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Spectro-analytical Research of Selected Heavy Metals (Cu, Cd, Cr, and Pb) in Four Different Single-use Plastics Commonly in Contact with Food from Sokoto, Nigeria

A.I Umar[1]; Sarkingobir Y[2], and Dikko, M[3]

[1] Department of Biochemistry, Sokoto State University, Sokoto, Nigeria
[2] Department of Biology, Shehu Shagari College of Education, Sokoto, Nigeria
[3] Sultan Abdulrahman College of Health Technology Gwadabawa, Sokoto State Nigeria
[#]**Corresponding author:** A.I Umar (email: superoxidedismiutase594@gmail.com)

ABSTRACT Single use plastics are types of plastics discarded after one usage. They are everywhere you go because of their wide range of applications in life. In plastics, additives are incorporated to supplant properties of plastics. One of the common additives is the heavy metals, which could leach out along the plastics lifecycle, thereby creating a problem. This study was stimulated to determine the levels of heavy metals in selected single-use-plastics commonly in contact with food (as containers or wrappings or relations) in Sokoto. The Atomic Absorption Spectroscopy methodology was utilized to determine the levels of copper, chromium, lead, zinc and cadmium. The results for determination of selected heavy metals in selected single use plastics from Sokoto State University, Nigeria were revealed using atomic absorption spectroscopy. Therein, the concentrations of copper (Cu) ranges from 0.335+0.002 to 0.540+0.002(ug/kg), levels of cadmium (Cd) ranges from 0.0551+0.003 to 0.0041+0.0003(ug/kg), levels of chromium (Cr) ranges from 0.0959 +0.004 to 0.0265+0.001(ug/kg), levels of lead (Pb) ranges from -1.791+0.02 to -0.0706+0.008(ug/kg). Thus, the results revealed disparity in the levels of the analyzed heavy metals in the selected single use plastics. However, Cu concentration was the most elevated in plastic bottle (PB) and lowest in Takeaway (T); Cd was highest in Straw (S), and lowest in PB; Cr was highest in Ice cream cup (IC) and lowest in S; Pb was highest in PB, and lowest in S. The concentrations of Cupper, Chromium, Lead, and Cadmium in plastic bottle, Takeaway, Straw and lce cream cup, have shown disparity. However, Cu concentration was the most elevated in plastic bottle (PB) and lowest in Takeaway; Cd was highest in Straw, and lowest in PB; Cr was highest in Ice cream cup and lowest in S; Pb was highest in PB, and lowest in S. They levels determined are within the permissible limits.

INDEX TERMS Heavy metals, single-use plastics, straw, lead, cadmium, cupper, food

I. INTRODUCTION

Plastic are polymers with large molecular weight. The plastic was originated from Greek words "plasticos" meaning moulded. The term plastics refer to the property of a material having ductility during the process of manufacturing [1] [2]. The nature of plastic renders them the ability to be converted into several products that are diversely applicable in human endeavour [3] [4]. Plastics are diverse, like their functions. Some plastics are thermosets, thermoplastics, micro plastics, macro plastics, nanoplastics, elastomers, bioplastics and single use plastics [1]. Commonly available plastics include: polyethene Terephthalate, found in soft drinks, salad trays, mouth wash bottle; high density polyethylene, found in food packaging, rest mats, cosmetics, raincoats; polyvinyl chloride, found in toys, dolls, beach balls, rubber medicine bottles; polypropylene, found in yoghurt bottles, medicine bottle; polystyrene, found in cassette cases, coffee cups, cutlery, computers; and polypropylenes, found in yoghurt bottles, medicine bottles [1][2][4]. From 1950 to date, plastic industry has increased to a very significant extent and serves as an important economic sector of the world[2] [5]. Plastic

Nobel properties such as malleability, durability, low-cost, multiple application and knowledge gap has led to a drastic growth in sector of plastic production over the years. Globally, in 2015 around 322 million tons of plastics were produced, leading to 6,300 million tons of plastic waste, 9% of it was recycled, 12% incinerated and 79% was in landfills or leaked into the environment [6][7][8]. If nothing tangible was implemented, the trend will skyrocket [2]. However, one of the leading types of plastics of concern is the single use-plastics. Single use-plastic are plastic products that design to be use and dispose once. Examples include: light-weight plastic bags, disposable utensils, beverage containers, coffee capsules, straws, food wrappers, takeaways, plastic bag, and drink bottles [9]. They are the leading plastics produced and used every day and are the most prevalent in the waste produced and discarded in our environment [10][11]. Similarly, every plastic is manufactured as a mixture of specific monomer resins and additives. In some of the additives added to these plastic materials are heavy metals [2]. Forsooth, there are revelations that shows these heavy metals in the plastics can leach to the environment or other contacts (such as food, water, human body) and might elicit negative effects [2][12]. All elements on earth can either be metals or nonmetals based on sets of criteria. Metals are large group of substances, which are opaque, form alloys, conduct electricity and heat. They are usually malleable [13]. Metals occur naturally in the environment, and in the crust. They vary significantly between different regions in spatial variations of background concentrations. Out of the 92 naturally occurring elements, about 30 metals and metalloids are potentially harmful to humans, Be, B, Li, Al, Ti, V, Cr, Mn, Co, Cu, Ni, As, Se, Sr, Mo, Pd, Li, Cd, Sn, Te, Sb, Cs, Ba, Lu, Pt, Au, Hg, Pb and Bi [14][15][16]. Heavy metals are the family of metals having an atomic weight above 40.04. Heavy metals enter the environment via natural or anthropogenic processes, such as in natural weathering, mining, soil erosion, industrial discharge, pest control methods, sewage effluents, air pollution fallout e.t.c. [13]. Heavy metals explored from the earth crust or industrial processes are released to the environment. Therein, humans contacted them through ingestion (drinking or eating) or inhalation (breathing) or absorption by the skin/other body openings [8][17].

Heavy metals cause a wide array of harmful effects to the body. Therein, main general effects of heavy metals resulted when they elicit neurotoxicity, oxidative stress, loss of cellular functions, carcinogenesis and cell damage [13]. That is why this work tried to determine the levels of heavy metals in some selected single use plastics in Sokoto, Nigeria. Plastic materials are remarkably resourceful and are utilized in variety of applications. More than half of the plastics produced are disposed when they are used once [18]. These single use plastics are ubiquitous in our environment and everywhere you go in Sokoto state and many other places in the country [2][8]. Therefore, they make majority of our waste which find it ways into the environment and exert negative effects to living organisms including humans, because of their component monomers and additives [1]. One of the additives found in plastics are the heavy metals, which are added deliberately and through impurities during production [2][19][20].

However, heavy metals have been shown to cause negative effects, such as cancer effect, neurotoxicity, oxidative stress, cell damage, apoptosis etc [13]. Parable, cancerous breast biopsies show higher level of nickel, chromium, cadmium, mercury and lead. Lead is proven to cause neurotoxicity, learning and land defects, behavioural effects, infertility, miscarriage, reduced fertility, etc. mercury is linked to nervous system toxicity, immune system toxicity, etc [13]. Nickel is a common cause of allergy [21]. Mercury induced nephrotoxicity, neurotoxicity, etc [22]. Arsenic is associated gastro intestinal disturbance, abnormal heart beat, respiration defects, enzyme defects, etc. Equally, other heavy metals exert their harmful effects on the body [21]. Several reports from certain organizations and reports availed that plastics contain heavy metals as additives or as impurities [2][3]. However, across the globe few empirical studies have reported levels of heavy metals in an array of plastics types. Most of the researches are dealing with levels of heavy metals in electronics and single use plastics in contacts with food or plastics in waste[20][23]. For instance, A study on plastic toys imported from China to Northwestern Nigeria determined lead, cadmium, nickel, copper, zinc, chromium, cobalt and manganese with 17% of them having high levels more than USFDA recommendations; which poses threat to children exposed to these toys, and public health [19].[20] performed an evaluation of lead and copper of selected components of waste computers, the results therein, exceeded the Toxicity Threshold Limit Concentration (TTLC) used in characterizing wastes as toxic, which in turn could be toxic to humans and environment in the inappropriate water disposal fashion.[24] performed a comparative assessment of heavy metals in plastic bottles and sachets. Therein, manganese, iron, copper, cobalt, cadmium, and nickel were detected. Virgin plastics contain very low heavy metals compared to used plastics. The metals are either added intentionally, or through impurities. [23] Reported the levels of heavy metals in selected plastic bags from China. Heavy metals content of polyethylene, High Density Polyethylene, Low Density Polyethylene and Polyvinyl Chloride bags revealed the presence of lead, chromium, cadmium, arsenic, copper, and zinc; which are potential pollution during treatment, recycling, and disposal. [25] in their study conducted a review of metals in plastics of televisions electronics from 1950-2000. The metals studied are zinc, copper, mercury and we're high, but below the Toxicity Threshold Limit Concentration

(TTLC). Also correlation analysis outlined that most of these metals declined in televisions over the subsequent years. A study performed an assessment of heavy metals in locally processed beverages in reused plastics bottles determined arsenic, cadmium, chromium, lead and mercury, saying that the consumption of beverages in repackaged plastic bottles is relatively unsafe for human health [26].Consequently, in view of the forgone studies, it can be states that only few types of plastics (electronics, toys, and some single use plastics (bottles, sachets) were studied for selected heavy metals in Nigeria. This revealed scarcity of data on heavy metals in plastics, let alone the single use ones, which need to be unearthed. It has been shown that, the plastics contain heavy metals, which is a risk phenomenon to public health and environment. Therefore, it is indeed called for to carry out a recent and updated analysis of heavy metals in some single use plastics to update the old information, and to assess the trend [26]. The main objective of this work was to conduct Atomic Absorption Spectroscopy Analysis of selected heavy metals (Cu, Cd, Cr, and Pb) in four different single-use plastics commonly in contact with food from Sokoto, Nigeria.

II. MATERIALS AND METHODS

A. SAMPLE PREPARATION

Different single-use plastics were brought from Sokoto State University. They were cut into pieces using knives to make tiny pieces. The pieces were thoroughly washed with distilled water. 1g of dried plastic sample was placed into beaker, then 5ml of sulfuric acid was and 2ml of perchloric acid (70% of HCLO4) were added. The preparation was heated to dryness. Then 15ml of water was added, filtered using filter paper into volumetric flask. Filter paper was washed with water, and then diluted with deionized water. The preparation was taken to AAS machine for analysis [27] (FIGURE 1).

B. ATOMIC ABSORPTION SPECTROSCOPY ANALYSIS

The final processed samples were analyzed by Perkins-Elmer 500 Atomic Absorption Spectroscopy (AAS). The instrument was firstly calibrated by using stock solution provided by MerCk. In the instrument, cathode lamp for metal to be analyzed was installed, desired wavelength was set. Lamp current was set and allowed to warm up. Then, burner was installed. Hence, standard and sample solutions were aspirated (converted to gas by the machine). Then the instrument showed the actual concentration of the metal in question[27].
The AAS is a spectro-analytical method for the quantitative determination of chemical elements in digested samples down to parts per million (ppm) in a sample. Quantitatively measures the concentrations of elements present in a liquid sample. It utilizes the principle that elements in the gas phase absorb light at very specific wavelengths which gives the technique excellent specificity and detection limits. In AAS principles, the sample may be an aqueous or organic solution, indeed it may even be solid provided it can be dissolved successfully. The liquid is drawn in to a flame where it is ionized in the gas phase. Light of a specific wavelength appropriate to the element being analyzed is shone through the flame, the absorption is proportional to the concentration of the element. Statistical analysis was performed. Triple samples were treated to determine every heavy metals for any given single use plastics. The trio results for each element were added and mean was obtained. Then standard deviation was computed[27].

FIGURE 1. Showing some single use plastics

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III. RESULT AND DISCUSSION

Values are expressed as mean+ standard deviation, values within the same column with different superscript differ significant at $p<0.005$. The results for determination of selected heavy metals (copper, chromium, lead and cadmium) in selected single use plastics from Sokoto State, Nigeria were shown in TABLE 1. Therein, the levels of copper (Cu) ranges from 0.335+0.002 to 0.540+0.002 (ug/kg), levels of cadmium (Cd) ranges from 0.0551+0.003 to 0.0041+0.0003 (ug/kg), levels of chromium (Cr) ranges from 0.0959 +0.004 to 0.0265+0.001 (ug/kg), levels of lead (Pb) ranges from -1.791+0.02 to -0.0706+0.008 (ug/kg). Thus, the results revealed varying degrees of the analyzed heavy metals in the selected single use plastics. However, Cu level was highest in plastic bottle (PB) and lowest in Takeaway (T); Cd was highest in Straw (S), and lowest in PB; Cr was highest in Ice cream cup (IC) and lowest in S; Pb was highest in PB, and lowest in S. Cadmium is found in the earth crust and harvested through industrialization or anthropogenic processes. Albeit, the levels of Cd in this study in all the single use plastics were lower than the allowed limit of 0.01ppm, the content might be available to leach into the surrounding food or contacts (plants or animals). Cd have the ability to elicits health effects such as diarrhea, stomach pain, vomiting, damage central nervous

TABLE 1
Results of determination of heavy metals (Cu, Cd, Cr, and Pb) in four different single use plastics collected from Sokoto State Nigeria.

Heavy Metal(Ug/Kg) Plastic Type	Copper	Cadmium	Chromium	Lead
Plastic Bottle	0.1335+0.002b	0.0041+0.0003b	0.0544+0.003a	-1.791+0.02b
Straw	0.0540+0.002a	0.0551+0.003a	0.0265+0.001a	-0.0706+0.008c
Take Away	0.0612+0.003a	0.0097+0.003c	0.0687+0.002a	-0.4095+0.2 B
Ice Cream Cup	0.0978+0.001a	0.0050+0.0002c	0.0959+0.004a	-0.8347+0.09b

system, immune damage, psychological disorders etc [5][18] 21,]. The finding is similar to result of Khan and Khan (2015)[18]; but lower that of Omolaoye et al., (2010)[19] from Nigeria and [23]Alam et al., (2019).

Cu is an essential element to humans, but critical doses lead to anemia, acne, cancer, diabetes, allergies, hair loss, depression, panic attack, tooth decay, kidney problems, and vitamin deficiencies. In this study, the levels of Cu found were below the limit of 1 ppm. The Cu levels (0.335+0.002 to 0.540+0.002 (ug/kg) found in this study are smaller than the levels found by Olubanjo et al., (2015)[20] in plastic computers in Nigeria. Also Omolaoye et al (2010)[19] found lower levels of Cu from soft plastic toys imported from China to Nigeria.

Cr levels determined were below the permissible limits. Cr is a micronutrient required for certain purposes in the body. It helps in glucose mobilization from the blood to cells, fats metabolism. On the other hand, chromium compounds are toxic at low concentration to plants and animals. They behave as carcinogens, causes breathing problems, asthma, cough etc. Long-term exposure to Cr may lead to liver, kidney damage [18]. The results (0.0959 +0.004 to 0.0265+0.001 (ug/kg), of Cr was lower than the results of other studies reported by Omolaoye et al (2010)[19] and Olubanja et al (2015)[20].

Pb too had shown very lower levels in the analyzed single use plastics of this study. The levels are below the permissible limit, albeit there is no known safe lead level to humans. It has ability to affects all organs in the body [21[[24]. The finding is similar to Khan and Khan (2015)[18]. The lead levels in this study (-1.791+0.02 to -0.0706+0.008 (ug/kg) are lower than the findings by Olubanjo et al (2015)[20] in plastic computers in Nigeria; and Omolaoye etal (2010)[19] who found lower levels of Pb from soft plastic toys imported from China to Nigeria.

Noteworthy, heavy metals including Pb, Cd, Cr, and Cu are natural elements that have a relatively high atomic mass and high density compared to water. Even through heavy metals are naturally present in our environment, but their environmental pollution and exposure to humans is speed up by anthropogenic processes of humans. One of the uses of heavy metals is the application in plastics. They are used as additives in plastics. Parable, Cr, Pb, Cd and Cu are used as colorants in plastics to improve the properties of the polymers. Other source of heavy metals to plastics is the ability plastics to absorb heavy metals from the environment whenever there is contact. The concerns about the presence of heavy metals in plastics are many. The metals can easily leach into the contacts (food, plant, and animal) when there is heat or rise in temperature because they are already loosely attached to the polymer chain. Moreover, the metals can be release when the plastics are heated, burned or incinerated. The waste of plastics has ability to dispose heavy metals in soils and water where they are discarded. Therefore there is need to carefully monitor heavy metals present in plastics especially the single use ones [8][23][24,].

Implications and disadvantages of finding heavy metals in plastics, especially those that are used once and discarded, are diverse. Single use plastics are indiscriminately discarded in the study area, in turn they act as major sources of pollution and contamination with heavy metals affecting humans, plants and environment [28]-[30]. Presence of heavy metals in single use plastics migrate to the humans in contacts causing devastating health effects, due to their toxicity at low concentration, persistence and bioaccumulation potential [28]. Humans and animals can be affected through consumption (feeding), burning of plastics (especially the volatile metals like lead, cadmium, zinc, chromium, zinc etc), intake of plants grown in polluted soils, drinking water, and many others[23][25]. Invariably, quantification of environmental load of toxicants is an initial store in monitoring and management of pollutants. It will serve scientists, public health experts, policy makers, and regulatory measures or phase-out some heavy metals additives from plastics [28]-[32].

V. CONCLUSION

The main objective of this work was to conduct Spectro-analytical Research of selected heavy metals (Cu, Cd, Cr, and Pb) in four different single-use plastics commonly in contact with food from Sokoto, Nigeria. The concentrations of Copper, Chromium, Lead, and Cadmium in plastic bottle, Takeaway, Straw and ice cream cup, have shown disparity. However, Cu concentration was the most elevated in plastic bottle (PB) and lowest in Takeaway; Cd was highest in Straw, and lowest in PB; Cr was highest in Ice cream cup and lowest in S; Pb was highest in PB, and lowest in S. All they levels determined are within the permissible limits. Based on

this study the following recommendations are made: a) Further studies are needed to ascertain the levels of heavy metals in single use plastics, b)There is need to seek for legislation to screen the levels of heavy metals in Nigeria as there are no safe levels for most of the heavy metals such as Lead. Many of them are of great concern such as Lead, Cadmium, c) there is need for bodies that should screen the levels of heavy metals in plastics to guard public health, d) If possible, alternative less harmful chemicals should be used as plasticizers or colorants in single use plastics, e) people should adhere to the norms of reuse, improvise, recycle, refuse, to limits the plastics pollution.

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BIOGRAPHY

Umar A.I. The author is an indigene of Sokoto State, Nigeria. He has obtained Bachelor's Degree in Biochemistry as his background, and has obtained Msc later. He holds PhD in Biochemistry from Usmanu Danfodiyo University Sokoto, Nigeria. Dr Aminu Umar Imam/ Dr Umar AI is currently the Head of Department of Biochemistry Sokoto State University Sokoto, Nigeria. His interest is mostly in nutritional biochemistry.

Yusuf Sarkingobir was born in Gwadabawa, Sokoto state Nigeria. He holds BSc. Biochemistry from Usmanu danfodiyo University Sokoto, Nigeria; and MSc Public Health from Maryam Abacha American University of Niger Maradi, Niger Republic. Presently, he taught at Shehu Shagari Colege of Education Sokoto, Nigeria which is now upgraded by the Executive Governor to serve as Shehu Shagari University of Education Sokoto. He is also currently pursuing PhD in Public health from Crown University International Chartered Incorporated. He study Almajiri and Public health, determinants of health, plastics and public health, drugs/ substances abuse and public health, and open defecation.

Malami Dikko. The author, Dr malami Dikko Tambuwal was born in Tambuwal local government, Sokoto State, Nigeria. He holds BSc Microbiology, MSc and Phd Pharmacology from Usmanu Danfodiyo University Sokoto, Nigeria. Presently, he is the College Examination Officer, Sultan Abdurrahman College of Health Technology, Gwadabawa, Sokoto, Nigeria.