International Journal of the Physical Sciences Vol. 6(22), pp. 5128-5132, 2 October, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.582
ISSN 1992-1950 ©2011 Academic Journals

Full Length Research Paper

Determination of total dissolved solid (TDS), nitrate and fluoride in 24 brands of Iranian bottled waters

M. B. Miranzadeh*, M. Hassanzadeh and S. Dehqan

Department of Environmental Health engineering, Faculty of Health, Kashan University of Medical Sciences, Kashan, Iran.

Accepted 9 August, 2011

Concentration of total dissolved solid (TDS), nitrate and fluoride in 24 different brands of Iranian bottled water were studied. A total of 78 bottle water was analyzed for TDS, NO_3^- and F^- according to standard methods. Also, results were compared to Iranian, World Health Organization (WHO) and Environmental Protection Agency (EPA) drinking water standards. The mean concentrations of F^- in all examined water samples were lower than acceptable ranges. In three brands the concentrations of nitrate were higher than Iranian legislations (NO_3^- ≥45 mg/l as NO_3^-). In addition, the mean concentration of TDS in 9 brands were higher than 500 mg/l (Iranian legislations) and in all brands were within the appropriate WHO guidelines values.

Key words: Bottled waters, total dissolved solid, nitrate, fluoride, Iran, drinking water.

INTRODUCTION

According to the Food and Drug Administration (FAD), bottled water can be defined as water that is intended for human consumption and is sealed in bottles or other containers with no added ingredients except that it may contain safe and suitable anti-microbiological agents (Misuned, 1999; Soupioni et al., 2006; Semerjian, 2010). Population growth coupled with rapid urbanization, changing lifestyles, and economic development has led to increasing pressure on water resources. Over 1 billion people not access to safe drinking water and an estimated 80% of child deaths are caused by consumption of contaminated drinking water (Cidu et al., 2011). Because of the lack and potential contamination of tap water and the taste of chemical components such as chloride in tap water, most people tend to consume safer source of drinking water, especially in developing countries. Bottled water is one of the kind of water which its consumption rate have increased steadily during the last 3 decades (Pip, 2000; Babaji et al., 2004; Fiket et al., 2007; Guler, 2007; Karamanis et al., 2007; Khodadadi et al., 2007; Baba et al., 2008; Guler et al., 2009; Qaderpouri et al., 2009; Ikem, 2010; Oyedeji et al., 2010; Semerjian, 2010; Cidu et al., 2011). Because it is available, natural, pure, has relative suitable price, better taste and devoid of chloride and other chemical components, it is mostly consume when traveling and at home. Also, consumers believe that natural water with mineral have beneficial medicinal and therapeutic effects and factories of bottled water had successful and efficiently promoted the use of clean, pure and ideal water production for infants and elderly people and propagate consumption, it has a higher social status from tap water (Babaji et al., 2004; Liu et al., 2004; Fiket et al., 2007; Khodadadi et al., 2007; Naddeo et al., 2008; Qaderpouri et al., 2009; Samadi et al., 2009; Amanlou et al., 2010; Ikem, 2010; Oyedeji et al., 2010; Semerjian, 2010). Bottled water is also utilized in emergency situation caused by natural disasters such as drought, earthquake, flood and hurricane or man-made disasters such as terrorism and war which can severely damage public water supplies for extended periods of time (Guler,

*Corresponding author. E-mail: miranmn@yahoo.com. Tel: 00989131612852.

Abbreviations: EPA, Environmental Protection Agency; **WHO,** World Health Organization; **PET,** polyethylene terphethalate; **TDS,** total dissolved solid; **RO,** reverse osmosis; **FAD,** Food and Drug Administration; **IBWA,** International Bottled Water Association.

2007; Guler et al., 2009; Samadi et al., 2009). The popularity of bottled water can be gauged by the number of brands produced worldwide over five thousands (Samadi et al., 2009; Semerjian, 2010). Worldwide bottled water consumption surged to 189 billion liters in 2007 from 98 billion liters in 1999 (Ikem, 2010; Semerjian, 2010). Bottled water is not necessarily safer than tap water. Literature reveals that the levels of some water constituents in bottled waters are in violation of action levels for various parameters, especially for some toxic natural radio elements and trace metals (Karamanis et al., 2007). Over the years, concerns have been raised about the quality of bottled water marketed worldwide (Semerjian, 2010). There are more than 100 registered manufacturers which provide and pack drinking water in bottles in Iran. The consumption of bottled water has increased particularly in urban population and among travelers in Iran during the recent years (Ghaderpoori et al., 2009). It is well known that much of bottled drinking water passes through treatment processes such as filtration, deionization, reverse osmosis, and ozonation to ensure its quality (Liu et al., 2004; Khodadadi et al., 2007). The main source of bottled water sold in Iran is from protected springs, drilled wells tapping an aquifer, urban water, rivers, lakes, dams, distribution network water and water with added mineral components (Misuned, 1999; Ghaderpoori et al., 2009; Samadi et al., 2009; Ikem, 2010). Also, illegal activities such as bottling tap water with no added health benefits by manufacturers are also sold as mineral water (Ikem, 2010; Semerjian, 2010). Container genus of bottled water is very important and should be controlled (Khodadadi et al., 2007). These bottles are made of polyethylene terphethalate (PET) in Iran (Amanlou et al., 2010). Leaching of volatile and semi-volatile organic compounds from packaging materials into the water has been shown to increase with lengths of storage time, temperature and exposure to sunlight (Pip, 2000).

Fluor is the lightest member of the group of halogen elements and come naturally into water by dissolving minerals that contain fluor such as fluorite, the most common fluor mineral, apatite, and cryolite. Transport and form of fluorides in water depends on environment pH value, water hardness and the presence of other ions (Rejkovic et al., 2007). The intake of excess fluoride can cause fluorosis which affects the teeth and bones. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to severe skeletal problems. Low levels of fluoride intake can help to prevent dental problems. Fluoride has also been used to treat osteoporosis (Babaji et al., 2004; Tokalioglu et al., 2004; Ghaderpoori et al., 2009; Amanlou et al., 2010). Fluoride ion in traces in drinking water helps in growth and development of healthy, resistant teeth and bones (Rejkovic et al., 2007). Optimum concentration of fluoride depends on climate conditions and water consumption. Most of the bottled water do not have enough amount of fluoride that is required for oral health (Ghaderpoori et al., 2009; Amanlou et al., 2010). It is very characteristic that fluoride prevents tooth decay at about 1 mg/l but causes mottled teeth and bone damage at around 5 mg/l when it is present in water (Tokalioglu et al., 2004). Toxicity dose of fluor in the body depends on age, weight and health status (Tokalioglu et al., 2004; Rejkovic et al., 2007).

Nitrate is a common contaminant in groundwater and has been implicated in gastric cancer mortality and other disorders. In conversion to nitrite, nitrate act as causative agent of methemoglobinemia in infants (Pip, 2000). If nitrate concentration in drinking water is than 50 mg/l, water will be the most important source of nitrate intake (Brody, 2006; Rejkovic et al., 2007).

The palatability of water with a TDS level less than 500 mg/l is generally considered to be good. Drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. the presence of high levels of TDS may also be objectionable to consumers (WHO, 2004).

Aims of this study were to quantify the levels of TDS, NO_3^- and F^- in bottled water in Iran and to compare obtained values with Iranian, World Health Organization (WHO) and Environmental Protection Agency (EPA) drinking water standards.

MATERIALS AND METHODS

This research was a descriptive study which has been carried out on 24 brands of Iranian bottled water in three seasons during 2010. The investigated bottled water samples are natural, mineral and desalinated water. A total of 78 bottled water in 1.5 L PET container were randomly purchased at supermarkets from some medium and large Iranian cities in January-September 2010. The numbers of samples for three brands (B_3, B_{12} and B_{20}) were two and for remaining brands were three to four samples to check variability of mineral concentrations. The TDS, nitrate and fluoride analyses were performed according to methods described in latest edition of standard methods for the examination of water and wastewater book (APHA et al., 2005) in water chemistry laboratory of Kashan University of medical sciences. Their brand names are given for information only but in text because of doing ethics in research. Brands are specified as B_1 to B_{24}. The trade names of investigated brands is as below: Sovana, Pure life, Bisheh, Allis, Desani, ZAmzam, Pars, Dalahoo, Aghigh, Damash, Plur, Sepidan, Koohrang, Damavand, Vata, Crystal, Ferdos, Sabalan, Hobab, Bidestan, Shiva, Abali, Rabi and Haraz.

RESULTS AND DISCUSSION

The concentration of the TDS, nitrate and fluoride in the 24 brands of Iranian bottled water were summarized in Table 1. The concentration range for TDS were (in $mg.l^{-1}$); 68 to 1170 (mean= 364) for NO_3^-; 0.4 to 96 (mean=26.8) for F^-; 0.1 to 0.75 (mean=0.35). When compared to various nation and international standards of quality for drinking water (Table 2), the mean concentration of F^- in all investigated brands (100%) were

Table 1. Concentration of TDS, NO3- and F- in 24 brands of Iranian bottled drinking water in 2010.

Brand	No. of sample	TDS(mg/l)				Nitrate as NO_3^- (mg/l)				Fluoride as F^- (mg/l)			
		Min.	Max.	mean	S.D	Min.	Max.	mean	S.D	Min.	Max.	mean	S.D
B_1	3	441	591	552	41	17.2	22	19.4	2	0.15	0.25	0.19	0.04
B_2	3	430	602	559	49	11.1	15.7	13.3	2.1	0.31	0.57	0.42	0.1
B_3	2	460	601	553	38	18	25	21.5	2.9	0.38	0.51	0.44	0.06
B_4	4	179	241	208	11	37	43	40.5	2.5	0.1	0.3	0.2	0.08
B_5	3	710	1170	851	130	4.3	7.1	5.7	1.1	0.45	0.67	0.55	0.09
B_6	4	198	210	201	4.7	18	25	21	3.8	0.19	0.3	0.25	0.04
B_7	4	208	225	212	10.7	0.4	0.7	0.5	0.1	0.51	0.75	0.59	0.11
B_8	4	440	498	472	21	38	43	40.7	2.2	0.2	0.3	0.24	0.05
B_9	3	449	557	506	45	60	77	66	7.6	0.41	0.57	0.48	0.07
B_{10}	3	570	691	628	60	16	21	17.7	2.2	0.13	0.19	0.16	0.02
B_{11}	3	789	849	817	24.7	27	33	29.7	2.5	0.3	0.52	0.41	0.09
B_{12}	2	271	315	291	18	20	25	22.2	2.2	0.22	0.35	0.29	0.05
B_{13}	3	275	305	290	12	32	38	35	2.5	0.46	0.61	0.53	0.06
B_{14}	3	265	291	278	13	11	15	13	1.8	0.13	0.25	0.19	0.05
B_{15}	3	307	871	653	178	32	54	48.5	4.8	0.31	0.59	0.45	0.1
B_{16}	3	341	391	369	20.8	23	26	25.7	2.2	0.41	0.69	0.55	0.11
B_{17}	4	365	411	386	19	72	96	86	11	0.45	0.68	0.58	0.11
B_{18}	4	85	111	96	11	10.1	14.5	12.2	1.7	0.13	0.19	0.16	0.02
B_{19}	3	68	98	71	11	4.8	7.2	5.6	1	0.21	0.33	0.22	0.02
B_{20}	2	121	169	142	20	13	17.4	15.7	1.9	0.21	0.35	0.29	0.06
B_{21}	4	151	199	178	20	11.3	15.1	12.7	1.6	0.23	0.37	0.3	0.05
B_{22}	4	469	592	525	56	41.5	45	43.3	1.9	0.48	0.67	0.54	0.08
B_{23}	4	68	105	86	17	16	23.4	19.8	3.1	0.17	0.27	0.21	0.04
B_{24}	3	141	172	156	13.7	35.5	38.1	36.4	1.1	0.29	0.45	0.37	0.07
total	78	68	1170	364	21.8	0.4	96	26.8	19.6	0.1	0.75	0.35	0.15

Table 2. Present guidelines and regulations for bottled drinking water.

Parameter	Unit	EEC (2002)	IBWA	WHO (2004)	EPA (2002)	Iranian legislation (2010)	FAD (2008)
TDS	mg/l	-	500	1000	500	500	500
Nitrate	mg/l as NO_3^-	50	45	50	45	45	44
Fluoride	mg/l as F^-	0.7-1.5	0.8-1.7	0.7-1.5	0.7-2	0.7-1.2	0.8-2.4

EEC, European Economic Community; IBWA, International Bottled Water Association; WHO, World Health Organization; EPA, U.S Environmental Protection Agency; FAD, U.S Food and Drug Administration.

lower than acceptable ranges (Institute, 1992; Baba et al., 2008; Naddeo et al., 2008; Samadi et al., 2009; Semerjian, 2010).

Insufficient fluoride content of Iranian bottled water can be dangerous to consumer health regarding to dental caries and bone disease. In addition, excessive fluoride in bottled water can have negative consequences on bone, teeth and the brain. Also, too much of the ion can lead to skeletal fluorosis, a condition in which teeth have weak enamel and bones have poor mineralization (Wang et al., 2007). Although, optimum level of fluoride in drinking water is depending on climatic condition, but minimum necessary for prevention of dental caries is 0.7-0.8 $mg.l^{-1}$. Low levels of fluoride in Iranian bottled drinking water is probably because of utilization of reverse osmosis (RO) for desalination and TDS reduction (Alfaraij et al., 1999; Pip, 2000; Naddeo et al., 2008; Ghaderpoori et al., 2009; Guler et al., 2009; Semerjian, 2010; Cidu et al., 2011). Another study on 17 brands of Iranian bottled water has been shown that mean concentration of F^- in studied water were 0.3 $mg.l^{-1}$ which is compatible with our study results (mean= 0.34 $mg.l^{-1}$) as revealed in Table 1

(Samadi et al., 2009). Ghaderpoori et al. (2009) reported that, the mean concentration of F^- Iranian bottled water (13 brands) were 0.29±0.16 $mg.l^{-1}$ which is compatible with our study results. Another study on 18 brands of bottled water in Iran has demonstrated fluoride content of Iranian bottled water to be below 0.7 $mg.l^{-1}$ which is not compatible with WHO, EPA and Iranian Legislation for drinking water (Khodadadi et al., 2007; Amanlou et al., 2010). Study in Lebanon, Turkey, Italy and other countries showed that fluoride content of bottled water in over 90% of tested brands are lower than permissible level recommended by national and international drinking water standard and confirm our study findings (Alfaraij et al., 1999; Pip, 2000; Babaji et al., 2004; Tokalioglu et al., 2004; Guler, 2007; Baba et al., 2008; Naddeo et al., 2008; Saleh et al., 2008; Guler et al., 2009; Samadi et al., 2009; Cidu et al., 2011).

The analysis results of present study have shown that out of 24 brands Iranian bottled water only in 3 brands (B_9, B_{15} and B_{17}) the mean concentration of nitrate were higher than Iranian legislations (NO_3^->45 $mg.l^{-1}$) and in 2 brands (8.44%) higher than WHO guide lines (NO_3^-> 50 $mg.l^{-1}$) for short term exposure. The primary health concern regarding nitrate is the formation of methemoglobinemia. So called blue baby syndrome and increasing cancer risk in human (Alfaraij et al., 1999; Naddeo et al., 2008; Samadi et al., 2009; Semerjian, 2010; Cidu et al., 2011). In some countries a limit of 10 $mg.l^{-1}$ NO_3^- has been recommended for the water destined to infants (Baba et al., 2008; Naddeo et al., 2008; Cidu et al., 2011). Twenty-one brands (87.4%) of bottled water considered in this study showed NO_3^- concentration higher than 10 $mg.l^{-1}$ (Table 1).

Regarding examined bottles water, the mean concentration of TDS in 9 brands (37.5%) were higher than 500 $mg.l^{-1}$ (Iranian legislations) and in all brands were within the appropriate WHO guide lines values (Institute, 2002; Khodadadi et al., 2007; Naddeo et al., 2008; Guler et al., 2009; Samadi et al., 2009; Semerjian, 2010; Cidu et al., 2011). An elevated TDS concentration in not a health hazard to consumer as it seen in Table 1, there is a great difference between TDS values of examined bottled water, which is related to the origin of the sores, and the treatment or perfection method applied during bottling process (Guler, 2007; Baba et al., 2008; Naddeo et al., 2008; Saleh et al., 2008; Cidu et al., 2011).

There are three brands (B_{18}, B_{19} and B_{23}) having low TDS values (<100 $mg.l^{-1}$). As previous studies have shown, long term consumption of waters low in minerals (example for, calcium, magnesium and fluoride) have in fact a number of health risks to consumer (Pip, 2000; Guler, 2007; Baba et al., 2008; Naddeo et al., 2008; Semerjian, 2010; Cidu et al., 2011). A study on chemical water quality of desalination plant in Kashan (a city in central of Iran) has been shown that, mean concentration of TDS, NO_3^- and F^- in inlet of this plant were 852.4, 9.12 and 0.83; and in desalinated water were 245.18, 2.46 and 0.2 $mg.l^{-1}$, respectively (Miranzadeh et al., 2010).

Conclusions

In Iran, many people now prefer bottled water to tap water for a number of reasons. Twenty four Iranian bottled water brands were analyzed for TDS, NO_3^- and F^- parameters. Results showed a wide spread variation in concentration of mentioned parameter due to geological variances in the water sources and treatment process applied. These results can be useful for guiding the consumers by paying more attention to the chemical composition and properties of specified bottled water brands. This study indicated that fluoride levels in all examined brands were not compatible with national and international standard and consumer are at risk of dental caries (Tokalioglu et al., 2004; Baba et al., 2008; Ghaderpoori et al., 2009; Amanlou et al., 2010). In addition, in 87.5% of brands the nitrate concentration were lower than Iranian standard and safe for human consumption. In general, the study found that bottled mineral water is not better than the public water supply from a health viewpoint (Baba et al., 2008; Naddeo et al., 2008; Guler et al., 2009). Finally, this study demonstrates the need for more stringent standardization of the bottled water market, particularly with regard to quality control, labeling and monitoring and further study is recommended.

AKNOWLEDGMENT

The authors gratefully acknowledge the financial support of research department of Kashan University of Medical Sciences.

REFERENCS

Alfaraij KM, Abdelaleem MK, Alajmy H (1999). Comparative study of potable and mineral waters available in the state of Kuwait. Desalination, 123: 253-264.

Amanlou M, Hosseinpour M, Azizian H, Khoshayand MR, Navabpoor M, Souri E (2010). Determination of Fluoride in the Bottled Drinking Waters in Iran. Iran. J. Pharm. Res., 9(1): 37-42.

APHA AWWA, WPCF (2005). Standard methods for the examination of water and wastewater. 21 th ed., American Public Health Association, Washington DC, USA.

Baba A, Erees FS, Hicsonmez U, Cam S, Ozdilek HG (2008). An assessment of the quality of various bottled mineral water marketed in Turkey. Environ. Monit. Assess., 139: 277-285.

Babaji I, Shashikiran NN, Reddy SVV (2004). Comparative evaluation of trace elements and residual bacterial content of different brands of bottled waters. J. Indian Soc. Pedod. Prev. Dent., 22(4): 201-204.

Brody JG (2006). Breast cancer risk and drinking water contaminated by wastewater: a case control study. Environ. Health, 5: 28.

Cidu R, Frau F, Tore P (2011). Drinking water quality: Comparing inorganic components in bottled water and Italian tap water J. Food Compos. Anal., pp. 1-10.

Fiket Z, Roje V, Mikac N, Kniewald G (2007). Determination of arsenic and other trace elements in bottled waters by high resolution inductivity coupled plasma mass spectrometry. Croat. Chem. Acta.,

80(1): 91-100.
Ghaderpoori M, Jahedkhaniki GR, Dehghani MH, Shams M, Zarei A (2009). Determination of fluoride in bottled water sold in Tehran market, Iran. American-Eurasian J. Agric. Environ. Sci., 6(3): 324-327.
Guler C (2007). Evaluation of maximum contaminant levels in Turkish bottled drinking waters utilizing parameters reported on manufacturers labeling and government-issued production licenses. J. Food Compos. Anal., 20: 262-272.
Guler C, Alpaslan M (2009). Mineral content of 70 bottled water brands sold on the Turkish market: assessment of their compliance with current regulations. J. Food Compos. Anal., 22: 728-737.
Ikem A (2010). Measurement of volatile organic compounds in bottled and tap waters by purge and trap GC–MS: Are drinking water types different? J. Food Compos. Anal., 23: 70-77.
Institute of Standards and Industrial Research of Iran (1992). Natural mineral water-Specifications, ISIRI number: 2441. Iran, Islamic Republic of Iran.
Institute of Standards and Industrial Research of Iran (2002). Water-Packaged (bottled) drinking waters-Specifications, ISIRI number: 6694. Iran, Islamic Republic of Iran.
Karamanis D, Stamoulis K, Ioannides KG (2007). Natural radionuclides and heavy metals in bottled water in Greece. Desalination, 213: 90-97.
Khodadadi M, Oudi Q, Dari H, Azizi M, Talaian Z, taheri Z, et al. (2007). Survey of microbial and chemical condition of bottled mineral waters in Birjand city during 2006. 10th Environmental Health Conference, Hamadan, Iran.
Liu Y, Mou S (2004). Determination of bromate and chlorinated haloacetic acids in bottled drinking water with chromatographic methods. Chemosphere, 55: 1253-1258.
Miranzadeh M, Rabbani D (2010). Chemical quality evaluation for the inlet and outlet water taken from of the desalination plants utilized in Kashan during 2008. Feyz, J. Kashan Univ. Med. Sci., 14(2): 120-125 (in Persian).
Misuned A (1999). Variation of 66 elements in European bottled mineral waters. Sci. Total Environ., 243: 21-41.
Naddeo V, Zarra T, Belgiorno V (2008). A comparative approach to the variation of natural elements in italian bottled waters according to the national and international standard limits. J. Food Compos. Anal., 21: 505-514.
Oyedeji O, Olutiola PO, Moninuola MA (2010). Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria. Afr. J. Microbiol. Res., 4(1): 96-102.
Pip E (2000). Survey of bottled drinking water available in Manitoba, Canada. Environ. Health Perspect., 108(9): 863-866.
Qaderpouri M, Jahedkhaniki Q, Nazmara S (2009). Determination of toxic trace element in bottled waters consumption in the of Tehran 12th Environmental Health Conference, Tehran, Iran.
Rejkovic MB, Novakovic ID (2007). Determination of fluoride content in drinking water and tea infusions using fluoride ion selective electrode. World J. Agric. Sci., 52(2): 155-168.
Saleh MA, Abbdelrahman FH, Woodard BB, Clark S, Wallace C, Aboaba A, et al. (2008). Chemical, microbial and physical evaluation of commercial bottled waters in greater Houston area of Texas. J. Environ. Sci. Health, Part A: Toxic/Hazard. Subst. Environ. Eng., 43: 335-347.
Samadi MT, Rahmani AR, Sedehi M, Sonboli N (2009). Evaluation of chemical quality in 17 brands of Iranian bottled drinking waters. J. Res. Health Sci., 9(2): 25-31.
Semerjian LA (2010). Quality assessment of various bottled waters marketed in Lebanon. Environ. Monit. Assess., 172(1-4):275-285.
Soupioni MJ, Symeopoulos BD, Papaefthymiou HV (2006). Determination of trace elements in bottled water in Greece by instrumental and radiochemical neutron activation analyses. J. Radioanal. Nucl. Chem., 268(3): 441-444.
Tokalioglu S, Kartal S, Sahin U (2004). Determination of Fluoride in Various Samples and Some Infusions Using a Fluoride Selective Electrode. Turk. J. Chem., 28: 203-211.
Wang SX, Wang ZH, Cheng XT, Li J, Sang ZP, Zhang XD (2007). Arsenic and fluoride exposure in drinking water: children`s IQ and growth in Shanyan county, Shanxi province, China. Environ. Health Perspect., 115(4): 643-647.
WHO (2004). Guidelines for drinking-water quality. 3rd Ed., World Health Organization, Geneva, pp. 296-459.