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Study of Trace and Heavy Metals Content of Soft Drinks in the State of Kuwait

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ABSTRACT
The levels of 25 trace and heavy metals were determined in 29 brands of soft drinks collected from supermarkets and grand stores in Kuwait using an Agilent ICP/MS.
Comparison of the elemental concentrations in the soft drinks samples with the international maximum allowable limits showed that the mean values as well as the ranges of all the investigated elements in all the samples analyzed were below both US-EPA and WHO regulatedlimits of drinking water. It was found that there is no significant effect on the material of the containers on the levels of the studied metals. In addition, these levels were found much lower than those found in other countries.
Keywords: Trace elements; Soft drinks; Kuwait; Nutrition

I. INTRODUCTION

Trace and heavy metals (TMs) occur in the body in a number of chemical forms, such as inorganic ions and salts or as constituents of organic molecules. Twenty-one of these TMs have been reported to be essential for human health[1]. They include the macronutrient metals calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) and the micronutrient elements chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), molybdenum (Mo), selenium (Se), and zinc (Zn). Based on emerging information, the metals boron (B), manganese (Mn), nickel (Ni), and vanadium (V) may be considered essential for humans and have some beneficial health effects. By contrast, potentially toxic metals include aluminum (Al), arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) [2]

Toxic metals may reach our body from ingestion of contaminated or polluted food which includes soft drinks (SDs). In the present, SDs represent an important part of our lifestyle. The essesence of SDs production is the creation of flavoured syrup. Each brand has its own proprietary recipe and, as we would expect, each is a closely-guarded company secret. The syrup is mixed with purified water and then carbonated by adding carbon dioxide gas under pressure. This carbonation creates the "tingly fizz" that gives soft drinks a refreshing taste. Soft drinks may be canned in glass jars, plastic or metal containers and require regular monitoring of the trace and heavy metals, in addition to the organics, arising from either the ingredients or the container material.

The consumption of SDs has steadily increased worldwide over the past decade. The huge increase in SDs consumption in all countries all over the world is a direct link to the bottom line profit that is generated for the SDs corporations. The United States ranks first among countries in SDs consumption. The per-capita consumption of SDs is in excess of 150 quarts per year, or about three quarts per week.

In human health, the elements Ca and Mg affect bone and membrane structure, and Na and K affect water and electrolyte balance. Cu, Mg, Mn, Mo, and Zn have roles in metabolic catalysis, whereas Fe is critical for oxygen binding and transport. Cr acts in hormone function [3]. Increased morbidity, anemia, impaired physical and mental development, and mortality related to reduced immune defenses are consequences of deficiencies in trace metal micronutrients [4]. At 8%, Al is the most abundant metallic element in the Earth’s crust. Diet is the main source of human exposure to Al, and the toxicity and uptake of Al are greatly dependent on the nature of the Al species, specifically its physico-chemical form [5]. As is one of the few contaminants of high concern in drinking water and has been shown to cause cancer in humans through its consumption [6]. Studies have reported that Cd is carcinogenic by the inhalation route, but there is no clear evidence of genotoxicity [7]. Occupational exposure to Cd causes lung diseases and renal functions [8]. Plumbing systems and pipes as well as solder and fittings used in the production processes are the main sources of Pb in SDs. This element is toxic and accumulates in the skeleton [9]. In humans, inorganic Hg affects the kidney, whereas methylmercury affects the central nervous system. The main source of Hg is food [10].

Recently, numerous studies have been conducted worldwide to evaluate the TEs in SDs[11-20]. Literature searches indicate that no anystudy on the TE content of SDs in Kuwait has been published. Thus, the objectives of the current study were as follows: (1) to determine the levels of TEs in locally processed and imported brands of SDs available in Kuwait market; (2) to compare the levels of TEs with WHO and international drinking water standards; (3) to compare the TE content of the SDs in Kuwait with those from other countries. The results of such investigation will be valuable for public health officials to assess any potential health risk to the public associated with the consumption of this type of drinks. The data obtained will also be useful for the Ministry of Health (MOH) officials and other governmental offices concerned with the quality of soft drinks, to determine the better approaches and materials to prevent or reduce the higher levels of trace and heavy metals may be found.

II. MATERIALS AND METHODS

2.1. Sample collection and preparation

Samples of softdrinks (Pepsi, 7Up, various Miranda brands, Dew, Shani, Coca Cola, Sprite, Fanta, Schwepps, and many other similar brands) bottled in various types of containers (glass, PET, and aluminum cans) were collected from supermarkets and grandstores in Kuwait. According to the AOAC method [21], samples were first degassed in an ultrasonic bath prior to digestion. A volume of 4 mL of nitric acid was added to 5 mL of the soft drink sample in microwave Teflon bomb. Digestion was completed in 90 min at 120OC. When cool, the digest was diluted to 25-mL volume with deionized water and stored refrigerated (at 4°C) in PE containers until analysis is completed. All samples analyzed were within the recommended holding times, and any sample exceeded it is discarded.

2.2. Analytical Procedure

Type I ICP/MS grade water is used for all preparations of reagents and standard solutions. It is obtained by using Ultra Pure Water Purification System specially equipped with Milli-Q element, Q-Guard II pak, Quantum VX cartridge, 0.22µm Millipak filter, and <0.1µm Optimizer Filter at the point of use (Millipore, Bedford, MA, USA). Certified high purity chemicals, acids, individual and calibration standards mixes and quality control as well as reference materials were obtained from Alfa Aeser, AccuStandard, and Agilent companies.The levels of 25 trace and heavy metalswere measuredaccording to US-EPA method 200.8 [**22**]with an Agilent ICP/MS 7500ce (Agilent, Palo Alto, CA, USA) that was equipped with an Octopole reaction system, a micromist nebulizer, a bonnet and shield, and an integrated autosampler with on-line addition of internal standard. Details regarding the analytical procedures, quality control (QC), quality assurance (QA), and detection limits (DLs) have been reported in details elsewhere[**23, 24**].

III. RESULTS AND DISCUSSION

Table 1

Twenty nine brands of SDs were collected from Kuwaiti markets. Twenty two brands were produced locally by three Kuwaiti companies COM1 (16), COM2 (4), and COM3 (2), while the remaining seven brands were imported from Jordan (4), and Austria (3). The 25 analyzed TEs in this study were Al, As, B, Barium (Ba), Beryllium (Be), Ca, Cd, Cr, Co, Cu, Fe, K, Pb, Mg, Mn, Hg, Mo, Ni, Na, antimony (Sb), Se, strontium (Sr), titanium (Ti), V, and Zn. Table 1 shows the summary of the statistics of the studied TEs of the SDs brands and their DL along with the World Health Organization guideline values (WHO-GV) [**25**], and the United States-Environmental Protection Agency maximum contaminant levels (US-EPA-MCL) [**26**] for drinking water. Additionally, the mean values of the TEs previously studied on the carbonated (CW), bottled (BW), and household (HW) waters of Kuwait[**23, 24**]are presented in Table 1. The table illustrates that Be and Hg were not detected in any of the analyzed samples and were found lessthan the corresponding DL values. The elements Sb, As, Cd, Pb, and Se were detected in 50%, 80%, 95%, 90%, 75% of samples analyzed. The other elements were detected in 100% of the samples. In all samples, the 25 elements were found lower than the recommended levels of United States-Environmental Protection Agency (US-EPA)[**27**] and World Health Organization (WHO) [**28**].

Figure 1

Figure 1 shows the graphical comparison of TEs in SD, CW, BW, and HW in Kuwait. The mean values of the major macronutrients Ca, Mg, K, and Na in SD were found much lower than those in CW, BW, and HW; whereas CW (with very low consumption compared to other waters) exhibited the highest values followed by HW as illustrated in Fig. 1a. The mean values of the micronutrient elements Cu, Fe, and Zn in HW were the highest and SD exhibited the lowest values (except for Fe in BW), Fig. 1b. Adult humans in Kuwait can therefore receive 8.6%, 5-7%, 3-4%, 50%, 30%, and 8% of their DRI of Ca, Mg, Na, Cu, Fe, and Zn, respectively, by drinking 2 liters of HW per day [16, 17] compared to negligble % from SDs. The mean values of the toxic elements As, Cd, and Pb were found very low and close to their DL values in SD, CW, BW, and HW; whereas Al exhibited the highest mean value (11.4µg L-1) in HW compared to the lowest value (0.3µg L-1) in BW. All mean values of toxic metals inall types of drinks were too much lower than the WHO and US-EPA recommended levels (Table 1).

Figure 2
The variation of the levels of selected TEs in the SDs with the type of container material is illustrated in Fig. 2. The figure shows that there is no significant variation between the mean values of Al, B, Fe, Ti, and Zn and the container material despite the slightly higher values of Fe, Ti, and Zn in SD brands packed in metal containers. The mean values of the metals Sb, As, Cd, Cr, Co, Cu, Pb, Se, and V in SDs packed in glass, metal, and plastic containers were very low (<0.5 µg L-1)in order to observe any significant differences. Only the mean value of Mn in SDs in metal containers was very high (1.75 µg L-1) compared to those in glass (0.32µg L-1) and in plastic (0.52µg L-1) containers. On the otherhand, the mean value of Ni was the highest in glass (1.5 µg L-1) compared to metal (0.5µg L-1) and plastic (0.4µg L-1) containers.Generally, there is no significant effect of the container meterial of various SDs on the levels of TMs.

Figure 3
Figure 3compares the mean values of some of the trace elements in SDs produced in Kuwait and those imported from other countries.The mean values of B, Ti, and Zn (12.1, 14.4, and 8.6 µg L-1, respectively) were the highest in the brands from Jordan. The SD brands from Austria were characterized by the highest mean values of Al (15.6 µg L-1) and Fe (38.2 µg L-1) and lowest values for B (3.8 µg L-1) and Zn (2.2 µg L-1).Variuos brands produced in Kuwaitby the three companies COM1, COM2, and COM3exhibited comparable mean values for B, Al and Zn with highest Ti values (5.7 µg L-1) in COM1 brands and lowest values for Fe (14.2 µg L-1), Ti (3.8 µg L-1), and Zn (3.8 µg L-1) in COM3 brands.

Table 2
Table 2 compares the mean values and ranges of micronutrient and toxic TMs found in the SDs of this study and those from other countries. The table shows that: (1) the mean values and ranges found for all metals in SD brands from Kuwait are significantly much lower than those SD brands from all mentiond countries, (2) the mean values 1240 µg L-, and 204.3 µg L-1 published for Al in SDs respectively, from Ghana [19] and Brazil [20] were foundextremely higher thanboth WHO and US-EPA permissble limits (200µg L-), (3) the detected toxic metals Cd (in Ghana [15], Libya [13] and Nigeria [14, 17]), Pb (in all countries except Ethiopia) and Hg (only in Nigeria [11]) were found extremly higher than the WHO permissible levels 5 µg L-1, 10 µg L-1 and 1.0 µg L-1, respectively.

IV. CONCLUSIONS

A study of the levels of 25 trace and heavy metals was conducted using a total of 29 samples of soft drinks collected from supermarkets and grandstores in Kuwait. The analysis of the data indicated that (1) None of the metals exceeded either the US-EPA or the WHO maximum recommended levels for drinking water. In addition, (2) the levels of micronuitiant and toxic metals were found much lowar than those mention in the published work worldwide. Moreover, we found from this study that (3) the containar material has no significant effect on the levels of detected metals. Furthermore, (4) the levels of trace metals in the soft drinks were found lower than those dovumented in carbonated water as will as bottled and household drinking water from Kuwait.
We conclude that soft drinks available in Kuwait are completely safe to drink with regard to toxic metals.The data from this study will be useful to health authorities as well as researchers interested in epidemiological studies.

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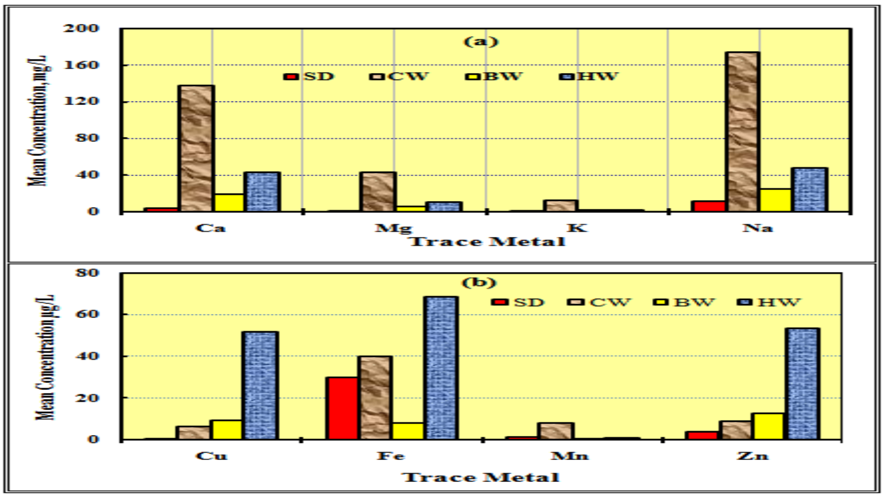

Figure 1. Graphical comparison of some trace elements in the soft drinks (SD), carbonated (CW), non-carbonated (BW) bottled waters and the household water (HW) in Kuwait.

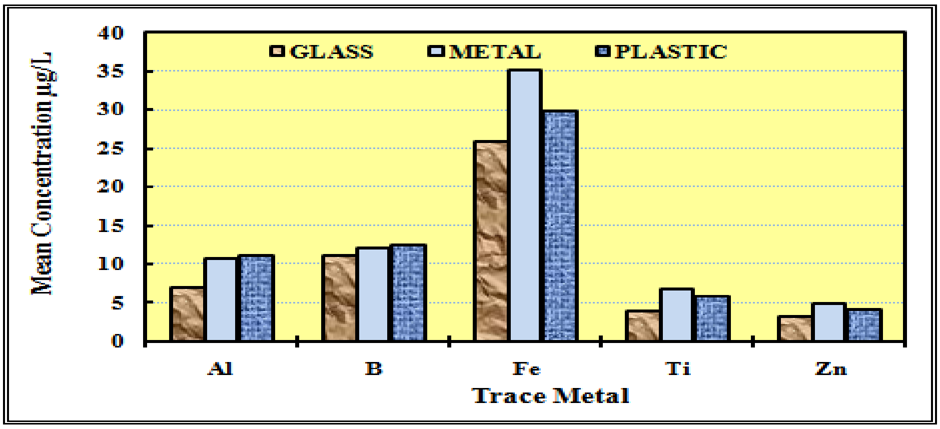

Figure 2. Variation of the levels of selected trace elements in soft drinks with the container material.

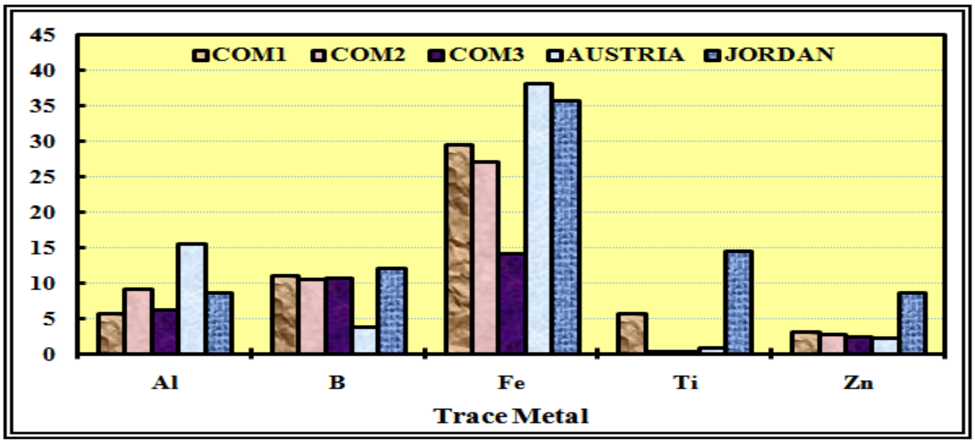

Figure 3. Comparison of the levels of selected trace elements in soft drinks producedin Kuwait(COM1, COM2, and COM3) and other countries.

Table 1. Summery statistics of various trace and heavy metals in soft drink samples and the mean values for carbonated (CW), bottled (BW), and household (HW) waters in Kuwait(1)

Element	Mean	STD	Med	Min	Max	CW	BW	HW	DL	Recommended levels WHO (USEPA)
Al	7.61	6.93	4.84	2.32	32.32	8.32	3.37	11.37	0.04	200 (50-200)
Sb	0.03	0.02	0.03	0.00	0.10	0.39	0.28	0.98	0.002	20 (6)
As	0.04	0.08	0.02	0.01	0.34	0.91	0.69	0.29	0.01	10 (5)
Ba	1.22	0.80	0.96	0.12	2.89	251.32	15.8	3.03	0.005	700 (2000)
Be	ND	ND	ND	ND	ND	0.29	0.02	ND	0.002	- (4)
B	10.35	2.49	10.98	2.06	13.13	2621.31	228.5	116.4	0.01	500 (-)
Cd	0.01	0.01	0.01	0.00	0.03	0.02	0.11	0.115	0.005	3 (5)
Ca	3.91	1.24	3.59	0.32	6.57	137.70	18.8	43.3	0.13	- (-)
Cr	0.25	0.11	0.20	0.08	0.52	1.00	1.21	0.68	0.006	50 (100)
Co	0.05	0.10	0.02	0.00	0.53	0.45	0.11	0.61	0.002	- (-)
Cu	0.42	0.26	0.33	0.14	0.93	6.60	9.16	51.9	0.005	2000 (1300)
Fe	29.90	14.90	27.17	3.12	89.30	402.57	8.06	68.5	0.003	- (300)
Pb	0.07	0.04	0.05	0.02	0.17	0.24	0.86	0.42	0.002	10 (-)
Mg	0.8	0.29	0.93	0.07	1.33	43.41	5.8	10.9	0.11	- (-)
Mn	1.08	2.40	0.33	0.08	9.94	83.08	0.34	0.86	0.001	400 (50)
Hg	ND	ND	ND	ND	ND	ND	0.47	1.93	0.02	1.0 (2.0)
Mo	0.57	0.22	0.57	0.02	1.14	3.12	1.01	5.98	0.001	70 (70)
Ni	0.82	2.21	0.29	0.13	12.20	1.73	1.77	6.56	0.005	20 (-)
K	1.21	1.22	0.48	0.22	4.21	12.24	1.7	1.5	0.07	- (-)
Se	0.07	0.07	0.05	0.00	0.30	0.34	0.28	0.86	0.005	10 (50)
Na	11.46	5.93	9.65	6.12	32.52	174.38	24.8	47.7	0.2	- (-)
Sr	0.08	0.02	0.08	0.01	0.11	2.45	0.17	1.07	0.005	- (-)
Ti	5.33	8.18	0.85	0.33	25.95	2.33	0.53	0.18	0.004	- (-)
V	0.33	0.68	0.12	0.03	2.86	0.49	1.8	1.97	0.005	- (-)
Zn	3.72	3.60	2.17	0.86	14.72	9.18	12.62	53.6	0.08	- (5000 SDWR)

(1) Concentrations of elements are in µg L^{-1}; except Ca, Mg, Na, K, and Sr, which are in mg/L.

Table 2. Mean concentration valuesand ranges of trace elements (µg L^{-1}) in soft drinks from Kuwait (present study) and from other countries(1)

Element	Brazil [20]	Ethiopia [12]	Ghana [19]	Ghana [15]	Ghana [16]	Libya [13]	Nigeria [11]	Nigeria [17]	Lagos Nigeria [14]	Turkey [18]	This study
Al	204.3 (34-461)		1240 (750-1912)								7.6 (2.3-32.3)
As			ND							37 (29-45)	0.04 (0.01-0.34)
Cd			ND	32		6 (2-9)	149 (one sample))	- (ND-309)	- (23-158)	5 (4-8)	0.01 (ND-0.03)
Cr	4.4 (0.4-32)	87.5 (23-183)						(ND-100)	2335 (one sample)		0.25 (0.08-0.52)
Co			ND	60						ND	0.05 (ND-0.53)
Cu	30.6 (2.5-72)	77 (36-135)		53	340 (330-370)	187 (123-275)		- (70-2220)		70 (31-125)	0.42 (0.14-0.93)
Fe	789.7 (187-1687)			723	7720 (5680-13410)	436 (184-770)		- (100-3810)			29.9 (3.1-89.3)
Pb		5.2 (3.5-7.9)		178	720 (ND-2780)	170 (125-214)	800 (170-3390)	- (ND-50)	- (505-3027)	29 (23-35)	0.07 (0.02=0.17)
Mn		27 (17-40)	ND							ND	1.08 (0.08-9.9)
Hg							2080 (290-11320)				ND
Ni	32.7 (12-65)	ND							26 (16-63)		0.82 (0.13-12.2)
Zn				71	1070 (420-2060)	1300 (614-2967)		- (20-2420)	ND	143 (78-225)	3.72 (0.86-14.7)

(1)Values between brackets represent the ranges, ND: not detected