Chemosphere 177 (2017) 102–108

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Risk assessment of fluoride exposure in drinking water of Tunisia

Wiem Guissouma [a, b], Othman Hakami [c], Abdul Jabbar Al-Rajab [d, *], Jamila Tarhouni [a]

[a] Rural Engineering Department, National School of Agronomy of Tunis, University of Carthage, Tunis, Tunisia
[b] National Agency of the Sanitary and Environmental Control of Products (ANCSEP), Tunis, Tunisia
[c] Chemistry Department, Faculty of Sciences, Jazan University, Jazan, Saudi Arabia
[d] Center for Environmental Research & Studies, Jazan University, Jazan, Saudi Arabia

HIGHLIGHTS

- Fluoride concentrations were ≤2.4 mg L^{-1} in 100 water consumption points in Tunisia.
- Risk assessment of Fluoride exposure was assessed depending on the age of consumers.
- Approximately 75% of the Tunisian population is at risk for dental decay.
- 25% of Tunisians have a potential dental fluorosis risk.
- 20% of Tunisians might have a skeletal fluorosis risk.

ARTICLE INFO

Article history:
Received 16 January 2017
Received in revised form
2 March 2017
Accepted 3 March 2017
Available online 3 March 2017

Handling Editor: A. Gies

Keywords:
Fluoride
Tap water
Daily exposure
Risk assessment
Fluorosis

ABSTRACT

The presence of fluoride in drinking water is known to reduce dental cavities among consumers, but an excessive intake of this anion might leads to dental and skeletal fluorosis. This study reports a complete survey of the fluoridated tap water taken from 100 water consumption points in Tunisia. The fluoride concentrations in tap water were between 0 and 2.4 mg L^{-1}. Risk assessment of Fluoride exposure was assessed depending on the age of consumers using a four-step method: hazard identification, toxicity reference values selection (TRVs), daily exposure assessment, and risk characterization. Our findings suggest that approximately 75% of the Tunisian population is at risk for dental decay, 25% have a potential dental fluorosis risk, and 20% might have a skeletal fluorosis risk according to the limits of fluoride in drinking water recommended by WHO. More investigations are recommended to assess the exposure risk of fluoride in other sources of drinking water such as bottled water.

1. Introduction

Water fluoridation is practiced by many developed countries as a routine measure of public health in order to help reduce dental cavities among the population (Jones et al., 2005; Petersen and Lennon, 2004; Podgorny and McLaren, 2015). However, more than 400 million citizens around the world receive artificially fluoridated water. Fluoride can prevent tooth decay by up to 40%; it has therefore been an official policy of the U.S. Public Health Service since 1951 to add fluoride to the public water supply, and it costs just about $1 per person/year. The Centers for Disease Control and Prevention (CDCP) reported that adding fluoride to tap water is among the most important achievements for public health in the 20th century (Horowitz, 1996). Yet many activists and political parties across the world campaign against water fluoridation. They claim that it simply isn't safe and point to possible side effects like the outbreaks of fluoride poisoning that occurred three times in the 1990s in Tunisia. Since its introduction in 1950, nine countries have outlawed water fluoridation. Is fluoride a potential health risk? The only proven side effect of water fluoridation is dental fluorosis, which is a discoloration or staining of the enamel in the teeth. This usually forms in children up to the age of four, and a study by the CDC shows rates of fluorosis increased by 9% between 1987 and 2002. Fluorosis may be harmless, but it is virtually impossible for children to avoid in countries where the entire water supply is fluoridated. Meanwhile, scientific studies arguing in favor of

* Corresponding author.
E-mail address: alrajab@hotmail.com (A.J. Al-Rajab).

http://dx.doi.org/10.1016/j.chemosphere.2017.03.011
0045-6535/

fluoridation have been criticized as insubstantially researched and dismissive of the long-term effects of excessive consumption of fluoride, which could potentially include weakened bones. This practice has raised the ethical debate about water fluoridation (Park and Kwon, 2016.).

In order to investigate the pros and cons of water fluoridation on human health, this study reports a complete survey of the fluoridated tap water in Tunisia and provides the scientific community with a health-risk assessment approach which was developed on a four-step method: hazard identification, toxicity reference values selection (TRVs), daily exposure assessment, and risk characterization (Wassie et al., 2012).

2. Materials and methods

2.1. Sample collection and analysis

Excessive fluoride concentrations in public water supplies have been largely reported in many Tunisian areas (Ketata et al., 2011a, 2011b; Perennes, 1993). In the present study, 100 water samples were collected from tap water points located in the 24 Tunisian regions. The sampling distribution was done empirically, based on the population density served by public water networks. At each collection point, tap water ran for 5 min before collecting a water sample in a 1 L polyethylene container washed twice with distilled water. Samples were labeled and transferred in a field cooler to the lab for analyses. Samples were analyzed within 24 h after collection at the Centre International des Technologies de l'Environnement de Tunis, Tunisia CITET, using an iCE™ 3300 AAS Atomic Absorption Spectrometer (ThermoFisher Scientific, Tunis, Tunisia). The probing rate, the number of samples per region, and the number of samples per delegation were taken into account in the sampling plan.

2.2. Fluoride risk assessment in tap drinking water of Tunisia

Laboratory analyses were done in order to assess the health risk of fluoride in tap water. Risk assessment involved 1) identifying the hazard element, 2) establishing the values of toxicological reference, 3) estimating the fluoride exposure, and 4) characterizing the risk.

3. Results and discussion

Table 1 presents the measured fluoride concentrations in drinking water for the 24 Tunisian regions. The number of samples was chosen with respect to population size and distribution along the different Tunisian regions. A significant difference is observed in the maximum and minimum values in the Gabes region. This difference can be explained by the heterogeneity of fluoride levels within the same governorate. The minimum (0.29 mg L^{-1}) and maximum (1.94 mg L^{-1}) concentration levels was found in El-Hamma city and in Mareth city respectively. A mixture of these two types of water could be a solution to obtain moderately fluoridated water (~1 mg L^{-1}). In the other hand, three sites (Gafsa, Tataouin and Mednine) present an exceedance over the Tunisian regulation for fluoride concentrations in drinking water; i.e. 1.5 mg L^{-1} (*standard NT09-13 and standard NT09-14*). This fluoride contamination is essentially due to nature of hard rock aquifers (Alaya et al., 2014; Ketata et al., 2011a, 2011b).

3.1. Fluoride risk assessment in tap drinking water of Tunisia

Following the basic four steps of the risk assessment process, different referential toxicity values were used to assess the exposure and to characterize the risk of consumed fluoride via drinking tap water in Tunisia.

3.1.1. Hazard identification

High exposure or deficiency of fluoride might lead to serious health issues for human teeth (Fluoride in Drinking Water (2006); Freeze and Lehr, 2009). Deficient fluoride levels may lead to tooth decay (Hong et al., 2006; Warren et al., 2009), and high fluoride exposure may cause dental fluorosis. With long-term exposure to high-fluoride levels, skeletal fluorosis may occur (Barbier et al., 2010; Dhar and Bhatnagar, 2009).

3.1.2. The toxicity reference value (TRV)

The TRV values shown in Table 2 were used to assess the health risk of fluoride to the human body due to oral ingestion and with respect to the duration of exposure (chronic, sub-chronic, or acute).

Fluoride levels of 0.5 mg L^{-1} or higher are recommended for prevention of dental cavities. (Petersen, 2004, 2003), and a daily intake of 122 mg kg^{-1} bw d^{-1} of fluoride might cause fluorosis (US EPA, 2005; Gupta, 2011), while more than 200 mg kg^{-1} bw d^{-1} of fluoride might lead to skeletal fluorosis issues. There are no harmful effect from daily fluoride intake lower than or equal to the fluoride safety limit of 0.5 mg L^{-1} (Anses - French Agency for Food, Environmental and Occupational Health and Safety, 2015).

3.1.3. Assessment of fluoride exposure

Exposure to fluoride from tap drinking water (ED) was calculated using Equation (1):

$$E_D = \frac{C_F \times C_d}{B_w} \tag{1}$$

where C_F is the concentration of fluoride in the water samples (mg L^{-1}), C_d represents the average daily consumption of water (L d^{-1}) and B_w represents the average body weight (kg).

The daily consumed amount of drinking water estimated by *WHO* depends on age group and body weight, as shown in Table 3.

Significant difference between levels of daily fluoride exposure (E_D) was observed for the three age groups (Fig. 1). Moreover, the fluoride exposure level was higher in the young group (infants and children) than in adults. Consequently, this group of young people is considered to be a hyper-sensitive population.

3.1.4. Risk characterization

The risk characterization involves a comparative analysis between the TRVs and the daily exposure to fluoride (Ramirez-Martinez et al., 2014).

3.1.4.1. Fluoride acute toxicity in the tap water of Tunisia. Calculated levels of exposure to fluoride with drinking water showed that the highest exposure level was observed in the area of *Medenine* for the three age groups with a maximum of 0.08, 0.24 and 0.36 mg kg^{-1} bw d^{-1} for adults, children and infant respectively. Assuming average body weights that were mentioned in Table 3, adults, children and infant, in the area of *Medenine*, are exposed to ingest 4.8 mg, 2.4 mg and 4.8 mg of fluoride respectively. According to Akiniwa, K. (Akiniwa, 1997), acute fluoride poisoning that causing first symptoms had occurred at an estimated dose of 0.3 mgF kg^{-1} bw (Gessner et al., 1994). Hence, in our case, a slight exceedance of these minimum doses is shown in the case of infant in *Medenine*, *Gafsa*, *Siliana* and *Tataouine* areas. All subjects from the other areas are not exposed to the acute toxicity of fluoride.

3.1.4.2. Fluoride chronic toxicity in the tap water of Tunisia. The origin of chronic toxicity of fluoride may be due to the long