

Original Article

Fluoride Concentration of Drinking-Water of Qom, Iran

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Abstract

Background and Purpose: Fluoride is a natural element essential for human nutrition due to its benefits for dental enamel. It is well-documented that standard amounts of fluoride in drinking-water can decrease the rate of dental caries. This study was conducted with the aim of measuring fluoride concentration of drinking-water supplies and urban distribution system in Qom, Iran.

Materials and Methods: Results were subsequently compared against national and international standards. All sources of drinking-water of rural and urban areas were examined. To measure fluoride, the standard SPADNS method and a DR/4000s spectrophotometer were used.

Results: Results showed that the mean of fluoride concentration in rural areas, mainly supplied with groundwater sources, was 0.41 mg/L, that of the urban distribution system 0.82 mg/L, that of Ali-Abad station 0.11 mg/L, and that of the private water desalination system 0.24 mg/L. Due to the hot climate of Qom, fluoride concentration means of all sources were lower than the permissible standards set by Iranian Standards and the WHO guidelines (except those of some of the groundwater sources and urban distribution systems).

Conclusion: It seems that in most of the drinking-water sources the average fluoride concentration is not enough to prevent dental caries or strengthen dental enamel. It is concluded that Qom's drinking-water would require at least 0.4 mg/L to reach the minimum desirable standard.

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Key words: Drinking-Water Sources, Fluoride Concentration, Dental Caries, Qom (Iran)

1. Introduction

Fluoride is one of the dissolved ions in water resources. It may come from artificial sources such as wastewater discharges from a variety of industries (e.g., glassware) or enter water from mineral deposits. When inadequate, it must be added artificially (1). Fluoride at low concentrations is essential for the body but can be detrimental at high concentrations. Fluoride is an important factor in the controlling and prevention of dental caries, in children and adolescents alike (2). Extensive studies have corroborated the anticaries properties of fluoride through strengthening dental tissue and decreasing the potential of dental plaque to create caries (3,4). The WHO announced that oral diseases such as dental caries, periodontitis (a gum disease) and oral and throat cancers are a global health problem affecting both industrialized and developing countries, especially the poor classes. According to the WHO report on the oral health of the international community, about five billion people worldwide had experienced dental caries (5). There are sound reasons in empirical evidence proving the inverse relationship between drinking-water fluoride and dental caries (6). While consumption of allowable amounts of fluoride is beneficial for dental health, its excess or inadequacy may entail severe harms to the teeth and bones (7). Dental fluorosis is a dental disease caused by harmful effects of fluoride ions on dental-forming cells during tooth formation and limestone, commonly referred to as "mottled enamel" (8). In addition to bone and tooth disorders, excessive fluoride intake is characterized by adverse health effects including damage to endocrine glands, thyroid, liver, tendons, ligaments, and space reduction between the vertebrae, especially the first two cervical vertebra (9,10). Since most systemic fluoride intake is from drinking-water, studies show when fluoride concentration in water is 0.1 mg/L, the concentration in saliva will be 0.3 mg/L,

whereas an increase of water fluoride concentration to 1.2 mg/L will also increase fluoride concentration in saliva to 0.9 mg/L (11). Hence, the direct relationship between water levels of fluoride and systemic absorption (12). It can thus be concluded that one of the systematic ways to furnish the body with fluoride, and also the best and most ideal method of preventing dental caries, is adding fluoride to drinking-water to reach the optimal range of 0.7-1.2 (ppm as per the area's climate). Provided that the amount of drinking-water's fluoride is within this range, the risk of dental caries can be expected to diminish (13).

Statistics show that one in every five Iranian children after the age of 6 has one decayed permanent tooth. Taking into account that by this age every child will have their first four permanent teeth, it can be calculated that there is one decayed permanent tooth in every 20. At the age of 9, every child will have one decayed permanent tooth (5 times the figure at age 6) and at age 12 this figure will increase by 1.5 times. Thus, every Iranian child will have 1.5 decayed permanent tooth by age 12. Unfortunately, lower than 60% of Iranian children up to age 12 are able to safeguard all their teeth against decay (14).

A study on the amount of fluoride in drinking-water in Behshahr, Iran, revealed that fluoride concentrations were between the range of 0.12 and 0.39 (15). The examining of drinking-water from some areas of Bushehr, Iran, showed that fluoride concentrations were lower than the national and WHO standards (13,16). Even so, dental fluorosis has been widespread in this region (17). Still another study in Mianeh, Iran, found the mean fluoride concentration was even lower than 0.7 mg/L in the drinking-water, which is below the optimal national and WHO standards (13,16). It was expected that dental caries were prevalent among children and adolescents living in the area (18).

Turning now to the case under study, the

Qom Province is a semi-arid region with hot dry summers and somewhat cold winters. Qom City is one of the few cities in Iran the sanitation and drinking-water distribution systems of which are totally separated due to high levels of total dissolved solids (TDS) in drinking-water. For this reason, in recent years, people have turned to private water desalination machines. These devices can dramatically reduce the minerals, and if their output water is not balanced, deleterious effects on health may ensue in the long-term. In Qom, the average annual temperature of 5 subsequent years up to 2008 was 18.8° C. The amount of fluoride in drinking-water must be adjusted to different climates and seasons (19) in accordance with WHO and national standards (13,16). Considering the importance of this issue and the fact that no comprehensive study has been conducted in this regard so far, we aimed to determine the qualities of rural and urban water supplies. It should be noted that Ali-Abad Station is a water supply source for sanitation purposes. As mentioned above, due to high levels of TDS and electrical conductivity (EC) in

Qom's drinking-water sources, people have preferred to use domestic desalination machines. Therefore, these two parameters were also measured.

2. Materials and Methods

This is an analytic cross-sectional descriptive study on water sources in the Qom Province conducted in 2013. Drinking-water sources in the cities of Qom and also of the villages with populations of over 100 people, plus sanitation water sources (Ali-Abad Station) were examined in terms of fluoride, EC and TDS. The Qom Province, with the capital of Qom, consists of 4 sections, 9 rural districts, and 363 villages, of which 144 with populations of more than 100 people were surveyed. Selected areas for sampling are shown in figure 1.

About 130 water samples were collected from water supplies, and then transferred to the laboratory to perform the EC, TDS and fluoride tests. All the steps of sampling, transferring, and testing were carried out as per the instructions in standard method (20).

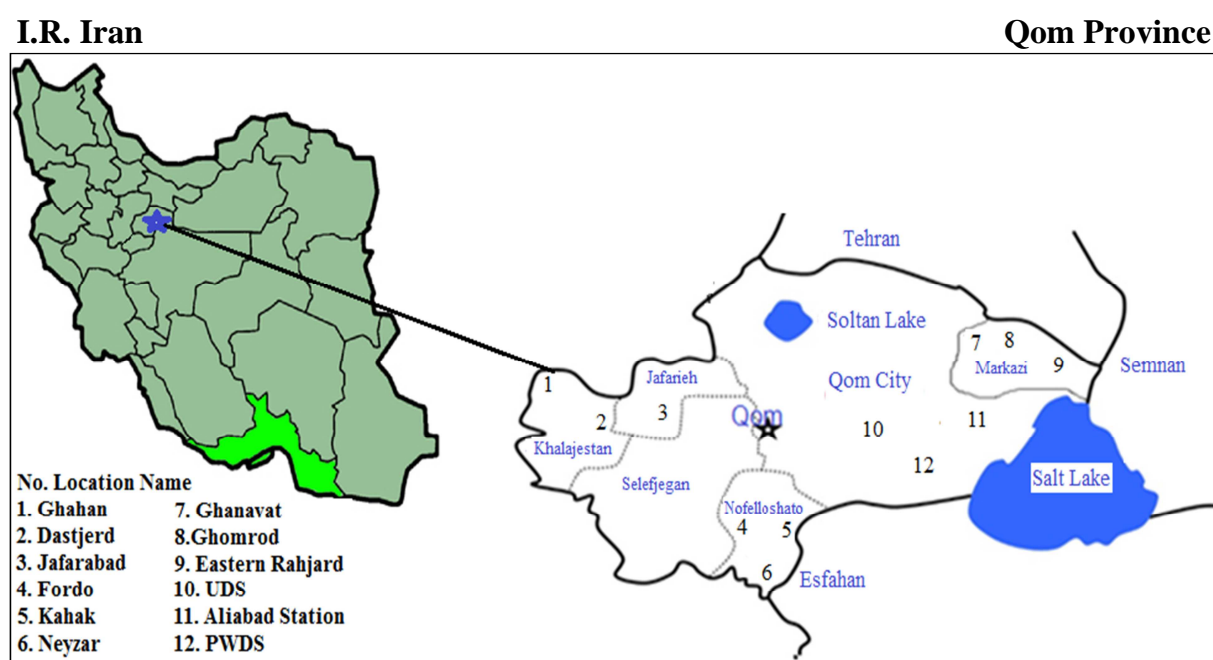


Figure 1. Location of study sites. Inset: Location of Qom in Iran

The optimal level of fluoride content in drinking-water has traditionally been calculated on the basis of annual mean maximum temperature (AMMT) and varied from 0.7 to 1.2 ppm depending on the temperature and climate of the region. These standards were based on the Galagan and Vermillion (20), which estimated the daily water intake under different temperature conditions. The original metric units employed by Galagan and Vermillion can be converted to SI units. The equation to calculate the optimal level of fluoride in drinking-water (mg/L) is:

$$\text{Optimal flouride concentration } \left(\frac{\text{mg}}{\text{L}}\right) = \frac{0.022}{0.0104 + 0.000724 \times \text{AMMT}}$$

Where, AMMT is the annual mean maximum temperature in centigrade. Background information about the provinces water supplies was made possible by referring to the organizations in charge of supplying drinking-water. To measure the amount of fluoride, the standard method of SPANDS and spectrophotometer DR 4000 (Model HACH) were used. This method complies with the standard USEPA, which is utilized for analyzing water and wastewater quality (21). TDS was measured using gravimetric methods at temperatures 103-105° C. EC was

measured using a portable EC meter (Model WTW-LF90). The basis of analyzing drinking-water quality was the Iranian and WHO standards (13,16).

For the analysis of data, software program Excel was employed, and the results were presented in tables and charts in terms of means.

3. Results

Table 1 presents the means, standard deviations, maximum and minimum of fluoride amounts in water sources in the Qom City. As is evident from table 1, the highest and lowest average concentrations of fluoride were in the villages of Neizar (0.9 mg/L) and Fordo (0.05 mg/L). To calculate the optimal level of fluoride in drinking-water of Qom Province by Galagan and Vermillion equation, AMMT records during the last 2 years (2011-2012) were collected from the meteorological center of Qom and it was 23 ± 3° C. According to Galagan formula, the recommended optimal fluoride in drinking-water in Qom should be 0.81 ppm. Furthermore in tables 2 and 3 the mean values, standard deviation, maximum and minimum of EC and TDS are presented. Figure 2 shows the mean changes in fluoride concentration in water sources in Qom.

Table 1. Mean amounts (mg/L) of fluoride in drinking-water in sections and villages in Qom

Index		Number of samples	Mean ± SD	Maximum	Minimum
Section	Village				
Nofelloshato	Fordo	6	0.050 ± 0.129	0.37	0
	Kahak	6	0.251 ± 0.308	0.95	0
	Neyzar	6	0.903 ± 0.353	2.18	0.47
Jafarieh	Jafarabad	6	0.263 ± 0.111	0.38	0
Markazi	Ghanavat	6	0.411 ± 0.219	0.8	0.03
	Ghomrod	6	0.315 ± 0.172	0.53	0.03
	Eastern Rahjard	6	0.499 ± 0.256	0.83	0.14
Khalajestan	Ghahan	10	0.497 ± 0.249	0.9	0.25
	Dastjerd	10	0.552 ± 0.219	0.95	0.1
Qom city	UDS	12	0.825 ± 0.270	1.28	0.21
	Aliabad station	12	0.115 ± 0.061	0.21	0
	PWDS	14	0.2411 ± 0.0960	0.4	0.07

PWDS: Private water desalination system

Table 2. Mean amounts of TDS (mg/L) in drinking-water in sections and villages of Qom

Index		Mean ± SD	Maximum	Minimum
Village	Section			
Nofelloshato	Fordo	512.25 ± 185.58	903	235
	Kahak	1260.90 ± 903.75	3550	492
	Neyzar	1470.76 ± 1391.64	6742	280
Jafarih	Jafarabad	977.25 ± 128.26	1379	584
Markazi	Ghanavat	647.75 ± 251.56	1090	205
	Ghomrod	754.82 ± 183.13	987	510
	Eastern Rahjard	748.82 ± 533.59	1736	88
Khalajestan	Ghahan	481.84 ± 262.1	1030	250
	Dastjerd	521.15 ± 217.4	870	215
Qom city	UDS	3111.85 ± 1065.09	5200	1790
	Aliabad station	192.65 ± 28.83	280	137
	PWDS	209 ± 92.51	340	56

PWDS: Private water desalination system, TDS: Total dissolved solids

Table 3. Mean amounts of EC (µmohs/cm) in drinking-water in sections and villages of Qom province

Index		Mean ± SD	Maximum	Minimum
Village	Section			
Nofelloshato	Fordo	815 ± 242	1290	471
	Kahak	1762 ± 1094	4440	757
	Neyzar	2047 ± 1823	8990	571
Jafarih	Jafarabad	1404 ± 169	1970	980
Markazi	Ghanavat	1016 ± 302	1560	406
	Ghomrod	1141 ± 199	1410	850
	Eastern Rahjard	1202 ± 722	2480	176
Khalajestan	Ghahan	708 ± 362	1466	362
	Dastjerd	969 ± 420	1780	428
Qom city	UDS	4216 ± 1298	6560	2540
	Aliabad station	385 ± 57.7	560	273
	PWDS	418 ± 185	677	112

EC: Electrical conductivity

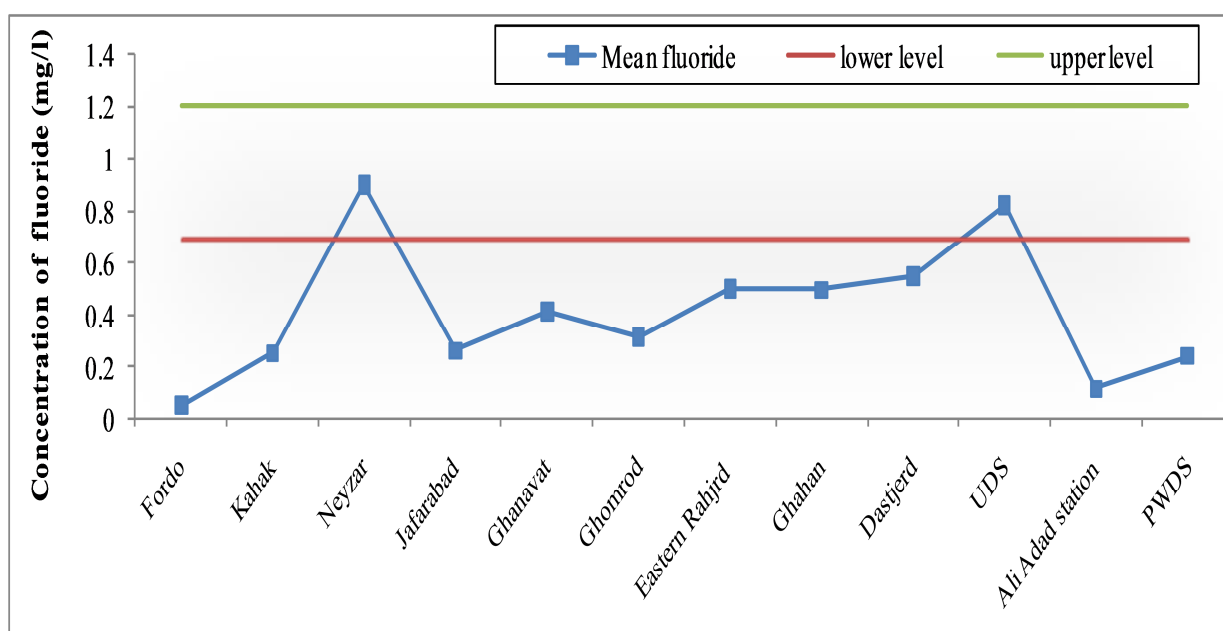


Figure 2. Comparison of the mean concentrations of fluoride with the WHO guideline

4. Discussion

As showed in results, the mean of fluoride concentration in Neyzar's villages was 0.9 mg/L with a maximum of 2.18 mg/L and minimum of 0.47 mg/L. In other villages, the mean amount of fluoride in drinking-water was lower than the allowable minimum standard set by the WHO and Iran. Qom's urban distribution network of drinking-water has an average fluoride concentration of 0.82 mg/L, lower than the minimum allowable standard developed by the WHO and Iran (13,16). Considering the role of fluoride in strengthening the teeth structure and bones (9), it is expected that the number of decayed, missing, and drawn teeth will increase in future years. Studies by the ministry of health, cure, and medical education in 2008 on the amounts decayed, missing, and filled teeth of permanent teeth and that of primary teeth at ages 3, 6, 9, and 12 reported a moderate increase (14,22,23). In recent years, there has been a rise in the distribution of treatment water from desalination machines. Comparing the results of this study indicates that the average fluoride concentration in drinking-water in Qom, like that of many other areas in Iran (15,17,18) is below WHO and Iranian standard levels (13,16). Fluoride levels of drinking-water in Khoozestan, Iran, were found to be is in the range of 0.12-2.17 mg/L (23). As for other countries, fluoride levels of 84% of samples collected in Pakistan was lower than 0.7 mg/L. It was also discovered that adding fluoride to drinking-water periodically is essential to prevent dental caries (24). A study conducted on 24 Mexican villages revealed that fluoride concentration of 77% of samples was above 1.5 mg/L, no wonder 79.69% of the population were suffering from dental fluorosis (25). Another study in Saudi Arabia showed that dental fluorosis was most prevalent at fluoride concentrations of above 1 mg/L (26). In Malaysia, a study concluded that the average fluoride levels in all the nine regions under

investigation were lower or equal to the standards (0.5-0.9 mg/L) developed by the country. Moreover, it was found that this standard might be insufficient to prevent caries of dental enamel, which was the main reason for adding fluoride to drinking-water (27). Results of a recent study in Qom indicated that, by taking into consideration the average fluoride concentration levels in drinking-water sources in the towns and villages of the province and the city of Qom (i.e., 0.4 mg/L) and the average temperature of 18.8° C for 5 years up to 2008, fluoride concentration should range from 0.8 to 1.8 mg/L as the national standard states. Therefore, Qom's drinking-water would require at least another 0.4 mg/L fluoride to provide minimum desirable levels of Iranian standard (16). The maximum and minimum means of TDS in drinking-water in UDS and Ali-Abad Station were 3,111.85 mg/L and 192.65 mg/L, respectively. The EC maximum was 4216 µmohs/cm for the urban distribution network, and the minimum mean was 385 µmohs/cm. Input water of private water desalination systems (PWDSs) in Qom often come from the UDS. As the TDS and EC values for distribution networks of drinking-water are unfavorably high, PWDSs reduce them to 209 mg/L and 418 µmohs/cm, respectively. As for fluoride, it is reduced from 0.82 mg/L in the input to 0.2411 mg/L in the output of PWDSs. Fluoride concentration is reduced by approximately 3.5 times. This is lower than the minimum optimal standard determined by the WHO and Iran, which may lead to the aggravation of dental caries. WHO guidelines define 500 mg/L and 1500 mg/L as the optimal and maximum allowable concentrations of TDS in drinking-water, respectively. Standards and Industry Research Institute of Iran have adopted the same standards, with the amendment of up to 2000 mg/L of fluoride in case there is scarcity of good drinking-water sources in a region (16). As for the EC values, the WHO and Standards

and Industry Research Institute of Iran have not issued any recommendations (13,16). However, Europe has used the minimum EC of 400-1000 $\mu\text{mohs/cm}$ as their optimal benchmark (28). Comparing these figures with that of our research, it was found that the TDS and EC levels of some of drinking-water sources such as those of the urban distribution system were much higher (13,16). With regard to the methods of supplying fluoride, adding fluoride to drinking-water is proposed as a proper way to compensate for the fluoride shortage. This can be a cost-efficient and convenient way to rural and urban areas alike as drinking-water and sanitation water are provided through entirely separate systems. If this approach is not adopted, however, fluoride must be added to food or other methods must be taken for satisfying the need of the body. The use of fluoride-containing foods should be further considered in children's growth.

Conflict of Interests

The Authors have no conflict of interest.

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