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Evaluation of potential dietary toxicity of heavy metals in some common Nigerian beverages: A look at antimony, tin and mercury

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ABSTRACT

There is currently little information on the composition of heavy metals in beverages imported and locally produced in Nigeria. The study quantitatively determined the composition of antimony (Sb), tin (Sn) and mercury (Hg) in 50 different beverage samples and evaluated the extent of violation of guideline values. Analysis of the beverage samples for the presence of Sb, Sn, and Hg was carried out using an atomic absorption spectrophotometer (AAS) 929. The mean values detected for mercury, tin and antimony (±SE) in fruit juices and soft drinks were 2.39 ± 0.25, 3.66 ± 0.22 and 0.49 ± 0.048 μg/l; 2.93 ± 0.34, 3.60 ± 0.46 and 0.49 ± 0.10 μg/l in dairy drinks and 0.94 ± 0.02, 4.34 ± 0.48 and 0.48 ± 0.05 μg/l in bottled water samples respectively. While antimony detected in all products was below guideline values, mercury and tin were above the acceptable levels established by the World Health Organization, United States Environmental Protection Agency and European Union in most samples tested.

Keywords: beverage, heavy metal, food contaminants, toxicology, risk assessment, public health

Classifications: biology, chemistry, medicine

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INTRODUCTION

The industrial processes of extraction and distribution of mineral resources which undergo synthetic changes yield chemicals such as heavy metals that have an atomic weight and density almost five times that of water. The pollution of our soil, atmosphere, underground and surface water with effluents of such industrial activities inevitably results in chemicals finding their way into our food chain and consequently into our foods and beverages. The presence of heavy metals in beverages has been documented in a number of worldwide studies. A recent study of beverages produced in Poland detected increased heavy metal content in fruit juice samples (Krejpcıo, Sıonkowskı& Bartela, 2005). This study highlighted the fact that beverages are rarely free from heavy metal contamination regardless of the environment they are produced. In particular, foodstuffs produced in regions suffering from high levels of pollution and environmental problems such as Nigeria, are thought to be more prone to violating guideline values of the permissible amounts of heavy metals in locally produced products. The recent proliferation of a number of different brands of Nigerian beverages has also necessitated the study of the extent of heavy metal contamination of these products.

Heavy metals such as mercury (Hg), antimony (Sb) and tin (Sn) are known to have toxic effects when administered acutely and chronically to laboratory animals. Although studies of heavy metal contamination in beverages have shown that concentrations are generally too low to cause any immediate toxic effects, chronic exposure has the potential to cause severe adverse effects to human health.

Antimony a suspected carcinogen with unknown biological function and effects on long term exposure is used as a catalyst in the production of polyethylene terephthalate (PET) plastics, with many applications including its use in the packaging of beverages and foodstuffs (Hansen et al., 2010). Low doses of antimony is known to cause headaches, dizziness and depression, but in larger doses can cause violent and frequent vomiting.

Food and water are the main sources of mercury in non-occupationally exposed populations. According to Galal-Gorchev (1991), the average daily intake of mercury from food and water ranges from 2–20 μg. Acute administration of mercury was found to induce severe vacuolation of the renal tubular epithelium and nephropathy in the kidneys (Carmignani, Boscolo & Preziosi, 1989) and caused a decrease in seminiferous tubule diameter, spermatogenic cell counts and leydig's cell nuclear diameter in the male reproductive structure (Lamperti and Printz, 1973). A study carried out by the WHO (1990), found mercury to be a neurotoxin particularly affecting the developing brain and causing mental retardation to the unborn foetus due to its ability to cross the placenta.

Tin was found to cause testicular degeneration in rats at a dose of 10 mg/kg daily for 13 weeks (de Groot, Feron & Til, 1973) and was carcinogenic at doses of between 0–2000 mg in B6C3F1 mice with increased incidence of hepatocellular adenomas (ATSDR, 2003). Higher concentrations of tin are typically found in canned foodstuffs as a result of dissolution of the tin coating or tin plate, the levels depending largely on the type and acidity of the food, the presence of oxidants, the duration and temperature of storage and the presence of air in the can headspace (Vannoort, Cressey & Silvers, 2000).

Several studies of Nigerian soft drinks and juice drinks (Orisakwe, Oragwu, Maduabuchi, Nzegwu & Nduka, 2009; Maduabuchi et al., 2008), dairy drinks and drinking water (Orisakwe et al., 2006) have detected the presence of trace quantities of heavy metals that have exceeded the maximum contaminant levels (MCL) recommended by the United States Environmental Protection Agency (USEPA), European Union (EU) and World Health Organization (WHO).

A recent renowned study of the concentration of antimony in 42 commercial juices (Hansen et al., 2010), found eight of the products to have antimony concentrations that were up by a factor of 2.7 above the EU limit for drinking water. Studies of mercury and tin in various foodstuffs have also indicated the presence of these heavy metals in excess of safety limits.

Many studies to date have described environmental exposure of humans to heavy metals in African populations, however little is known about the exposure to heavy metal toxins from processed or unprocessed foods consumed in Africa. No data currently exists on the concentrations of antimony, tin and mercury in Nigerian beverages and findings from studies conducted worldwide are varied.

This study determined the concentrations of antimony, tin and mercury in a number of commonly sold and consumed beverages in Nigeria and assessed the extent of the violation of recommended limits set by the USEPA, EU and WHO guidelines.

MATERIALS AND METHODS

Fifty different samples of beverages were utilized in the study including dairy drinks, soft drinks, water, and various types of juice drinks such as fresh juice, juice concentrates and mixed fruit juices, which were purchased in May 2010 in the Niger Delta area of Nigeria. The samples chosen were considered to be a fair representation of the beverages available on the Nigerian market, with the minor exception of a few products that were newly introduced to the market such as energy drinks.

The samples were prepared for analysis by hydrolysing 20 ml of the beverage with 10 ml of hydrochloride (HCL) and 20 ml water (H_2O). The hyrdrolyzed samples were well shaken and transferred to a centrifuge tube for centrifugation at the rate of 3000 rpm to remove solid particles. The resulting homogenised samples were thoroughly mixed before sub-samples were taken for analysis to ensure homogeneity of the mixture. The presence of antimony and tin were analysed in samples using the Unicam Atomic Absorption Spectrophotometer (AAS) Model 929, employing an air-acetylene oxidizing (lean, blue) flame at the recommended wavelength of 217 nm and a nitrous-oxide-acetylene reducing (rich red) flame of wavelength 286.3 nm for antimony and tin respectively. Determining the presence of tin and antimony in dairy drinks involved precipitation of the milk proteins including casein by adding trichloroacetic acid (TCA) to the samples. All other determinations were carried out in malt drinks, soft drinks, energy drinks and the table waters by the direct aspiration method.

Mercury was determined by the cold vapour technique after reduction with stannous chloride ($SnCl_2$), in order to release the mercury in the sample solution. Precaution was taken at all times due to the toxic nature of mercury. A Stock Standard Solution was prepared by dissolving 1.08 g of mercury (II) oxide, in a minimum volume of 1:1 HCL and diluted to 1 litre with de-ionised water. This solution was then analysed by the AAS using an air-acetylene, oxidizing (lean, blue) flame at a wavelength of 253.7 nm.

The concentration of the contaminant was calculated using the arithmetic mean according to Parkhurst (1998), by multiplying the amount of the chemical element/volume of the sample beverage. The volume of one and a half litres was assumed in the calculations of the concentration of antimony, tin and mercury, as it was considered the average intake volume for adults.

Appropriate quality procedures and precautions were carried out to assure the reliability of the results. Reagents used to calibrate the instrumentation were of analytical grades. A spike-and-recovery analysis was performed to assess the accuracy of the analytical techniques used. Post-analysed samples were spiked and homogenized with varying amounts of the standard solutions of the different metals. The spiked samples were then processed for the analysis by the dry ashing method.

RESULTS

The results of the analysed samples were grouped into three subgroups: fruit juices and soft drinks, dairy drinks and bottled waters, as shown in Tables 1–3. The group with the highest and broadest concentration ranges of the heavy metals studied were of the fruit juices and soft drinks group.

The results of the analyses of mercury, tin and antimony in 37 fruit juice and soft drink samples are shown in Table 1. Tin had the highest concentration recorded amongst all heavy metals analysed. The concentration range of tin within the fruit juices and soft drinks group was $0.97 - 6.33$ μg/L, which represented a mean concentration of 3.70 ± 0.22 μg/L. Both mercury and antimony were also of the highest concentrations recorded within the fruit juice and soft drinks group. Mercury ranged from $0.61 - 6.04$ μg/L, giving a mean concentration of 2.39 ± 0.25 g/L and antimony ranged between $0.21 - 1.86$ μg/L with a mean concentration of 0.49 ± 0.05 μg/L.

Table 2 shows the levels of mercury, tin and antimony detected in ten dairy drinks. Amongst all the beverage samples, mercury was calculated as having the highest mean concentration of 2.93 ± 0.34 μg/L, owing to the lesser variation of concentrations detected, $1.44 - 4.88$ μg/L. The mean concentration of tin was the lowest detected within this group and levels of antimony recorded were similar to that of the fruit juices and soft drinks group.

In the bottled water sample group tin had a narrower range of concentrations recorded, however the mean concentration calculated for tin was the highest of all the beverage samples. The mean concentration of 4.34 μg/L was detected for tin, while conversely the mean values of mercury and antimony were the lowest recorded amongst all the samples, as shown in Table 3.

Table 1. Antimony, tin and mercury (μg/L) levels in fruit juices and soft drinks.

Product name	Producer	Place of manufacture	Batch number	Antimony (μg/l)	Tin (μg/l)	Mercury (μg/l)
GRAND MALT	PABOD BREWERIES LTD.	Nigeria	C2262130	0.57	5.43	3.16
COCA-COLA	NIGERIAN BOTTLING COMPANY NIG	Nigeria	R300:37072F	0.41	4.22	0.61
GINGER BEER	SUN MARK LTD	UK	L22730	0.22	6.33	3.11
FANTA ORANGE	NIGERIAN BOTTLING COMPANY	Nigeria	AB305:12051F	0.52	0.97	0.96
SPRITE	NIGERIAN BOTTLING COMPANY	Nigeria	AB301:42005F	0.24	3.06	0.88
SCHWEPPES BITTER LEMON	NIGERIAN BOTTLING COMPANY	Nigeria	AB301:48007F	0.24	4.21	1.03
RUBICON GUAVA	RUBICON DRINKS LTD	UK	9324	0.33	4.22	4.63
FAYROUZ PREMIUM SOFT DRINK	NIGERIAN BREWERIES PLC	Nigeria	-	0.44	5.06	1.59
CAPRI-SONNE ORANGE DRINK	CHI LTD	Nigeria	Z130910A5	0.46	5.22	1.21
DANSA FRUIT DRINKS	DANSA FOODS LTD	Nigeria	01414:11:08	0.41	4.26	2.83
DELITE ORANGE FRUIT JUICE	UAC DAIRES	Nigeria	24/2D	0.61	4.06	1.22
CHIVITA PREMIUM PINEAPPLE JUICE	CHI LTD	Nigeria	Z010710B9	0.61	3.14	1.01
CHI EXOTIC PINEAPPLE AND COCONUT NECTAR	CHI LTD	Nigeria	Z160610C9	0.36	1.66	1.14
TROPICAL PURE FRUIT JUICE	DANSA FOODS LTD	Nigeria	00703:50:26	0.21	1.26	1.87
ICE TEA LEMON	CHI LTD	Nigeria	Z020610A12	1.86	4.16	1.33
LUCOMALT	GLAXOSMITHKLINE	Nigeria	ETSILN	0.54	3.64	4.03
5 ALIVE BERRY BLAST	NIGERIAN BOTTLING COMPANY	Nigeria	ADJ322:44063	0.46	2.45	1.57
LUCOZADE BOOST	GLAXOSMITHKLINE	Nigeria	DT2IER	0.25	3.74	1.87
RIBENNA BLACKCURRENT	GLAXOSMITHKLINE	Nigeria	ET17OR	0.36	3.27	1.59
FRUCHTEGUT	MERTINGER	Germany	EHM4	0.87	3.51	5.87
LA CASERA APPLE DRINK	CLASSIC BEVERAGES NIG. LTD	Nigeria	522032511	0.39	4.01	1.33
BOBO APPLE MILK DRINK	BOBO FOOD AND BEVERAGE LTD	Nigeria	A-03	0.31	3.66	2.14

(*continued on next page*)

Table 1 (*continued*)

Product name	Producer	Place of manufacture	Batch number	Antimony (μg/l)	Tin (μg/l)	Mercury (μg/l)
V8 SPLASH BERRY BLEND	CAMPBELL SOUP COMPANY	USA	CUBTZL0503	0.44	3.21	5.41
FUZE HEALTHY INFUZIONS	FUZ BEVERAGES LLC	USA	UTDU01576756	0.26	3.64	3.84
SPRITE	NIGERIAN BOTTLING COMPANY	Nigeria	A0621:16038	0.69	2.44	1.06
SANS CREAM SODA	PHARMA DEKO PLC	Nigeria	A328	0.33	4.36	2.41
SCHWEPPES BITTER LEMON	NIGERIAN BOTTLING COMPANY	Nigeria	AFS11:10166F	0.26	1.33	1.63
COCA-COLA	NIGERIAN BOTTLING COMPANY	Nigeria	AD612:48041	0.54	4.02	1.31
FANTA ORANGE	NIGERIAN BOTTLING COMPANY	Nigeria	AD611:01089	0.51	4.17	1.24
TANGO	BALL	UK	RO3L0134	0.54	5.79	3.16
OLD JAMAICA GINGER BEER	COTT BEVERAGES LTD	UK	5814148	0.51	1.34	4.88
AMSTEL MALTA	NIGERIAN BOTTLING COMPANY	Nigeria	O:35556Z1316	0.79	5.47	3.26
BETAMALT	INTERNATIONAL BREWERIES PLC (NID.)	Nigeria	31081017:02	0.26	2.79	4.26
NESTLE MILO ENERGY DRINK	NIHON CANPACK	Malaysia	OU20155BA	0.39	2.35	2.53
ROBUST SUGAR FREE	SUN MARK LTD	UK	8E01D14A	0.45	5.36	6.04
SEVEN UP	SEVEN UP BOTTLING COMPANY PLC	Nigeria	-	0.98	4.82	0.84
COCA COLA (Glass Bottle)	NIGERIAN BOTTLING COMPANY	Nigeria	-	2.77	0.45	1.38
% (number) of products Violating the WHO, USEPA and EU Limits for Heavy Metals in drinking water				EU (5 μg/L) 0% (0) WHO (20 μg/L) 0% (0) USEPA (6 μg/L) 0% (0)	EU (No Limit)* WHO (2 μg/L) 86.5% USEPA (No Limit)*	EU (1 μg/L) 89.2% WHO (1 μg/L) 89.2% USEPA (2 μg/L) 43.2%

Mercury Range: 0.61–6.04; Mean Value = 2.39 ± 0.25 (n = 37); Antimony Range: 0.21–1.86; Mean Value: 0.49 ± 0.05 (n = 37); Tin Range: 0.97–6.33; Mean Value: 3.70 ± 0.22 (n = 37).

Table 2. Antimony, tin and mercury (μg/L) levels in dairy drinks.

Product name	Producer	Place of manufacture	Batch number	Antimony (μg/l)	Tin (μg/l)	Mercury (μg/l)
THREE CROWNS EVAPORATED MILK	FRIESLAND COMPINIA WAMCO NIG. LTD	Nigeria	11:47:39	0.32	6.17	1.44
HOLLANDIA YOGHURT DRINK	CHI LTD	Nigeria	Z190810C9	0.47	3.22	1.84
YO! YOGHURT FLAVOURED DRINK	PZ CUSSONS NIG PLC	Nigeria	175P	0.49	2.46	2.67
ZIZA DAIRY PRODUCTS	DANSA FOODS LTD	Nigeria	01313:32:58	0.37	3.44	2.34
DICTA YOGHURT PLAIN	DICTACHI FOODS NIG. LTD	Nigeria	526XXXXXX	0.44	2.64	2.06
GARDEN CITY YOGHURT	SIMPLEX PACKAGES AND ALLIED RESOURCES LTD	Nigeria	21217	1.35	3.54	2.95
VIJU MILK	VIJU INDUCTRIES (NIG.) LTD	Nigeria	A2-03	0.33	5.14	3.85
VITAMILK	GREEN SPOT LTD	Thailand	31-1-11135-2-001	0.34	2.47	4.88
PEAK CONDENSED MILK	FRIESLAND COMPINIA	Holland	NPOLIA07:21	0.49	5.22	4.06
NUTRICIMA YOGHURT FLAVOURED DRINK	NUTRICIMA INDUSTRIES	Nigeria	NA	0.28	1.69	3.16
% (number) of products Violating the WHO, USEPA and EU Limits for Heavy Metals in drinking water				EU (5 μg/L) 0% (0) WHO (20 μg/L) 0% (0) USEPA (6 μg/L) 0% (0)	EU(No Limit)* WHO (2 μg/L) 90% USEPA (No Limit)*	EU (1 μg/L) 100% WHO (1 μg/L) 100% USEPA (2 μg/L) 80%

Mercury (Range: 1.44–4.88; Mean Value = 2.93 ± 0.34 (n = 10), Tin (Range: 1.69–6.17; Mean Value = 3.60 ± 0.46 (n = 10),Antimony (Range: 0.28–1.35; Mean Value = 0.49 ± 0.10 (n = 10).

Table 3. Antimony, tin and mercury (μg/L) levels in bottled water samples.

Product name	Producer	Place of manufacture	Batch number	Antimony (μg/l)	Tin (μg/l)	Mercury (μg/l)
EVA TABLE WATER	NIGERIAN BOTTLING COMPANY	Nigeria	A0313:52	0.55	5.26	0.91
LA VOLTIC TABLE WATER	VOLTIC LTD	Nigeria	29/06/RSP	0.37	4.11	0.97
PURE LIFE PREMIUM DRINKING WATER	NESTLE NIGERIA PLC	Nigeria	102323087	0.51	3.66	0.94
% (number) of products Violating the WHO, USEPA and EU Limits for Heavy Metals in drinking water				EU (5μg/l) 0% (0) WHO (20 μg/L) 0% (0) USEPA (6 μg/L) 0% (0)	EU (No Limit)* WHO (2 μg/L) 100% (0) USEPA (No Limit)*	EU (1μg/l) 0% (0) WHO (1 μg/L) 0% (0) USEPA (2 μg/L) 0% (0)

Mercury (Range: 0.91–0.97; Mean Value = 0.94 ± 0.02 (n = 3), Tin (Range: 3.66–5.26; Mean Value = 4.34 ± 0.48 (n = 3), Antimony (Range: 0.37–0.55; Mean Value = 0.48 ± 0.05 (n = 3).

On comparison of the levels of the three heavy metals in the fruit juices and soft drinks, dairy drinks and bottled water samples with standards set by the WHO, USEPA and EU, as shown in Tables 4–6, the dairy drinks group were found in most violation of mercury 100%, 100% and 80% violating the EU, WHO and USEPA guidelines respectively. Fruit juices and soft drinks were found 89.2%, 43.2% and 89.2% in violation of WHO, USEPA and EU permissible levels of mercury respectively.

Tin however was in most violation in the bottled water group with 100% of samples violating the WHO permissible levels and 90% and 86.5% estimated violations within the dairy drink and fruit juices and soft drink groups respectively. Antimony on the other hand was found to be generally low in comparison to the other heavy metals detected, with none of the samples violating the guideline values.

The 'worst case scenario' estimation of the intake of the heavy metals as a result of consumption of beverages from each sample group, on an average weekly basis volume of 4.5 L (1.5 L of the three most contaminated beverage products) was 26.63 μg/L, 5.64 μ/L and 17.79 μg/L respectively, as shown in Table 7.

Table 4. Heavy metal content of different brands of fruit juice and soft drinks.

Heavy metal	Average	Range	WHO limits Lower	WHO limits Upper	USEPA Limits Lower	USEPA Limits Upper	EU Limits Lower	EU Limits Upper	Percentage of samples in violation (WHO/EPA/EU)
Mercury	2.35	0.61 - 6.04	1 μg/L	1 μg/L	-	2 μg/L	-	1 μg/L	89.20% /, 43.24% / & 89.20%
Tin	3.88	0.97 - 6.33	2 μg/L*	-	-	-	-	-	86.50% *
Antimony	0.50	0.22 - 1.86	-	20 μg/L	-	2 μg/L	-	5 μg/L	Nil

Table 5. Heavy metal content of different brands of dairy drinks.

Heavy metal	Average	Range	WHO limits lower	WHO limits upper	USEPA Limits lower	USEPA Limits upper	EU Limits lower	EU Limits upper	Percentage of samples in violation (WHO/EPA/EU)
Mercury	2.93	1.44 - 4.88	1 μg/L	1 μg/L	-	6 μg/L	-	1 μg/L	100% /, 80% & 100%
Tin	3.60	1.69 - 6.17	2 μg/L*	-	-	-	-	-	90%*
Antimony	0.49	0.28 - 1.35	-	20 μg/L	-	2 μg/L	-	5 μg/L	Nil

Table 6. Heavy metal content of different brands of bottled water.

Heavy metal	Average	Range	WHO limits lower	WHO limits upper	USEPA Limits lower	USEPA Limits upper	EU Limits lower	EU Limits upper	Percentage of samples in violation (WHO/EPA/EU)
Mercury	0.94	0.91 - 0.94	1 μg/L	1 μg/L	-	6 μg/L	-	1 μg/L	Nil
Tin	4.34	3.66 - 5.25	2 μg/L	-	-	-	-	-	100%*
Antimony	0.48	0.37 - 0.55	-	20 μg/L	-	2 μg/L	-	5 μg/L	Nil

Table 7. Example of calculating heavy metal weekly intake.

$$\text{True Sb intake} = 1.5 * \times 1.86 + 1.5 \times 0.55 + 1.5 \times 1.35 = 5.64\ \mu g/L\ \text{Sb}$$
$$\text{True Hg intake} = 1.5 \times 6.04 + 1.5 \times 0.94 + 1.5 \times 4.88 = 17.79\ \mu g/L\ \text{Hg}$$
$$\text{True Sn intake} = 1.5 \times 6.33 + 1.5 \times 5.25 + 1.5 \times 6.17 = 26.63\ \mu g/L\ \text{Sn}$$

*(1.5 L is assumed the weekly beverage consumption, which is multiplied by the highest concentration of heavy metal contaminant from each beverage group: the volume of the each beverage was assumed to be one litre).

DISCUSSION

On analysis of the levels of antimony, tin and mercury detected in the beverage samples, it was found that the concentration of heavy metals varied considerably between each sample group. Some samples were below the recommended safety limits, others within this and some exceeding the threshold limits established by the European Union, World Health Organization and the US Environmental Protection Agency guidelines.

The levels of antimony recorded in this study were found to be within the limits stipulated by the WHO (20 μg/L), EU (5 μg/L) and USEPA (2 μg/L) for antimony in drinking water (WHO, 2003; USEPA, 2011). These levels reported however, were much lower than the antimony levels recorded in the study by Hansen et al. (2010), despite the beverage samples similarly having been packed in PET containers. The different instrumentation techniques may have accounted in part for the difference in antimony levels detected.

The intake estimates for antimony calculated using the arithmetic mean for a Nigerian consuming one and half litres of beverages per week was 5.64 μg/L, which was found to be in line with the World Health Organization recommended daily tolerable intake of antimony at 6.0 μg/kgbw/day (Egan, Tao, Pennington & Bolger, 2002).

Alarmingly the mercury levels analysed in 100% of dairy drinks and 89.2% fruit juices and soft drinks were found to violate both the WHO (1 μg/L), EU (1 μg/L) and USEPA (2 μg/L) regulations (WHO, 2003; USEPA, 2011). These results are contrary to findings by Cheung Chung, Kwong, Yau & Wong (2008), who reported extremely low mercury concentrations in Nigerian beverages. Considering the daily intake of these beverages in particular dairy drinks by children, young adults and pregnant women, it is feared that long-term exposure may pose significant health risks.

Although fish and other seafood products have been documented as being the main source of mercury in the diet (WHO, 1990), this has been disproved by our findings due to the high levels of total mercury that were detected in both the dairy drinks group and fruit juices and soft drink samples.

Although previous authors have recorded detectable concentrations of tin in beverages such as tea, carbonates, fruit drinks, bottled water, herbal drinks and iced tea (MAFF UK 1998) these levels were all below 1 mg/kg and lower than the regulatory limit set by the WHO The Tin in Food Regulations (1992) of 200 mg/kg. In this study however, the levels of tin were found to violate 100%, 88.9% and 90% of bottled water samples, fruit juices and soft drinks and dairy products respectively, exceeding the WHO (2 μg/L) regulation.

The present study has confirmed that contrary to common belief, beverages sold and consumed in Nigeria are not free of contamination of the toxic heavy metals tin and mercury. The values of tin and mercury detected were both found in severe violation of WHO, USEPA and EU safety standards.

Possible routes that are believed to result in the contamination of beverages during the production process include the use of contaminated water, poor assaying of raw materials, poor hygiene, low quality packaging materials and inadequate storage conditions.

Imported beverages were also found to contain high levels of the contaminants, which implies that heavy metals are yet to be regulated and consequently Nigeria has become a dumping ground for beverages untested for these toxic heavy metals.

CONCLUSION

As the heavy metal content in beverages constitutes a significant source of exposure to the general population, increased consumption of beverages unregulated for such contaminants represents a worrying problem. Limited studies of the chronic effects of some of these heavy metals warrants further investigation to determine blood concentrations of highly susceptible population groups such as in children and pregnant women.

This study also calls for mandatory testing of heavy metals in beverages and food as a way of monitoring the extent of violation of guideline values. Tighter regulation on the composition of beverages locally produced and imported into Nigeria would help to greatly reduce the extent of this problem.

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