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# An Assessment of metal contaminant levels in selected soft drinks sold in Nigeria

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**Abstract**
The concentrations of Fe, Zn, Cu, Cr, Pb and Cd, were determined in twenty four selected soft drinks bought from retail markets in Nigeria. The results obtained were compared with the recommended safe limits for drinking water set by WHO and USEPA, with a view to ascertaining whether or not the studied samples are contaminated by metals. The concentrations of Fe in the soft drinks ranged from 0.10 mg/l – 3.81mg/l and the Zn contents ranged from 0.02 –2.42mg/l. Cu concentration was in the range 0.07-2.20mg/l and Cr concentration ranged from not detected (ND) – 0.10mg/l. Pb and Cd concentrations were found to from range ND – 0.05mg/l and ND – 0.03mg/l respectively. This study showed that 53.35% of the samples had Fe concentration above safe limits and Cu concentration exceeded acceptable limits in 7.14% of the samples. None of the soft drinks analysed had Zn concentrations above safe limits. The proportion of the samples that exceeded the set limits for Cr, Pb and Cd were 20.83%, 29.17% and 16.67% respectively.

***Keywords:*** *Soft drinks, Beverages, Metals, Contaminant, level, Nigeria*

## 1. Introduction

Soft drinks are non-alcoholic water-based flavoured drinks that are optionally sweetened, acidulated and carbonated. They include all beverages which comply with the above definition, and which do not claim to be part of adjacent categories such as fruit juices and nectars, dairy drinks, mineral waters, etc. [1]. Globally, carbonated soft drinks are the third most consumed beverages; Per capita annual consumption of carbonated soft drinks is nearly four times that of fruit beverages [1].

In Nigeria, soft drinks are consumed daily in large amounts by both the young and old due to its affordability, characteristic taste, and thirst quenching potential. They are the usual beverages served in most festivities and celebrations across the country. The hot weather conditions in the country also contribute to the high consumption of soft drinks. The increasing demand for food safety is stimulating research regarding the benefits and risks associated with consumption of foodstuffs and drinks. Metal composition of foods is of interest because of their essential and/or toxic nature to man. The widespread roles of metals in health and diseases range from the requirement for intake of essential trace elements to toxicity associated with metal overload. In small quantities, certain metals such as Fe, Cu, Mn, Cr, Co and Zn are nutritionally essential for a healthy life. However, these metals can still cause ill effects when ingested in high amounts. Metals like Pb, Cd, Hg and As are considered non-nutritive and toxic and are known to have deleterious effects even in small quantities. Several cases of human disease, disorders, malfunction and malformation of organ due to metals toxicity has been reported [2].

Metals are widely found in our environment and food sources either naturally or as a result of human activities such as agricultural practices, industrial emissions, or contamination during manufacture. A key potential source of exposure to metals is processed beverages that are known to contain metals [3]. Food and beverage contamination may occur due to raw materials and water used. Numerous steps during processing and packaging may also add to the metal ion load of processed beverages.

The evaluation of commercial beverages is an important issue for consumer safety, as they are widely consumed throughout the world. Some studies have quantified levels of metals in soft drinks and established the presence of toxic metals above recommended levels; other studies have reported low values of metals in soft drinks. Common beverages are assessed for their metal content with regulatory controls over maximum permitted levels in place in most countries [3]. There is however, little data on Nigerian soft drinks. The high consumption of soft drinks globally and the dearth of information on metallic contents of Nigerian soft drinks indicates requirements for regular quality assessment. This is necessary so as to ascertain the gains and consequences to the teeming consumers.

The objective of this study is to investigate the metal contents of soft drinks sold in Nigeria and to evaluate whether or not the metal levels comply with the drinking water standards set by two international organizations; World Health Organization (WHO) and Environmental Protection Agency (EPA) and also compare values obtained with data available in literature.

## 2. Materials and Methods

### 2.1 Sample Collection and Preparation

Twenty four brands of soft drinks commonly consumed in Nigeria were purchased from retail outlets in Zaria, Nigeria. 25 ml of each sample was measured into a clean digestion flask. 10 ml concentrated nitric acid was added, and the mixture was heated on a hot plate until brown fumes disappear. The mixture was allowed to cool and 50 ml of distilled water added. It was then filtered and made up to mark in a 100ml volumetric flask.

### 2.1 Metal Analysis

The concentrations of the metals; Iron, Zinc, copper, Chromium, lead and Cadmium in the digested samples were determined using Atomic absorption spectrophotometer (Shimadzu AA-6300). Calibration standards for AAS analysis were prepared by serial dilution of concentrated stock solutions (1000 mg/ l) of the respective metals. Five working standard solutions were prepared for each metal. A calibration curve of absorption versus concentration was plotted for each metal and used for the determination of the concentrations in the samples.

## 3. Results and Discussions

The concentrations of the metals (Fe, Zn, Cu, Cr Pb and Cd) in the soft drinks analysed are presented in table 1. Table 2 presents the recommended maximum permissible limits (MPL) for the investigated metals in drinking water as given by the WHO [4]. The US Environmental Protection Agency (USEPA) has carried out risk assessments dealing with the toxicity of a wide range of chemicals including metals and established Maximum contaminant levels (MCLs) for the substances in drinking water. The Maximum contaminant levels are further categorized into; primary Maximum Contaminant Level (PMCL) and Secondary Maximum Contaminant Level (SMCL). PMCLs are based on health considerations and designed to protect people from pathogens, radioactive elements, and toxic chemicals whereas the SMCL are based on aesthetic issues, such as tastes, odours, or colours in the water which does not pose a risk to health [5]. The PMCLs and SMCLs for our metals of interest as given by USEPA are presented in table 3.

We compared the metal contents of our samples with the drinking water standards of WHO and USEPA (Tables 2 and 3). Recommended levels for drinking water are used as the standard for assessing soft drinks, juices and other water based beverages. The results of our analysis indicate that some of the metals investigated were present in concentrations above permissible limits. The concentration of Fe in the soft drinks studied ranged from 0.10mg/l in SD 12 to 3.81 mg/l in SD 7. Iron is regulated under the USEPA SMCL. The SMCL for iron in drinking water is 0.3 mg/l. 14 out of the 24 samples studied had iron concentration above this limit. This indicates that 53.33% of the studied samples are contaminated by Fe. Being regulated under secondary contaminant levels, no deleterious effects to health may arise from the Iron contents of the samples. Only effects related to aesthetic issues would be expected; Iron above 0.3mg/l in water may contribute to bad taste, teeth staining and formation of sediment and yellow, red, and orange films [5]. Although toxicity from iron overload is known, the condition is usually associated with a genetic disorder [6]. The high concentration of iron found in some of the studied samples may be attributed to poor water treatment and bad production practices. Possible sources of iron in water are from the corrosion of cast iron pipes in distribution systems [7].

The lowest concentration for Zinc (0.02mg/l) was found in SD6 while the highest concentration (2.42mg/l) was in SD1. The maximum contaminant level for Zn in drinking water is 5mg/l. Zinc is also regulated under secondary maximum contaminant level. At a level of/or above 5 mg/L zinc, water can have a metallic bitter taste and 25-40mg/l concentration may cause nausea and vomiting [5]. The Zinc contents of the samples were all below this limit. This implies that none of the effects associated with Zinc contamination will be expected from all the studied samples. Zn is given as no guideline (NGL) by WHO (Table 2) because it is considered as occurring in drinking water at concentrations well below which toxic effects may occur. Our findings agree with this assertion.

The amount of Copper in the soft drink samples ranged from 0.07 in SD 5 to 2.20mg/l in SD 18. The WHO maximum permissible limit for Cu in drinking water is 2mg/l. Only one sample (SD18) had Cu concentrations above this limit. EPA recommends a maximum limit of 1.3mg/l PMCL and 1.0mg/l SMCL for Cu in drinking water. Among the soft drinks analysed, samples SD18 and SD21 had Cu above this concentration.

Table 1: Concentrations of metals (Fe, Zn, Cu, Cr, Cd and Pb) in the soft drink Samples (mg/l)

| Sample code | Fe | Zn | Cu | Cr | Pb | Cd |
|---|---|---|---|---|---|---|
| **SD1** | 0.81 ± 0.02 | 2.42 ± 0.06 | 0.11 ± 0.01 | 0.04 ± 0.01 | ND | ND |
| **SD2** | 0.18 ± 0.07 | 1.24 ± 0.02 | 0.20 ± 0.04 | 0.10 ± 0.02 | ND | ND |
| **SD3** | 0.78 ± 0.10 | 0.82 ± 0.00 | 0.34 ± 0.02 | ND | ND | 0.01±0.00 |
| **SD4** | 1.21 ± 0.05 | 0.52 ± 0.02 | 0.23 ± 0.01 | 0.07 ± 0.03 | 0.05±0.02 | 0.03±0.01 |
| **SD5** | 1.84 ± 0.11 | 0.85 ± 0.01 | 0.07 ± 0.01 | 0.06 ± 0.02 | ND | ND |
| **SD6** | 0.17 ± 0.01 | 0.02 ± 0.00 | 0.32 ± 0.06 | 0.03 ± 0.00 | ND | 0.01±0.00 |
| **SD7** | 3.81 ± 0.02 | 1.92 ± 0.04 | 0.58 ± 0.03 | 0.05 ± 0.02 | 0.01±0.00 | 0.002±0.00 |
| **SD8** | 1.58 ± 0.04 | 1.02 ± 0.10 | 0.15 ± 0.00 | 0.04 ± 0.01 | ND | ND |
| **SD9** | 1.27 ± 0.03 | 1.22 ± 0.02 | 0.38 ± 0.04 | ND | 0.02±0.01 | 0.02±0.01 |
| **SD10** | 2.91 ± 0.12 | 0.66 ± 0.05 | 0.43 ± 0.02 | 0.08 ± 0.02 | ND | ND |
| **SD11** | 0.25 ± 0.04 | 0.08 ± 0.15 | 0.25 ± 0.03 | 0.01 ± 0.00 | 0.01±0.01 | 0.01±0.01 |
| **SD12** | 0.10 ± 0.03 | 0.05 ± 0.02 | 0.18 ± 0.05 | ND | ND | ND |
| **SD13** | 1.73 ± 0.40 | 0.20 ± 0.04 | 0.26 ± 0.10 | 0.01 ± 0.00 | ND | ND |
| **SD14** | 0.24 ± 0.10 | 0.18 ± 0.01 | 0.18 ± 0.06 | ND | 0.01±0.01 | 0.01±0.00 |
| **SD15** | 0.97 ± 0.02 | 2.01 ± 0.10 | 0.51 ± 0.00 | ND | ND | ND |
| **SD16** | 0.39 ± 0.20 | 0.15 ± 0.02 | 0.38 ± 0.02 | 0.03 ± 0.00 | 0.02±0.01 | 0.003±0.00 |
| **SD17** | 0.24 ± 0.15 | 0.51 ± 0.06 | 0.55 ± 0.01 | 0.05 ± 0.01 | 0.01±0.00 | ND |
| **SD18** | 2.30 ± 1.20 | 1.12 ± 0.02 | 2.20 ± 0.00 | 0.06 ± 0.01 | 0.04±0.01 | 0.005±0.00 |
| **SD19** | 1.91 ± 0.45 | 1.78 ± 0.10 | 0.64 ± 0.02 | ND | ND | ND |
| **SD20** | 0.20 ± 0.03 | 0.25 ± 0.05 | 0.30 ± 0.08 | 0.02 ± 0.00 | 0.01±0.00 | 0.02±0.01 |
| **SD21** | 0.67 ± 0.05 | 0.47 ± 0.04 | 1.54 ± 0.15 | ND | ND | 0.01±0.00 |
| **SD22** | 0.28 ± 0.00 | 0.70 ± 0.03 | 0.08 ± 0.02 | 0.01 ± 0.01 | ND | ND |
| **SD23** | 0.27 ± 0.80 | 0.41 ± 0.03 | 0.09 ± 0.03 | 0.04 ± 0.00 | ND | ND |
| **SD24** | 0.14 ± 0.02 | 0.21 ± 0.01 | 0.36 ± 0.01 | 0.02 ± 0.00 | ND | ND |

All results are expressed as mean ± Standard deviation for 3 determinations
ND signifies non-detectable levels of the metals.

Table 3: maximum permissible limits of metals in drinking water as given by World Health organization (WHO) [8]

| **Metals** | **WHO Maximum permissible limits (mg/l)** |
|---|---|
| Zn | NGL |
| Cu | 2.00 |
| Cr | 0.05 |
| Pb | 0.01 |
| Cd | 0.005 |

NGL: no guideline, because it occurs in drinking water at concentrations below those at which toxic effects may occur

Copper is one of many metal ions that are required for essential body functions but are toxic in excess. Copper toxicity can occur from eating acid foods cooked in uncoated copper cookware or from exposure to excess copper in drinking water or other environmental sources [9]. Acute symptoms of exposure to excess copper by ingestion include vomiting, hematemesis (vomiting of blood), hypotension, melena (black "tarry" feces), coma, jaundice and gastrointestinal distress [10]. Chronic (long-term) exposure to high amounts of copper may damage the liver and kidneys [5]. Some of the above mentioned effects may be expected from ingestion of soft drinks with high copper content. The water used for soft drinks production could be a source of Cu in the beverages. Common sources of Copper contaminant in water supplies are from corrosion of plumbing systems [5].

Table 4: Primary maximum and secondary maximum contaminant levels (PMCL and SMCL) for drinking water as set by USEPA (mg/l) [5]

| **Metals** | **PMCL** | **SMCL** |
|---|---|---|
| Fe | None | 0.3 |
| Zn | None | 5.0 |
| Cu | 1.3 | 1.0 |
| Cr | 0.1 | None |
| Cd | 0.015 | None |
| Pb | 0.005 | None |

Chromium, a metallic element once believed to be toxic, has now been proven to be essential to health. It is generally recognized to play an important role in glucose and lipid metabolism. [11]. Chromium exists in the environment primarily in two valence states; trivalent chromium (Cr III) and hexavalent chromium (Cr VI). Chromium (III) is regarded as an essential element; it is the form that is required for the maintenance of normal glucose, lipid and protein metabolism [12]. It is however also toxic when it exceeds the tolerance limit. Cr (VI) is toxic and has no beneficial role in human body. The maximum concentration of Cr detected in the soft drinks was 0.18mg/ while the lowest detected concentration was 0.01mg/l. Cr was not detected in 29.2% of the samples analysed. The maximum allowed limit for Cr in drinking water is 0.05mg/l and 0.1mg as given by WHO and EPA respectively. Of the twenty four soft drink samples analysed, five had Cr content above the WHO limit but none of the Cr concentrations were above the EPA standard. Overall, 37.5% of the studied samples had Cr content above the permissible limit. Ingestion of high amounts of chromium may result in potentially fatal, effects in the respiratory, cardiovascular, gastrointestinal, hepatic, renal, and neurological systems [5, 13].

Lead and Cadmium are metals that are considered non-essential and toxic even at very low levels. Lead and cadmium toxicity is well documented and recognized as a major health risk throughout the globe [14]. Both metals are regulated under USEPA's PMCL. This clearly indicates that adverse health effects are associated with ingestion of the metals. The concentration of Pb in the soft drinks analysed ranged from ND to 0.05. Pb was not detected in 65.5% of the samples. However the concentration in 16.67% of the samples exceeded the permissible limits set by WHO and USEPA. Lead is known to have acute and chronic effects on human health. It is a multi-organ system toxicant that can cause neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects [15]. Pb is considered the most ubiquitous of toxic metals in drinking water; it can leach from water pipes and soldered joints which deliver water during soft drink production.

Cd was not detected in 58.33% of the studied samples. The lowest concentration of Cd detected was 0.002mg/l while the highest was 0.05mg/l. The maximum allowed limit for Cd in drinking water is 0.005mg/l as set by both WHO and USEPA. The level of Cd in 29.17% of the studied samples exceeded this limit. Cadmium has been found to potentially cause the following health effects when people are exposed to it at levels above the MCL for relatively short periods of time: nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure [5]. Long-term exposure to Cadmium above the MCL has the potential to cause kidney, liver and bone damage. Cadmium is also a known carcinogenic element [16] (Rubio et al., 2006). Corrosion of galvanized pipes, erosion of natural deposits, discharge from metal refineries, runoff from waste batteries and paint are all sources of Cd in water [5] from where it may have been introduced into the soft drinks. The presence of Pb and Cd above safe limits in soft drinks is an issue of great risk to the consumers due to the highly detrimental effects of the metals on human health.

Studies on the levels of metals in Nigerian beverages have been previously reported; some of the reported data are higher than what we report while others are lower. Maduabuchi *et al*., [17] reported Cd and Pb levels as 0.003–0.081 mg/l and 0.002–0.0073 mg/l respectively in canned drinks and 0.006–0.071 mg/l and 0.092 mg/l in non-canned drinks. The cadmium contents reported in our study fall within this range, however, the lead contents we report are higher. Fe concentrations within range of 0.02 - 2.460mg/l have also been reported by Maduabuchi *et al.*, [18]. These values are similar to the ones we report in this study. In a study of metallic impurities in soft drinks marketed in lagos, Nigeria, the following concentrations were reported: Pb: ND-0.002mg/l; Cd: ND-0.0003mg/l; Cr: ND-2.3346mg/l and Zn: ND [19]. With the exception of Cr, the concentrations we report in this study are higher than these. Obuzor et al., [20] analysed popular malt drinks produced in Nigeria and reported the metal concentrations as, Zn: 0.05-0.10ppm; Fe: 0.11- 0.28ppm; Cu: 0.01-0.02pm; Cr: 0.01-0.03ppm; Cd and Pb were 0.01ppm in all the samples. Ogunlana et al., [21] showed Zn, Cd, Cu, Fe and Pb contents in selected beverages in Nigeria to range from 0.190 to 2.280, >0.001 to 0.010, 0.040 to 0.790, 0.080 to 0.550 and >0.001 to 0.040mg/l respectively. The present study showed higher slightly metal levels than these.

Our study revealed lower concentrations than was reported by Engwa and other collaborators [22] in a similar study. They found Cd and Pb contents to be 0.005-0.149mg/l and 0.015- 2.379mg/l respectively. We also report far lower concentrations than data by Garba et al., [23] who revealed Chromium concentration range from 0.528-1.509 mg/l for canned and 0.176 - 1.358 mg/l for non-canned beverages. The Zinc levels they reported ranged from 27.652 – 35.447 mg/l for canned and 29.649– 42.442 mg/l for non- canned drinks. They showed that 100% of the beverages studied had Cr and Zn levels above the allowed limits. Some studies in other countries have also revealed certain levels of soft drinks contamination by metals: Poland [24]; Turkey [14]; Pakistan [25]; Spain [26]; Ghana, [27]; Romania [8]. The variations in the range of reported data in literature could be attributed to the variability in the quality of water and other materials used in the production processes. Overall these findings show that while soft drinks can serve as sources of important metals for the human body, they can also be potential sources for metal toxicity.

## 4. Conclusions

This study reveals that some soft drinks sold in Nigeria contain certain metals above safe limit. A long term and/or excessive consumption of foods containing metals above the permissible levels will have hazardous impact on human health. Because soft drinks are widely consumed in Nigeria, they would contribute a large fraction to the metals intake of the public. Water is likely the major source of metals in soft drinks. For this reason, soft drinks producers should employ good water treatment procedures and quality control measures to ensure the safety of their products. Extra care should also be taken by the manufacturers to avoid introducing metals from the industrial processes; the equipments used, packing/storage materials and industrial emissions. Regulatory bodies in the country should carry out regular monitoring of metal levels in foods and drinks in order to safe guard public health.

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