Expo Health (2016) 8:465–474
DOI 10.1007/s12403-016-0204-z

ORIGINAL PAPER

Fluoride in Drinking Water in 31 Provinces of Iran

Z. KheradPisheh[1] · M. H. Ehrampoush[1] · Ahmad Montazeri[2] · M. Mirzaei[3] · M. Mokhtari[1] · A. H. Mahvi[4,5]

Received: 16 January 2016 / Revised: 24 March 2016 / Accepted: 25 March 2016 / Published online: 16 April 2016

Abstract The effects of acute fluoride toxicity have been well documented in the literature. Drinking water is an important source of fluoride intake by humans, hence studies need to be carried out to determine the concentration of Fluoride in water. Therefore, this study tends to demonstrate the fluoride concentration in drinking water in thirty-one provinces of Iran during 2014. This cross-sectional study on drinking water was conducted in 2014. SPADNS method was determined for fluoride concentration examination according to instruction of Standard Methods. The minimum concentration of fluoride in provinces, such as Fars, Kermanshah, Kohgiluyeh and Boyer-Ahmad, Markazi, and Hormozgan, was observed to be 0.01 mg/L, while the maximum concentrations were observed to be 3.72 and 3.52 mg/L for Bushehr and Fars, respectively. The minimum and maximum average mean concentrations were 0.193 (SD = 0.11) and 0.889 (SD = 0.31) for Kermanshah and Bushehr, respectively. Due to the disadvantages of fluoride and because of the existence of different ecological conditions in Iran, there are different concentrations of water fluoride in the country. Therefore, proper policies should be made for water treatment plants based on the regional conditions in order to achieve a desirable fluoride concentration standard.

Keywords Concentration · Drinking waters · Fluoride · Iran

✉ A. H. Mahvi
ahmahvi@yahoo.com

1 Department of Environmental Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

2 Water Quality Control Bureau, National Water and Wastewater Engineering Company, Tehran, Iran

3 Cardiovascular Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

4 School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

5 Center for Solid Waste Research, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran

Introduction

Iran is located between 25°30′ and 39°47′ of the northern latitude and 44°14′ and 63°20′ of the eastern longitude. It has an area of 1,648,195 km^2, making it the 18th-largest in the world and the second-largest nation in the Middle East. With 78.4 million inhabitants, Iran is the world's 17th most populous nation (World Bank). Fluoride enters the drinking water from atmospheric sources, precipitation (suspended particulates, emissions of volcanic gases, and rainfall contaminated with industrial wastes), human sources (inducing industrial aerosols), minerals (rocks often contain 100–1300 mg/kg of fluorine), and geothermal sources (hot springs) (David and Ozsvath 2009). The entrance of fluoride into the water environment mainly occurred through natural resources (Mesdaghinia et al. 2010). The Earth crust contains fluoride with an average concentration of 0.3 g/kg and the concentration of fluoride in air across the globe is about 3 ng/m^3 (Mesdaghinia et al. 2010). Fluorine has a higher electron affinity than other elements, existing as a negatively charged ion in water. It can be absorbed into the body as soon as it gains access into the human digestive system, thus forming HFo complex with the stomach acid. HFo complex is easily absorbed through the stomach and small intestine by a simple diffusion process and then changes as a free

Table 1 Fluoride variation with temperature changes according to Iran Industrial Standards Institute (Mesdaghinia et al. 2010; Ebrahimi 2015)

The annual average of daily maximum temperature (°C)	Minimum average quantity of fluorine (mg/L)	Desirable quantity of fluorine (mg/L)	The maximum amount of fluorine (mg/L)
10–12	1.1	1.2	2.4
12–14.6	1.0	1.1	2.2
14.6–17.7	0.9	1.0	2.0
17.7–21.5	0.8	0.9	1.8
21.5–26.5	0.7	0.8	1.6
26.5–32.5	0.6	0.7	1.4

fluoride (David and Ozsvath 2009). The effects of acute fluoride toxicity are well documented in the literature (Mannina et al. 2013). Some fluoride-related diseases include genetic mutations, birth defects, infants' height and weight disorders (Aghaei et al. 2015), increased allergic reactions, allergic diseases, damage to bones, abnormal skeletal effects, Fluorosis (Azami-Aghdash et al. 2013), blood pressure (Amini et al. 2011), fertility effects, effects on kidney and liver (Xiong et al. 2007), neurological effects, impaired intelligence of children (Seraj et al. 2012; Karimzade et al. 2014; Anna and Guifan 2012; Nagarajappa and Pujara 2013), hyperactivity (Ashley and Till 2015), thyroid hormone effects (Sachdeva et al. 2015; Momeni and Dehghani 2011; Swati and Shashi 2013; Coperchini and Pignatti 2015; Vandana et al. 2015; Susheela 2005; Wolka et al. 2014), carotid atherosclerosis (Liu et al. 2014), cancerous effects, and Alzheimer's disease; in spite of these, more studies are needed in this area (David and Ozsvath 2009; Mannina et al. 2013). Linear regression analyses by Dobaradaran et al. (2008a, b) showed weak increases of the number of decayed permanent teeth and the number of decayed deciduous teeth scores with increasing water F levels (Dobaradaran et al. 2008a, b). The mean fluoride content in the air of Arak city was investigated by Dobaradaran et al. (2008a, b) and it was found to be 73.43 $\mu g/m^3$ (Dobaradaran et al. 2009a). The range of fluoride content of tea liquor was reported from 0.53 ± 0.07 to 2.60 ± 0.18 mg/L by Mahvi et al. (2006). The mean fluoride content of bottled drinking water was measured by Dobaradaran et al. (2008a, b) and it was 0.3 mg/L with a range of 0.00–0.59 mg/L in Iran (Dobaradaran et al. 2008b). Fluoride concentrations in the Shush aquifer of Khuzestan had ranged from 0.12 to 2.17 mg/L (mean 0.6 ± 0.44 mg/L) (Nouri et al. 2006). Correlation of fluoride with noncarbonated hardness, SO4 2−, Ca2+, and Mg2+ was found to be positive in groundwater of Dashtestan (Dobaradaran et al. 2009b). Fluoride adsorption in aqueous solution by a hybrid resin was studied by Boldaji et al. (2009), where this adsorbent had 61 percent efficiency for water with fluoride less than 4 mg/L (Boldaji et al. 2009). Iran's drinking water standard is based on the guidelines recommended by the World Health Organization (WHO) on drinking water that contains less than 1.5 mg/L of fluoride. This guideline is based on a water consumption of 2 l per day for adults. The Iranian standard for fluoride concentration in drinking water is shown in Table 1. Many studies measured fluoride in drinking water and water wells in different parts of Iran including the daily fluoride intake for residents of Bushehr Province which was estimated by Battaleb-Looie et al. (2013) in this location, of which 44.4 % of the drinking water exceed the guideline value of 1.5 mg/L recommended by WHO (Battaleb-Looie et al. 2013). Fluoride in the main drinking water source was assessed by Derakhshani et al. (2014) in the Zarand in Kerman Province of Iran. The maximum groundwater fluoride concentration was 3.51 mg/L (Derakhshani et al. 2014). Fluoride in drinking water of Muteh was obtained (1.8–2.2 ppm) by Keshavarzi et al. (2010). Fluoride in drinking water of kuhbanan was assessed by Poureslami et al. (2011) and the average content was 2.38 ppm (Poureslami et al. 2011). Fluoride level in Maku was reported to be more than 1.5 mg/L by Ejlali et al. (2015). The maximum of F content in Zarrin Dasht was reported as 2.45 mg/L by Momenifar and Moosavinasab (2013). This study demonstrates the fluoride concentration in drinking water for community water supply in urban areas of 31 provinces of Iran during 2014.

Materials and Methods

Iran, a Middle Eastern country south of the Caspian Sea and north of the Persian Gulf, shares borders with Iraq, Turkey, Azerbaijan, Turkmenistan, Armenia, Afghanistan, and Pakistan. This cross-sectional study was conducted in 2014 on drinking water, and information related to fluoride concentrations in drinking water of Iran's provinces was extracted from the Iranian Wastewater Engineering Company in 2014. Some county with the maximum concentration of fluoride in Drinking Water has been re-sampling and measurement by university that Shown in Table 2. This study was conducted in provinces of Iran by the Iranian

Table 2 The fluoride content in drinking water in the provinces of Iran and location with the maximum fluoride content

No	Province/county	Min of conc. (mg/L)	Max of conc. (mg/L)	Mean of conc.(mg/L)	Standard deviation SD (mg/L)	Latitude	Longitude
1	Bushehr/Bushkan	0.05	3.52	0.889	0.31	28.923384	50.820314
		–	3.52	–	–	28.827959	51.700211
2	Khorasan-north	0.04	1.52	0.783	0.29	37.471035	57.101319
3	Semnan	0.13	1.49	0.742	0.32	35.578797	53.379811
4	Qazvin	0.18	1.8	0.662	0.45	36.273659	49.998236
5	Qom	0.1	1.5	0.648	0.32	34.639944	50.875942
6	Fars/Zarrin Dash	0.01	3.72	0.617	0.57	29.104381	53.045893
		–	3.72	–	–	31.513357	52.124896
7	Razavi Khorasan-M/ khvaf	0.03	1.5	0.59	0.23	35.102025	59.104176
		–	1.5	–	–	34.571826	60.147409
8	Chaharmahal and Bakhtiari	0.033	1.23	0.532	0.22	29.610683	50.755955
9	Hormozgan/Bandar Lengeh	0.01	3	0.53	0.49	27.138723	55.137583
		–	3	–	–	26.550941	54.886188
10	Khuzestan/Shush	<0.02	2.38	0.504	0.25	31.436015	49.041312
		–	2.38	–	–	32.195795	48.254283
11	Yazd/Behabad	<0.02	1.39	0.5	0.27	31.897423	54.356856
		–	1.39	–	–	31.871595	56.019424
12	Hamedan	0.06	1.23	0.472	0.26	34.798857	48.515022
13	Kerman/kuhbanan	0.02	1.74	0.471	0.25	30.283938	57.083363
		–	1.74	–	–	31.412630	56.280060
14	Ilam	0.16	1.18	0.46	0.23	33.634974	46.415281
15	Lorestan	<0.02	1.2	0.446	0.27	33.581839	48.398819
16	Sistan Baluchestan	<0.02	1.15	0.439	0.25	27.529991	60.582068
17	Zanjan	0.14	1.56	0.42	0.19	36.683005	48.508721
18	Khorasan -south	0.1	1.1	0.419	0.21	32.517564	59.104176
19	Tehran	0.02	1.58	0.399	0.2	35.689197	51.388974
20	Alborz	0.029	1.548	0.352	0.23	35.996047	50.928925
21	East Azerbaijan	0.19	0.847	0.343	0.12	37.903573	46.268211
22	Mazandaran	<0.02	1.16	0.335	0.21	36.226239	52.531860
23	Ardebil	0.12	0.58	0.328	0.11	38.253736	48.299990
24	Markazi	0.01	1.52	0.31	0.4	34.612305	49.854727
25	Isfahan	<0.02	1.5	0.292	0.23	32.654627	51.667283
26	Kurdistan	<0.02	0.8	0.282	0.16	35.955358	47.136213
27	West Azerbaijan/Maku	<0.02	2.2	0.281	0.29	37.455006	45.000000
						39.295621	44.514185
28	Kohgiluyeh and Boyer-Ahmad	0.01	0.81	0.264	0.17	30.724586	50.845632
29	Golestan	0.09	0.72	0.264	0.11	37.289812	55.137583
30	Gilan	<0.02	0.82	0.219	0.13	37.280946	49.592413
31	Kermanshah	0.01	0.86	0.193	0.11	34.327692	47.077769

Water and Wastewater Engineering Company in cooperation with 41 regional water and wastewater companies located in 31 provinces, all across the country. Because this study was done extensively in all 31 provinces of Iran, we should use the standard method for measuring drinking water fluoride content that was present in all 31 provinces; therefore, SPADNS method was used for fluoride concentration examination according to the instructions of standard methods (Lenore et al. 2005). The SPADNS colorimetric method is based on the reaction between

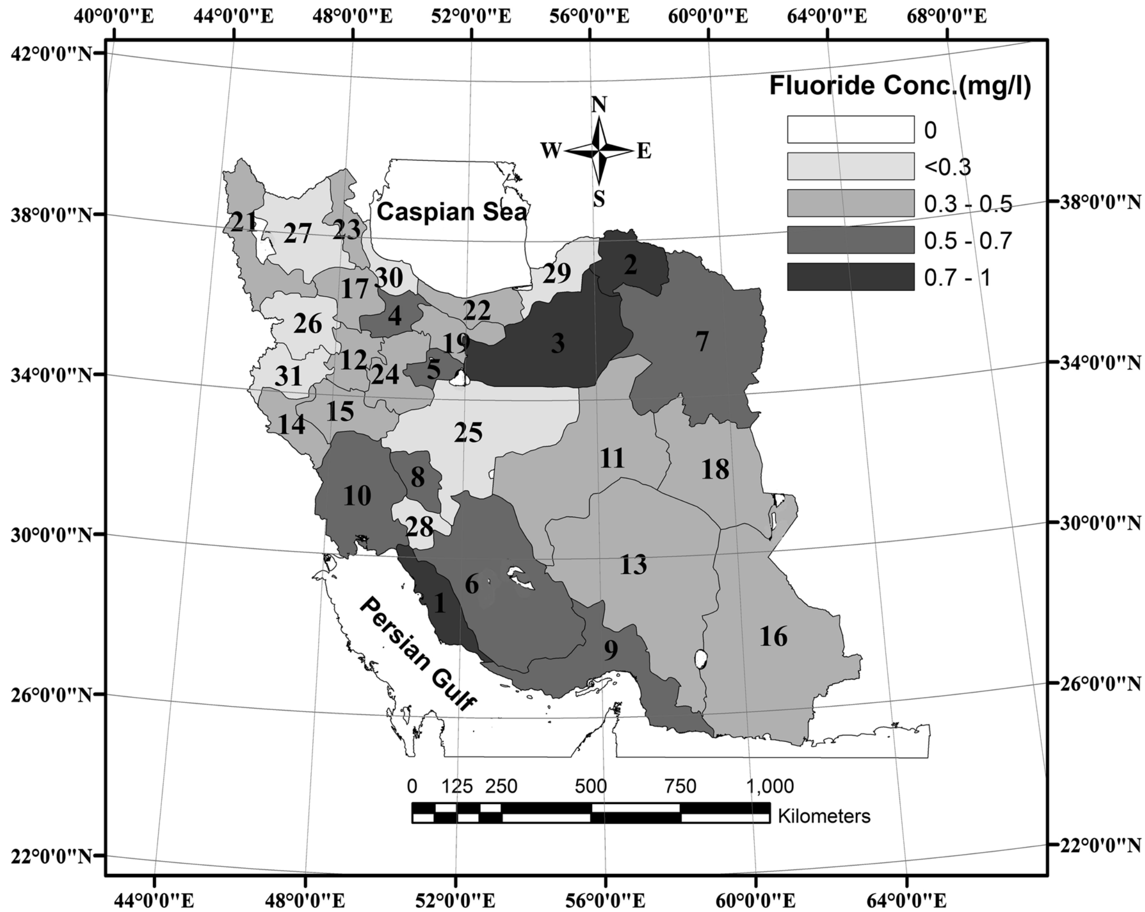

Fig. 1 Provincial mean of fluoride content in the drinking water of Iran

fluoride and a zirconium-dye lake (Merck, Germany). Fluoride reacts with the dye lake, dissociating a portion of it into a colorless complex anion (ZrF_6^{2-}). As the amount of fluoride increases, the color produced becomes progressively lighter (Lenore et al. 2005). Finally, the resulting solution color is measured in a spectrophotometer (DR 2000 Spectrophotometer, HACH Company, USA) at 570 nm. A calibration curve was prepared using concentrations ranging from 0 to 0.4 mg F^-/L (Battaleb-Looie et al. 2013; Lenore et al. 2005). All reagents were purchased from Merck. The minimum detectable level of the SPADNS method is 0.02 mg/L, as reviewed, analyzed, and compared by the World Health Organization and Iran national standards. The data obtained were evaluated using SPSS19, GIS 2010, and EXCEL 2007, and the resulted graphs and tables were extracted.

Results

The data for mean, minimum, and maximum concentrations of fluoride in drinking waters for each province across the country in 2014 were measured in milligrams per liter as shown in Table 2. As shown in Table 2, the minimum concentration of fluoride in provinces, such as Fars, Kermanshah, Kohgiluyeh and Boyer-Ahmad, Markazi, and Hormozgan, was observed to be 0.01 mg/L.

However, the maximum concentrations of fluoride were observed as 3.72 and 3.52 mg/L for Bushehr and Fars, respectively, while the minimum and maximum average mean concentrations were 0.193(SD = 0.11) and 0.889 (SD = 0.31) standard deviation for Kermanshah and Bushehr, respectively.

Discussion

In this study, the fluoride concentrations in drinking water of Iran's provinces were studied. As shown in Table 2, Figs. 1 and 2, Bushehr, north of khorasan and Semnan, had a higher mean concentration of fluoride than other provinces, but all provinces had an average concentration of fluoride lower than the WHO guideline value of 1.5 mg/L. The high-fluoride concentration of drinking water in some districts of Bushehr province was higher than the WHO guideline value, which was also reported by Mesdaghinia

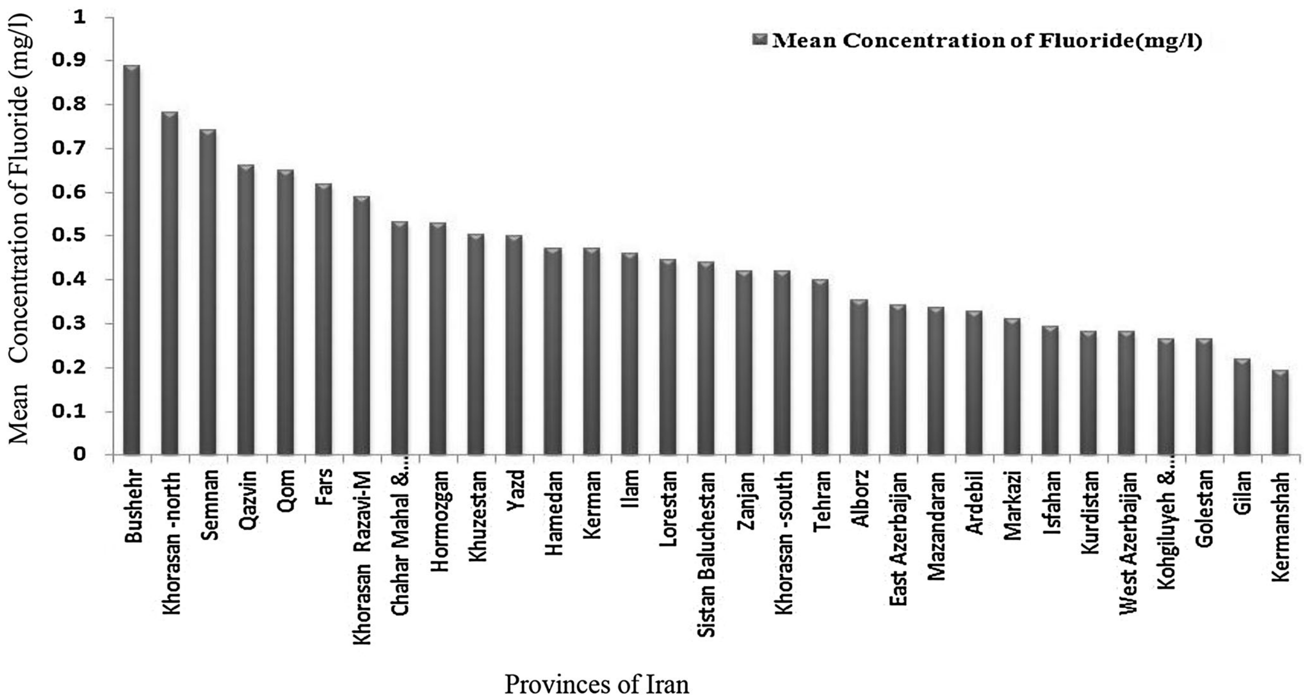

Fig. 2 Mean concentration of fluoride in drinking water in Iran

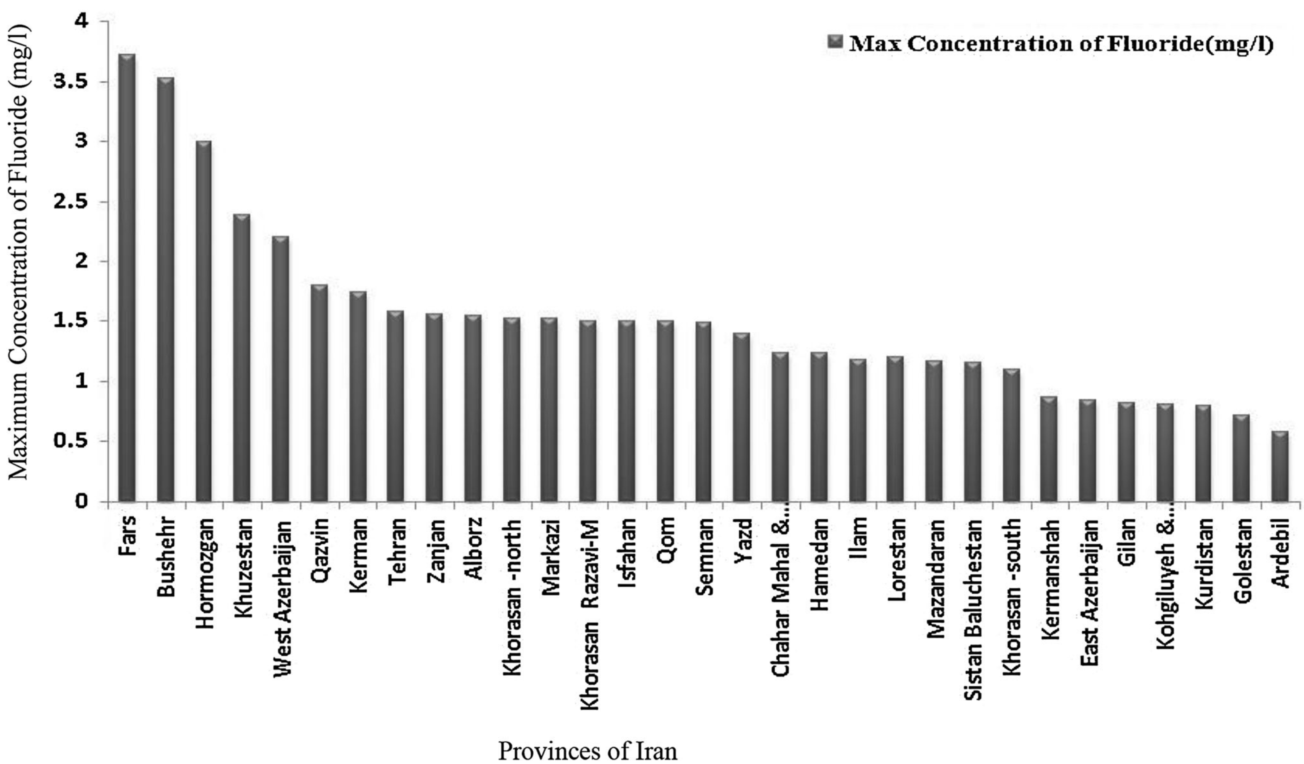

Fig. 3 Maximum concentration of fluoride in drinking water in Iran

et al. (2010). Some districts of Fars also had higher fluoride concentration in drinking water than the WHO guideline value, but was not reported in the study of Mesdaghinia et al. (2010).

According to Figs. 3 and 4, the sensitive regions in which the fluoride concentration in drinking water was higher than the WHO guideline value are located in Fars > Bushehr > Hormozgan > Khuzestan > East Azer-

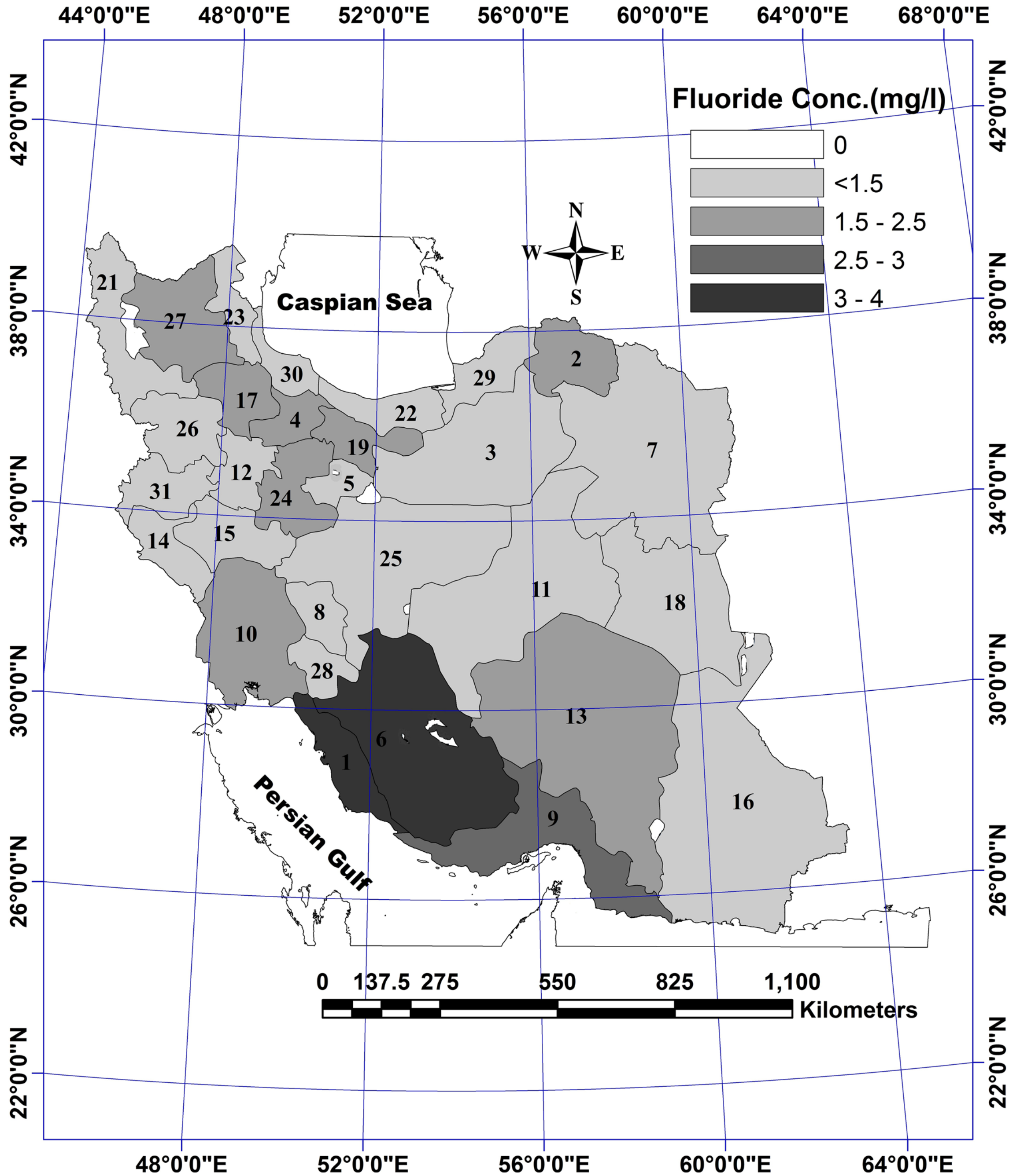

Fig. 4 Provincial maximum fluoride content in drinking water of Iran

baijan > Qazvin > Kerman > Tehran > Zanjan > Alborz > Khorasan -north > Markazi, in the order of the highest to lowest fluoride concentration. In these provinces, the maximum values of fluoride were 3.72, 3.52, 3, 2.38, 2.2, 1.8, 1.74, 1.58, 1.56, 1.55, 1.52, and 1.52 mg/L, respectively. Therefore, further studies could be conducted in areas associated with the prevalence of common diseases and more attention is needed in the case of treatment of drinking water. In this study, fluoride concentration was observed to be in the range of 0.05–3.52 with a mean of 0.889 mg/L in Bushehr Province, which was higher than that reported in the study of Dobaradaran et al. (2008a, b) in which fluoride concentration in the range of 0.99–2.5 was obtained with a mean of 0.270 mg/L (Dobaradaran et al. 2008b). The aforementioned results were lower than that reported by Mesdaghinia et al. (2010) which investigated the fluoride concentration in groundwater resources, and a concentration in the range of 1.11–4.06 was obtained

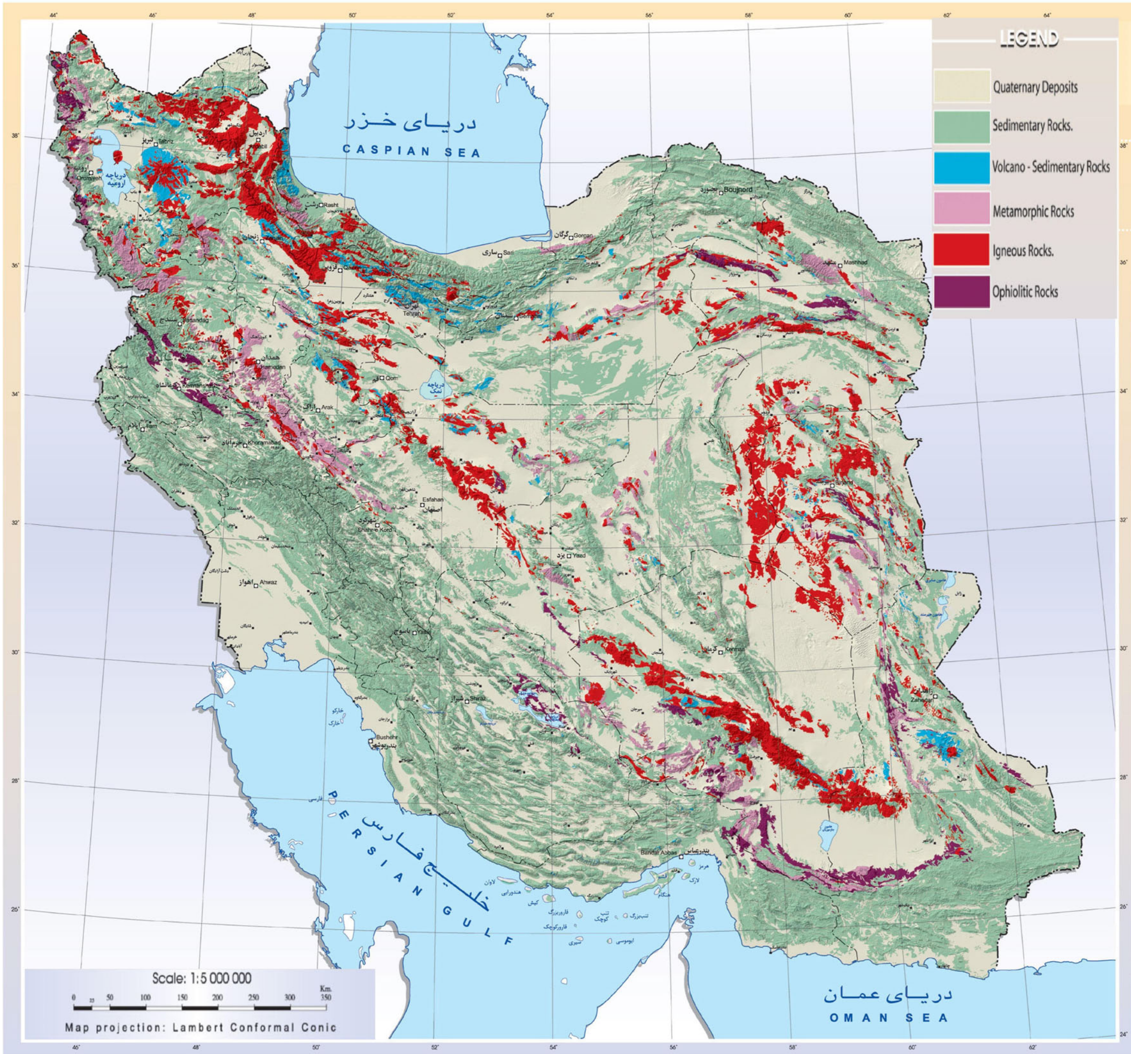

Fig. 5 Simplified Geological Map of Iran Based on Rock type (http://www.gsi.ir/) (Geological Survey of Iran)

with a mean value of 1.86 mg/L. Thus, this could be attributed to the portion of groundwater in water supply (Mesdaghinia et al. 2010). The range of F concentration in Fars Province was (0.01–3.72) with a mean value of 0.617 mg/L and this could be attributed to its ecological conditions which are more than that reported in the study of Mesdaghinia et al. (2010).

The high concentration of fluoride in Fars Province shows that the use of underground water resources is on the increase. Recently, sinkhole has been created with a depth of 100 m in Estahban county of Fars Province. Figure 5 represents the distribution map of three major groups of rocks such as sedimentary, igneous, and metamorphic rocks that constituent the continental crust. In addition to these three major groups of lithologies, rocks comprised sedimentary and volcanic units and quaternary unconsolidated deposits. It is considered that the sedimentary rocks have a wider distribution relative to other groups. Because water resources for drinking water in rural areas of Maku such as Takhteh Duz, Kharmanyeri, Rend, and Ali Qandu are from basaltic aquifers, which are the main source of fluoride, it increases fluoride content in ground water in these regions. Last Ararat volcano flows just to Takhteh Duz and Danalu village (North Maku) in this place, then continues along the river until coverage with sedimentary rocks. Izadkhvast is located in Zarrin dash County of Fars Province, because of gypsum and salt tissue of their soils and correlation between fluoride and calcium, sodium, sulfate ions. It seems that weathering and dissolution of sulfate and evaporated minerals are the reason for increasing fluoride in ground water in these regions. Bushkan is a village in Dashtestan County, Bushehr Province, Iran. Bandar Lengeh is a harbor city in, and capital of Bandar Lengeh County, in Hormozgan Province of Iran on the coast of the Persian Gulf. Their rocks composes of sedimentary and quaternary unconsolidated deposits, and as mentioned, it can be the cause high-fluoride content of drinking water in these areas (Derakhshani et al. 2014; Keshavarzi et al. 2010; Poureslami et al. 2011; Ejlali et al. 2015; Momenifar and moosavinasab 2013).

Conclusion

The results of this research showed that although the average fluoride concentration in drinking waters of Iran's provinces is less than the WHO guideline value, the fluoride concentration in some other regions is still higher than the WHO guideline value. The relationship between fluoride and human health was first discovered in the late nineteenth century, when several chemists recognized the contents of fluoride in bones and teeth of humans (David and Ozsvath 2009). Despite some of the benefits of fluoride in the body, the effects of acute fluoride toxicity have been well documented in several literatures. Some researchers, such as Anna Augustsson from Sweden, have studied the risk assessment of fluoride intake from various sources, including food and beverage (tea, water, and other drinks), toothpaste, soil particles, and certain medications in 2014 and found that fluoride intake through drinking water is 77 % in comparison with other factors (Augustsson and Berger 2014). The minimum risk level of 0.05 mg/kg/d calculated by Agency for Toxic Substances and Disease Registry, and Battaleb-Looie et al. (2013) estimated the maximum fluoride intakes (from dates and drinking water) for children and adults were 3.4 and 1.6 times higher than the minimum risk level, respectively (Battaleb-Looie et al. 2013). Due to the disadvantages of fluoride and as a result of the existence of different ecological conditions in Iran, there are different concentrations of fluoride in drinking water in this country. Therefore, proper policies should be made for water treatment plants based on regional conditions, in order to achieve the desirable fluoride concentration standard. Fluoride standards in drinking water should be based on human health concerns, socio-economic conditions, culture, and environment of that region. As a result, further studies should be carried out in Iran to assess the prevalence of some diseases in areas with fluoride concentrations higher than the standard. There are many methods to remove extra fluoride from drinking water that have been reported by researchers. These include application of home-based water purifier on fluoride concentration of drinking water by Jaafari-Ashkavandi and Kheirmand (2013) which gained the removal efficiency of 85.6 % (Jaafari-Ashkavandi and Kheirmand 2013). To reduce the amount of fluoride to acceptable drinking water standard, Rahmani Boldaji et al. (2009) evaluated the effectiveness of a hybrid sorbent resin. They found that adsorbent with 61 % efficiency is suitable for the regions where F concentration is less than 4 mg/L (Boldaji et al. 2009).

Fresh and modified manganese oxide bone char can be useful for the removal of fluoride from water (Yazdanbakhsh et al. 2015). Other study for remove extra fluoride from drinking water are such as: Absorption in the bauxite containing Titanium (Das et al. 2005), reverse osmosis (Gopal et al. 2004), bone absorption, coagulation with alum, absorbed in the activated Alumina (Kagne et al. 2008; Srimurali et al. 1999; Tripathy and Raichur 2008), absorbed in granular ferric iron (Kumar et al. 2009), activated carbon absorption in conventional and modified (Daifullah et al. 2007) and absorbed in Kaolinite (Meenakshi et al. 2008), soften with lime in the presence of high levels of magnesium, by the use of Tricalcium phosphate granules (Maliyekkal et al. 2006; Sarkar et al. 2006). These researches show that most of these methods cannot be used in cross-country condition and faced with limitations of technical and economical conditions (Ghanizadedh 2002). Due to the most of places with high concentrations of fluoride in drinking water in Iran are in areas with low population like Behabad in Yazd Province, Kuhbanan in Kerman Province, Bandar Lengeh in Hormozgan Province, Maku in West Azerbaijan province, Zarrin Dasht in Fars Province, Shush in Khuzestan, Khvaf in Razavi Khorasan, and most of them use supply wells as drinking water, it is better to apply home-based water purifier or reverse osmosis in these areas. The government should provide the cost of buying those devices for the residents of these areas by bank loans.

Acknowledgments The authors are grateful to the Iranian Wastewater Engineering Company for their cooperation.

References

Aghaei M, Derakhshani R, Raoof M, Dehghani M, Mahvi AH (2015) Effect of fluoride in drinking water on birth height and weight: an ecological study in Kerman Province, Zarand County, Iran, research report. Fluoride 48(2):160–168

Amini H, Taghavi Shahri SM, Amini M, Ramezani Mehrian M, Mokhayeri Y, Yunesian M (2011) Drinking water fluoride and blood pressure? An environmental study. Bio Trace Elem Res 144:157–163. doi:10.1007/s12011-011-9054-5

Anna L, Guifan S (2012) Developmental fluoride neurotoxicity: a systematic review and meta-analysis. Environ Health Perspect 120(10):1362–1368

Ashley JM, Till CH (2015) Exposure to fluoridated water and attention deficit hyperactivity disorder prevalence among children and adolescents in the United States: an ecological association. Malin Till Environ Health 14:17. doi:10.1186/s12940-015-0003-1

Augustsson A, Berger T (2014) Assessing the risk of an excess fluoride intake among Swedish children in households with private wells—expanding static single-source methods to a

probabilistic multi-exposure-pathway approach. Environ Int 68:192–199
Azami-Aghdash S, Ghojazade M, Jamali Z (2013) Fluoride concentration of drinking waters and prevalence of fluorosis in Iran: a systematic review. J Dent Res Dent Clin Dent Prospect 7(1):1–7. doi:10.5681/joddd.2013.001
Battaleb-Looie S, Moore F, Malde MK, Jacks G (2013) Fluoride in groundwater, dates and wheat: estimated exposure dose in the population of Bushehr, Iran. J Food Compos Anal 29:94–99
Boldaji MR, Mahvi AH, Dobaradaran S, Hosseini SS (2009) Evaluating the effectiveness of a hybrid sorbent resin in removing fluoride from water. Int J Environ Sci Technol 6(4): 629–632
Coperchini F, Pignatti P (2015) Exposure to per fluorinated compounds: in vitro study on thyroid cells. Environ Sci Pollute Res 22:2287–2294. doi:10.1007/s11356-014-3480-9
Daifullah AA, Yakout SM, Elreefy SA (2007) Adsorption of fluoride in aqueous solutions using KMnO4-modified activated carbon derived from steam pyrolysis of rice straw. J Hazard Mater 147(1–2):633–643
Das N, Pattanaik P, Das R (2005) Defluoridation of drinking water using activated titanium rich bauxite. J Colloid Interface Sci 292(1):1–10
Derakhshani R, Tavallaie M, Raoof M, Mohammadi TM, Abbasnejad A, Haghdoostf AA (2014) Occurrence of fluoride in groundwater of Zarand region, Kerman province, Iran. Fluoride 47(2):133–138
Dobaradaran S, Mahvi AH, Dehdashti S, Abadi DRV (2008a) Drinking water fluoride and child dental caries in Dashtestan, Iran. Fluoride 41(3):220–226
Dobaradaran S, Mahvi AH, Dehdashti S (2008b) Fluoride content of bottled drinking water available in Iran. Fluoride 41(1):93–94
Dobaradaran S, Fazelinia F, Mahvi AH, Hosseini SS (2009a) Particulate airborne fluoride from an aluminium production plant in Arak, Iran. Fluoride 42(3):228–232
Dobaradaran S, Mahvi AH, Dehdashti S, Dobaradaran S, Shoara R (2009b) Correlation of fluoride with some inorganic constituents in groundwater of Dashtestan, Iran. Fluoride 42(1):50–53
Ebrahimi D (2015) Assessment of fluoride in drinking waters in the city of Poldasht. Intl Res J Appl Basic Sci 9(8):1235–1238
Ejlali A, Taghipour H, Khashabi E (2015) The study of fluoride level in drinking water in villages of MAKOO. J Urmia Univ Med Sci 26(9):754–763 (Persian)
Geological Survey of IRAN. http://www.gsi.ir/General/Simlified.Geological.MapofIran.Based.on.rock.type.html
Ghanizadedh GH (2002) Fluoride, risks and removal methods. In: First conference on health and military. Tehran (Persian)
Gopal K, Srivastava SB, Shukla S, Bersillon JL (2004) Contaminants in drinking water and its mitigation using suitable adsorbents: an overview. J Environ Biol 25(4):469–475
Jaafari-Ashkavandi Z, Kheirmand M (2013) Effect of home-used water purifier on fluoride concentration of drinking water in southern Iran. Dental Res J 10(4):489–492
Kagne S, Jagtap S, Dhawade P, Kamble SP, Devotta S, Rayalu SS (2008) Hydrated cement: a promising adsorbent for the removal of fluoride from aqueous solution. J Hazard Mater 154(1–3): 88–95
Karimzade S, Aghaei M, Mahvi AH (2014) Investigation of intelligence quotient in 9–12-year-old children exposed to high- and low-drinking water fluoride in west Azerbaijan province, IRAN. Res Rep Fluoride 47(1):9–14
Keshavarzi B, Moore F, Esmaeili A, Rastmanesh F (2010) The source of fluoride toxicity in Muteh area, Isfahan, Iran. Environ Earth Sci 61(4):777–786
Kumar E, Bhatnagar A, Ji M, Jung W, Lee SH, Kim SJ (2009) Defluoridation from aqueous solutions by granular ferric hydroxide (GFH). Water Res 43(2):490–498
Lenore S, Arnold E, Andrew D (2005) Standard methods for the examination of water and wastewater, American Public Health Association, American Water Works Association, Water Environment Federation, the twentieth edition, 4500-F-B. METHOD, 4500-F-C. Ion-selective electrode method, 4500-F-D. SPADNS method for FLUORIDE
Liu H, Gaoa Y, Sun L (2014) Assessment of relationship on excess fluoride intake from drinking water and carotid atherosclerosis development in adults in fluoride endemic areas, China. Int J Hyg Environ Health 217:413–420
Mahvi AH, Zazoli MA, Younecian M, Esfandiari Y (2006) Fluoride content of Iranian black tea and tea liquor. Fluoride 39(4): 266–268
Maliyekkal SM, Sharma AK, Philip L (2006) Manga-nese-oxide-coated alumina: a promising sorbent for defluoridation of water. Water Res 40(19):3497–3506
Mannina M, Morgan N, Murphy B (2013) Effects of water fluoridation in the United States positive and negative impact of water fluoridation policy
Meenakshi S, Sundaram CS, Sukumar R (2008) Enhanced fluoride sorption by mechanochemically activated kaolinites. J Hazard Mater 153(1–2):164–172
Mesdaghinia A, Azam Vaghefi K, Montazeri A, Mohebbi MR (2010) Monitoring of fluoride in groundwater resources of Iran. Bull Environ Contam Toxicol 84:432–437. doi:10.1007/s00128-010-9950
Momeni VR, Dehghani M (2011) Thyroid function tests in aluminum pot room workers exposed to fluoride emissions. Res Note Fluoride 44(3):173–174
Momenifar F, Moosavinasab Z (2013) the amount of fluoride in drinking water Izad Khast, Zarrin Dasht county, Fars province. Seventeenth conference of the geological society of Iran (Persian)
Nagarajappa R, Pujara P (2013) Comparative assessment of intelligence quotient among children living in high and low fluoride areas of Kutch, India- a pilot study. Iranian J Pub Health 42(8):813–818
Nouri J, Mahvi AH, Babaei A, Ahmadpour E (2006) Regional pattern distribution of groundwater fluoride in the Shush aquifer of Khuzestan county, Iran. Fluoride 39(4):321–325
Ozsvath DL (2009) Fluoride and environmental health: a review. Rev Environ Sci Biotechnol. doi:10.1007/s11157-008-9136-9
Patil VV, Varsha T (2015) Exposure to sodium fluoride affects thyroid follicular cells in albino rats. Int J Plant Animal Environ Sci 5(1):25. www.ijpaes.com
Poureslami HR, Horri A, Garrusib Koohbanan B (2011) A comparative study of the IQ of children age 7–9 in a high and a low fluoride water city in Iran. Res Rep Fluoride 44(3):163–167
Sachdeva S, Ahmed J, Singh B (2015) Thyroid dysfunction associated with excess fluoride intakes: scope for primary prevention. Departments of Community Medicine, and General Medicine. Thyroid Res Practice 12(2). http://www.thetrp.net on Sunday, May 24, 2015, IP: 85.185.157.2
Sarkar M, Banerjee A, Pramanick PP, Sarkar AR (2006) Use of laterite for the removal of fluoride from contaminated drinking water. J Colloid Interface Sci 302(2):432–441
Seraj B, Shahrabi M, Shadfar M, Ahmadi R (2012) Effect of high water fluoride concentration on the intellectual development of children in Makoo/Iran. J Dent Tehran Univ Med Sci 9(3):221–229
Srimurali M, Pragathi A, Karthikeyan J (1999) A study on removal of fluorides from drinking water by adsorption onto low-cost materials. Environ Pollut 99(2):285–289
Susheela AK, Bhatnagar M (2005) Excess fluoride ingestion and thyroid hormone derangements in living in dehli, INDIA. 98. Fluoride 38(2):98–108

Swati S, Shashi A (2013) Thyroid peroxidase activity as toxicity target for fluoride in patients with thyroid dysfunction. Curr Res Microbiol Biotechnol 1(2):53–57

Tripathy SS, Raichur AM (2008) Abatement of fluoride from water using manganese dioxide-coated activated alumina. J Hazard Mater 153(3):1043–1051

Wolka E, Shiferaw S, Biadgilign S (2014) Epidemiological study of risk factors for goiter among primary schoolchildren in southern Ethiopia. Food Nutr Bull 35(1):20–27

Xiong XZ, Liua JL, Hong Wei (2007) Dose–effect relationship between drinking water fluoride levels and damage to liver and kidney functions in children. Environ Res 103:112–116. doi:10.1016/j.envres.2006.05.008

Yazdanbakhsh AR, Ghanizadeh Gh, Adibzadeh A (2015) Evaluating the efficiency of fresh and modified manganese oxide bone char for the removal of fluoride from water: an Isotherm Study. J Military Med 17(1):9–16 **(Persian)**