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Monitoring and health risk assessment of fluoride in drinking water in Babol, Mazandaran Province, Iran

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ABSTRACT

Because of high variations in fluoride concentration and many contaminated areas, Iran has been known as an interesting country regarding different fluoride studies. However, researches on fluoride concentration and its effects in northern strip of Iran are limited; moreover, risk assessment studies have been neglected in these areas. Therefore, this study focused on the measurement and risk assessment of fluoride in water supplies of villages around Babol County in north of Iran. Therefore, this descriptive cross-sectional research was performed in the city of Babol, Iran, 2017. Eighty water samples were taken from 40 wells in the rural areas (40 and 40 samples in cold and warm seasons). The SPANDS method was used for the measurement of fluoride concentration. The non-carcinogenic risk of fluoride was assessed in four age groups (infant, children, teenager and adult). The risk of dental and skeletal fluorosis was counted based on the international standard. From all villages ($n = 24$), respectively, 4 and 3 villages in cold and warm seasons had proper fluoride concentrations according to the WHO standard; fluoride concentration of other villages was lower than the WHO minimum standard of. Any observable risk of dental and skeletal fluorosis in all studied villages for the whole age groups was not observed; the HQ of all the villages was lower than 1 except for Kalhu Dasht because its HQ was higher than 1 in infants and children in cold season. Infant and children of this village were exposed to risk of dental fluorosis. In northern areas of Iran, not only there is not a risk of dental or skeletal fluorosis, which is related to high concentration of fluoride, but also there is a risk of dental decay due to low fluoride concentration in water drinking water. However, this hypothesis needs to further study.

Keywords: Fluoride; Groundwater; Health risk assessment; Babol; Monitoring

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1. Introduction

The content of fluoride (F) in water supplies is of the greatest important [1]; low concentrations of fluoride (≤0.5 $mg \cdot L^{-1}$) lead to dental decay [2], but teethes are protected against decay at lower concentrations (0.5–1.5 $mg \cdot L^{-1}$) [3]. Besides, dental and skeletal fluorosis can be caused at higher concentrations of fluoride (> 4 $mg \cdot L^{-1}$) [4]. In addition, high concentrations of fluoride correlate with a wide range of health disorders in human and animals such as anemia, low weight birth of babies, nervous system problems, abortion, hypertension and so forth [5–7]. It is also responsible for reducing intelligence quotient (IQ) in children [8]. Scientists are hesitant about the fluoridation of water supplies and different impacts of fluoride to human health; despite a number studies conducted on this issue, the results are very different and paradoxical. Some countries and international institutes advise water fluoridation, however, a few other ones do not agree with this [9]. In order to answer these questions, it is important that risk assessment studies about the hazards of consumption of water containing different concentrations of fluoride be conducted. The steps of risk assessment for fluoride include hazard identification (determination of low and high level of fluoride exposure that can lead to a hazard), definition of the toxicity of reference value (TRV) of fluoride, the assessment of fluoride exposure (it is calculated with multiplying fluoride concentration in water and average amount of water consumption per day), and risk characterization [10]. It should be noted that, in some countries, risk assessment for fluoride in drinking water has been done. For example, Yousefi and et al. indicated that young, teenager and children are affected by fluoride poisoning [11]. Moreover, in a study by Mirzabeygi et al. [12] the risk assessment of fluoride in drinking water was surveyed; the results of this study showed that the high concentration of fluoride has more hazards to infants than other age groups. Based on previous studies, Iran is a heterogeneous country regarding fluoride concentration of drinking water in different areas; West Azerbaijan, especially Poldasht, is a well-known area with water supplies that are poisoned with high fluoride content. In contrast, in east areas such as Khorasan, major water wells contain low concentration of fluoride [7]. This issue may be resulted from different species of aquifer rocks in each region. Despite these impressive differences among regions throughout Iran, most studies have been conducted in the west and northwest region of the country and other areas have been neglected; therefore, the objectives of this study were quantification of fluoride in water supplies and non-carcinogenic health risk assessment associated ingestion of fluoride in different villages in Babol (a county in north of Iran).

2. Materials and methods

2.1. Description of study area

Babol County is situated between the latitude from (N 40°36′ to N36°35′) and longitude (E33°52′ to E43°51′) is in Mazandaran Province in Iran. The Babol Plain has an area of 1578 km^2 and urban population of 230973. The mean annual temperature, rainfall, and mean humidity of this county are 15.9°C, 525.6 mm and 78%, respectively (Fig. 1.**)**

2.2 Determination of fluoride in drinking water

This descriptive cross-sectional research was conducted in the city of Babol, Iran, in 2017. Eighty water samples were taken from 40 wells in the rural areas (40 and 40 samples in cold and warm seasons). It should be pointed that the samples were collected in all seasons of the year using plastic containers under standard conditions. The samples were transferred to the water and wastewater chemistry laboratory of the Deputy of Health Services and the Rural Water and Wastewater Company in Babol. All the samples were stored in sterile plastic containers under 4°C and then transported to the lab. The SPADNS method was used to detect fluoride concentration according to the instructions of standard methods [13]. The SPADNS colorimetric method is based on the reaction between fluoride and a zirconium-dye lake (Merck, Germany). Fluoride reacts with the dye lake, dissociating a portion of it into a colorless complex anion (ZrF62-). As the amount of fluoride increases, the color produced becomes progressively lighter [14]. Finally, the resulting solution color is measured in a spectrophotometer (DR5000 Spectrophotometer, HACH Company, USA) at the wavelength of 570 nm. All reagents were purchased from Merck (Germany). The minimum detectable level of the SPADNS method is 0.02 mg/L, as reviewed, analyzed, and compared by the World Health Organization (WHO) and Iran national standards. The obtained data were analyzed by means of SPSS version 19 to compare the results between seasons. Further, Arc GIS software was utilized to determine the location of the wells and the distribution of fluoride concentration.

2.3. Risk assessment of fluoride

The human health risk assessment is an approach to help understand the nature and probability of adverse health effects of contaminants on humans who may be

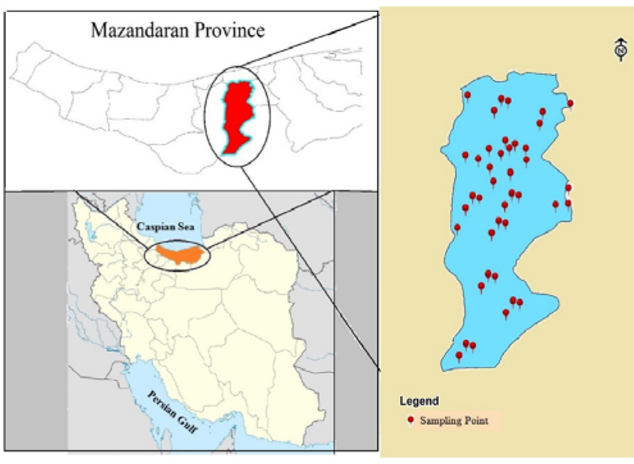

Fig. 1. The map and location of the sampling villages in Babol County, Mazandaran Province, Iran.

exposed to chemicals in polluted environments, now or in the future. Therefore, the quantitative risk assessment of fluoride consumed via drinking water in the rural population of Babol County, Mazandaran Province, was investigated. First, the drinking water samples were taken from different villages. The population was divided into four age groups. According to physiological and behavioral differences, they were categorized in six groups: infants (aged less than 2 years), children (aged 2–6 years), teenager (aged 6–16 years), adults (aged 16 years and higher) and pregnant and lactating women, who were exposed to fluoride. Exposure to fluoride was calculated in these groups using Eq. (1):

$$\text{EDI} = \frac{\text{CF} \times \text{Cd}}{\text{BW}} \tag{1}$$

Estimated daily intake (EDI) of fluoride was calculated based on daily drinking water consumption (Cd), concentration of fluoride in drinking water (Cf), and body weight (Bw) [8] using Eq. (1). In this study, the weights of infants, children, adolescents, and adults were assumed to be 10, 15, 50 and 78 kg, respectively. And, the EDI of fluoride was calculated as mg per each kg of weight per day (mg kg d). The information related to drinking water consumption and Bw was collected using the questionnaire of the target groups (infants, children, adolescents and adults). Low Bw is one of the reasons for the high non-carcinogenic risk for the children [15].

Table 1
The consumption of water in warm session was higher than that in cold session (around 20%) [16]

	Age groups			
	Infants	Children	Teenagers	Adults
Average weight (Kg)	10	15	50	78
Consumption of water in warm season (as liter)	0.72	1.2	1.92	2.4
Consumption of water in cold season (as liter)	0.5	1	1.6	2

HQ is the health risk index of metal or hazard quotient index: if HQ is higher than 1, it shows a potential health risk and; if it is less than 1, it does not shows a potential health risk. The non-carcinogenic risk of fluoride to human health can be expressed as hazard quotient (HQ) using Eq. (2): [17]. In the present study, CDI and RfC are annual average

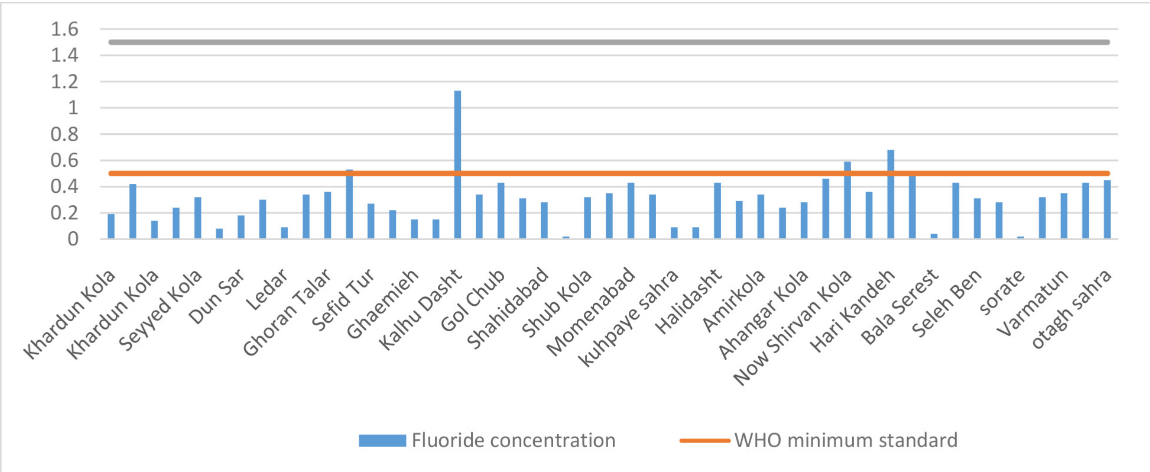

Fig. 2. Fluoride concentrations in cold season compared to the WHO standards.

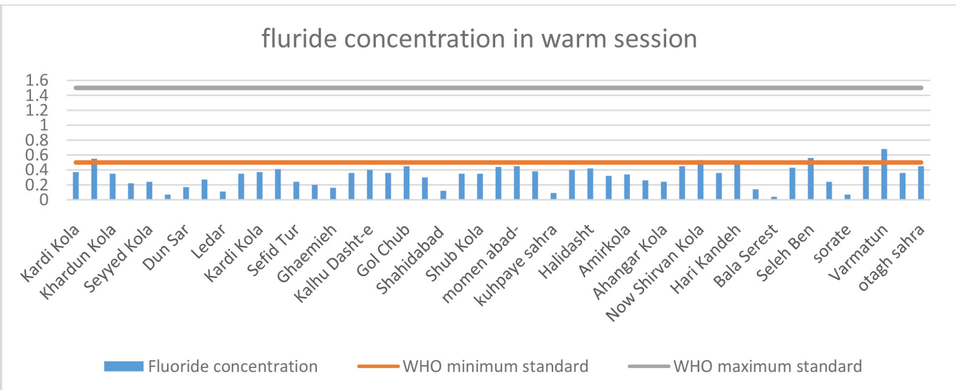

Fig. 3. Fluoride concentrations in warm season compared to the WHO standards.

of daily received concentration ($mg \cdot L^{-1}$) and non-carcinogenic reference concentration of the pollutant.

$$HQ = \frac{CDI}{RFD} \tag{2}$$

3. Results

The spatial distribution of fluoride concentration in two cold and warm seasons is shown in Fig. 4. According to these GIS maps, central regions had lower fluoride concentration than other regions. People living in northeast regions and some regions in east and west were exposed to higher fluoride concentrations in drinking water than those ones living in central regions in both seasons. It also seems that in cold season fluoride concentration was higher than that in warm seasons in most regions.

Fig. 4 illustrates the concentration of fluoride in different villages around Babol County in low and high rainfall seasons. There was not any significant difference between cold and warm seasons. But fluoride concentration in cooler season in a few villages was more than that in warmer season. According to the figures, only 3 and 4 of the villages, respectively, in low and rainy seasons, had a safe level of fluoride concentration, based on the WHO standards for dental decay prevention.

In this study, the risk of fluoride in drinking water supplies was assessed. First, we calculated estimated daily intake (EDI) in four age groups. Moreover, we compared these results with two standards of the US EPA and Health Canada for dental fluorosis in low and high rainfall seasons. According to Figs. 5 and 6, only Kalhu Dasht village, in high rainfall season, had higher EDI than the US EDA standard for dental fluorosis (only in infant and children groups).

Another main ratio in risk assessment is hazard quotient (HQ). It is calculated with splitting EDI to RDF (the reference dose without an appreciable risk of deleterious impacts over a lifetime). HQ value more than 1 indicates non-carcinogenic health risk for consumer populations.

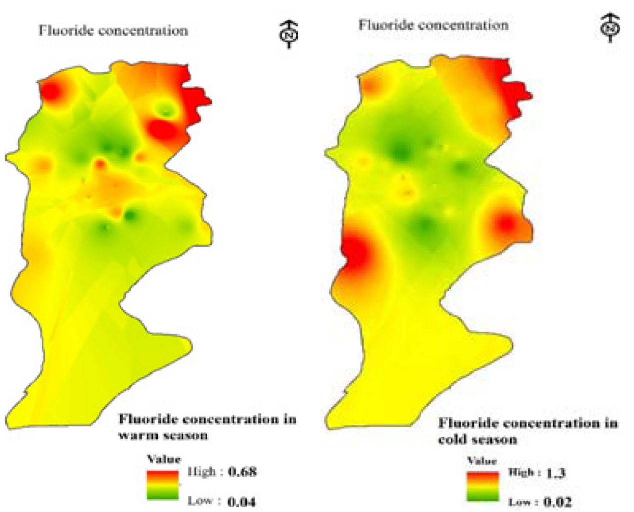

Fig. 4. Spatial distribution of fluoride concentration in two cold and warm seasons in the study area.

According to Figs. 7 and 8, HQ rates of all villages were lower than 1 in four age groups, except for the infant and children group of Kalhu Dasht in high rainfall session. Most villages had HQ rate lower than 0.5, especially in low rainfall seasons.

4. Discussion

There is a great ambiguity about the content of fluoride in water drinking in scientific societies. The WHO has recommended a lower maximum level of fluoride in water drinking supplies (1.5 $mg \cdot L^{-1}$) than that by the US EPA (4 mg·L). Fluoride concentration in cooler season is more than that in warmer season. Although the amount of water consumed is directly related to the increase in ambient temperature, due to rain in the northern part of Iran in cold season, water passes through stones and dirt that can increase the amount of fluoride [18]. Most standards have paid attentions to the maximum level of fluoride while the minimum level is important in terms of the protection of teeth. In addition, there are many risk assessment studies in areas with high concentrations of fluoride in water supplies but in areas with low concentrations they have been neglected [19–21]. The concentration of fluoride in Iran's water supplies is different and there is a significant verity in various areas. Two well-known areas with fluoride contamination in Iran are Poldasht (in northwest) and Ardakan (in center), but there are some supplies containing low concentrations of fluoride in northeast such as Saraian County [5,7,22,12]. Despite a number of studies on fluoride in water supplies in different parts of Iran, north regions have been neglected by researchers. Therefore, in this study, we focused on the spatial distribution and risk assessment of fluoride in drinking water of Babol County (north of Iran) [24]. Fluoride concentrations were measured in both low and high rainfall seasons and the GIS maps of spatial distribution were designed in both ones. Then, the risk of non-carcinogenic disorder was assessed for four age groups (infant, children, teenager and adults). According to the spatial distribution maps in warm and cold seasons, central areas had lower fluoride concentrations than other areas; this is related to different structures of underground aquifers where water moves; for example, high concentrations of fluoride are resulted from of passing water through crystalline igneous rocks [24]. In whole villages, the concentration of fluoride was lower than the minimum level of the WHO standard (0.5 $mg \cdot L^{-1}$) except for three villages in warm season and four villages in cold season illustrating that these villages have safe level of fluoride concentration (0.5–1.5 $mg \cdot L^{-1}$) for dental cavity prevention. There are many doubts about this safe standard level and some researchers believe that this level cannot definitely guarantee dental health. Despite all of these, it seems that the level of fluoride in drinking water supplies of Bobol County to make a protective effect is very low. Besides Babol, it seems that the entire northern strip of Iran is suffering from this problem. In a systematic review that conducted by Taghipur et al., the means of fluoride concentration in three northern provinces were lower than 0.5 $mg \cdot L^{-1}$ [23]. According to these studies, water supplies of a great population in the north of Iran need to fluoridation

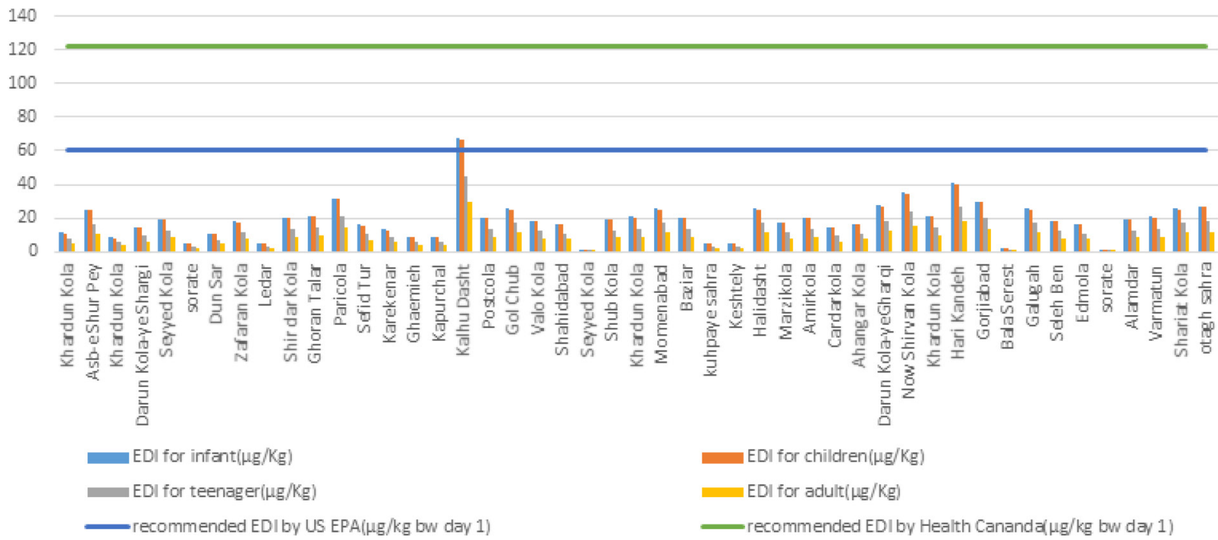

Fig. 5. Comparison of estimated daily intake (EDI) in four age groups with two standards of US EPA and Health Canada in cold season.

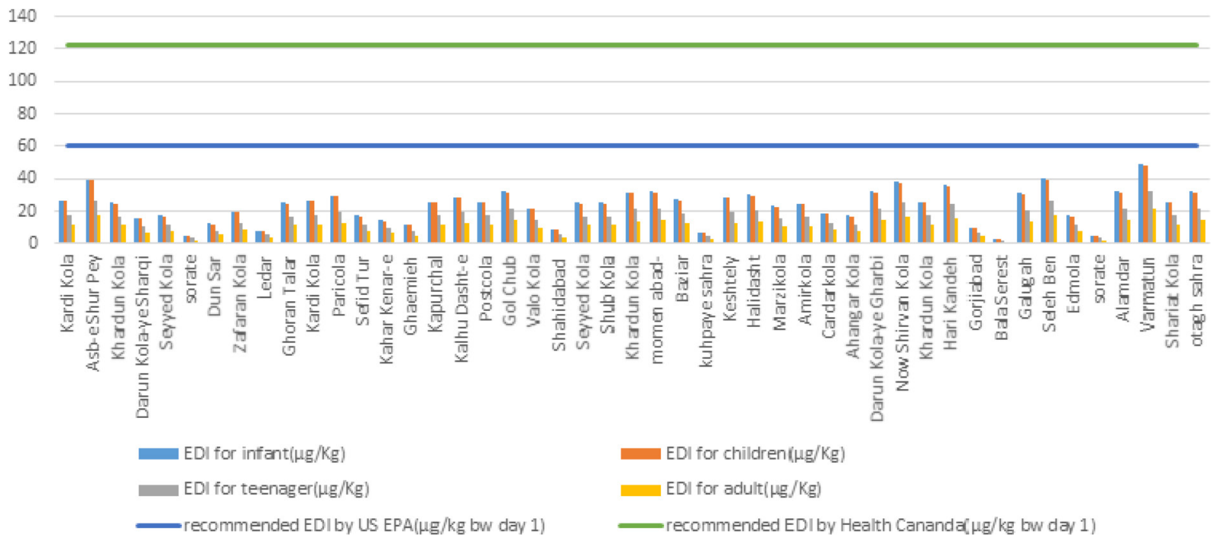

Fig .6. Comparison of estimated daily intake (EDI) in four age groups with two standards of US EPA and health Canada in warm season.

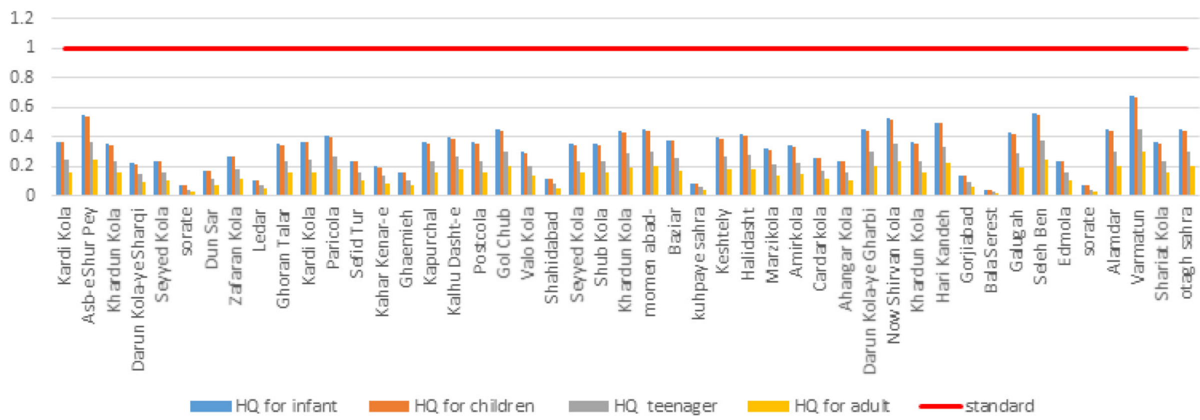

Fig. 7. HQ value for different regions of the city of Babol's villages over four age groups in cold season.

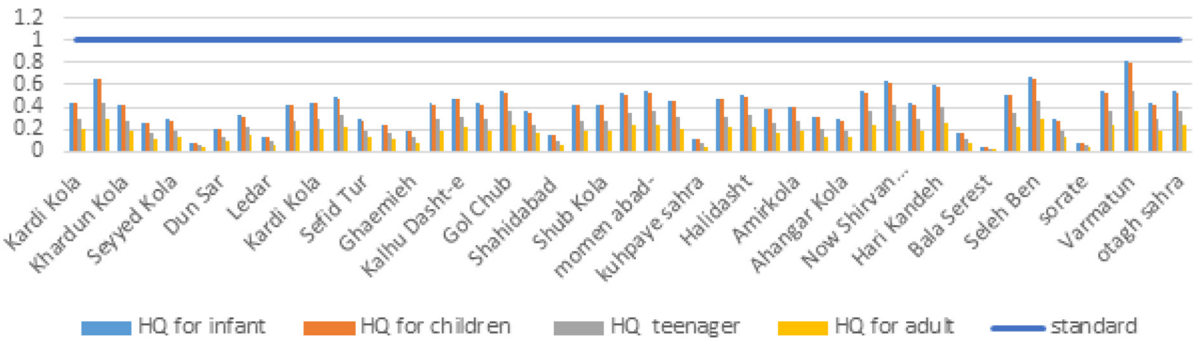

Fig. 8. HQ value for different regions of the city of Babol's villages over four age groups in warm season.

[25]. The EDI measurements are very little in comparison with the US EPA and Health Canada except for one village in warm season for two age groups (infant and children). Therefore, we are not sure about dental and skeletal fluorosis in this county. Some studies with the same concentration of fluoride in drinking water have reported more EDI because of lower selected weight and more defined water consumption for age groups; for example, Guissouma et al. selected three groups for their study in Tunisia; five kg was assumed as the average weight of the infants (0–2 years) and water consumption of this age group was 0.75 $L \cdot d^{-1}$. In addition, the weight of the children was assumed to be 10 kg, which these selected measures are not similar to those of children; it seems that these assumptions can lead to overestimate calculated risk [10]. HQ was also similar to EDI and all calculated HQs were lower, except for Kalhu Dasht village; that is, there is not any risk of non-carcinogenic damage for fluoride in drinking water except for the mentioned village. Fortunately, because of low concentration of fluoride in villages around Babol, there are quite a few villages with HQ more than 1 in comparison with other studies. Some studies reported higher HQ despite the same concentration with our study. It seems that there is a great discrepancy between assumed weights and water consumption in age groups through different studies resulting in a difference in the results of the studies [11,26,28]. This study was conducted to assess drinking water supplies in a low fluoride region in the north of Iran. Similar results have been reported by other studies [13,29,30]. In contrast with many studies, we focused on problems of low concentration of fluoride. There are quite a few people affected by high concentrations of fluoride in water supplies; however, due to intake of fluoride from other supplies (drinking water and toothpaste), there is no certainty about low risk of exposure and this issue needs to further studies.

5. Conclusion

In this study, fluoride content in 40 wells used for supplying drinking water in four seasons and its health risk were investigated. Of the 80 samples taken from these wells, all of them were within the standard range set by the WHO guidelines. According to the results of spatial distribution performed with GIS software, the village Kalhu Dasht of had the highest concentration of fluoride. According to this report, the level of fluoride in drinking water in the most areas of Babol County was lower than the protecting level for dental decay. The results showed that HQ was less than 1 for all age groups, indicating that children in study area were not at high risk. Also, dental and skeletal problems do not threaten the people from northern Iran. The most important factor affecting the increase of non-carcinogenic risk in children is the drinking water ingestion rate. It seems that health policy makers should make new decision to oral ingestion of fluoride regarding the of results risk assessment. In addition, these people are exposed to lack of fluoride in their water supplies. It should be pointed out that this plan needs to further studies and hold new screenings, as well as the amount of fluoride received through other ways of contact such as food and its health risk should be investigated.

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Conflict of interest

The authors of this article declare that they have no conflict of interest.

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