17.9</td>
<td>0.94</td>
</tr>
<tr>
<td>KRIVA PALANKA</td>
<td>17.6</td>
<td>0.95</td>
</tr>
<tr>
<td>OHRID</td>
<td>17.8</td>
<td>0.94</td>
</tr>
<tr>
<td>BERVO</td>
<td>16.7</td>
<td>1.00</td>
</tr>
<tr>
<td>LAZAROPOLE</td>
<td>13.5</td>
<td>1.09</td>
</tr>
<tr>
<td>SKOPJE ZAJČEV RID</td>
<td>19.3</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Table 5: Optimal amounts of fluoride according to average annual air temperatures expressed in mg F/L.
WHO guidelines for drinking water quality contain the following:

"Upon determination of national standards related to fluorides or upon evaluation of possible consequences on human health coming from exposition to fluorides, it is very important to take into consideration the uptake of water by the population in question, as well as the uptake of fluorides from other sources (for example, from food, air and dental preparations). In the cases where the uptake from other sources shall approximate or shall be higher than 6 mg/day, it would be more appropriate to consider the possibility for determining standards with lower concentration than the recommended value [12]. "Besides the above-mentioned, it has been suggested that:

"In regions with high natural concentrations of fluorides in potable water, it might be difficult to reach the recommended value in certain circumstances only by means of available water treatment technology".

When setting up the national standards/legislation for the content of the fluoride in the drinking water one should always have in mind how much content of fluoride is going to be consumed through the drinking water, as well as through the other sources (food, toothpastes, etc.), as well as to take into consideration climatic factors. According to the recommendations of the WHO [12], as well as according to the existing regulation (Regulation for the safety of water, Official Gazette No 46/08), the content of fluoride in the drinking water has to be up to 1.5 mg/l.

The protective role of the fluoride in the drinking water against the appearance of dental caries is most evident when the fluoride concentration is from 0.8 to 1.2 mg/l. The appearance of the fluoride in the drinking water varies from the type/structure of the soil.

In general, the drinking water in the Republic of Macedonia is poor with fluoride that is in correlation with the frequent appearance of caries among our population.

Conclusions

This type of approach for assessing the optimal fluoride level in drinking water is helpful for governmental and non-governmental organization in supplying drinking water with appropriate fluoride content. The optimal fluoride concentration in drinking water from different cities from the Republic of Macedonia was calculated to be between 0.84 -1.09 mg F/L.

References

10. World Health Assembly (1975) Fluoridation and dental health resolution.