Toxic Elements Content Of Selected Industrialized Beverages

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***Abstract*—The objective of this study was to identify and quantify toxic metals in selected beverages marketed worldwide. Forty-eight samples, comprising ready-to-drink juices, coffee (from capsules), beers and soft drinks (from cans), were subjected to elemental analysis by inductively coupled plasma mass spectrometry (ICP-MS). Fifteen samples (beer, coffee and soft drinks) showed values above the recommended for toxic metals such as mercury (Hg), silver (Ag), antimony (Sb), beryllium (Be), thallium (Tl) and titanium (Ti). These elements, even as trace concentrations, can pose a threat to human health when consumed over a lifetime We now recommend a more in-depth study to possible identify the origin of the contamination, whether the raw materials, the packing material or the production process itself.**

Keywords— Metals; Inductively Coupled Plasma Mass Spectrometry (ICP-MS); industrial beverages; Toxicity of metals

I. INTRODUCTION

Nowadays, the production and consumption of alcoholic and non-alcoholic beverages such as ready-to-drink juices, beer, and coffee, are on a large scale around the world [1,2]. Apart from their nutritional composition, they may also contain substances considered as non-beneficial to the health, e.g., high concentrations of sodium and sweeteners (like aspartame) [3,4]. It is also possible that these beverages could also contain other types of contaminants, such as heavy metals [5,6,7].

Although the content of trace metals can be low for a single dose of these beverages, the continued exposure of toxic elements increase the risks of potential bio-magnification effect on body tissues, which can lead to complications such as dysfunction of central nervous, reproductive and gastro-intestinal systems, as well as genotoxicity [8,9]. For instance, it is known the carcinogenic effect of cadmium, and the long-term exposure of this metal may cause kidney and liver damages [10].

In fact, authors around the world have already investigated the incidence of toxic elements in industrialized beverages in some countries, which demonstrated contamination with toxic elements as cadmium, lead, mercury, aluminum, arsenic and tin in samples [11,12,13]. Most of these contaminations occur by a cascade effect, where soil or water containing heavy metals contaminate flowers, fruits or leaves used as ingredients for these beverages. Another factor that can contribute for contamination is the failure on hygiene process of the vegetables, since the use of pesticides in the cultivation of fruits is common and are hardly to remove without proper sanitization – it is well known that pesticides and fertilizers can be sources of toxic elements to human health [14,15,16].

In order to enquire the possible risk that ready-to-drink beverages can provide, this study aimed to evaluate the concentration of 17 potentially toxic metals via inductively coupled plasma mass spectrometry (ICP - MS) in 48 processed beverages.

II. MATERIALAND METHODS

Forty-eight samples of industrial beverages were used in this study: 10 beers (in cans), 10 coffee capsules, 17 juices (10 from carton-pack boxes and 7 from aluminum cans), and 11 soft drinks (in cans). All samples were purchased in the local market of Juiz de Fora (Minas Gerais State, Brazil) in December of 2017.

The samples were submitted to elemental analysis by inductively coupled plasma mass spectrometry (ICP-MS) in an Agilent 7700x spectrometer (Japan). Aliquots (10 mL) of each sample were transferred to heavy metal-free vials, acidified with 1% nitric acid (HNO3) Suprapur® to pH <2.0 and stored until the time of analysis.

For analysis, the aliquots were diluted to 25 mL with Milli-Q water and then injected into the nebulizer of the spectrometer by a peristaltic pump. Analyses were conducted under an argon plasma flux of 15 mL/min at 26.00 MHz with 40 seconds of sample uptake at 0.3 rps and using a helium collision cell to selectively attenuate all polyatomic interferences based on their size. Standard curves (5 points) were used to quantify the following elements: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be) bismuth (Bi), cadmium (Cd), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag), tellurium (Te), thallium (Tl), tin (Sn), titanium (Ti), tungsten (W), , and uranium (U). All

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analyses were conducted in 7 (seven) replicates and using metal-free plastic glassware.EASE OF USE

III. RESULTS AND DISCUSSION

The data for toxic metal concentrations of the 48 beverages samples, on each group, are depicted in Tables 1, 2, 3, 4 and 5.

Table 1 Trace elements quantification in beers (B).

Elements	Results									
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Al	0.003 (2.000)	0.002 (1.867)	0.003 (1.234)	0.123 (1.312)	0.159 (2.452)	0.031 (9.706)	0.026 (4.792)	0.153 (1.351)	0.052 (1.957)	0.054 (0.876)
Be	<0.000)	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ti	0.002 (4.553)	0.002 (5.700)	0.001 (3.709)	**0.066 (0.599)**	**0.052 (2.383)**	**0.095 (3.684)**	**0.051 (3.329)**	**0.045 (1.897)**	**0.053 (4.298)**	0.007 (8.838)
Ni	0.000 (8.832)	0.000 (6.882)	0.000 (8.562)	0.011 (0.789)	0.003 (3.213)	0.001 (2.693)	0.002 (2.935)	0.003 (3.640)	0.001 (10.447)	0.003 (3.739)
As	0.000 (11.438)	0.000 (11.474)	0.000 (17.378)	0.021 (1.766)	0.026 (0.948)	0.023 (1.156)	0.027 (1.069)	0.017 (1.226)	0.023 (2.730)	0.009 (2.309)
Sb	0.001 (2.452)	0.000 (2.828)	0.000 (6.228)	0.000 (3.415)	0.000 (6.705)	0.000 (5.215)	0.000 (12.956)	0.000 (4.267)	0.000 (9.843)	0.000 (7.679)
Te	<0.000	<0.000	<0.000	0.001 (6.656)	0.001 (5.650)	0.001 (8.905)	0.001 (8.577)	0.001 (5.87)	0.001 (12.739)	0.001 (20.838)
Ba	0.001 (3.859)	0.001 (5.203)	0.001 (6.658)	0.052 (0.884)	0.058 (0.865)	0.061 (0.477)	0.049 (1.344)	0.065 (0.493)	0.051 (0.728)	0.042 (0.751)
W	0.000 (3.746)	0.000 (4.436)	0.000 (4.567)	0.003 (3.107)	0.001 (2.826)	0.001 (3.014)	0.002 (2.626)	0.002 (1.806)	0.001 (6.135)	0.004 (0.551)
Tl	<0.000	<0.000	<0.000	**0.000 (11.209)**	0.000 (11.075)	0.000 (8.080)	0.000 (2.213)	0.000 (41.659)	0.000 (12.357)	0.000 (11.438)
Ag	<0.000	<0.000	<0.000	<0.000	0.000 (18.674)	0.001 (1.060)	**0.11 (2.058)**	0.001 (4.890)	<0.000	<0.000
Cd	<0.000	0.000 (60.661)	<0.000	0.006 (4.070)	0.002 (3.832)	0.002 (4.821)	0.002 (8.744)	0.001 (5.832)	0.002 (6.752)	0.000 (3.944)
Sn	0.000 (6.462)	0.000 (6.520)	0.000 (5.069)	0.000 (9.622)	<0.000	0.000 (223.400)	0.000 (8.416)	0.000 (14.199)	<0.000	<0.000
Pb	0.000 (6.542)	0.000 (2.775)	0.000 (26.112)	0.001 (2.316)	0.000 (2.957)	0.001 (1.321)	0.001 (2.638)	0.000 (2.519)	0.000 (2.929)	0.000 (9.916)
Bi	0.000 (4.206)	0.001 (1.587)	0.000 (12.057)	0.003 (4.003)	0.001 (1.973)	0.001 (1.736)	0.001 (2.071)	0.002 (1.428)	0.001 (15.667)	0.001 (2.069)
U	0.000 (1.619)	0.000 (2.302)	0.000 (2.253)	0.000 (1.966)	0.000 (5.512)	0.000 (2.688)	0.001 (0.784)	0.000 (2.172)	0.000 (7.987)	<0.000
Hg	1.405 (9.015)	**6.349 (1.957)**	2.239 (9.452)	0.402 (9.548)	0.202 (10.492)	0.373 (2.890)	0.077 (22.910)	0.162 (13.948)	0.046 (39.867)	0.024

Results expressed as [mean in mg/L (relative standard deviation)]. The results above limits are highlighted in bold.

Table 2 Trace elements quantification in coffees marketed in capsules(C).

Elements	Results									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Al	0.005 (12.559)	0.011 (4.483)	0.018 (4.969)	0.009 (6.686)	0.01 (2.732)	0.007 (3.688)	0.003 (1.285)	0.007 (1.032)	0.003 (6.093)	0.004 (3.547)
Be	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	0.000 (93.336)
Ti	0.001 (18.271)	0.003 (5.767)	0.002 (18.154)	0.002 (20.863)	0.002 (9.692)	0.003 (4.301)	0.004 (2.167)	0.012 (1.526)	0.004 (11.742)	0.004 (14.188)
Ni	<0.000	0.005 (2.909)	0.002 (3.465)	0.002 (4.083)	0.002 (4.142)	0.004 (3.514)	0.001 (4.854)	0.001 (4.109)	0.001 (6.340)	0.001 (4.927)
As	<0.000	0.001 (15.411)	0.000 (228.54)	<0.000	0.000 (107.7)	<0.000	0.000 (24.348)	0.000 (15.149)	0.000 (24.998)	0.001 (13.853)
Sb	0.000 (15.234)	0.000 (9.964)	0.000 (5.554)	0.000 (15.009)	0.000 (8.310)	0.000 (12.085)	0.000 (4.503)	0.000 (6.682)	0.000 (6.729)	0.000 (3.527)
Te	0.000 (38.807)	0.000 (14.003)	0.000 (23.641)	0.000 (9.565)	0.000 (22.788)	0.000 (9.221)	<0.000	<0.000	<0.000	0.001 (24.032)
Ba	0.004 (2.045)	0.027 (0.937)	0.028 (1.010)	0.016 (1.104)	0.017 (1.142)	0.08 (0.833)	0.009 (1.480)	0.004 (2.286)	0.008 (0.937)	0.004 (1.480)
W	0.000 (28.230)	0.000 (7.459)	0.000 (2.864)	0.000 (3.415)	0.000 (7.067)	0.000 (2.491)	0.001 (1.937)	0.000 (6.148)	0.000 (4.072)	0.002 (2.128)
Tl	0.000	**0.000**	0.000	**0.000**	0.000	0.000	<0.000	<0.000	<0.000	0.000

	(1.870)	**(3.189)**	(7.634)	**(3.847)**	(18.231)	(4.156)				(4.709)
Ag	<0.000	0.004 (1.442)	<0.000	<0.000	0.003 (18.384)	0.002 (3.269)	**0.155 (1.567)**	<0.000	<0.000	**1.254 (0.567)**
Cd	0.000 (26.672)	0.000 (13.253)	0.000 (10.068)	0.000 (17.496)	0.000 (34.061)	0.000 (17.317)	<0.000	<0.000	<0.000	<0.000
Sn	<0.000	0.001 (4.404)	0.000 (13.437)	0.000 (21.139)	0.000 (13.405)	0.000 (19.141)	0.000 (5.755)	0.000 (7.286)	0.000 (2.781)	0.001 (2.747)
Pb	0.001 (1.086)	0.001 (1.772)	0.001 (1.960)	0.001 (1.615)	0.000 (0.346)	0.001 (1.352)	0.000 (9.273)	0.000 (3.076)	<0.000	0.000 (4.059)
Bi	0.001 (5.121)	0.001 (2.648)	0.001 (2.566)	0.001 (3.059)	0.001 (3.294)	0.001 (1.934)	0.001 (4.117)	0.000 (7.344)	0.000 (6.988)	0.002 (1.407)
U	0.000 (20.197)	0.000 (5.528)	0.000 (23.392)	<0.000	0.000 (43.510)	0.000 (73.831)	0.000 (1.284)	0.000 (2.724)	0.000 (3.311)	0.000 (1.640)
Hg	0.024	0.143 (11.356)	0.053 (36.773)	1.203 (2.973)	0.497 (4.356)	0.166 (9.951)	**6.397 (4.132)**	2.168 (5.773)	1.439 (14.576)	4.052 (4.983)

Results expressed as [mean in mg/L (relative standard deviation)]. The results above limits are highlighted in bold.

Table 3 Trace elements quantification in juices marketed in carton-pack boxes (JB).

Elements	**Results**									
	JB1 (Grape /apple)	**JB2 (Orange)**	**JB3 (Passion fruit)**	**JB4 (Guava)**	**JB5 (Grape)**	**JB6 (Grape)**	**JB7 (Strawberry)**	**JB8 (Peach)**	**JB9 (Apple)**	**JB10 (Peach)**
Al	0.018 (0.674)	0.004 (6.215)	0.004 (7.322)	0.002 (6.843)	0.006 (1.898)	0.003 (3.375)	0.009 (5.271)	0.010 (3.750)	0.006 (6.328)	0.011 (1.377)
Be	0.000 (150.962)	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	**0.000 (4.595)**	<0.000	<0.000
Ti	<0.000	0.000 (20.118)	0.000 (181.088)	<0.000	0.000 (60.879)	0.000 (22.111)	0.000 (63.539)	0.001 (28.166)	0.000 (47.754)	0.001 (6.990)
Ni	0.000 (6.971)	0.000 (10.162)	0.000 (14.718)	0.000 (3.036)	0.000 (5.003)	0.000 (5.373)	0.002 (2.674)	0.001 (2.721)	0.000 (7.955)	0.000 (6.926)
As	0.000 (44.971)	0.000 (12.928)	0.000 (35.929)	0.000 (52.934)	0.000 (25.101)	0.000 (12.935)	0.000 (22.418)	0.000 (15.079)	0.000 (70.478)	0.000 (21.593)
Sb	0.001 (2.265)	0.000 (2.158)	0.000 (3.735)	0.000 (1.783)	0.000 (3.826)	0.000 (4.887)	0.000 (7.558)	0.000 (1.555)	0.000 (5.681)	0.000 (6.506)
Te	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ba	0.002 (2.803)	0.002 (3.104)	0.001 (4.949)	0.002 (2.145)	0.001 (1.736)	0.001 (2.489)	0.001 (1.822)	0.007 (1.392)	0.002 (2.704)	0.001 (3.231)
W	0.000 (3.074)	0.000 (6.849)	0.000 (4.207)	0.000 (3.655)	0.001 (3.448)	0.001 (3.565)	0.001 (2.090)	0.000 (2.116)	0.000 (6.059)	0.000 (2.566)
Tl	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ag	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Cd	<0.000	<0.000	0.000 (14.756)	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Sn	0.000 (110.554)	0.000 (8.346)	0.000 (10.957)	0.000 (10.673)	0.000 (12.354)	0.001 (2.534)	0.001 (2.823)	0.000 (4.683)	0.000 (10.373)	0.000 (78.655)
Pb	0.000 (4.422)	0.000 (11.465)	0.000 (342.005)	<0.000	0.000 (22.975)	<0.000	0.000 (4.218)	0.000 (2.010)	<0.000	0.000 (11.414)
Bi	<0.000	<0.000	0.000 (6.018)	<0.000	<0.000	<0.000	0.000 (6.055)	0.000 (66.123)	<0.000	<0.000
U	0.000 (2.857)	0.000 (2.163)	0.000 (2.733)	0.000 (3.014)	0.000 (2.501)	0.000 (3.941)	0.000 (1.725)	0.000 (2.393)	0.000 (2.425)	0.000 (3.110)
Hg	2.647 (4.496)	1.656 (5.372)	0.770 (11.265)	0.496 (6.727)	0.639 (8.331)	0.795 (42.648)	0.455 (12.703)	1.686 (7.798)	0.890 (8.133)	1.191 (6.096)

Results expressed as [mean in mg/L (relative standard deviation)]. The results above limits are highlighted in bold. Flavors of the samples are described between parentheses.

Table 4 Trace elements quantification in juices marketed in cans (JC).

Elements	Results						
	JC1 (Grape)	JC2 (Grape)	JC3 (Peach)	JC4 (Guava)	JC5 (Guava)	JC6 (Mango)	JC7 (Grape)
Al	0.013 (1.160)	<0.000	0.006 (13.631)	0.004 (7.096)	0.005 (1.899)	0.007 (6.977)	0.02 (2.225)
Be	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ti	0.000 (284.278)	<0.000	0.000 (21.285)	0.000 (359.58)	<0.000	0.000 (105.821)	0.000 (8.102)
Ni	0.000 (3.923)	<0.000	0.000 (5.289)	0.000 (11.539)	0.000 (11.364)	0.000 (8.024)	0.000 (5.259)
As	0.000 (17.223)	<0.000	0.000 (28.298)	0.000 (17.498)	0.000 (39.959)	0.000 (14.762)	0.000 (11.870)
Sb	0.000 (2.438)	<0.000	0.000 (3.704)	0.000 (4.714)	0.000 (2.306)	**0.003 (0.855)**	0.000 (4.868)
Te	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ba	0.002 (3.779)	<0.000	0.005 (1.918)	0.005 (0.606)	0.004 (2.610)	0.011 (1.645)	0.007 (1.401)
W	0.000 (2.459)	<0.000	0.000 (4.833)	0.000 (3.037)	0.000 (4.387)	0.000 (11.288)	0.000 (5.653)
Tl	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ag	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Cd	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Sn	0.000 (6.078)	<0.000	0.000 (11.595)	0.000 (12.847)	0.000 (13.452)	0.000 (9.024)	0.000 (4.819)
Pb	0.000 (31.067)	<0.000	<0.000	<0.000	<0.000	<0.000	0.000 (7.816)
Bi	0.000 (77.361)	<0.000	<0.000	0.000 (12.969)	<0.000	<0.000	<0.000
U	0.000 (3.229)	<0.000	0.000 (3.294)	0.000 (4.063)	0.000 (1.968)	0.000 (4.618)	0.000 (6.402)
Hg	0.551 (11.385)	0.517 (9.775)	0.755 (9.971)	1.779 (3.305)	3.407 (6.469)	0.487 (13.750)	1.264 (79.984)

Results expressed as [mean in mg/L (relative standard deviation)]. The results above limits are highlighted in bold. Flavors of the samples are described between parentheses.

Table 5 Trace elements quantification in soft drinks (S).

Elements	Results										
	S1 (Guarana)	S2 (Cola)	S3 (Grape)	S4 (Grape)	S5 (Lemon)	S6 (Cola)	S7 (Cola)	S8 (Orange)	S9 (Grape)	S10 (Guarana)	S11 (Lemon)
Al	0.009 (0.828)	0.001 (5.090)	0.002 (3.124)	0.003 (4.936)	0.001 (4.563)	0.025 (2.237)	0.473(0.545)	0.021 (4.550)	0.072 (14.373)	0.011 (23.371)	0.022 (4.111)
Be	0.000 (37.993)	<0.000	<0.000	0.000 (41.461)	0.000 (2979.248)	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Ti	<0.000	0.001 (3.708)	<0.000	<0.000	<0.000	0.006 (5.289)	0.015 (5.715)	**0.018 (2.695)**	0.000 (45.364)	0.000 (234.573)	0.000 (227.054)
Ni	0.000 (19.91)	0.000 (4.371)	0.000 (5.195)	0.000 (6.162)	0.000 (11.079)	<0.000	<0.000	<0.000	0.001 (93.232)	<0.000	<0.000
As	0.000 (46.014)	<0.000	0.001 (8.990)	0.000 (34.987)	0.000 (40.965)	0.000 (16.484)	0.004 (3.614)	0.003 (8.562)	0.001 (78.185)	0.002 (12.628)	<0.000
Sb	0.000 (4.583)	0.001 (1.372)	0.001 (1.581)	0.000 (3.140)	0.000 (4.973)	0.000 (14.305)	0.000 (21.600)	0.000 (2.647)	0.000 (158.375)	0.000 (18.886)	<0.000
Te	<0.000	<0.000	<0.000	<0.000	<0.000	0.000 (123.289)	0.001 (20.212)	0.009 (9.554)	0.000 (33.595)	0.001 (30.926)	0.000 (2107.608)
Ba	0.001 (2.744)	0.001 (3.780)	0.001 (2.795)	0.004 (1.813)	0.001 (0.710)	0.001 (8.667)	0.002 (3.305)	0.009 (1.571)	0.008 (11.482)	0.005 (3.574)	0.016 (1.425)
W	0.000 (7.194)	0.000 (5.038)	0.001 (1.554)	0.000 (8.470)	0.000 (10.711)	0.001 (2.935)	0.001 (3.615)	0.003 (3.065)	0.000 (19.191)	0.000 (18.824)	0.000 (13.437)
Tl	<0.000	<0.000	<0.000	<0.000	<0.000	0.000 (30.305)	0.000 (3.951)	<0.000	0.000 (317.263)	0.000 (37.177)	0.000 (25.951)
Ag	<0.000	**0.390 (1.190)**	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
Cd	0.000 (80.554)	0.000 (85.093)	<0.000	0.000 (1019.877)	<0.000	0.000 (25.521)	0.000 (8.161)	0.000 (4.292)	0.000 (12.031)	0.000 (19.846)	0.000 (17.104)
Sn	0.000 (22.808)	0.000 (8.263)	0.000 (12.868)	0.000 (20.92)	0.000 (215.258)	<0.000	<0.000	0.000 (20.991)	<0.000	0.000 (14.496)	<0.000
Pb	0.001 (3.551)	0.000 (7.467)	0.000 (4.354)	0.000 (1.470)	0.000 (10.798)	<0.000	<0.000	0.000 (370.530)	0.000 (315.767)	0.002 (3.323)	0.000 (9.124)
Bi	<0.000	<0.000	0.002 (1.750)	0.000 (8.763)	<0.000	0.000 (1.472)	0.001 (2.819)	0.001 (2.812)	0.000 (62.739)	0.001 (8.668)	0.000 (2.285)
U	0.000 (2.880)	0.000 (3.731)	0.000 (0.764)	0.000 (2.103)	0.000 (1.158)	<0.000	<0.000	0.001 (1.890)	<0.000	<0.000	<0.000
Hg	1.431 (4.444)	3.441 (5.691)	2.442 (5.549)	1.907 (4.879)	0.999 (4.954)	0.024	0.004 (352.359)	0.024	0.024	0.024	0.043 (36.305)

Results expressed as [mean in mg/L (relative standard deviation)]. The results above limits are highlighted in bold. Flavors of the samples are described between parentheses.

In majority, elements selected for this study does not have maximum concentrations limits determined for beverages or food from governmental agencies as World Health Organization (WHO), Central Disease Control (CDC) or European Food Safety Authority (EFSA). Therefore, for comparison parameters the concentration limits established for drinking water by those agencies were used [19,20,21,22].

Seventeen out of the 48 samples analyzed presented some degree of contamination with toxic metals, considering the acceptance concentration limits described by World Health Organization for potentially toxic metals [20,21]. The elements that presented such high values were mercury (Hg), silver (Ag), antimony (Sb), beryllium (Be), thallium (Tl) and titanium (Ti). On the other hand, arsenic (As), lead (Pb), barium (Ba), bismuth (Bi), uranium (U) and aluminum (Al) presented values considered suitable for human consumption [19-27].

Mercury has no safety concentration level in beverages determined by World Health Organization up to date, but some works tried to establish concentration limits for this metal and found results between 0.003 mg/L and 0.005 mg/L [21,23,28]. The analysis conducted in this study found higher levels than those related in such study: 0.006 mg/L for sample C7 and 0.006 mg/L for sample B2. Although the main source of mercury contamination in the world is the seafood consumption, an extensive study analyzed the traces of metals in beer samples from Poland and determined the highest level to be 0.00064 mg/L, considerably lower than the found in this study [28,30]. Mercury has no known function in the human body and its presence in the environment comes from industrial and agricultural contamination or by burning fossil fuels [17]. Its toxic effects include mental, physical and respiratory diseases, besides to be a pro-inflammatory element, which triggers pro-oxidative processes and homeostasis-promoting cells [15].

Silver contamination (quantities above the 0.08 mg/L) [21] was found in the samples B7 (0.110 mg/L), C7 (0.155 mg/L), C10 (1.254 mg/L) and S2 (0.390 mg/L). This transition metal, known to have antimicrobial properties, led the nanotechnology industry to use silver nanoparticles in products such as clothing, toothpaste, household appliances and in packaging commonly used in beverages [29]. Nevertheless, the buildup of this metal can cause on human cells membrane damage, reduction of mitochondrial functions and increase of oxidative damage [30].

According to the analysis performed in this study for antimony, the sample JC6, whose value found were 0.003 mg/L, presented levels above the recommended for drinking water by the World Health Organization, which is 0.002 mg/L[31]. Exposure to antimony may cause nausea, vomiting, and irritation of the gastrointestinal mucosa. In addition, long-term exposure may lead to myocardial atrophy, whereas at higher doses it may affect the lungs and may promote liver disease and gallbladder insufficiency [32].

The presence of thallium beyond the recommended limit of 0.00010 mg/ L [21] was found in samples B4 (0.00018 mg/L), C2 (0.00011 mg/L) and C4 (0.00012 mg/ L). A study evaluating traces of thallium in drinking and non-potable water samples found different concentrations of the oxidative forms for this element, Tl^{+} and Tl^{3+}: 0.00084 mg/L and 0.00067 mg/L, respectively. These findings suggests that beverages contamination may originate from the water used in the productive process [33]. In the body stream, thallium accumulates on cells, and a study showed correlation between elevated levels of thallium and the occurrence of premature births [34].

For beryllium, sample JB8 demonstrated levels beyond the limits established for drinking water, which is 0.0003 mg/L [34] (0.00037 mg/L). A similar study with different wines showed beryllium concentrations ranging from 0.00008 – 0.0032 mg/L, indicating a certain trend in the presence of traces of this metal in beverages derived from fruits [35]. In nature, this element occurs as beryllium silicate, which are found in rocks, oil and volcanic dust. The excess of this metal is reliable to soil contamination, and the plants from the contaminated ground will present a higher concentration for this metal [34, 35].

Titanium were found in higher concentrations in more samples than other analyzed metals. It can indicate that contamination by titanium in beverages are commonly. Seven samples had values above the recommended concentration for World Health Organization for any kind of exposure (0,015 mg/mL) [21]. The samples were B4 (0.0066 mg/L), B5 (0.052 mg/L), B6 (0.095 mg/L), B7 (0.051 mg/L), B8 (0.045 mg/L), B9 (0.053 mg/l) and S8 (0.018 mg/l). One possible reason for this contamination is the anticorrosion application attributed for titanium dioxide (TiO_2) and its use as beverage colorant [37]. High levels of continuous exposure to titanium dioxide can cause cardiorespiratory dysfunction, exercising catalytic functions [21].

The contaminations found in this study could be related to a sort of events, and a few of them can be detected and/or neutralized: contamination of the soil were the natural ingredients (plants) grow; contamination of the water used on the manufacturing process; the cross contamination by a synthetic compound used on the formulation; or the contamination by failure on packaging process.

I. Acknowledgment

Based on results, the four types of beverages tested on this study (beers, coffee capsules, juices, and soft drinks) were mostly free of toxic elements. However, from the 48 samples, 15 of them showed values above the recommendation concentration for one toxic element and 2 of them demonstrated values above for two toxic elements (the C7 sample had values above for silver and mercury and B4 for thallium and titanium).

These findings contribute to the conclusion that ready-to-drink beverages have to improve quality control standards, since only 62.5% of all samples are on accordance for concentration of toxic elements. Although in majority samples values of toxic elements did not present risks to health in single doses, the continuous consumption can led to biomagnification and toxicity. Another problem of the beverages of this study that is exclusive of beers is the possible liver damages trigged by alcohol intake.

II. References

The

[1]. O'Keefe, DiNicolantonio JJ, Lavie CJ. Coffee for Cardioprotection and Longevity. Progress in Cardiovascular Diseases. 2018.

[2]. Reis CEG, Paiva CLRDS, Amato AA, Lofrano-Porto A, Wassell S, Bluck LJC, Dórea JG, da Costa THM. Decaffeinated coffee improves insulin sensitivity in healthy men. British Journal of Nutrition.2018; 8:1-10.

[3]. Mandlate JS, Soares BM, Seeger TS, et al. Determination of cadmium and lead at sub-ppt level in soft drinks: An efficient combination between dispersive liquid-liquid microextraction and graphite furnace atomic absorption spectrometry. Food Chemistry 221 (2017) 907–912

[4]. Okamura A,Ida S,Mori M,Shumizu T. Vitamin B1 Deficiency Related to Excessive Soft Drink Consumption in Japan. Journal of Pediatric Gastroenterology and Nutrition Publish Ahead of Print.2017.

[5]. Henning SM,Yang J,Shao P,Lee R,Huang J,Ly A,Hsu M,Lu QY,Thames G,Heber D,Li Z. Health benefit of vegetable/fruit juice-based diet: Role of microbiome.Scientific reports.2017;7:2167.

[6]. Chen W, Becker T, Qian F, Ring J. Beer and beer compounds: physiological effects on skin health. European Academy of Dermatology and Venereology.2014;28(2):142-50.

[7]. Gaetano G, Costanzo S, Di Castelnuovo A, Badimon L, Bejko D, Alkerwi A, Chiva-Blanch G, Estruch R, La Vecchia C, Panico S, Pounis G, Sofi F, Stranges S, Trevisan M, Ursini F, Cerletti C, Donati MB, Iacoviello L. Effects of moderate beer consumption on health and disease: A consensus document. Nutrition Metabolism and Cardiovascular Diseases.2016;26(6):443-67.

[8]. Mohmand J, Eqani SAMAS, Fasola M, et al. Human exposure to toxic metals via contaminated dust: Bio-accumulation trends and their potential risk estimation. Chemosphere 132 (2015) 142–151

[9]. Godwilla EA, Janea IC, Scholastica IU, et al. Determination of some soft drink constituents andcontamination by some heavy metals in Nigeria. Toxicology Reports 2 (2015) 384–390.

[10]. Wen-Si Zhong WS, Ren T, Zhao LJ. Determination of Pb (Lead), Cd (Cadmium), Cr (Chromium), Cu (Copper), and Ni (Nickel) in Chinese tea with high-resolution continuum source graphite furnace atomic absorption spectrometry. Journal of food and drug analysis 24 (2016) 46:55.

[11]. Moraes MM,Mediano MFF,Souza RAG,Moura AS,Veiga GV,Sichieri R. Discouraging soft drink consumption reduces blood glucose and cholesterol of Brazilian elementary students: Secondary analysis of a randomized controlled trial. Preventive Medicine.2017;100:223-228.

[12]. USDA (United States Department of Agriculture), 2018. Citrus: World Markets and Trade.

[13]. Concil of europe.Metals and alloys used in food contact materials and articles.A pratical guide for manufactures and regulators. European Directorate for the Quality of Medicines & HealthCare (EDQM) 2013;7.

[14]. Francisco BBA, Brum DM, Cassela RJ. Determination of metals in soft drinks packed in different materials by ETAAS. Food Chemistry 185 (2015) 488–494.

[15]. Atafar Z, Mesdaghinia A, Nouri J, Homaee M, Yunesian M, Ahmadimoghaddam M, Mahvi AH. Effect of fertilizer application on soil heavy metal concentration. Environ Monit Assess.2010;160(1-4):83-9.

[16]. Godwill EA,Jane IC,Scholasticca IU,Marcellus U,Eugene AL,Gloria AO.2015;2:384-390.

[17]. Marrugo-Negrete J, Pinedo-Hernández J, Díez S. Assessment of heavy metal pollution, spatial distribution and origin in agricultural soils along the Sinú River Basin, Colombia. Environmental Research. 2017;154:380-388.

[18]. ANVISA. RDC Nº 42, DE 29 DE AGOSTO DE 2013. Disponível em: www.portal.anvisa.gov.br/documents/33916/393845/RDC%2Bnº%2B42_2013_final.pdf/eec629cf-8d17-422b-a362-366b275c1a00?version=1.0 Accessed in 03/21/2018.

[19]. Concil of europe.Metals and alloys used in food contact materials and articles.A pratical guide for manufactures and regulators. European Directorate for the Quality of Medicines & HealthCare (EDQM) 2013;7

[20]. Brzezicha-Cirocka J, Grembecka M, Szefer P. Monitoring of essential and heavy metals in green tea from different geographical origins. Environ Monit Assess (2016) 188:183.

[21]. WHO Study Group on Recommended Health-Based Limits in Occupational Exposure to Heavy Metals & World Health Organization.

(1980). Recommended health-based limits in occupational exposure to heavy metals : report of a WHO study group [meeting held in Geneva from 5 to 11 June 1979]. Geneva : World Health Organization. http://www.who.int/iris/handle/10665/41401

[22]. EFSA, 2006.Tolerable Upper Intake Levels for Vitamins and Minerals. Scientific Committee on Food.2006

[23]. Drobnik M, Latour T Sziwa D. The assessment of health exposure resulted from barium, boron, and fluoride intake from therapeutic waters available for resident people in water abstraction points of health resorts. Rocz Panstw Zakl Hig.2010;61(4):373-8

[24]. Levado-Garcia JM, Puerto-Parejo LM, Roncero-Martin R, Moran JM, Pedrera-Zamorano JD, Aliaga IJ, Leal-Hernandez O, Canal-Macias ML. Dietary Intake of Cadmium, Lead and Mercury and Its Association with Bone Health in Healthy Premenopausal Women. Int J Environ Res Public Health.2017;14(12)

[25]. Yan D, Jin C, Cao Y, Wang L, Lu X, Yang J, Wu S, Cai Y. Effects of Aluminium on long-term Memory in Rats and on SIRT Mediating the Transcription of CREB-Dependent Gene in Hippocampus. Basic Clin Pharmacol Toxicol.2017;121(4):342-352.

[26]. WHO (World Health Organization). Mercury in Drinking water. World Health Organization. 2005

[27]. Alcala-Orozco M,Morillo-Garcia Y,Caballero-Gallardo K,Olivero-Vebel J. Mercury in canned tuna marketed in Cartagena, Colombia, and estimation of human exposure.Food Addit Contam Part B Surveill.2017;10(4):241-247

[28]. Wyrzykowska B, Szymczyk K, Ichichashi H, Falandysz J, Skwarzec B, Yamasaki S. Application of ICP sector field MS and principal component analysis for studying interdependences among 23 trace elements in Polish beers. J Agric Food Chem.2001;49(7):3425-31

[29]. Weldon BA, M Faustman E, Oberdörster G, et al. Occupational exposure limit for silver nanoparticles: considerations on the derivation of a general health-based value. Nanotoxicology. 2016 Sep;10(7):945-56.

[30]. Barbasz, Anna, Magdalena Oćwieja, and Jakub Barbasz. "Cytotoxic activity of highly purified silver nanoparticles sol against cells of human immune system." Applied biochemistry and biotechnology 176.3 (2015): 817-834.

[31]. WHO (World Health Organization). Antimony in Drinking water. World Health Organization. 2003.

[32]. Payán L, Poyatos MT, Muñoz L, et al. Study of the influence of storage conditions on the quality and migration levels of antimony in polyethylene terephthalate-bottled water. Food Science and Technology International 2017, 23:4 318 – 327.

[33]. Escudero LB1, Wuilloud RG, Olsina RA. Sensitive determination of thallium species in drinking and natural water by ionic liquid-assisted ion-pairing liquid-liquid microextraction and inductively coupled plasma mass spectrometry. J Hazard Mater.2013;244-245:380-386.

[34]. Jiang Y, Xia W, Zhang B, Pan X, Liu W, Jin S, Huo W, Liu H, Peng Y, Sun X, Zhang H, Zhou A, Xu S, Li Y. Predictors of thallium exposure and its relation with preterm birth. Environ Pollut.2018;233:971-976.

[35]. WHO (World Health Organization). Beryllium in Drinking water. World Health Organization. 2001.

[36]. Cooper RG, Harrison AP. The uses and adverse effects of beryllium on health. Indian Journal of Occupational and Environmental Medicine. 2009;13(2):65-76.

[37]. 37. Coccini, Teresa, et al. "Comparative cellular toxicity of titanium dioxide nanoparticles on human astrocyte and neuronal cells after acute and prolonged exposure." Neurotoxicology 48 (2015): 77-89.

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