Original Article

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Evaluation of Chemical Quality in 17 Brands of Iranian Bottled Drinking Waters

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Abstract

Background: The purpose of study was to evaluate and compare chemical quality of Iranian bottled drinking water reported on manufacturer's labeling and standards.

Methods: This study was a cross-sectional descriptive study and done during July to December 2008. The bottled mineral water collected from shops randomly were analyzed for all parameters address on manufacturer's labeling and the results were compared with the manufacturer's labeling data, WHO Guideline Values, USEPA Maximum Contaminant Levels and the maximum contaminant levels of drinking water imposed by the Iranian legislation. Statistical analysis on data was done with the Kolmogorov-Smirnov test for normal distribution, the paired t-test to compare the data with manufacturer's labeling and the one-sample t-test to compare with standard and MCL values at $P < 0.05$ of confidence level.

Results: The results showed a statistically significant difference with manufacturer's labeling values, however there was no significant difference between the values of magnesium and pH and manufacturer's labeling values ($P > 0.05$). In addition, pH and calcium values were significantly higher than their proposed values indicated by Iranian National Legislation and international MCLs ($P < 0.05$).

Conclusion: Our results are extremely important for the health supervisory agencies such as Ministry of Health and Institute of Standards & Industrial Research of Iran to have more effective controls on bottled water industries, and to improve periodical the proposed standard values.

Keywords: *Bottled water, Chemical quality, Drinking water standards, Iran*

Introduction

The quest for high-quality water has been an objective of human society going back to prehistoric times. Early humans gathered in locations with readily accessible sources of water and if the water was believed to be of questionable quality, entire settlements would be abandoned. The first documented drinking water treatment can be found in Egyptian hieroglyphics, describing procedures to purify water. The basic principles were the same then as they are today; boiling, chemical treatment and filtration were recommended treatments. Although the importance of drinking water quality was known, the specific contaminants would not be identified for centuries to come (1).

Bottled water consumption has been steadily growing up the last three decades in a global level (2). The main reason for this rapid consumption was the lack of safe and accessible drinking water and the taste of chemicals, particularly chlorine, used to purify tap water (3-5). Today, 450 million people in 29 countries suffer from water shortages. Water-related concerns are also the most acute in arid or semi-arid areas. Many countries with scarce water resources rely on alternative or non-conventional water resources (6). In some countries, for instance, it is allowed to have 5L water bottles which may increase the probability of contamination because bottles will stay opened for an extended time(7). Furthermore, the ancient marketing and advertising strategies followed by the bottled water

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producers enhanced this consumption. The evidence supporting this fact is that especially consumers who live in developed countries buy bottled water as a healthy alternative to other beverages, to improve their diet and health. Bottled water is called the packaged water that is commercially available for human consumption (4). Bottled water is also utilized in emergency or water shortage situations caused by natural disasters (e.g. drought, earthquake, flood and hurricane) or human-made disasters (e.g. sabotage, siege, terrorism and war), which can severely damage public and private water supplies for extended periods of time (6). The popularity of bottled water can be gauged by the number of brands produced worldwide (over 5000); a significant portion of these brands are traded internationally. In a 2002 survey, published by a market research company, it was estimated that people all over the world drink annually about 131×10^9 L of bottled water (8). Western Europeans, as a whole, drink nearly half of all the world's bottled water (9).

The European Federation of Bottled Water (EFBW) estimates the consumption of bottled water in the European Union during 2003 as 45,000 ml (excluding bottles> 10 l). The water-sales worldwide exceed a value of 5 billion euros (10). Western Europe is not only the largest regional market, but it is also the most developed. It is dominated by Italy, France, Belgium, Germany and Spain, in all of which per capita consumption of bottled water has exceeded the 100 L barrier in L per capita per year. This estimated US$45 billion worldwide industry is growing faster than ever as water quality concerns, fitness and health awareness increase among the consumers (based on an estimated price of 0.35 US$ per L of bottled water (11).

Non-carbonated bottled water has become more popular than carbonated, being a substitute for tap water in many homes (6). The usage of bottled water in the world (2007) and the increasing of bottled water consumption in Asian countries in the last years are shown in Figure 1 and Table 1, respectively. The present regulations and standards for the control of chemical quality of drinking water are also summarized in Table 2.

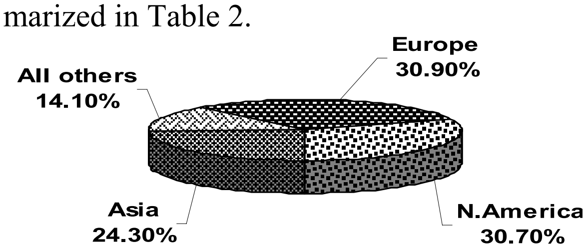

Fig. 1: The usage of bottled water in the world (2007)[a].

[a] Beverage Marketing Corporation (2008)

Table 1: Asian bottled water market change in consumption by country (2002-2007)[a]

Countries	2002/03	2003/04	2004/05	2005/06	2006/07	5 yr CAGR
China (with Taiwan)	17.9%	26.1%	14.9%	13.9%	15%	17.5%
Indonesia	13%	6%	3.4%	7.3%	11.4%	8.2%
Thailand	2%	0.6%	0.5%	8.3%	7.5%	3.7%
India	45.6%	32.7%	23.8%	4.9%	6.5%	21.7%
Korea, (Republic of)	20%	20%	17.2%	11.5%	11.4%	16%
Japan	9.3%	11.1%	12.8%	28.3%	8.3%	13.7%
Philippines	5.5%	3.8%	4.4%	10%	8.8%	6.4%
Pakistan	5.9%	9.8%	11.2%	13.8%	9.5%	10%
China, Hong Kong SAR	10%	10%	10.1%	11.9%	8.4%	10.1%
Malaysia	8.5%	12%	11.3%	4.6%	9.5%	9.1%
Viet Nam	9.1%	3.6%	4.2%	15.9%	8.6%	8.2%
Singapore	8%	7.8%	7.8%	11.5%	9.8%	9%
Brunei	9%	9%	9%	4.2%	2.1%	6.6%
Subtotal	**13.6%**	**14.4%**	**10.2%**	**11.3%**	**11.5%**	**12.2%**
All others	9.2%	5.7%	6.3%	5.9	4.5%	6.3%
Global Total	**10.1%**	**7.5%**	**7.2%**	**7.1%**	**6.1%**	**7.6%**

During the past decade, there has been a considerable increase in the household consumption of bottled water in Iran, especially in the summer. The main source of bottled water sold in Iran is from protected springs, and the remaining is pumped from drilled wells tapping an aquifer (6).

Table 2: Present regulations and standards for the drinking water

Parameter	Unit	EEC[a] (1998) (MAC)[d]	WHO[b] (1998) (GV)[e]	EPA[c] (2002) (MCL)[f]	Iranian Legislation (1997) (MCL)
Arsenic (As)	mg L^{-1}	0.01	0.01	0.01	0.05
Barium (Ba^{2+})	mg L^{-1}	-	0.7	2	1
Beryllium (Be)	mg L^{-1}	-	-	0.004	-
Cadmium (Cd^{2+})	mg L^{-1}	0.005	0.003	0.005	0.01
Calcium (Ca^{2+})	mg L^{-1}	-	-	-	200
Chloride (Cl^{-})	mg L^{-1}	250	-	250	600
Chromium (Cr)	mg L^{-1}	0.05	0.05	0.1	0.05
Copper (Cu)	mg L^{-1}	2	2	1.3	1
Fluoride (F^{-})	mg L^{-1}	1.5	1.5	2	1.7
Iron (Fe)	mg L^{-1}	0.2	-	0.3	1
Lead (Pb)	mg L^{-1}	0.01	0.01	0.015	0.05
Magnesium (Mg^{2+})	mg L^{-1}	-	-	-	30[g] -150[h]
Manganese (Mn^{2+})	mg L^{-1}	0.05	0.4	0.05	0.5
Mercury (Hg)	mg L^{-1}	0.001	0.001	0.002	0.001
Nitrate (NO_3^{-})	mg L^{-1}	50	50	44	45
Nitrite (NO_2^{-})	mg L^{-1}	0.5	0.2	3.3	0.004
Potassium (K^{+})	mg L^{-1}	-	-	-	-
Sulfate (SO_4^{2-})	mg L^{-1}	250	-	250	250
TDS	mg L^{-1}	-	-	500	500
Turbidity	NTU	-	-	1	25
pH	-	6.5 -9.5	-	6.5 – 8.5	6.5 – 8.5

[a] European Economic Community, [b] World Health Organization, [c] US Environmental Protection Agency,
[d] Maximum admissible concentration., [e] Guideline value., [f] Maximum contaminant level
[g] IF SO_4^{2-}>250, [h] IF SO_4^{2-}<250

This is a proof that the bottled water industry has done an outstanding job in marketing its product as a safe alternative to tap water, even though the price of bottled water in Iran is over than 1000 times higher than that of tap water.

In the present study, we investigated the chemical characteristics of domestic brands of bottled water sold in Iran market and questioned their accuracy and precision with the levels reported on manufacturer's labeling. Also a review of the current regulations regarding bottled water in Iran (12) was made and compared to current drinking water standards around the world including European Economic Community Council Directive 98/83/EC (13), United States Environmental Protection Agency (2004), and draft third edition of the WHO Guidelines for Drinking-Water Quality (2004).

Materials and Methods

Water samples

In this study, 51 bottles with 17 brands which produced domestically and distributed all over the country were purchased from local supermarkets in Hamadan (west of Iran) during the period 2006-2007. The samples imported noncarbonated water in polyvinyl chloride (PVC) 1.5 liters bottles capacity and all with the same production date were carried out by the Laboratory of Water and Wastewater Chemistry of Hamadan School of Public, certified by Iranian Department of Environment (DOE).

Chemical analysis

All water samples were examined for the chemical parameters addressed on the manufacturer's labeling including pH, alkalinity, chloride, fluoride, sulfate, nitrate, total dissolved solids (TDS), magnesium, total hardness, calcium, sodium and potassium. Chemical analysis was carried out according to the standard methods of water and wastewater examinations: pH (electronic pH meter), TDS (gravimetric method), alkalinity, chloride, total hardness, calcium and magnesium (tetrimetric method), sulfate (both spectrophotometry in Shimadzu model UV-1700 and turbidimetry methods), fluoride (spectrophotometry by applying SPADNS reagent), sodium and potassium (spectrophotometry) and nitrate (UV-Vis spectrophotometry).

Statistical analysis

The data from chemical examinations were analyzed by Kolmogorov-Smirnov for evaluation of normal distribution of data, paired *t*-test for the comparison of data with manufacturer's labeling and one sample *t*-test for the comparison of obtained records with standard and MCL values at *P* values< 0.05 of confidence level.

Results

The results from physical and chemical examinations of bottled waters compared with the constituents reported on bottle labels are shown in Table 3. For most elements the difference between the lowest (pH) and highest (total hardness) concentration was 20 orders of magnitude. pH was changed by about 1.2 order of magnitude, however the total hardness values showed 282 folds increase. Also our data analysis showed a wide dispersion in the source and chemical composition of Iranian bottled waters (Table 3).

Discussion

The evaluation and comparison of data obtained by physicochemical examination of bottled samples chemicals were analyzed by Statistical tests (Table 4). Kolmogorov-Smirnov statistical test showed that all data had a normal distribution ($P< 0.05$). Therefore, parametric paired *t*-test and one sample *t*-test would be applicable.

Results of paired *t*-test indicated that values from analytical examinations of fluoride, nitrate, chloride, sulfate, sodium, potassium, TDS, total hardness, calcium and alkalinity had a significant statistical difference with manufacturer's labeling values ($P< 0.05$). Nevertheless there was no significant difference among the values for magnesium and pH from analytical examinations and manufacturer's labeling values ($P> 0.05$). One sample *t*-test results indicated that pH and calcium had significant statistical difference with Iranian National Legislation and International MCLs, respectively ($P< 0.05$), however these parameters had no sever averse health effects for consumers. The values for fluoride, nitrate, magnesium, chloride, sulfate, sodium, potassium, TDS, total hardness and alkalinity had no significant statistically difference with Iranian national Legislation and international MCLs.

Table 3: Chemical and physical analysis of bottled waters in comparison of the constituents reported on the it's labels.

	Nitrate [c]		Sulfate [c]		Chloride		Fluoride		Magne-sium		Sodium		Potas-sium		Calcium		Total Hardness		pH		Alkalinity		TDS	
Brand	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**	**M[a]**	**L[b]**
B1	9.2	3.1	50	40	8.5	6	0.21	0.22	13.4	26.7	4	4.1	0.8	1	64	48	120	200	8.2	7.4	1.7	-	155	-
B2	6.2	-	24	11	22.7	6	0.22	0.2	9.6	15.4	11	4.6	0.5	0.6	180	57	220	-	7.6	7.3	3	-	252	-
B3	8.8	0.5	5	2	7.1	6	0.21	0.1	0.9	7.2	8.5	5.4	1	0.4	100	40	104	-	8.1	7.9	290	120	125	-
B4	5.3	7	12	10	4.3	6	0.22	2	-	-	2	6	0.4	1	20.1	28	26	90	8.1	7.3	1.6	-	180	-
B5	16.3	12.1	58	76	10.7	15	0.3	0.3	0.5	0.6	41.5	43	0.5	1	30	13	32	60	8	7.8	1.2	-	188	160
B6	1.8	0.6	16	24	34.4	45	0.47	0.07	10	13.3	28	22	2	0.3	186	71.1	228	-	8	7	480	200	303	-
B7	9.2	17	63	49	28	118	0.28	0.9	17.3	35	4	37	1	0.4	50	24	122	-	7.5	7.2	160	63	219	-
B8	7.5	7.3	19	100	63	68	0.2	0.1	0	9.6	44.5	76	1	2	0	22.5	0	96	8	7.6	92	56	188	320
B9	4.4	2.3	17	19	10	0.7	0.47	0.11	0	2.3	7.5	4.7	3	1.9	0	9.8	0	-	7.9	7	60	29	46	-
B10	14.1	6.5	13	-	14.2	6	0.12	0.6	15.5	12.5	4	18	0.8	1	3.2	62	39	-	8.4	-	30	104	94	95
B11	3.1	6	10	10	11.1	8	0.52	0.3	-	-	2.3	6	0.8	0.5	61	62.8	144	-	7.9	7.7	179	-	190	-
B12	14.1	4	19	21	14.2	16.4	0.34	0.23	9.1	20.3	8	10.8	1	1.4	172	-	210	-	8.2	7.5	222	260	236	-
B13	5.3	0.5	3	3	-	-	0.42	0.07	0.5	7.6	5.5	1	0.5	0.1	60.1	-	82	-	-	-	240	144	106	-
B14	11.9	-	71	120	-	-	0.46	0.37	19.2	26	16.5	-	4.5	-	202	-	282	-	-	-	534	-	319	-
B15	6.5	6.1	22	17	44	32	0.54	0.45	0.8	0.5	8.5	5.5	0.7	0.5	75	50	120	-	7.8	-	352	275	196	-
B16	10.1	7.9	15	10	13.1	10	0.24	0.3	12.4	10	15.7	10.5	2.4	1.5	105	100	155	50	8.7	7.8	480	-	220	170
B17	8.9	5.4	8	7	22.3	30	0.42	0.5	7.8	5.5	4.9	5	1.6	1	62	45.5	175	80	7.1	7.2	320	225	145	-
Ave.	**8.4**	**5.8**	**25.0**	**32.4**	**20.5**	**24.9**	**0.3**	**0.3**	**7.8**	**12.8**	**12.7**	**16.2**	**1.3**	**0.9**	**80.6**	**45.3**	**121.1**	**96.0**	**8.0**	**7.4**	**202.7**	**147.6**	**186.0**	**186.3**
Min.	**1.8**	**0.5**	**3**	**2**	**4.3**	**0.7**	**0.12**	**0.07**	**0**	**0.5**	**2**	**1**	**0.4**	**0.1**	**0**	**9.8**	**0**	**50**	**7.1**	**7**	**1.2**	**29**	**46**	**95**
Max.	**16.3**	**17**	**71**	**120**	**63**	**118**	**0.54**	**2**	**19.2**	**35**	**44.5**	**76**	**4.5**	**2**	**202**	**100**	**282**	**200**	**8.7**	**7.9**	**534**	**275**	**319**	**320**

[a] Measured Value [b] Labeled Value [C] mg/L [d] mg/L ($CaCO_3$)

Table 4: The evaluation and comparison of results by Statistical methods

Parameter	Kolmogorov-Smirnov *P*-Value	Paired *t*-test (Parametric) *P*-Value	95% Confidence interval of the difference Lower	Upper	One Sample *t*-test (Parametric) *P*-Value
Fluoride	0.000	0.000	-0.11	0.23	0.609
Nitrate	0.000	0.015	-0.63	5.97	0.960
Magnesium	0.010	0.103	-10.99	-4.04	0.427
Chloride	0.000	0.000	-23.58	11.29	0.300
Sulfate	0.000	0.024	-25.08	7.53	0.217
Sodium	0.034	0.000	-13.14	2.78	0.221
Potassium	0.000	0.037	-0.32	0.58	0.066
TDS	0.000	0.026	-247.16	176.43	0.988
pH	0.022	0.547	0.35	0.74	0.030
Total Hardness	0.000	0.000	-438.15	-331.99	0.900
Calcium	0.000	0.000	-14.22	61.07	0.012
Alkalinity	0.000	0.012	-20.41	169.76	0.772

The average pH value for the Iranian bottled water samples was 8.0 and has a range of 7.1 to 8.7. The standard value for pH has a range of 6.5 to 8.5 based on The Iranian National Legislation and USEPA guideline and less than 8.0 based on the WHO guideline. About 40% of the samples had pH values higher than 8.0, however there was no sample with acidic pH. The calcium values for our samples were between 0-202 mg/L. This range is compatible with the Iranian national Legislation value for calcium (200 mg/L).

In a similar study on bottled-water samples in Kuwait, about 44% of samples had pH values higher than 8.0, and 8% were slightly acidic (less than 7.0). They also showed a range of calcium values between 1.8 and 103.3 mg/L (14). Turkish bottled water range value varied from 6.36 to 7.1 for pH and from 16.8 to 179.8 mg/L for calcium, respectively (6). In Greek bottled water, pH values were between 6.0 and 8.2. In this study maximum values of calcium, sulfate and chloride were 486 mg/L, 118.7 mg/L and 100 mg/L, respectively (4). Sulfate, chloride and calcium values of Greek bottled water were higher than Iranian bottled water. Twenty five brands of bottled waters consisting of both purified and spring types collected randomly from three different Alabama cities, USA, the selected water-quality constituents analyzed in water samples were pH, conductivity, alkalinity, chloride, nitrate, nitrite, sulfate, phosphate, total carbon (TC), inorganic carbon (IC) and total organic carbon (TOC). The obtained results showed that no sample had pH>8.5, but seven bottled water brands analyzed were acidic (pH<6.5). Most of the brands had TOC concentrations exceeding 3 mg/L. The majority of the water-quality elements analyzed in this study, had a higher concentration in the spring water brands compared to the purified or distilled brands (15). Bottled mineral waters (132 samples) of 19 different districts in Italy were characterized in terms of physico-chemical and chemical compositions and compared to the values reported on their labels by applying proper statistical analysis. The mineral water parameters showed a wide variation range: the minimum pH value (5.68 for sample 103), and the maximum content of sodium (746 mg/L for sample 119), potassium (250 mg/L), magnesium (151 mg/L for sample 125), chloride (329 mg/L for sample 120), sulfate, (1371 mg/L for sample 106), fluoride (8.40 mg/L for sample 120) and aluminum (0.074 mg/L for sample 109) being noticeable (8).2It is well known that the composition of mineral water is affected by precipitation rate and geological substrates involved in water circulation.

Conclusively, the results showed that fluoride, nitrate, chloride, sulfate, sodium, potassium, TDS, total hardness, calcium and alkalinity had a statistically significant difference with manufacturer's labeling values. In addition, pH and calcium had significant statistical difference with Iranian National Legislation and International MCLs. Our results are important, not only for the very many Iranian people who drink bottled water but also for the health supervisory agencies such as Ministry of Health and Institute of Standards & Industrial Research of Iran (ISIRI) to have more effective control on bottled water industry as well as to improve periodically in proposed standard values.

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