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Full Length Research Paper

Analysis of selected metallic impurities in soft drinks marketed in Lagos, Nigeria

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Twenty brands of soft drinks commonly consumed in Lagos, Nigeria were analyzed for lead, cadmium, nickel, silver, chromium and zinc using standard biochemical procedures. The aim was to determine whether the concentrations of toxic metals in commonly consumed soft drinks are below or above the upper limit for each of the metals as set by World Health Organization (WHO). Results showed that cadmium was present in four of the samples at a concentration ranging from 0.023 to 0.158 mg/L, lead was present in three of the samples at a concentration ranging from 0.5045 to 3.0275 mg/L, nickel was present in six of the samples at a concentration ranging from 0.016 to 0.063 mg/L while silver was absent in all of the samples. Some of the samples analyzed can be said to be safe for human consumption because the values of the metals were below the allowable limits as set by WHO while others could not be said to be safe as the levels of metals were above the allowable limits set by WHO. Therefore, it is suggested that health authorities and soft drink producing companies should pay more attention to the sources of these metals in soft drinks.

Key words: Soft drinks, toxic metals, maximum contaminant level, atomic absorption spectrophotometry.

INTRODUCTION

Soft drinks, also known as ready-to-drink beverages are sweetened water-based non-alcoholic beverages, mostly with balanced acidity (Eyong et al., 2010). They are frequently flavoured and coloured and the principal component being water which is needed for hydration. Soft drinks are commonly consumed by both the young and older members of the Nigerian society to quench thirst. Manufacturers of soft drinks require special attention to the purity and uniformity of ingredients, raw materials, sources of water and packaging material which are actually the sources of impurities in the drinks. The presence of metallic impurities in soft drinks can constitute health hazards to the public (Onianwa et al., 1999; Bakare-Odunola, 2005; Krepcio et al., 2005).

It has been shown that environmental pollution is the main cause of heavy metal contamination in the food chain. Lead and cadmium are two potentially harmful metals that have stimulated considerable interest. Atmospheric contamination, the excessive use of fertilizers and pesticides and sewage sludge or irrigation with residual water is among the source of contamination of foodstuffs and beverages. As a result of soil, atmosphere, underground and surface water pollution, foods and beverages are contaminated with heavy metals (Demirozu and Saldamli, 2002; Adepoju-Bello et al., 2009; Bingol et al., 2010).

Lead and cadmium toxicity is well documented and is recognized as a major environmental health risk throughout the globe (Bingol et al., 2010). Lead is known to affect humans and animals of all ages; however, the effects of lead are most serious in young children. Cadmium is a toxic and carcinogenic element (Rubio et al., 2006). Due to the high toxicity of lead and cadmium, it is of public health interest that these metals are quantified in beverages and foodstuffs. For instance, cadmium intake in relatively high amounts can be detrimental to human health. Over a long period of intake, cadmium

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may accumulate in the kidney and liver because of its long biological half life and may lead to kidney damage (Maduabuchi et al., 2006). In addition, heavy metals composition is of interest because of their essential or toxic nature. For example, iron, chromium and cobalt are essential while lead, cadmium and nickel are toxic at certain levels (Al Rmalli *et al*., 2005).

Nickel is a compound that occurs in the environment only at very low levels. Humans use nickel for many different applications. The most common application of nickel is its use as an ingredient of steel and other metal products. It can be found in common metal products such as jewellery (Wilson, 2009). Foodstuffs naturally contain small amounts of nickel. Chocolate and fats are known to contain severely high quantities (Wilson, 2009). Toxicity of nickel has the following consequences: higher chances of development of lung cancer, nose cancer, larynx cancer and prostate cancer, sickness and dizziness after exposure to nickel gas, lung embolism, respiratory failure, birth defects, asthma, chronic bronchitis and allergic reactions (Kasprzak et al., 2003).

Prolonged exposure to silver dust or to the silver compounds in medicines or supplements can result in a permanent blue-gray staining of the eyes, nose, mouth, throat and skin (Ibrahim et al., 2006).Zinc is an essential mineral that is found in almost every cell and its toxicity has been seen in both acute and chronic forms. Intakes of 150 to 450 mg of zinc per day have been associated with low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins (the good cholesterol). One case report cited severe nausea and vomiting within 30 min after the person ingested four grams of zinc gluconate (570 mg elemental zinc) (Valko et al., 2005).

Food is the main source of chromium intake by man and it is fairly and evenly distributed throughout the various food groups but highest concentrations of chromium are found in meat, fish, fruit and sugar groups. Potable water, fruit juices and soft drinks are some of the most widespread beverages in the habitual diet and they can contribute to chromium dietary intake. Chromium poisoning can be acute or chronic and death in acute chromium poisoning is usually due to uraemia (Maduabuchi et al., 2006).

It should be known however, that toxicity is a function of solubility. Insoluble compounds as well as the metallic forms often exhibit negligible toxicity. In some cases, organometallic forms, such as dimethyl mercury and tetraethyl lead, can be extremely toxic. In other cases, organometallic derivatives are less toxic such as cobaltocenium cation (Wilson, 2009).Various studies have described environmental exposure of humans to heavy metals in African populations. However, little is known about the exposure to heavy metals from soft drinks consumed in Africa as a whole and Nigeria in particular and no data exist on levels of heavy metals in soft drinks in Lagos, Nigeria. This study was carried out to ascertain the presence or absence of some toxic metals in selected commonly consumed soft drinks marketed in Lagos State and also to determine their concentrations/ levels.

MATERIALS AND METHODS

Twenty brands of soft drink beverages purchased in May 2009 in Lagos, Nigeria were used in the study. The samples were digested using 96% of nitric acid to remove organic material by decomposing them into carbon dioxide (CO_2); $(CH_2)_n + 2HNO_3 \rightarrow CO_2 + 2NO + 2H_2O$ and also to convert the metals present into soluble forms.

All chemicals and reagents used are of analytical grade. Nitric acid (GFS Chemicals Inc., Columbus, 69%) was used to digest the samples for analysis. Deionised water (from Federal Environmental Protection Agency, Lagos), analytical reagent grade (BDH Ltd, Poole, Dorset, UK), Zinc chloride analytical reagent grade (BDH Ltd, Poole, Dorset, UK), analytical reagent grade (BDH Ltd, Poole, Dorset, UK), and Chromium (II) Potassium Sulphate 12 hydrate analytical reagent grade (BDH Ltd, Poole, Dorset, UK) were used to prepare the standard solutions for the calibration plot.

The soft drink samples were randomly selected for analysis. Determination of toxic metal ion concentration was carried out using the atomic absorption spectrophotometry (AAS) Analyst 200 Copyright©20003 Perkin Elmer, incorporation.

Sample digestion

Concentrated nitric acid (69%), 10 ml, was added to 25 ml of the sample (soft drink). The mixture was evaporated on a hot plate in a fume cupboard until the brown fumes disappears leaving white fumes. 50 ml of distilled water was added and this was concentrated by evaporation on a hot plate to 25 ml. Subsequently, additional 25 ml of distilled water was added to make up to 50 ml. This was then filtered and ready for AAS analysis (Wallace, 2001).

Standard metal ion preparation

The calibration plot method described in the British pharmacopoeia, 2005, was adopted for the analysis (Langford and Ferner, 1999). A stock standard solution, 1000 ppm, of the metal ion was prepared by dividing the molar mass of the compound containing the element by the molar mass of the element. The weight obtained was equivalent to 1.0 g of the metal ion. This weight (which is equivalent to 1.0 g of the metal) was dissolved in 1000 ml to give 1000 ppm. A working solution of 100 ppm was prepared from the stock solution.

Serial dilutions were prepared from the working solution. The absorbance of these solutions was obtained using the AAS. The calibration graph was plotted and the regression equation was obtained. Deionised water was used as control.

Sample analysis

The calibration plot method was used using the AAS equipped with appropriate filter for each metal ion (British Pharmacopoeia, 2005). The concentration of the digested soft drink samples was derived from the regression equation and the samples were analyzed in duplicates.

RESULTS

There was no detectable metal ion in the distilled water used as control. We also reported non-detectable levels

Table 1. Regression data for the calibration plot.

Metal ion	Pb^{2+}	Cd^{2+}	Ni^{2+}	Ag^{+}	Cr^{2+}	Zn^{2+}
Regression equation	y = 0.0013x	y = 0.0025x	0.0664x	y = 0.0196x	y = 0.011x	y = 0.4567x
Coefficient of determination (R^2)	0.9963	0.9847	0.9813	0.9902	0.9993	0.9897

Table 2. Average concentration of detectable metal ions in soft drink samples.

Sample code	Pb^{2+} (mg/L)	Cd^{2+} (mg/L)	Ni^{2+} (mg/L)	Ag^{+} (mg/L)	Cr^{2+} (mg/L)	Zn^{2+} (mg/L)
SD1	0.0022	ND	0.0235	ND	ND	ND
SD2	ND	ND	0.0630	ND	ND	ND
SD3	ND	ND	ND	ND	ND	ND
SD4	ND	ND	0.0460	ND	ND	ND
SD5	0.0002	ND	ND	ND	ND	ND
SD6	ND	0.0002	ND	ND	ND	ND
SD7	ND	0.0003	ND	ND	ND	ND
SD8	0.002	ND	0.0160	ND	ND	ND
SD9	ND	ND	0.018	ND	ND	ND
SD10	ND	ND	ND	ND	ND	ND
SD11	ND	0.0003	ND	ND	ND	ND
SD12	ND	ND	ND	ND	ND	ND
SD13	ND	ND	ND	ND	ND	ND
SD14	ND	0.0001	0.0210	ND	ND	ND
SD15	ND	ND	ND	ND	ND	ND
SD16	ND	ND	ND	ND	ND	ND
SD17	ND	ND	ND	ND	2.3346	ND
SD18	ND	ND	ND	ND	ND	ND
SD19	ND	ND	ND	ND	ND	ND
SD20	ND	ND	ND	ND	ND	ND

for silver and zinc. Chromium showed non-detectable level in 95% of the samples. Nickel showed the highest levels (30%) of metal ions among the metals analyzed. The regression equation and coefficient of determination (R^2) for the calibration plots are show in Table 1.

The R^2 obtained from Pb^{2+}, Cd^{2+}, Ag^{+}, Cr^{2+} and Zn^{2+} calibration plots are 0.9963, 0.9847, 0.9902, 0.9993 and 0.9897, respectively. The average concentrations of detectable metal ions in the soft drink analyzed are shown in Table 2.

DISCUSSION

Accumulations of heavy metals found in soft drinks are detrimental to human health. Maximum contaminant level goal (MCLG) is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. On the other hand, maximum contaminant level (MCL), the highest level of a contaminant that is allowed in drinking water and MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards. The MCL is measured in milligrams per liter (mg/L) which is equivalent to parts per million (United States Environmental Protection Agency, 2009). Our data shows that the cadmium, silver and lead levels found in all of the soft drink samples were within acceptable standard values and agrees with previous studies elsewhere (Maff, 1999; Oktem and Kocer, 2004; Bingol et al., 2010).

It should be that both adults and youth including children do enjoy taking soft drinks in Nigeria at parties, and soft drinks are used for entertaining visitors. They are available in different forms, colours and tastes. Analysis of the toxic metals in these soft drinks in our society is very important because of the health hazards emanating from drinking them. Our study is very important in view of it being the first study on soft drinks in Lagos (Lagos, the most populous city in Africa). Although the toxic metal ions may be present in concentrations lower than the maximum contaminant level, they are not easily eliminated from the system and could accumulate over the years causing diseases like skin cancer, lung cancer, liver cancer, heart diseases, brain damage, lymphatic cancer, lung diseases, kidney failure, memory loss and mental retardation in children.

In this study twenty brands of soft drinks were analyzed. 15% of the brands contain lead. The MCL of lead is 0.01 mg/L (World Health Organization, 2007). The lead content obtained was less than the MCL (Table 2). 20% of the samples contain cadmium at concentrations lower than the maximum contaminant level (Table 2). Nickel was detected in 30% of the samples, 20% have concentrations higher than the MCL (0.02 mg/L). This should be a major health concern to the producers, the health agencies and the consumers since accumulation of nickel in the body may cause lung cancer, lung embolism, nose cancer, larynx cancer, prostate cancer, asthma, chronic bronchitis, respiratory failure and birth defects. Silver was not detected in the samples analyzed.

Chromium was detected in one of the soft drink samples, which was one of the popular children's' drink (5% of the samples), at a concentration higher than the MCL (0.05 mg/L). The chromium levels observed in our study is higher than the chromium levels reported in a Spanish study (Garcia et al., 1999). This calls for serious public health concern on the part of the Nigerian consumers and the regulatory agencies. Chromium is considered to be essential for the maintenance of lipid, protein and glucose metabolism. However, chromium supplements are becoming increasingly popular. In a double-blind randomized placebo-controlled clinical trial in a Chinese population with type 2 diabetes mellitus, supplementation with 1000 µg of chromium led to a fall in the glycosylated haemoglobin level by 2%. Previously, it was thought that toxic effects of chromium are seldom seen; recently however, the safety of one of the dosage forms of chromium (chromium picolinate) has been questioned. It is important to be aware that individual patients with type 2 diabetes mellitus might have increased risk of hypoglycaemic episodes when taking chromium supplements as self-medication (Kleefstra et al., 2004). This raises concern for persons who may potentially increase their chromium levels to a toxic level from frequently but low-level intake. Despite the popular opinion on increasing chromium intake as one of the essential elements, consumers of soft drinks may be exposed to higher levels considering the relative contribution of chromium to the diet by soft drink beverages. Accumulation of chromium in the body can cause damage to the liver, kidney, nose, lungs; and possible asthma attack (Kleefstra et al., 2004).

Zinc was not detected in the any of the samples analyzed. Special attention should be taken in the production of these soft drinks because of the toxicity of the metal ions and most of them do cause oxidation of some compound present in the soft drink which could result in the production of dangerous compounds which when ingested could result in harmful effects. A long-term and/or excessive consumption of foods containing heavy metals above the tolerance levels has a hazardous effect on human health.

Conclusion

In this study, 15% of the soft drink samples contained lead, 20% contained cadmium; nickel was detected in 30% of the samples, and 5% contained chromium. Zinc and silver were not detected in the soft drink samples. The health agencies and the soft drink producing companies should handle this issue urgently to safe guard the health of the people.

Recommendations

Further investigations into the level of exposure of humans to these heavy metals, the systemic availability of these contaminants upon consumption of soft drinks and the short-and long-term toxicological implications and impact of consumer are recommended among Lagos residents.

Also, research should be centered on the sources of these contaminants, how to avoid and eliminate them from the soft drinks before passing the products into the market for consumption. Due to the wide consumption of soft drinks, they contribute a large fraction to heavy metals intake and therefore strict control of these elements is advisable. For this purpose, the steps in all processes must be monitored to prevent contamination by heavy metals. Application of agricultural wastes should be made at a rate which exceeds their levels in water. Heavy metal contamination in food and drinks has been an important factor; therefore, facility modernization and quality manufacturing are required to prevent heavy metal contamination in drinks and thus the possible health hazards to the consumer.

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