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Quality Level of Bottled Drinking Water Consumed in Saudi Arabia

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ABSTRACT

The quality of drinking water is a universal health concern and access to safe water is a fundamental human right. Many national and international organizations set certain parameters and levels for Bottled Drinking Water (BDW) to ensure their quality. The present work aims to analyze the quality of various brands of BDW used in Saudi Arabia and to compare the quality levels to the BDW standards. One hundred and twenty six samples of 54 different BDW brands were collected from the Saudi market. The quality level parameters were analyzed using portable meters for pH, EC and TDS; spectrophotometer, HACH DR-2800 for F, SO_4 and NO_3; Inductively Coupled Plasma (ICP) Mass Spectrometer (MS) and atomic emission spectrometer (AES) for elemental analysis. To evaluate the quality level parameters of BDW, the parameters were classified as following: (1) Parameters and substances affect the quality of BDW (pH, EC, TDS, HCO_3, F, NO_3 and SO_4). (2) Macronutrients (Ca, K, Mg and Na). (3) Micronutrients-trace elements (Co, Cr, Cu, Fe, Mo, Se and Zn), (4) Potentially essential elements that have some beneficial health effects (B, Mn, Ni and V) and (5) Toxic elements (Al, As, Cd, Hg, Pb, Th and U) using Inductively coupled plasma-mass spectrometry, ICP-MS. The concentrations of the detected elements were compared with the Golf and international standard like World Health Organization.

Key words: Bottled drinking water, quality levels, Saudi Arabia, HACH DR-2800-ICP-MS

INTRODUCTION

The World Health Organization (WHO) asserts that drinking water an essential source of minerals-can play an important role in human nutrition (WHO, 2007). Due to the availability of minerals in their ionic form in drinking water, it has been suggested that the intake of minerals in drinking water can help to enhance their absorption by the gastrointestinal tract (Azoulay *et al.*, 2001). Human beings have a fundamental requirement for water, needing 1.8-2.0 L day^{-1} to maintain good health under normal circumstances. Drinking water is water pure enough to be consumed with low immediate or long-term risks. In many parts of the world, humans have inadequate access to drinking water and use sources contaminated with disease vectors, pathogens, or unacceptable levels of toxins or suspended solids. Using such water leads to widespread acute and chronic illnesses and is a major cause of death and misery in many countries. For these reasons, the reduction of water borne diseases is considered as a main public health goal in developing countries. Drinking water with different qualities is now bottled and sold for public consumption throughout the world (Al-Omran *et al*., 2012). The average annual renewable freshwater resources of the Arabian Gulf countries Bahrain, Kuwait, Oman, Qatar, Saudi Arabia (SA) and the United Arab Emirates (UAE) are 0.1, 0.02, 1.0, 0.1, 2.4 and 0.2 km^3 $year^{-1}$, respectively (Gleick, 2008).

According to the latest statistical report (Table 1). the global consumption of bottled water reached 232 billion liters (61.4 million Gallon) in 2011, increased by 31% from the 178 billion liters (47 million Gallon) consumed 5 years earlier (Rodwan, 2011). While in 2005, the global consumption of bottled water was reached 162 billion liters and increased by 52% from the 107 billion liters consumed 5 years earlier. In Saudi Arabia, water is a scarce and extremely valuable resource. The majority of water consumption is supplies by depleting nonrenewable

Table 1: List of bottled drinking bottled water samples, brands, codes and No. of bottles of each brand

Local				Importer			
Ser.	Brand	Code	N	Ser.	Brand	Code	N
L-1	Safa	S	6	I-1	Highland	G	4
L-2	AL-qassium	Q	4	I-2	Evian	EI	2
L-3	Hada	D	4	I-3	Volvic	V	2
L-4	Aquafina	A	2	I-4	Nord	R	2
L-5	Pure-life	B	6	I-5	Galfa	GG	1
L-6	Hana	H	2	I-6	Masafi	SS	2
L-7	One	M	2	I-7	Buokein	BO	2
L-8	Nova	N	6	I-8	Vittel	VI	2
L-9	Nova-glass	F	2	I-9	Hamidya	HA	2
L-10	Mozen	T	2	I-10	Alit	EI	2
L-11	Haley	I	2	I-11	Tanouren	TN	1
L-12	Najran	NJ	2	I-12	Voban	VN	1
L-13	Panda	P	2	I-13	Jovance	JO	1
L-14	Arwa	U	2	I-14	Jovance-2	JOO	1
L-15	Fayha	J	2	I-15	Padwa	BR	4
L-16	Hana	EF	2	I-16	Grand perrier	GB	2
L-17	Alain	X	2	I-17	Fiji	FJ	2
L-18	Hilwa	OP	2	I-18	Watweiler	WA	2
L-19	Hayat	CD	2	I-19	Voss	VS	2
L-20	Maeen	KN	2	I-20	Apollinaris classic	C	3
L-21	Alwaid	KL	2	I-21	S. pellegino	L	4
L-22	Hail	AB	2	I-22	Sorti	O	1
L-23	Qatrat sahab	QS	2	I-23	Perrier	K	2
L-24	Juman	ST	2				
L-25	Taiba	UV	2				
L-26	Tania	XY	2				
L-27	Dala	DL	2				
L-28	Manhal	MM	2				
L-29	Yanabeaalwadi	YA	1				
L-30	Zamzam	Z	4				
L-31	Bambini	Y	2				
Total No. of samples			79	Total No. of samples			47
Total No. of brands			31	Total No. of brands			2 3

groundwater and desalination. Saudi Arabia is the world's largest producer of desalinated water which covers 70% of the total water demand (Ahmad and Bajahlan, 2009). Although, tap water is safe to drink, demand for bottled water is increasing. Saudi Arabia was the 12th largest country per capita consumption of bottled water in 2005. In that year, about 2.4 billion liters bottled water was consumed by Saudi inhabitants. That translates into an annual average of 92.3 L capita^{-1}.

The quality of drinking water is a universal health concern and access to safe water is a fundamental human right and basic human need. Drinking water is considered an essential nutrient and an important source of Trace Elements (TE) and minerals for humans. In addition to its basic necessity for all known forms of life, water can play a central and important role in human health and nutrition (WHO, 2007).

Several publications focused on the quality of bottled water that consumed in Saudi Arabia (Kawther and Suaad, 2007; Ahmad and Bajahlan, 2009; Alabdulaaly and Khan, 1999; Al-Omran *et al*., 2012; Al-Saleh and Al-Doush, 1998; Al-Abdulaaly, 1997; 1998; Alabdulaaly and Khan, 2009; Aldrees and Al-Manea, 2010; Khan and Chohan, 2010; Tayyeb *et al*., 1998; Zahad and Mohamed, 2002) and in other countries (Al-Mudhaf and Abu-Shady, 2012; Al-Mudhaf *et al*., 2009; Baba *et al*., 2008; Bertoldi *et al*., 2011; Birke *et al*., 2010; Bityukova and Petersell, 2010; Bong *et al*., 2009; Brencic and Vreca, 2007; Cicchella *et al*., 2010; Cidu *et al*., 2011; De Sousa *et al*., 2005; Desideri *et al*., 2007; Dinelli *et al*., 2010; Feru, 2004; Frengstad *et al*., 2010; Fugedi *et al*., 2010; Guler *et al*., 2002; Guler and Alpaslan, 2009; Karamanis *et al*., 2007; Kim *et al*., 2012; Krachler and Shotyk, 2009; Kralik *et al*., 2003; Mills *et al*., 2010; Misund *et al*., 1999; Palomo *et al*., 2007; Peh *et al*., 2010; Rosborg *et al*., 2005; Seghour and Seghour, 2009; Smedley, 2010; Sullivan and Leavey, 2011; Vandevijvere *et al*., 2009; Yao and Byrne, 1999). Due to the importance of water for human life, its quality must be strictly controlled. The present work aims at ensuring the quality of bottled drinking water consumed in the Saudi market according to the gulf and international standards.

MATERIALS AND METHODS

Bottled drinking water samples were collected, from the local market of Riyadh and Hail Cities-Saudi Arabia. According to their manufacture (Table 1) 79 locally produced from 31 Saudi's brands and 47 imported from 23 brands from different countries such as France, USA, Jordan, Germany and Lebanon, a total of 126 water bottles were collected. Most of the collected bottles were 1.5 L capacity and some bottles were from 0.5-2 L capacity. Collected samples were kept in dark place for sample preservation. Composite samples of about 40 mL were prepared for each brand from the collected bottles. These samples were acidified using ultra-pure nitric acid (HNO_3). Two analytical techniques were used.

Spectrophotometer: Florid (F), nitrate (NO_3^-) and sulfate (SO_4^-) concentrations (mg L^{-1}) in each of the 126 bottles were measured in our laboratory in Riyadh using spectrophotometer, HACH DR-2800. Also, bicarbonate (HCO_3^-) concentrations were measured using alkalinity kit from HACH Co.-Germany.

Inductively coupled plasma-mass spectrometry, ICP-MS: Inductively coupled plasma-mass spectrometry (ICP-MS) is undoubtedly the fastest growing trace element technique available today because its ability to carry out rapid multi-elements determination at ultra-trace level. An ICP-MS can be thought of as four main processes, including sample introduction and aerosol generation,

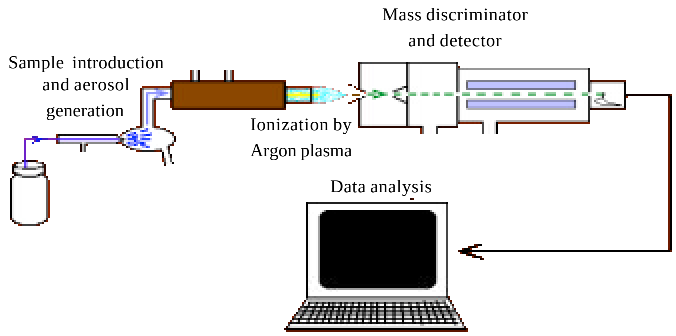

Fig. 1: Schematic diagram of ICP-MS main processes

ionization by an argon plasma source, mass discrimination and the detection system. The schematic diagram below illustrates this sequence of processes (Fig. 1). For inductively coupled plasma-mass spectrometry (ICP-MS) and Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) analysis a composite sample of each bottled water brand was sent to ALS-chemical laboratories-Vancouver-Canada. The instrument used for trace elements measurements was a Perkin Elmer SCIEX ELAN6100 quadruple based ICP-MS.

RESULTS AND DISCUSSION

Drinking water supplies may contain some of the fourteen essential minerals for good human health. These minerals in combination affect bone and membrane structure (Ca, Mg, P), water and electrolyte balance (Na, K, Cl), metabolic catalysis (Zn, Cu, Se, Mg, Mn, Mo), oxygen binding (Fe) and hormone functions (I, Cr). Micronutrient deficiencies may increase morbidity, mortality due to reduced immune defense systems and impaired physical and mental development. Deficiencies of some mineral elements, particularly iron and iodine are the main cause of health concerns in many parts of the world Usually only major elements concentrations are reported on the labels, while trace elements are ignored. As long as the mineral water is consumed in limited amounts or for short periods of time this may not constitute a problem but this may not be the case if consumption rates are high. It has long been recognized that trace elements content of drinking water can have either adverse or beneficial effects on human health depending on concentrations (Selinus *et al*., 2005). Standards might be influenced by national priorities and economic considerations and thus the conclusion on whether or not the health benefit of a specific standard justifies the costs involved is left to each individual country.

According to GSO (2009), water parameters were classified into the following categories:

- General characteristics and material that affect the water quality
- Macronutrients (major elements)
- Micronutrients (trace elements)
- Toxic elements

Table 2: Descriptive statistics of pH value, electrical conductivity (EC), total dissolved salts (TDS), total hardness as bicarbonate (HCO_3), florid (F), nitrate (NO_3) and sulphate (SO_4) in bottled drinking water

Element	pH (µS cm^{-1})	EC (mg L^{-1})	TDS (mg L^{-1})	HCO_3 (mg L^{-1})	F (mg L^{-1})	NO_3^-N (mg L^{-1})	NO_3 (mg L^{-1})	SO_4(mgL^{-1})
Mean	7.18	454	226.5	168	0.81	0.95	4.21	62
Standard error	0.07	49	24.5	24	0.04	0.08	0.34	12
Median	7.43	235	116.5	80	0.99	0.65	2.9	25
Mode	7.43	201	100.0	60	1.17	0.50	2.3	35
Standard deviation	0.83	552	275.2	268	0.50	0.87	3.85	128
Sample variance	0.68	304675	75757	71899	0.25	0.76	14.84	16347
Kurtosis	2.01	8	8.6	14	-1.39	9.04	8.90	14
Skewness	-1.56	3	2.9	3.68	-0.32	2.79	2.78	3.8
Range	4.34	2896	1450	1520	1.69	5.1	22.5	669
Minimum	4.04	7	3	20	0.01	0.1	0.4	1
Maximum	8.38	2903	1453	1540	1.7	5.2	22.9	670
Count	126	126	126	126	126	126	126	114
GSO (2009)	6.5-8		100-600		0.8-1.5		50	250
WHO (2011)	6.5-9.5	-	-	-	1.5	-	50	-

General characteristics and material that affect the water quality: The pH value, Electrical Conductivity (EC), Total Dissolved Salts (TDS), total hardness as bicarbonate (HCO_3), florid (F), nitrate (NO_3) and sulphate (SO_4) are parameters that affect the quality of the water. Usually their values are written in the bottle's label. The descriptive statistics data for all these parameters were given in Table 2.

pH value: The pH of drinking water is often considered to be one of the most important operational parameters, although it usually has no direct impact on the consumer (Al-Mudhaf *et al.*, 2009). The pH number is an expression of the concentration of H+ ion in the solution. The pH lower than 4 will produce sour taste and higher value above 8.5 bitter tastes. The pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Ct, Cu etc. An optimal pH range of 6.5-9.5 is recommended by the (WHO, 2011), whereas, a range of 6.5-8.5 has been set by the (USEPA, 2004). The average±SD (range), No. of data of pH values were 7.18±0.82 (4.04-8.34), 126; 7.36±0.06 (4.04-8.34), 79 and 6.85±1.09 (4.95-8.1), 47 for all, locally produced and imported samples, respectively. The pH value should be between 6.5 and 8.

Total dissolved salts (TDS) and electrical conductivity (EC): The EC reflects the amount of TDS and can (in some cases) predict the concentrations of individual ions. EC can also be used to identify and analyze the sources of the various types of natural water and to provide information regarding the hydrologic behavior of ground water. The large difference between the minimum and maximum EC values of the bottled waters was related to their TDS content which depends on the origin of the water source and the operational technology, i.e., used to treat or purify the water during the bottling process (Guler and Alpaslan, 2009).

The TDS and EC values of the samples vary in a quite wide range from 3 to 2903 mg L^{-1} and from 7-2903 µS cm^{-1}. According to TDS values, samples could be separated into two main groups, the major group 80% of the whole samples of TDS value less than 250 mg L^{-1} (with 90% of them are below 200 mg L^{-1}), the rest of the samples, about 20% have a TDS value above 250 mg L^{-1} up 2903 mg L^{-1}. The average±SD (range), No. of data for TDS values were 227±275

(3-1453), 126; 122±65 (39-475), 79 and 391±389 (3-1453), 47 for all, locally produced and imported samples, respectively. According to GSO (2009), the TDS value should be within the range of 100-600 mg L^{-1}. Some of the locally produced samples were below the lower limit of TDS of GSO. While some of the imported samples were out of the GSO standard range (100-600 mg L^{-1}). The average±SD (range), No. of data for EC values were 431±555 (8-2903), 126; 244±130 (78-951), 79 and 782±781 (7-2903), 47 for all, locally produced and imported samples, respectively. TDS is the second-most important parameter of water quality. TDS includes the inorganic salts (principally Ca, Mg, K, Na, HCO_3, Cl and SO_4) and small amounts of dissolved organic matter in the water. A maximal TDS concentration of 500 mg L^{-1} is recommended by the USEPA (2004).

Florid (F): It is generally recognized that fluoride levels in drinking water can have both positive and negative effects on human health. The role of fluoride was studied by Clarkson and McLoughlin Clarkson and McLoughlin (2000) and lower fluoride concentrations have been correlated with dental caries. To prevent dental caries, many studies (WHO, 2002, 2003; Bruvo *et al.*, 2008) recommend that the fluoride levels in drinking water should be adjusted in areas in which the concentration of fluoride is below 1.5 mg L^{-1}.

Florid concentrations vary in a quite wide range from 0.01-1.7 mg L^{-1}. According to F concentration, samples could be separated into two equal groups, one below 1 mg L^{-1} and the second higher than 1 mg L^{-1}. The average±SD (range), No. of data for F concentration were 0.81±0.5 (0.01-1.7), 126; 1.06±0.36 (0.01-1.64), 79 and 0.4±0.42 (0.01-1.7), 47 for all, locally produced and imported samples, respectively. According to GSO (2009), the F concentration should be within the range 0.8-1.5 mg L^{-1}. Only one imported sample (code, VN) exceeded the F concentration limit. The F concentration was less than 0.8 mg L^{-1} in three locally produced samples (codes, KL, AB and Z) and in most of the imported samples. The standard of quality and maximum admissible concentration for F is 0.8-2.4 mg L^{-1} tgfhat was given by IBWA and FDA, respectively.

Nitrate (NO_3^-): NO_3^- and NO_2^- are part of the nitrogen cycle and are naturally occurring ions. High NO_3 concentrations (>50 mg L^{-1}) have been linked to increased rates of miscarriage and birth defects, reduced body growth and slower reflexes, stomach cancer, leukemia, non-Hodgkin's lymphoma, increased thyroid size and "blue baby" syndrome (Virkutyte and Sillanpa, 2006; Entry and Framer, 2001). The average±SD (range), No. of data for NO_3^- concentration were 3.96±3.34 (0.4-23), 126; 4.56±3.93 (0.4-23), 79 and 2.96±1.65 (1.1-9.5), 47 for all, locally produced and imported samples, respectively. For NO_3^- concentrations as N were 0.89±0.75 (0.1-5.2), 126; 1.03±0.89 (0.1-5.2), 79 and 0.66±0.37 (0.2-2.1), 47 for all, locally produced and imported samples, respectively. According to GSO (2009), NO_3^- concentration should not exceed 50 mg L^{-1}.

Sulfate (SO_4^{-2}): The ingestion of drinking water with high SO_4^{-2} levels can lead to gastrointestinal irritation and can have life-threatening effects such as catharsis and dehydration (Saleh *et al.*, 2001). The average±SD (range), No. of data for SO_4^{-2} concentration were 55±124 (ND-670), 126; 28±23 (0.4-23), 79 and 100±192 (ND-670), 47 for all, locally produced and imported samples, respectively. According to GSO (2009), the maximum SO_4^{-2} concentration should be 250 mg L^{-1}.

Total Hardness as HCO_3^-: Several studies have linked the prevalence of eczema with drinking water hardness (McNally *et al.*, 1998; Miyake *et al.*, 2004; Arnedo-Pena *et al.*, 2007). It is also been suggested that eczema is indirectly triggered by patterns of soap use. A recent study has suggested

Table 3: Descriptive statistics of calcium (Ca), potassium (K), magnesium (Mg) and sodium (Na) concentrations, mg L^{-1}, in bottled drinking water

Element	Ca	K	Mg	Na
All				
Mean	36.6	3.7	14.1	34.5
Standard error	6.87	1.18	3.03	8.82
Median	15.95	0.95	5.10	19.00
Mode	14.00	1.07	2.11	26.00
Standard deviation	51.4	8.8	22.7	66.0
Sample Variance	2641	77	515	4354
Kurtosis	5.91	14.24	11.50	32.70
Skewness	2.43	3.77	3.19	5.30
Range	242	43	125	459
Minimum	0.3	0.07	0.038	1.7
Maximum	242	43	125.5	461
Sum	2048	206	789	1929
Count	56	56	56	56
Locally produced				
Mean	15.7	3.8	4.9	27.9
Standard error	2.4	1.9	0.8	3.9
Median	14.1	0.8	3.3	22.0
Mode	14.0	1.1	2.1	26.0
Standard deviation	13.7	10.5	4.5	21.9
Sample variance	188	110	20	482
Kurtosis	6.5	12.0	3.1	5.8
Skewness	2.1	3.6	1.9	2.3
Range	68	43	19	98
Minimum	0.3	0.08	0.308	1.7
Maximum	69	43	20	100
Sum	503	122	158	893
Count	33	33	33	33
Imported				
Mean	64.4	3.5	26.3	43.2
Standard error	13.9	1.2	6.2	20.0
Median	42.45	1.065	13.85	7.05
Mode		0.71		12
Standard deviation	68.2	6.1	30.5	98.1
Sample variance	4650	37	933	9624
Kurtosis	0.85	11.71	3.97	15.34
Skewness	1.28	3.21	1.98	3.74
Range	242	28	125	459
Minimum	0.4	0.07	0.038	2.3
Maximum	242	28	126	461
Sum	1545	84	631	1036
Count	23	23	23	23
GSO (2009)	-	-	150	-

that soap can disrupt the skin barrier, particularly in children. The average±SD (range), No. of data for HCO_3^- concentration were 169±270 (20-1540), 126; 69±270 (40-280), 79 and 331±385 (20-1540), 47 for all, locally produced and imported samples, respectively. According to GSO (2009), the total hardness should not exceed 200 mg L^{-1}.

Macronutrients (major elements): Macronutrients (major elements) in water include calcium (Ca), potassium (K), magnesium (Mg) and sodium (Na). According to GSO (2009) and other international organization (WHO, 2008; Bruvo *et al*., 2008), there is no certain specification of their concentrations in bottled drinking water. Descriptive statistics of macronutrient and their concentrations are given in Table 3. According to Lebanon standard organization, the following limits were set for the major elements in bottled drinking water; Calcium (Ca), 81 mg L^{-1} Potassium (K), 12 mg L^{-1} Magnesium (Mg), 50 mg L^{-1} Sodium (Na) 150 mg L^{-1} Drinking calcium poor water is considered dangerous for the risk of coronary diseases. An excess in calcium can alter the water taste or cause scaling problems in pipes and household appliances. The World Health Organization (WHO) recommends a minimum calcium daily intake of about 700 mg. The daily recommended intake for Mg is 150-500 mg (Kawther and Suaad, 2007).

Micronutrients (trace elements): It has long been recognized that trace elements content of drinking water can have either adverse or beneficial effects on human health depending on concentrations (Selinus *et al*., 2005). Micronutrients (trace elements) include cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), molybdenum (Mo), selenium (Se) and zinc (Zn). Descriptive statistics of macronutrients and their concentrations are given in Table 4.

Cobalt (CO): The average Co concentration (μg L^{-1})±SD (range), No. of data were 0.15±0.08 (0.1-0.4), 20; 0.14±0.08 (0.1-0.3), 7 and 0.15±0.09 (0.1-0.4), 13 for all, locally produced and imported samples, respectively. According to GSO (2009), as well as other international organizations, there is no maximum admissible concentration for cobalt.

Chromium (Cr): The solubility of Cr in most water is low; however, with decreasing pH the solubility increases. The average Cr concentration (μg L^{-1})±SD (range), No. of data were 5.8±6.9 (1-23), 12; 5.0±5.1 (1-12), 7 and 7.0±9.4 (1-23), 5 for all, locally produced and imported samples, respectively. According to GSO (2009), Cr concentration should not exceed 50 μg L^{-1}.

Copper (Cu): The average Cu concentration (μg L^{-1})±SD (range), No. of data were 2.6±5.7 (0.3-27), 20; 4.03±7.37 (0.4-27), 6 and 0.77±0.59 (0.3-2.3), 16 for all, locally produced and imported samples, respectively. According to GSO (2009), Cu concentration should not exceed 1000 μg L^{-1}.

Iron (Fe): The average Fe concentration (μg L^{-1})±SD (range), No. of data were 145±124 (20-460), 20; 57±27(20-100), 6 and 183±131 (30-460), 14 for all, locally produced and imported samples, respectively. According to GSO (2009), Fe concentration should not exceed 300 μg L^{-1}.

Molybdenum (Mo): The average Mo concentration (μg L^{-1})±SD (range), No. of data were 9±15 (1-39), 16; 17±20 (1-39), 5 and 6±10 (1-37), 11 for all, locally produced and imported samples, respectively. According to GSO (2009), Mo concentration should not exceed 70 μg L^{-1}.

Selenium (Se): Selenium concentration in all samples was less than 10 μg L^{-1}, except one sample, code-Z (10 μg L^{-1}). According to GSO (2009), Se concentration should not exceed 10 μg L^{-1}.

Zinc (Zn): The average Zn concentration (μg L^{-1})±SD (range), No. of data were 7±9 (2-57), 56; 8±11 (2-57), 33 and 5±4 (2-21), 23 for all, locally produced and imported samples, respectively. According to GSO (2009), Zn concentration should not exceed 100 μg L^{-1}.

Table 4: Descriptive statistics of cobalt (Co), chromium (Cr), cupper (Cu), iron (Fe), molybdenum Mo), selenium (Se) and zinc (Zi) concentration in bottled drinking water

Element	Co	Cr	Cu	Fe	Mo	Se	Zn
DL	0.1	1	0.3	20	1	10	2
Unit	ug L^{-1}	ug L^{-1}	ug L^{-1}	ug L^{-1}	ug L^{-1}	ug L^{-1}	ug L^{-1}
All							
Mean	0.15	5.83	2.55	145	9.13	10	6.9
Standard error	0.02	1.98	1.21	28	3.64		1.15
Median	0.10	1.50	0.70	100	2.50	10	4.0
Mode	0.10	1.00	0.60	60	2.00		3.0
Standard deviation	0.08	6.87	5.67	124	14.54		8.58
Sample variance	0.01	47	32	15458	211		74
Kurtosis	3.44	2.48	17	0.76	1.26		22
Skewness	1.86	1.57	4.02	1.24	1.75		4.2
Range	0.3	22	26.3	440	38	0	55
Minimum	0.1	1	0.3	20	1	10	2
Maximum	0.4	23	26.6	460	39	10	57
Sum	3	70	56.1	2900	146	10	388
Count	20	12	22	20	16	1	56
Locally produced							
Mean	0.14	5.00	4.03	56.67	16.60	10	8.22
Standard error	0.03	1.91	2.16	10.85	9.15	0	1.88
Median	0.10	1.00	1.05	60.00	2.00	10	5.00
Mode	0.10	1.00	1.30	60.00	2.00		3.00
Standard deviation	0.08	5.07	7.47	26.58	20.45		10.62
Sample variance	0.01	25.67	55.74	706.67	418.30		112.89
Kurtosis	2.36	-2.35	9.18	1.33	-3.33		14.85
Skewness	1.76	0.50	2.96	0.44	0.61		3.60
Range	0.2	11	26.2	80	38	0	55
Minimum	0.1	1	0.4	20	1	10	2
Maximum	0.3	12	26.6	100	39	10	57
Sum	1	35	48.4	340	83	10	263
Count	7	7	12	6	5	1	33
Imported							
Mean	0.15	7	0.77	183	5.73		5.21
Standard error	0.02	4.21	0.19	35.03	3.15		0.88
Median	0.1	2	0.55	160	3		4
Mode	0.1	1	0.5	50	4		2
Standard deviation	0.09	9.41	0.59	131.06	10.45		4.30
Sample variance	0.01	89	0.35	17176	109		19
Kurtosis	4.83	2.97	5.79	-0.21	10.56		7.29
Skewness	2.05	1.8	2.28	0.79	3.23		2.45
Range	0.3	22	2	430	36		19
Minimum	0.1	1	0.3	30	1		2
Maximum	0.4	23	2.3	460	37		21
Sum	2	35	7.7	2560	63		125
Count	13	5	10	14	11	0	23
GSO (2009)	-	50	1000	300	70	10	100
WHO (2011)	--	50	2000	-	-	40	-

Potentially essential elements that have some beneficial health effects: Boron (B), Manganese (Mn), Nickel (Ni) and Vanadium (V) are elements that may be considered essential for human and have some beneficial health effects. Descriptive statistics of their concentrations are given in Table 5.

Boron (B): The average B concentration (μg L^{-1})±SD (range), No. of data were 143±159 (10-870), 51; 212±168 (60-870), 32 and 36±47 (10-160), 19 for all, locally produced and

Table 5: Descriptive statistics of boron (B), manganese (Mn), nickel (Ni) and vanadium (V) concentration in bottled drinking water

Element	B	Mn	Ni	V
Unit	ug L^{-1}	ug L^{-1}	ug L^{-1}	mg L^{-1}
DL	10	0.1	0.5	1
All				
Mean	143	1.32	2.11	0.013
Standard error	22	0.67	0.35	0.002
Median	110	0.3	1.4	0.01
Mode	10	0.2	0.6	0.01
Standard deviation	159	5.0	2.05	0.01
Sample variance	25296	25	4.2	9.79E-05
Kurtosis	8.9	43	1.9	16
Skewness	2.5	6.4	1.6	3.8
Range	860	36	7.9	0.05
Minimum	10	0.1	0.5	0.01
Maximum	870	36	8.4	0.06
Count	51	56	34	33
Locally produced				
Mean	212	0.38	1.47	0.013
Standard error	30	0.07	0.52	0.0013
Median	180	0.3	0.8	0.01
Mode	180	0.2	0.6	0.01
Standard deviation	168	0.40	2.01	0.006
Sample variance	28281	0.16	4.04	0.00004
Kurtosis	7.8	17.7	11.8	3.9
Skewness	2.5	3.93	3.33	2.23
Range	810	2.2	7.9	0.02
Minimum	60	0.1	0.5	0.01
Maximum	870	2.3	8.4	0.03
Count	32	33	15	23
Imported				
Mean	36	2.6	2.61	0.015
Standard error	10	1.5	0.46	0.005
Median	10	0.3	2.2	0.01
Mode	10	0.2	0.60	0.01
Standard deviation	47	7.5	1.99	0.02
Sample variance	2183	57	4.0	0.0002
Kurtosis	3.8	18	-0.64	11
Skewness	2.1	4.1	0.80	3.3
Range	150	36	6	0.05
Minimum	10	0.1	0.5	0.01
Maximum	160	36	6.5	0.06
Count	19	23	1919	10
GSO (2009)	500	10	20	-
WHO (2011)	2400	-	70	-

imported samples, respectively. According to GSO (2009), B concentration should not exceed 500 μg L^{-1}. The WHO guideline value for B in drinking water is 2400 μg L^{-1}.

Manganese (Mn): The average Mn concentration (μg L^{-1})±SD (range), No. of data were 1.32±5 (0.1-36), 56; 0.38±0.40 (0.1-2.3), 33 and 2.6±7.5 (0.1-36), 23 for all, locally produced and imported samples, respectively. According to GSO (2009), Mn concentration should not exceed 100 μg L^{-1}.

Nickel (Ni): The average Ni concentration (μg L^{-1})±SD (range), No. of data were 2.1±2.1 (0.5-8.4), 34; 1.5±2.0 (0.5-8.4), 15 and 2.6±2.0 (0.5-6.5), 19 for all, locally produced and imported samples, respectively. According to GSO (2009), Ni concentration should not exceed 20 μg L^{-1}.

Vanadium (V): The average V concentration (μg L^{-1})±SD (range), No. of data were 13±10 (10-60), 33; 13±6 (10-30), 23 and 15±20 (10-60), 10 for all, locally produced and imported samples, respectively. There are no data on V oral toxicity. The lack of data on acute or chronic oral toxicity is not surprising because of the extremely low absorption of V from the gastrointestinal tract. Inhaled V can produce adverse health effects but the available evidence does not indicate that V in drinking water is a problem.

Toxic elements: Toxic elements that have harmful effects on the human health include aluminum (Al), Arsenic (As), Cadmium (Cd), lead (pb), mercury (Hg), Thorium (Th) and Uranium (U)). Descriptive statistics of their concentrations are given in Table 6.

Aluminum (Al): Aluminum is the third most abundant metallic element and constitutes about 8% of Earth's crust. Aluminum salts are widely used in water treatment as coagulants to reduce organic matter, colour, turbidity and microorganism levels (WHO, 2011). The average Al concentration (μg L^{-1})±SD (range), No. of data were 422±754 (50-1770), 5; 515±837 (70-1770), 4 and 50±-(50-50), 1 for all, locally produced and imported samples, respectively. According to GSO (2009), Al concentration should be less than 100 μg L^{-1}. Several epidemiological studies demonstrate that aluminum exposure is a risk factor in the development or acceleration of onset of Alzheimer's disease in humans (Exley, 2001).

Arsenic (As): Arsenic is widely and evenly distributed in solids and water in low concentrations. Generally, the earth crust contains an average of 2 mg kg^{-1} or less of arsenic. Most of the arsenic in water occurs naturally from erosion of rock surfaces. Where arsenic concentrations are abnormally high, the source is usually industrial. Arsenic (AS) concentration in all samples was less than 10 μg L^{-1}, except one sample, code-Z (10 μg L^{-1}). According to GSO (2009), Se concentration should not exceed 10 μg L^{-1}.

Cadmium (Cd): Humans are exposed to Cd as a result of its ingestion from food or water, with the major contribution coming from food. The average Cd concentration (μg L^{-1})±SD (range), No. of data were 0.19±0.17 (0.1-0.7), 16; 0.14±0.10 (0.1-0.4), 9 and 0.26±0.23 (0.1-0.7), 7 for all, locally produced and imported samples, respectively. According to GSO (2009), Cd concentration should not exceed 3 μg L^{-1}.

Mercury (Hg): Mercury is one of the earth's rarest elements. In its natural state it occurs mainly in combination with sulfur. The average Hg concentration (μg L^{-1})±SD (range), No. of data

Table 6: Descriptive statistics aluminum (Al), arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), thorium (Th) and uranium (U) concentration in bottled drinking water

Element	Al	As	Cd	Hg	Pb	Th	U
Unit	μg L^{-1}	μg L^{-1}	μg L^{-1}	μg L^{-1}	μg L^{-1}	μg L^{-1}	μgL^{-1}
DL	50	10	0.1	0.2	0.02	0.01	0.01
All							
Mean	422	10	0.19	0.53	0.3	0.05	0.49
Standard error	337	0	0.04	0.13	0.04	0	0.17
Median	100	10	0.1	0.3	0.3	0.05	0.1
Mode		10	0.1	0.3	0.4		0.01
Standard deviation	754	0	0.17	0.65	0.1		1.09
Sample variance	568570	0	0.03	0.43	0.01		1.20
Kurtosis	4.97		4.09	17.95	-2.6		22.3
Skewness	2.23		2.05	4.05	9.33		4.39
Range	1720	0	0.6	3.2	0.2	0	6.53
Minimum	50	10	0.1	0.2	0.2	0.05	0.01
Maximum	1770	10	0.7	3.4	0.4	0.05	6.54
Sum	2110	20	3.1	12.6	2.1	0.05	22
Count	5	2	16	24	7	1	44
Locally produced							
Mean	515	10	0.14	0.61	0.3	0.05	0.18
Standard error	418	0	0.03	0.17	0.044721	0	0.04
Median	110	10	0.1	0.35	0.3	0.05	0.095
Mode	-	10	0.1	0.3	0.4		0.01
Standard deviation	837	0	0.10	0.74	0.1		0.20
Sample variance	700433	0	0.01	0.54	0.01		0.04
Kurtosis	3.99		6.34	14	-3		0.26
Skewness	2.00		2.51	3.58	1.11		1.17
Range	1700	0	0.3	3.2	0.2	0	0.67
Minimum	70	10	0.1	0.2	0.2	0.05	0.01
Maximum	1770	10	0.4	3.4	0.4	0.05	0.68
Sum	2060	20	1.3	10.9	1.5	0.05	4.33
Count	4	2	9	18	5	1	25
Imported							
Mean	50		0.26	0.28	0.4		0.87
Standard error	-		0.09	0.05	0		0.35
Median	50		0.10	0.20	0.4		0.26
Mode			0.10	0.20			0.01
Standard deviation			0.23	0.13			1.55
Sample variance			0.05	0.02			2.39
Kurtosis			1.50	-0.46			9.77
Skewness			1.43	1.21			2.93
Range	0		0.60	0.30	0	0	6.53
Minimum	50		0.10	0.20	0.4	0	0.01
Maximum	50		0.70	0.50	0.4	0	6.54
Sum	50		1.80	1.70	0.4	0	17.37
Count	1	0	7	6	1	0	19
GSO (2009)	100	10	3	1	20	-	15
WHO (2011)	-	10	3	6	10	-	30

were 0.53±0.65 (0.2-3.4), 23; 0.61±0.74 (0.2-3.4), 17 and 0.28±0.13 (0.2-0.5), 6 for all, locally produced and imported samples, respectively. According to GSO (2009), Hg concentration should not exceed 1 μg L^{-1}.

Lead (pb): The average Pb concentration (μg L^{-1})±SD (range), No. of data were 0.3±0.1 (0.2-0.4), 7; 0.3±1.1 (0.2-0.4), 6 and 0.4±-(0.4-0.4), 1 for all, locally produced and imported samples, respectively. According to GSO (2009), Pb concentration should not exceed 20 μg L^{-1}.

Uranium (U): The average U concentration (μg L^{-1})±SD (range), No. of data were 0.49±1.09 (0.01-6.5), 44; 0.18±0.2 (0.01-0.68), 25 and 0.87±1.55 (0.01-6.54), 19 for all, locally produced and imported samples, respectively. According to GSO (2009), U concentration should not exceed 15 μg L^{-1}. The health and environmental protection agencies have recommended a safe limit of U in drinking water for human beings that do not result in any significant risk to health over a lifetime drinking water. The World Health Organization (WHO, 2011) and U.S. Environmental Protection Agency (USEPA, 2011) have recommended 30 μg L^{-1} of U in water as the safe limit. However, UNSCEAR (2000) recommended the safe limit as 9 μg L^{-1} and the International Commission on Radiological Protection (ICRP, 1994) has recommended the safe limit as 1.9 μg L^{-1}.

CONCLUSION

Parameters and substances affect the quality of BDW (pH, EC, TDS, HCO_3, F, NO_3 and SO_4). For most of the samples, their ranges were within the acceptable limit except for F. Some samples had F higher or below the acceptable limit:

- Macronutrients (Ca, K, Mg and Na). The limit was set only for Mg (150 mg L^{-1}). All samples were below the maximum limit of Mg concentration
- Micronutrients-trace elements (Co, Cr, Cu, Fe, Mo, Se and Zn); GSO sets an upper limit for these elements concentration except Co. All samples were below the maximum limit, except 18% of sample importer may be the upper limit
- Potentially essential elements that have some beneficial health effects (B, Mn, Ni and V). For all samples the concentration of these elements were blow the maximum concentration set by GSO (2009)
- Toxic elements (Al, As, Cd, Hg, Pb, Th and U); All samples were below the maximum limit, except 12% of sample local may be the upper limit

It would be possible to conclude that most of the samples quality level was complied with the GSO standards except for pH value, TDS, SO_4 and F in some samples. The label of the BDW should include more details about the source of the water and the concentration of the F.

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