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RESEARCH ARTICLE

Fluoride Levels of Drinking Water in Bitlis Province (Turkey) [1]

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Summary

In the present study, fluoride levels of drinking water from the province of Bitlis and its towns (Adilcevaz, Ahlat, Güroymak, Hizan and Tatvan) were investigated. A total of 164 water samples, collected from tanks or tap in autumn (November 2006) and spring (May 2007) were used as material. The fluoride levels were measured by Orion model 720A potentiometer, using an ion-selective electrode. The fluoride values in drinking water samples obtained from tanks and tap were found to be 0.36±0.05 and 0.35±0.03 ppm respectively. These values were the highest in Ahlat (0.75±0.04 ppm), and the lowest in the center of Bitlis (0.01±0.01 ppm). Fluoride levels were determined below 0.50 ppm in the 62% of water samples, and below 1.50 ppm in all water samples. The effect of season on the fluoride levels were found to be statistically insignificant (P>0.05), while the effect of residential areas were significant (P<0.05). As a result, it was demonstrated that the fluoride levels investigated in all water samples were within standard ranges, which poses no risk for fluoride toxication in the province of Bitlis.

Keywords: *Drinking water, Fluoride level, Public health, Bitlis*

Bitlis İli İçme Sularında Florür Düzeyleri

Özet

Bu çalışmada, Bitlis ve ilçeleri (Adilcevaz, Ahlat, Güroymak, Hizan ve Tatvan) içme sularında florür düzeyleri araştırıldı. Çalışma materyalini, sonbahar (Kasım 2006) ve ilkbahar (Mayıs 2007) mevsimlerinde depo ve musluk sularından alınan toplam 164 örnek oluşturdu. Örneklerde florür düzeyi Orion 720A model potansiyometrede flor seçici elektrot ile ölçüldü. İncelenen depo ve musluk suyu örneklerinde florür düzeyleri sırasıyla 0.36±0.05 ve 0.35±0.03 ppm olarak tespit edildi. Bu değerler Ahlat ilçesinde en yüksek (0.75±0.04 ppm), Bitlis merkezde en düşük (0.01±0.01 ppm) seviyede belirlendi. Florür düzeyi örneklerin %62'sinde 0.50 ppm'in, tümünde ise 1.50 ppm'in altında saptandı. Florür düzeyi üzerine mevsimin etkisi önemsiz (P>0.05), yerleşim yerlerinin etkisi ise istatistiksel olarak önemli (P<0.05) bulundu. Sonuç olarak, örneklerde belirlenen florür düzeylerinin standart değerlere uygun bulunması, Bitlis bölgesi içme sularının florür toksikasyonu açısından risk oluşturmadığını gösterdi.

Anahtar sözcükler: *İçme suyu, Florür düzeyi, Halk sağlığı, Bitlis*

INTRODUCTION

Fluoride can be found in small amounts as a compound in all natural waters. Even though it is generally found in higher amounts in underground waters than surface waters, its amount is quite variable [1]. Geographical location, the structure of rocks and the presence of fluoride containing minerals are main factors contributing to this situation. Fluoride levels are quite high in water resources in volcanic and industrial regions. In these regions, the amount of fluoride can rise up to 30-50 mg/L [2,3].

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Drinking water is important fluoride resource for living beings. According to international and national standards the amount of fluoride in drinking water must be between 0.5-1.5 mg/L. When the concentration of fluoride drops to less than 0.5 mg/L, it causes important disorders in teeth and bone metabolism. If it rises up to 2.0 mg/L and more, it causes fluorosis [3-5].

Fluorosis is an important health problem for human and animals. Two forms of fluorosis occur; acute and chronic. In typical chronic fluorosis, loss of appetite, deformation of bones and joints, deformation in long bones, loss of teeth, permanent color changes in teeth (light yellow, green-brown, black dots and horizontal lines) and deformations occur [1,6].

Ruminants such as cattle, sheep, and goat are susceptible to fluorosis. Chronic fluorosis, beside its health risks, is especially important economically due to reduction in meat and milk production [7,8].

In many countries including Turkey, endemic chronic fluorosis cases related to drinking water are seen [9]. Ritle Valley in the Eastern Africa, Sudan, Etyopia, Uganda, Kenya, and Tanzania are the main geographical areas where endemic chronic fluorosis is an important health problem. In Turkey, it is seen frequently in Isparta (Kandak River and surroundings), Ağrı (Doğubeyazıt), Kırşehir (Kaman and Kırkpınar), Nevşehir (Ürgüp, Avanos and Hacıbektaş), Kayseri (İncesu), Eskişehir (Beylikahır), and Uşak (Eşme) regions [3,10].

Daily amount of fluoride required for human varies according to age; typically, it is about 1.5-4.0 mg for adults [11]. This amount is supplied from resources such as food and tooth care products as well as drinking water. For this purpose, while water with low amounts of fluoride is suplemented with fluoride, water with high luoride is distilled by reverse osmosis and ion exchange processes [6].

At present, 0.7-1.0 ppm fluoride is added into drinking waters in many countries. About 50-70% reduction has been reported in tooth decay cases in societies consuming fluorinated water [12]. According to the Centers for Disease Control and Prevention (CDC), about 405 million people in 60 countries and 2/3 of the population in the USA use fluorinated water in order to protect their tooth health [13].

In this study, fluoride levels of drinking water were determined and evaluated in terms of public health in the province of Bitlis, which is located in a volcanic zone.

MATERIAL and METHODS

A total of 164 samples collected from tank and tap waters in and around the province of Bitlis were used as research material. Sample size and sampling strategies were determined according to population distribution and standard methods. Water samples were collected periodically from different locations shown as in *Table 1* during autumn (November 2006) and spring (May 2007). Samples were transferred to the laboratory in polyethylene bottles and kept at 4°C until analysis.

Fluoride levels in the samples were measured with an Orion 720A model potentiometer using a fluoride selective electrode (Orion 96 09 00BN) [14,15]. Standard fluoride solutions of 190 ppm ($1x10^{-2}$ mol/ℓ), 19 ppm ($1x10^{-3}$ mol/ℓ), 1.9 ppm ($1x10^{-4}$ mol/ℓ), 0.19 ppm ($1x10^{-5}$ mol/ℓ) and 0.019 ppm ($1x10^{-6}$ mol/ℓ) were prepared from 0.1 molar sodium fluoride standard stock solution (Orion 940906), and 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1.5, 2.0 and 5.0 ppm standard solutions were prepared by dilution 100 ppm sodium solution was added an equal volume of TISAB II (Total Ionic Strength Adjustment Buffer, Orion 940909) and mixed using a magnetic stirrer. Values in mV were read with an ionometer. These values were used to draw calibration curve. The same procedure was repeated for the water samples with a combined fluoride electrode. Using a Minitab program, the mV values of samples were plotted on the calibration curves of standard solutions out of which fluoride levels (ppm) were calculated with a sensitivity of 0.01 ppm.

The results were evaluated by three way variance analysis. The significance of the difference between means of groups was determined by Duncan test. Statistical analysis was performed using SAS version 6 [16].

Table 1. *Numerical distribution of water samples collected in Bitlis district*
Tablo 1. *Bitlis ili içme sularından alınan örneklerin sayısal dağılımı*

Season	Source	Bitlis	Adilcevaz	Ahlat	Güroymak	Hizan	Tatvan	Total
Spring	Tank	6	3	3	4	3	6	25
	Tap	15	9	8	6	5	14	57
	Total	21	12	11	10	8	20	82
Autumn	Tank	7	4	3	4	3	5	26
	Tap	14	8	8	6	5	15	56
	Total	21	12	11	10	8	20	82
General Total		**42**	**24**	**22**	**20**	**16**	**40**	**164**

RESULTS

Fluoride levels determined in drinking water in the province of Bitlis are given in *Table 2*. Seasonal distribution of fluoride levels is shown in *Table 3* and numerical distribution is given in *Table 4*. *Fig. 1* shows seasonal distribution of mean fluoride levels.

The mean fluoride level in analysed water samples were found to be 0.35±0.03 ppm which was higher in autumn. The highest fluoride level was detected in Ahlat (0.75±0.04 ppm). Fluoride levels were below the limit of measurement in tank waters (autumn) in Hizan.

Table 2. *Fluoride levels in drinking waters in Bitlis district (ppm)*
Tablo 2. *Bitlis ili içme sularında tespit edilen florür düzeyleri (ppm)*

Source		Bitlis	Adilcevaz	Ahlat	Güroymak	Hizan	Tatvan	Total
Tank	X±Sx Min-Max	0.01±0.01 0.00-0.10	0.55±0.01 0.51-0.59	0.71±0.13 0.08-0.87	0.47±0.04 0.36-0.59	0.04±0.03 0.00-0.15	0.58±0.14 0.00-1.16	0.36±0.05 0.00-1.16
Tap	X±Sx Min-Max	0.02±0.01 0.00-0.13	0.50±0.09 0.00-0.65	0.77±0.03 0.49-0.86	0.47±0.03 0.33-0.58	0.01±0.08 0.00-0.08	0.43±0.09 0.00-1.14	0.35±0.03 0.00-1.14
Total	X±Sx Min-Max	0.01±0.01c 0.00-0.13	0.51±0.02b 0.00-0.65	0.75±0.04a 0.08-0.87	0.47±0.02b 0.33-0.59	0.02±0.01c 0.00-0.15	0.47±0.07b 0.00-1.16	0.35±0.03 0.00-1.16

Differences between mean values with different letters are significant (P<0.05)

Table 3. *Seasonal distribution of fluoride levels in drinking waters in Bitlis district (ppm)*
Tablo 3. *Bitlis ili içme sularında tespit edilen florür düzeylerinin mevsimsel dağılımı (ppm)*

Season	Source		Bitlis	Adilcevaz	Ahlat	Güroymak	Hizan	Tatvan	Total
Spring	Tank	X±Sx Min-Max	0.01±0.01 0.00-0.04	0.52±0.01 0.51-0.52	0.57±0.26 0.08-0.87	0.43±0.05 0.36-0.58	0.08±0.05 0.00-0.15	0.46±0.21 0.00-1.16	0.32±0.07 0.00-1.16
	Tap	X±Sx Min-Max	0.02±0.01 0.00-0.13	0.44±0.06 0.00-0.54	0.78±0.03 0.66-0.86	0.43±0.05 0.33-0.58	0.02±0.02 0.00-0.08	0.44±0.13 0.00-1.14	0.34±0.05 0.00-1.14
	Total	X±Sx Min-Max	0.02±0.01 0.00-0.13	0.46±0.04 0.00-0.54	0.72±0.07 0.08-0.87	0.43±0.03 0.33-0.58	0.04±0.02 0.00-0.15	0.46±0.11 0.00-1.16	0.33±0.04 0.00-1.16
Autumn	Tank	X±Sx Min-Max	0.02±0.01 0.00-0.10	0.58±0.01 0.57-0.59	0.85±0.01 0.83-0.86	0.51±0.05 0.36-0.59	ND	0.71±0.17 0.17-1.15	0.41±0.01 0.00-1.15
	Tap	X±Sx Min-Max	0.01±0.01 0.00-0.09	0.56±0.02 0.46-0.65	0.76±0.05 0.05-0.85	0.52±0.03 0.42-0.57	0.01±0.01 0.00-0.03	0.43±0.12 0.00-1.14	0.36±0.05 0.00-1.14
	Total	X±Sx Min-Max	0.01±0.01 0.00-0.10	0.57±0.01 0.46-0.65	0.78±0.04 0.49-0.86	0.52±0.02 0.36-0.59	0.01±0.01 0.00-0.30	0.50±0.10 0.00-1.15	0.38±0.04 0.00-1.15

Differences between seasons are insignificant (P>0.05), ND: Not detected (below the level of measurement)

Table 4. *Numerical distribution of fluoride levels in drinking waters in Bitlis district (%)*
Tablo 4. *Bitlis ili içme sularında tespit edilen florür düzeylerinin sayısal dağılımı (%)*

Source	0.000-0.499 ppm		0.500-1.000 ppm		1.100-<1.500 ppm	
	Tank	Tap	Tank	Tap	Tank	Tap
	%(n_1/n)	%(n_1/n)	%(n_1/n)	%(n_1/n)	%(n_1/n)	%(n_1/n)
Bitlis	100(13/13)	100(29/29)				
Adilcevaz		41(7/17)	100(7/7)	59(10/17)		
Ahlat	17(1/6)	6(1/16)	83(5/6)	94(15/16)		
Güroymak	50(4/8)	50(6/12)	50(4/8)	50(6/12)		
Hizan	100(6/6)	100(10/10)				
Tatvan	56(6/11)	65(19/29)	18(2/11)	14(4/29)	27(3/11)	21(6/29)
TOTAL	62%(102/164)		32%(53/164)		6% (9/164)	

n: *number of samples,* ***n_1:*** *positive sample numbers among 'n'*

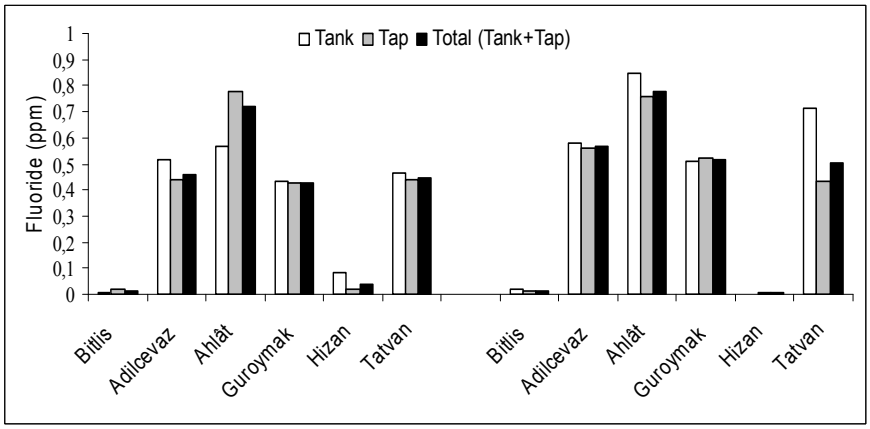

Fig 1. Seasonal distribution of fluoride levels in drinking waters in Bitlis district (ppm) (Left: Spring, Right: Autumn)

Şekil 1. Bitlis ili içme sularında tespit edilen florür düzeylerinin mevsimsel dağılımı (Sol: İlkbahar, Sağ: Sonbahar)

DISCUSSION

Drinking water is the most important source of fluoride which is an important biological element. Determining the levels of fluoride in drinking water is useful in terms of public health [17-19]. In the former studies performed in Turkey, fluoride levels in drinking waters were reported as 0.02-3.9 ppm [20], 0.64-0.95 ppm [19], 0.254 ppm [21] and 0.174 ppm [22].

Ağaoğlu et al.[23], reported 0.387 and 0.457 ppm fluoride in the tap water in the city centre and surroundings of the province Van, 0.125 and 0.606 ppm in tank waters, respectively. Şener et al.[24], determined between 0.006-0.146 ppm fluoride in three spring water samples in Konya. Furthermore, in bottled waters fluoride levels reported to be lower than optimal values [25,26].

In Turkey, natural fluorosis reported regions are either volcanic areas or locations close to fluoride reservoirs. In the studies performed in these regions, the effects of natural fluorosis on animals and public health have been shown [27-29]. Soil composition, volcanic structures, phosphate stones, fluoride reservoirs, fertilizers containing phosphate in agriculture, insecticides used in veterinary field, antihelmintic tablets containing fluoride, aluminium, glass, iron-steel, brick and concrete factories are the risk factors causing fluorosis in environment [1,28,30-32]. In the studies done in the areas close to fluoride reservoirs, average fluoride levels were reported to be 4.80 ppm [28], 1.50-2.38 ppm [33], and 0.11-0.23 ppm [34].

In this study, fluoride levels were measured as 0.35±0.03 ppm in all analysed samples (n=164). In tank (n=51) and tap (n=115) water, fluoride levels were determined as 0.36±0.05 and 0.35±0.03 ppm, respectively *(Table 2)*. Considering seasonal variations, fluoride levels were 0.33±0.04 ppm in spring and 0.38±0.04 ppm in autumn *(Table 3)*. The effect of seasons was insignificant (P>0.05) while the effect of locations was found statistically significant (P<0.05). The highest fluoride level was detected in Ahlat and the lowest level in Bitlis *(Table 2)*.

The results obtained in this study are higher compared to some other studies [21,22] and lower than some others [19,20]. Our results were also partially similar to those reported by Ağaoğlu et al.[23]. The difference between the results could be due to seasons, chemical structure of soil, rainfall and interlaboratory differences in method for analysis.

According to Turkish Standards Institute [4] and The Ministry of Health [5], the recommended fluoride level is 1.5 ppm in drinking water. World Health Organization (WHO) suggests 0.50-1.50 ppm fluoride in drinking water in terms of public health concerns [3]. Environmental Protection Agency (EPA) stated maximum 4 mg/L fluoride in drinking waters [6]. In this study, fluoride levels were less than 0.50 ppm in 62% of samples *(Table 4)*.

A fluoride level between 0.8-1.2 ppm in drinking water has protective effect against tooth decay. 0.50-0.75 mg/kg fluoride per day has been indicated for children in terms of tooth health. Taking fluoride more than this amount (1 mg/kg/day) poses a risk of fluorosis [1,12]. Protective effect of fluoride is achieved by continuous consumption of this element. Water containing fluoride between 0.7-1.0 ppm are defined as 'optimal fluoride water' and it is stated that in case of consuming water containing fluoride lower than this amount requires fluoride supplementation [11,35]. For this purpose, sodium fluoride (NaF) tablets, fluoride containing tooth pastes and jells as well as fluoride addition into water are suggested [12,13].

In conclusion, the fluoride levels determined in analysed water samples were in the range of normal standards indicating that drinking water in the province of Bitlis does not pose a risk in terms of fluoride toxicosis. However, since it is a volcanic area, possibility of contamination should be taken into account and regular controls should be done in terms of public health.

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