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Chemical Composition of Different Brands of Bottled Drinking Water Sold in Oman as Labelled by Manufacturers

Zakariya M. Al Aamri* and Badreldin H. Ali[1]

College of Medicine & Health Sciences, Sultan Qaboos University, Al-Koud, Oman
[1]Department of Pharmacology, College of Medicine & Health Sciences, Sultan Qaboos University, Al-Koud, Oman
✉ zakariya.alaamri@gmail.com

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Abstract: Information about the safety of bottled drinking water in Oman is lacking. Therefore, we aimed to compare the chemical composition (as labelled by manufacturers) of 17 local and imported brands of bottled drinking water sold in Oman, and compare them with WHO and USEPA standards. Seventeen brands of bottled drinking water were purchased from local stores in Muscat, Oman. The chemical composition of those brands was recorded from the labels, and compared with WHO and USEPA standards. The results showed that the pH of the bottled water of all the brands was within the normal range prescribed by both WHO and USEPA. Total dissolved solids, hardness, sodium, chloride and nitrate were less than the primary or secondary (aesthetic) maximum limits set by WHO and/or USEPA. Fluoride levels were not reported in 53% of the brands and were less than recommended limits in the remaining brands. Further studies are warranted to analyze water samples of those brands and compare them with the labels.

Key words: Bottled drinking water, chemical composition, Oman, safety.

Introduction

Water is a vital liquid for humans to stay alive, but the rapid rise in the population, and the expansion of human activities that can induce contamination increase the demand for providing enough safe sources of drinking water (Mahajan et al., 2006; Chiarenzelli and Pominville, 2008; Gangil et al., 2012; Moazeni et al., 2013). Therefore, bottled drinking water industries were established to bridge that gap between supply and demand (Mahajan et al., 2006). Bottled water is obtained from many sources such as springs, aquifers, reservoirs, highly mineralized springs, and/or directly from municipal water, as many manufacturers do (Momani, 2006; Chiarenzelli and Pominville, 2008).

In the USA and the European Union, the average amount of bottled drinking water consumed by each individual per year is between 90.5 L and 105 L (Saleh et al., 2008; Bityukova and Petersell, 2010). However, the global average is 24.2 L (Saleh et al., 2008). Bottled drinking water is used by consumers not only for drinking but also in the preparation of infant formula, for cooking, skin care, cleaning contact lenses and filling humidifiers (Ikem et al., 2002; Yekdeli Kermanshahi et al., 2010). However, many concerns have been raised regarding the safety of bottled drinking water, prompting scientists to study its composition and safety.

The demand for bottled drinking water in our region is relatively high because of the scarcity of fresh water, and of the relative affluence of the population. For

*Corresponding Author

example, in the United Arab Emirates, about 90% of the population consume bottled drinking water, and about 153 L were consumed per-capita in 2010 (Nsanze et al., 1999; Gleick et al., 2012). About 95 L were consumed per-capita in Saudi Arabia in 2010 (Gleick et al., 2012). Whereas the contribution of bottled water to drinking water was given as 20% in Qatar by Momani (2006), it is conceivable that this percentage has increased significantly by now, although no new data on that have been reported, as far as we are aware.

The chemical composition of bottled drinking water varies among different brands, and this may increase the concern about its possible effects on health (Garzon and Eisenberg, 1998; Momani, 2006; Chiarenzelli and Pominville, 2008). Bottled drinking water may contain sodium (Na), magnesium (Mg), calcium (Ca), fluoride (F) and other minerals, but there are many elements that should not be present in bottled drinking water such as lead (Pb) and cadmium (Cd) due to their harmful effects on humans (Mahajan et al., 2006). A study by Chiarenzelli and Pominville (2008) showed that Ca, chloride (Cl^-), potassium (K), Mg, Na, sulphur (S), and silicon (Si) were the dominant inorganic elements found in their samples. Garzon and Eisenberg (1998) recommended that ideal bottled water should be high in Ca and Mg and low in Na.

Mg is known for its potential ability to decrease the frequency of sudden death, prevent insulin resistance and atherosclerosis, and is a cofactor for a high number of enzymes, whereas calcium is good for osteoporosis prevention (Garzon and Eisenberg, 1998; Mahajan et al., 2006, Chiarenzelli and Pominville, 2008; Maraver et al., 2015). However, water with high Ca is contraindicated in patients with upper urinary tract stones because it may deteriorate their condition (Garzon and Eisenberg, 1998; Mahajan et al., 2006; Yekdeli Kermanshahi et al., 2010). On the other hand, Na is linked with hypertension occurrence (Garzon and Eisenberg, 1998; Mahajan et al., 2006).

Pd and Cd are heavy metals that can cause brain damage in infants (especially Pd) and kidney problems (Momani, 2006; Mahajan et al., 2006; USEPA, 2015). An Indian study conducted to analyze the contents of heavy metals in 17 brands of bottled drinking water showed that, in seven samples, Pd was present in more than the upper limits of WHO and USEPA (Mahajan et al., 2006). The existence of Pd can be attributed to either the factories' piping system or materials used in filters (Mahajan et al., 2006; Chiarenzelli and Pominville, 2008).

Proper storage of bottled water is an important factor to maintain its safety and quality (WHO, 2011). A study conducted by Nsanze et al. (1999) showed that the storage of bottled drinking water at 4 °C prevents microbial growth, whereas at 42 °C, most of the contaminants were destroyed, but they noticed that the multiplication of microorganisms increased at room temperature (25-37 °C). Outdoor storage of bottled drinking water can lead to leaching of Bisphenol A from plastic containers due to high temperature and exposure to sunlight, as indicated by many studies. Bisphenol A is known for its disruptive endocrinal effects that can result in many diseases like diabetes, cancer and reproductive defects (Vom Saal and Myers, 2008; Elobeid et al., 2012).

As far as we are aware, there are no reports on either the composition or safety of bottled drinking water in Oman. Therefore, in the current preliminary study we aimed to compare the chemical composition of 17 brands of bottled water sold in the country, as shown by manufacturers and to compare these with the WHO and USEPA standards.

Methodology

Seventeen brands of bottled drinking water (500 mL except for LuLu (150 mL) and Salsabeel (1.5 L)) were bought from a local store in Muscat, Oman. Data on the chemical composition (as labelled by manufacturers) (pH, dissolved solids, hardness, Ca, Mg, Na, K, F, nitrate (NO_3^-), Cl, bicarbonate (HCO_3^-) and sulphate (SO_4^{2-})) of each brand was extracted and recorded. Chemical compositions were analyzed using simple comparison and were compared with WHO and USEPA standards. The precision and accuracy of those labels have not been verified in this study, but will be the subject matter of future work.

Results and Discussion

pH

Our results showed that pH of all brands of bottled drinking water is within normal levels of aesthetic quality set by WHO and USEPA (6.5–8.5) with a range of 6.90-7.80 and an average of 7.38. pH has no direct effects on consumers, but it should be well monitored to ensure the safety of water during all processes of treatment because pH has certain effects on disinfection by chlorine (i.e. preferred to be <8.00) (WHO, 2011). The taste of acidic water (<4.00) is sour, but it is bitter

in the case of alkaline water (>8.50) (Mahajan et al., 2006). Furthermore, acidic water has corrosive effects on water pipes, which may lead to the release of some metals (Momani, 2006; Mahajan et al., 2006; Saleh et al., 2008; Bityukova and Petersell, 2010; WHO, 2011). A study conducted in India showed that after analysis of samples from 17 brands of bottled drinking water for pH, all samples were within recommended limits prescribed by WHO and USEPA (Mahajan et al., 2006) and a similar result was found in another study (Momani, 2006).

Total Dissolved Solids (TDS), Hardness, Calcium and Magnesium

Total inorganic mineral content of drinking water is indicated by TDS (Momani, 2006), whereas water hardness represents its contents of both Ca and Mg (Mahajan et al., 2006). In the current study, TDS for all 17 brands was less than the maximum limits recommended by both WHO (1000 mg/L) and USEPA (500 mg/L). As shown in Table 1, hardness of seven brands was not reported in the manufacturers' labels and another brand (Arwa) did not specify the number exactly, whereas the values of the other nine brands range from 10.00 to 90.00 mg/L. There are no maximum or minimum limits for hardness reported by USEPA but there is a maximum limit prescribed by WHO for aesthetic quality of bottled drinking water (500 mg/L). Mahajan et al. (2006) found that all analyzed samples had lower TDS and hardness values than WHO or USEPA recommended levels. A Qatarian study found that most of their samples had TDS less than 500 mg/L except for two brands (TDS >500 mg/L) and the same study showed that hardness of analyzed samples is within WHO levels (Momani, 2006). Water can be divided into four classes according to its hardness: soft (0-60 mg/L), moderately hard (61-120 mg/L), hard (121-180 mg/L) and very hard (≥180 mg/L) (Varrica et al., 2013). The results showed that the range of Ca concentration of the 17 brands is quite wide (1.00-80.00 mg/L), which indicates the variation of chemical compositions among the different brands of bottled drinking water. On the other hand, Mg has a range of 0.3-26.00 mg/L with an average of 9.80 mg/L. Some natural water sources contain Ca concentrations up to 800 mg/L (Momani, 2006).

Sodium and Potassium

Sodium concentration of 16 brands of our samples varied from 2.50 mg/L to 23.60 mg/L with an average of 11.56 mg/L, whereas the value of one brand (Crystal) was not provided. Arwa had the highest concentration of K (9.00 mg/L) and LuLu the lowest (<0.10 mg/L). High Na concentration contributes to the risk of hypertension and cardiovascular diseases (Garzon and Eisenberg, 1998; Momani, 2006; Mahajan et al., 2006). People with hypertension should not consume more than 20 mg/L/day of Na, as prescribed by both WHO and USEPA. In our samples, only one brand (Barzaman) had a Na concentration more than 20 mg/L. Momani (2006) found that Na concentration in all analyzed brands was less than the maximum limit recommended by WHO (200 mg/L). K is found in the body as the major intracellular cation and its low concentration may lead to glucose metabolism impairment (Mahajan et al., 2006). There are no established limits for K in drinking bottled water because it occurs in water in low concentrations that are below those levels that can cause health concern. However, health concerns may be raised regarding the effects of 'potassium based treatment' of water (i.e. potassium chloride treatment leads to exchange of K with Mg or Ca ions) on high risk groups (such as individuals with diabetes, hypertension, kidney dysfunction, heart disease, etc.) (WHO, 2011).

Chloride

From Table 1, the Cl^- concentration varied widely among the different brands studied here (<1.00 - 62.00 mg/L), but those concentrations were within normal level (<250 mg/L) reported by both WHO and USEPA for assurance of aesthetic quality of bottled drinking water. The local brand Aquafina did not report the value of Cl^- concentration. Cl^- level has no serious effects on human health but its concentration has an effect on the taste of drinking water. Water with chloride concentration more than 250 mg/L tastes salty and may affect plumbing systems (Momani, 2006; Saleh et al., 2008; WHO, 2011).

Nitrate

In this study, all analyzed brands that labelled NO_3^- concentrations had NO_3^- levels lower than the USEPA primary MCL (10 mg/L) and WHO maximum limit (50 mg/L), which is within normal limits. Four brands did not provide NO_3^- concentrations on their labels. NO_3^- is one of the inorganic contaminants of ground water and it has been implicated with mortality due to gastric cancer (Mahajan et al., 2006; Momani, 2006). NO_3^- can be converted to nitrite (NO_2^-), which is one of the causes of acquired methemoglobinemia in infants

Table 1: Composition of different commercial brands of bottled drinking water sold in the Sultanate of Oman

Composition (mg/L)	*Barzaman**	*Masafi**	*Oasis**	*Aquafina**	*Alazb**	*Darbat**	*EljabalElakhdar**	*Salsabeel*[¥]	*Majan**	*Jeema**	*Arwa**	*Alain**	*LuLu**	*Tanuf**	*Evian #*	*Volvic **	*Crystal **
pH	7.10	7.10	7.30	7.00	7.60	7.80	7.80	7.80	7.60	7.20	6.90	7.30	7.50	7.70	7.20	7.00	7.60
Calcium	8.60	9.00	6.35	< 5.00	12.00	5.20	7.90	8.00	12.00	<5.00	1.00	8.00	18.00	7.50	80.00	11.50	7.00
Magnesium	12.60	4.00	3.22	13.00	11.00	3.00	9.70	9.50	4.40	12.00	20.70	13.00	8.00	9.20	26.00	8.00	0.30
Sodium	23.60	15.00	7.73	16.00	15.00	11.50	11.90	12.00	12.00	8.00	2.50	8.00	12.00	11.60	6.50	11.60	NP
Potassium	0.80	0.60	0.26	1.00	1.20	0.80	1.00	1.00	1.400	< 5.00	9.00	2.00	< 0.10	1.00	1.00	6.20	1.40
Nitrate	3.10	3.50	NP	< 0.10	NP	NP	1.00	1.00	NP	0.10	< 1.00	< 0.30	< 0.10	1.00	3.70	6.30	0.16
Bicarbonate	34.40	30.00	NP	NP	NP	18.40	23.00	24.00	42.00	20.00	12.00	30.00	26.00	22.50	360.00	71.00	27.00
Fluoride	< 0.20	0.20	NP	NP	NP	0.06	NP	NP	0.60	0.02	< 0.10	< 0.10	0.00	NP	NP	NP	NP
Chloride	44.20	25.00	6.50	NP	12.00	14.00	36.00	36.50	23.00	12.00	< 1.00	40.00	62.00	35.00	6.80	13.50	48.00
Sulfate	18.60	13.00	NP	51.00	3.00	5.00	16.00	NP	32.00	55.00	77.40	5.00	< 5.00	15.00	12.60	8.10	5.00
Silica	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	15.00	31.70	NP
Total Dissolved Solids	100-150	105.00	107.00	110.00	120.00	120.00	120.00	110.00	120.00	115.00	115.00	110.00	120.00	115.00	309.00	130.00	110.00
Total hardness	NP	39.00	90.00	53.00	80.00	NP	NP	NP	48.00	60.00	<100.00	75.00	60.00	NP	NP	NP	10.00

NP: Not provided; Cost: * – $ 0.26, ¥ – $ 0.52, # – $ 1.30

(Mahajan et al., 2006; Momani, 2006; Saleh et al., 2008; Moazeni et al., 2013; USEPA, 2015).

Fluoride

Table 1 shows that about 53% (nine brands) of the 17 brands did not report the concentrations of F in the water. The companies which reported F contents gave values of ≤0.6 mg/L, which are less than the USEPA primary and secondary maximum contaminant levels (4.00 mg/L and 2.00 mg/L, respectively) and the health significance level recommended by WHO (1.5 mg/L). Moreover, one brand (LuLu) indicated that its water is free of F. Flourine is known for its beneficial effects on teeth within certain concentrations (1 mg/L or more), but it can cause fluorosis if its concentration is more than 2.0 mg/L (Mahajan et al., 2006; Momani, 2006). Johnson and DeBiase (2003) found that only 12.3% of tested brands had optimum levels of F and for that reason people who are dependent only on bottled water are strongly advised to use supplemental fluoride. Some parents use bottled drinking water for preparation of infant formula, which raises the concern about F concentration and its effects on infants' health in the case of either its excess or deficiency (Steinmetz et al., 2011).

Sulphate, Bicarbonate and Silica

In Table 1, almost all brands have a SO_4^{2-} concentration lower than 77.40 mg/L, except for two brands that did not indicate sulphate levels on their labels. SO_4^{2-} is harmless, but it has an effect on the taste of drinking water (Momani, 2006; Saleh et al., 2008; WHO, 2011). However, if its concentration exceeds 1000 mg/L, it may cause gastrointestinal irritation and dehydration due to its laxative effects (Momani, 2006; Saleh et al., 2008; WHO, 2011; Rabee et al., 2012). The recommended values by both WHO and USEPA for SO_4^{2-} concentration in bottled water are only for aesthetic quality and they are 500 mg/L and 250 mg/L, respectively. HCO_3^- concentrations varied from 12.00 mg/L to 360.00 mg/L, with an average of 52.88 mg/L in 82.40% of the brands. Silica was only reported by two of the brands, but Rondeau et al. (2008) reported that a 10 mg increase in daily intake of silica was associated with a decrease in the risk of dementia.

It should be mentioned that some companies in this study referred to their water as "mineral drinking water" which is not true because there are many characteristics that distinguish mineral drinking water from purified drinking water.

Table 2: U.S. Environmental Protection Agency (USEPA) and World Health Organization (WHO) drinking water quality regulations

Chemical compositions (mg/L)	*USEPA*		*WHO limits*	
	MCL[a], primary[b]	*MCL, secondary[c]*	*Guidelines for health significance*	*Guidelines for aesthetic quality*
pH	-	6.5-8.5	-	6.5-8.5
Calcium	-	-	-	-
Magnesium	-	-	-	-
Sodium	-	-	-	200
Potassium	-	-	-	-
Nitrate	10	-	50	-
Bicarbonate	-	-	-	-
Fluoride	4.0	2.0	1.5	-
Chloride	-	250	-	250
Sulfate	-	250	-	500
Silica				
Total Dissolved Solids	-	500	-	1000
Total hardness	-	-	-	500

[a]MCL: Maximum Contaminant Level,

[b]Primary Drinking Water Regulations: are legally enforceable to protect health.

[c]Secondary Drinking Water Regulations: are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odour, or colour) in drinking water.

Conclusion

The analysis of the labels of 17 brands of bottled drinking water sold in Oman revealed that pH of all brands was within normal limits prescribed by both WHO and USEPA. Concentrations of TDS, hardness, nitrate, chloride and sodium were lower than primary or secondary maximum contaminant levels prescribed by USEPA and/or WHO maximum limits. Fluoride was not reported by about 53% of the brands and it was very low in all brands that reported it.

To conclude, we recommend the following:

- Despite the fact that trace metals like Se, As, Ba, Cu, Fe, Mn, Zn, Cr, Cd and Pd may contaminate bottled drinking water, their levels were not reported on the labels of all brands. Therefore, we recommend that the companies should analyze and report the levels of those metals.
- Bottled drinking water should be continuously monitored to ensure absence of contamination by those metals.
- Analysis of water samples of bottled water sold in Oman and comparison of those samples with manufacturers' labels, and detection of the presence of microbes are warranted.

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