Health Risk Assessment of Heavy Metals Accumulation Through the Consumption of Fresh Fruits and Vegetables

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Abstract*— Laboratory analysis of heavy metal concentrations in fruits and vegetables obtained from three different locations around Delta state with the use of the Atomic Absorption Spectrophotometer (DR 2800) was carried out with the aim of evaluating health risk of heavy metals accumulation through the consumption of fresh fruit and vegetables. The results obtained revealed that average concentration of copper was 2.33 mg/kg for pawpaw, 8.0 mg/kg for cucumber and 6.0 mg/kg for pumpkin; average concentration of the total iron was 80.17 mg/kg for pawpaw, 79.83 mg/kg for cucumber, 96.50 mg/kg for pumpkin; average concentration of Magnesium was 1401.7 mg/kg for pawpaw, 2063.3 mg/kg for cucumber and 1648.7 mg/kg for pumpkin; average concentration of zinc was 14.7 mg/kg for pawpaw, 35.17 mg/kg for cucumber and 24.17 mg/kg for pumpkin which exceed the minimum and maximum allowable limits recommended by Food and Agricultural Organization (FAO). Cobalt was the only heavy metal concentration that was within the FAO safe limit. The results of statistical analysis of the data show that all the results are significant at $p<0.05$. It is therefore concluded that the heavy metals concentrations in the fruits and vegetables investigated in this study exceed daily dietary intake as stipulated by FAO and are unfit for human consumption.

***Keywords*— Fruits: Health: Heavy metals: Risk: Vegetables.**

I. INTRODUCTION

Heavy metals are naturally occurring elements with a high atomic weight and a density greater than 5 times that of water. Because of their numerous industrial, residential, agricultural, medical, and technical applications, they are widely distributed in the environment, raising worries about their possible effects on human health and the environment. The dose, method of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of those exposed, all influence their toxicity. Arsenic, cadmium, chromium, lead, and mercury are among the priority metals that are of public health concern due to their high toxicity. Even at low levels of exposure, these metallic elements are considered systemic toxicants that cause various organs damage [1].

Heavy metals serve a crucial function in maintaining cell homeostasis. These elements, on the other hand, have a number of negative environmental effects and toxicities, and hence have a significant impact on living cells and creatures. Some heavy metal pollutions have been reported to have negative impacts on crop quality in recent years, threatening both food security and human health. Chromium, cadmium, copper, lead, and mercury, for example, have been found in natural foods. These components appear to be environmental pollutants in natural foods, according to evidence [2].

Food security issue for the purpose of sustaining both qualitative and quantitative global development cannot be overemphasized. Unexpected pollutants' negative impacts on crop quality have posed a threat to both food security and human health in recent decades. Heavy metals and metalloids (e.g., Hg, As, Pb, Cd, and Cr) can wreak havoc on human metabolomics, causing illness and even death [3]. Dietary exposure is a major route for trace metals to reach people, accounting for over 90% of all exposure. Long-term metal exposure from food, drinking water, or other occupational sources causes serious problems such as hepatotoxicity, kidney failure, and neurotoxicity. The current scenario revealed that heavy metal concentrations have decreased over time, but they are still hotspots for home trash, agrochemicals such as pesticides and fertilizers, and industrial wastes. Some metal levels have exceeded the legal limits as a result of pollution sources in hot regions, posing serious health risks to humans. Due to a lack of data for groups potentially exposed to high metal concentrations and their concentrations in foodstuffs [4]. Waste water from sewage treatment plants is utilized to irrigate vegetable fields in some locations. Heavy metals have accumulated in the soil as a result of the continuous application of waste water for more than 20 years. As a result, Cd, Pb, and Ni concentrations in all vegetables have exceeded the permissible limits for human consumption [5]. This research was carried out to evaluate the health risk of heavy metals accumulation through the consumption of fresh fruits and vegetables (cucumber, paw-paw, and apple).

II. METHODOLOGY

Sample Preparation for Analysis

The samples (pumpkin leave, cucumber and paw paw) was washed at first with running water to remove dust, then in 0.01M HCl followed by 2 times bi-distilled water. The samples were air dried for few hours then dried in a ventilated oven at 70^0C. After dryness, the samples were grinded in a stainless steel mill and passed through 0.5mm sieve, then kept in a polyethylene cups till analysis.

Digestion of Sample before AAS Analysis

1g of each sample was measured into a 50ml beaker and 10ml of HNO3 was added and left to stand overnight. 4ml of perchloric acid ($HClO_4$) was then added and heated on a hot plate until brown fumes was seen and waited till the brown fumes ceases to appear which indicated that the digestion is complete, then the solution of the samples was allowed to cool. The digested solution was filtered through a filter paper into a 50ml volumetric flask and distilled water was used to make it up to 50ml. The digested solution was then taken to the spectrophotometer for analysis.

Apparatus: Atomic Absorption Spectrophotometer (DR 2800)

Reagents: Nitra Ver®6 Nitrate Reagent Powder Pillow, Nitra Ver® 3 Nitrite Reagent Powder Pillow.

III. RESULT

The results of the analysis done on the vegetables and fruit are presented below;

TABLE I: Concentration of Copper (mg/kg) in Vegetables and Fruit from Three Different Markets

	Vegetables and Fruit		
Sample location	Pawpaw	Cucumber	Pumpkin
A	3.00	8.50	8.50
B	1.00	6.00	2.50
C	3.00	9.50	7.00
Average	2.33	8.00	6.00
FAO Standard	0.05 – 0.5	0.05 – 0.5	0.05 – 0.5

TABLE II: Concentration of Cobalt (mg/kg) in Vegetables and Fruit from Three Different Markets

	Vegetables and Fruit		
Sample location	Pawpaw	Cucumber	Pumpkin
A	1.65	1.00	0.80
B	1.20	0.85	0.45
C	1.80	1.40	1.00
Average	1.55	1.08	0.75
FAO Standard	2.00	2.00	2.00

TABLE III: Concentration of Magnesium (mg/kg) in Vegetables and Fruit from Three Different Markets

	Vegetables and Fruit		
Sample location	Pawpaw	Cucumber	Pumpkin
A	2175.00	2550.00	2568.00
B	780.00	1510.00	835.00
C	1250.00	2130.00	1543.00
Average	1401.67	2063.33	1648.67
FAO Standard Adult	350.00	350.00	350.00

TABLE IV: Concentration of Total Iron (mg/kg) in Vegetables and Fruit from Three Different Markets

	Vegetables and Fruit		
Sample location	Pawpaw	Cucumber	Pumpkin
A	120.00	94.50	107.50
B	40.50	74.50	82.00
C	80.00	70.50	100.00
Average	80.17	79.83	96.50
FAO Standard	0.80	0.80	0.80

TABLE V: Concentration of Zinc (mg/kg)

	Vegetables and Fruit		
Sample location	Pawpaw	Cucumber	Pumpkin
A	16.50	41.00	31.50
B	9.00	28.00	12.00
C	18.50	36.50	29.00
Average	14.67	35.17	24.17
FAO Standard	0.1 – 1	0.1 – 1	0.1 – 1

Key: A = Igbudu Market; B = Effurun Market; C = Jigbale Market

TABLE VI: T-Test Calculations

Heavy Metals	t-value	p-value	The result is significant at
Cobalt	-3.76249	0.009866	p< 0.05
Copper	2.97740	0.02042	p< 0.05
Magnesium	7.01705	0.001086	p< 0.05
Total Iron	15.39755	0.000052	p< 0.05
Zinc	3.9961	0.008091	p< 0.05

Table VI, is the results of statistical analysis of the data in table I, which shows that all the results are significant at $p<0.05$.

TABLE VII: Average Concentrations of Heavy Metals in Vegetables and Fruit from the Three Markets

	Copper (mg/kg)	Total Iron (mg/kg)	Magnesium (mg/kg)	Zinc (mg/kg)	Cobalt (mg/kg)
FAO Standard	0.50	0.80	350.00	1.00	2.00
Pawpaw	2.33	80.17	1401.70	14.70	1.55
Cucumber	8.00	79.83	2063.30	35.17	1.08
Pumpkin	6.00	96.50	1648.70	24.17	0.75

Figure 1 below is a line graph of all the concentrations of heavy metals as analysed in pawpaw, cucumber and pumpkin. The graph shows cucumber had the highest concentration of heavy metals (copper, magnesium and zinc). Pawpaw has the lowest concentration of heavy metals (copper, magnesium and zinc).

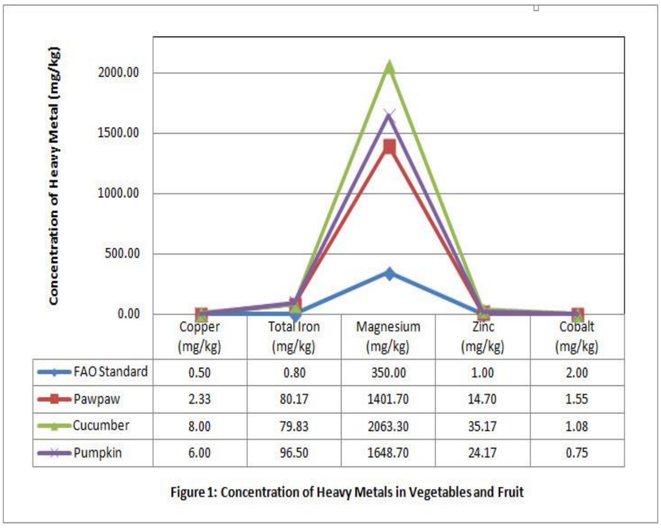

Fig. 1.

IV. DISCUSSIONS

Concentrations of Cobalt

The results obtained for average concentrations of Cobalt for pawpaw, cucumber and pumpkin were 1.55 mg/kg, 1.08 mg/kg and 0.75 mg/kg respectively, which was within the recommended limit set by FAO. Cobalt enters the air through burning of oil and cobalt compounds that are used as colorants in glass, ceramics, and paints, as catalysts, and as paint driers. After it enters the air cobalt is associated with particles which will settle to the ground within few days. Anthropogenic activities result in the rise of cobalt in fruits and vegetables as cobalt settles from air. [6], observed a similar result with

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cobalt being absent (not detected) in some areas in southern Nigeria. This can be attributed to the absence of cobalt release into the air around cultivating sites of farm produce.

Concentrations of Copper

Copper is an essential element for plant nutrients as it is by humans. It is an essential nutrient that is incorporated into a number of metalloenzymes involved in haemoglobin formation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the cross linking of collagen, elastin, and hair keratin, and the antioxidant defense mechanism. However, it becomes toxic at high concentrations which can result in a number of adverse health effects including liver and kidney damage, anaemia, immunotoxicity, and developmental toxicity as described by [6].

From results obtained, the average level of copper contents in pumpkin was observed to be 6.0 mg/kg. This concentration exceeds recommended limits of 0.05 – 0.5 mg/L set by the Food and Agriculture Organization which reveals that consumers were at high risk of possible effects of excess exposure to copper. This result is higher than average result of 0.02 ug/kg obtained by [7] on analysis of pumpkin in Delta State. Phyto-extraction potential of vegetables may have elevated copper concentration in pumpkin. This high concentration was also observed by [8] to be high in concentration of 1.07 mg/kg and 0.12 mg/kg for bitter leave and waterleaf respectively, cultivated in Delta State.

Observed average concentration of copper in pawpaw was seen to be 2.33 mg/kg which is lower than the observed results 5.29 mg/kg obtained by [9] from home grown pawpaw. The variation in the results can be attributed to high copper content of soil with which pawpaw was cultivated leading to increased concentrations of copper. While, for cucumber, excessive concentration of copper was observed which is likened to soil-water concentration and absorption by cucumber leading to increased concentrations. This concentration exceeds for both pawpaw and cucumber exceed recommended limits of 0.05 – 0.5 mg/L set by the Food and Agriculture Organization. According to the World Health Organization, effect of copper toxicity includes headache, febrile reactions, prostration, and gastrointestinal symptoms [10].

Concentrations of Zinc

The results obtained for zinc with an average of 14.7 mg/kg for pawpaw, 35.17 mg/kg for cucumber and 24.17 mg/kg for pumpkin indicated that fruits consumed from these regions have a high possibility to cause symptoms such as tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatitis and damage of hepatic parenchyma [10]. In addition, this may also obstruct the copper absorption in the body as these values highly exceed the recommended limits of 0.1 – 1 mg/kg as recommended according to Food and Agricultural Organization. In Southern Nigeria, zinc levels in vegetables are also observed to exceed recommended limits as indicated by [6] with observed concentration of zinc being between 0.00 to 795.17 mg/kg for vegetable samples. Study by [11] revealed that zinc levels in pawpaw to reach concentrations up to 3.1 mg/kg for fruits from southern Nigeria (Rivers state). Studies carried out by [12] and [13] revealed zinc levels have reached a minimum of 7 mg/kg for pumpkin and maximum of 46 mg/kg for cucumber in southern Nigeria. Direct comparison with this study shows that zinc levels in the assessed vegetable and fruits are similar. The availability of zinc in these fruits is due to plant intake. Although, [13] exclaimed that toxic and major metals concentrated more in the root of plants and are absorbed. The availability of this zinc is due to petroleum contamination and other anthropogenic activities which increases bioavailability.

Concentrations of Total Iron

In humans, increased body stores of iron have been shown to increase the risk of several estrogen-induced cancers. Iron acts as a catalytic centre for a broad spectrum of metabolic functions. Iron is also a component of various tissue enzymes, such as the cytochromes, that are critical for energy production, and enzymes necessary for immune system functioning. Research studies have been carried out on the levels of heavy metals in a variety of fruits cultivated in other parts of Southern Nigeria [14]. The values of total iron obtained across all samples were significantly above the FAO recommended maximum limit of 0.8 mg/kg. Fruits and vegetables are widely used for culinary and dietary purposes. This makes their composition extremely important especially for consumers. These patterns of high concentrations of iron in crops from the highly industrialized areas reinforce the presence of environmental pollution, particularly in the areas of increased industrial activities. This is observed across all samples especially for the industrialized area such as Warri (Igbudu Market) and Udu (Jigbale Market). These activities are attributed to increase the concentrations of iron [15]. Average concentration of 80.17 mg/kg, 79.83 mg/kg and 96.5 mg/kg of iron was observed in pawpaw, cucumber and pumpkin. This is due to increase in amount of Iron in soil. The availability of iron in soil can create high absorption of Fe by the tissues of the fruits and vegetable samples [6]. This was observed for pumpkin with high concentration of 10256.37 mg/kg. This observed result was higher compared to average result for this study and it is attributed to soil polluted. In pawpaw, [9] observed concentration of 29.60 mg/kg which is slightly lower than observed average concentrations from this study. The most common iron overload disorder is hereditary hemochromatosis. This leads to the buildup of iron in tissues and organs. Over time, untreated hemochromatosis increases the risk of arthritis, cancer, liver problems, diabetes and heart failure [16].

Concentrations of Magnesium

Magnesium is an important mineral to the body and serves as an important component for normal bone structure in the body. Magnesium is also required for the proper function of nerves, muscles, and many other parts of the body. The World Health Organization has set a dietary uptake limit for magnesium (350mg) due to the side effects (stomach upset, nausea, vomiting, diarrhea, irregular heartbeat, low blood pressure, confusion, slowed breathing, coma, and death) of excessive exposure [10]. These risks are faced by humans when this metal have been consumed way beyond the recommended limit and have bio accumulated over time.

The concentration of magnesium in fruits and vegetables in local markets in Delta state is extremely high. These concentrations are more than twice the recommended limit which are unsafe to consumers. Average concentrations of magnesium in pawpaw, cucumber and pumpkin was seen as 1401.7 mg/kg, 2063.3 mg/kg and 1648.7 mg/kg respectively which indicates that consumers within these regions are likely to suffer from irregular heartbeat, low blood pressure, confusion, slowed breathing, coma, and early death as earlier stated by the World Health Organization. According to a study, magnesium levels can reach up to 389 mg/kg for fruits and 491 mg/kg for vegetables in more organized agricultural sites. In locally uncontrolled produce, the levels are seen to be elevated as observed on laboratory report by [17]. According to their report on variation of magnesium content, it was stated that the magnesium content observed is highly influenced by the food origin and processing especially for raw vegetables. This study observed a similar result with statistical test indicating a significant difference between the concentrations of magnesium per location obtained. The concentrations observed in pawpaw, cucumber and pumpkin may be due to the magnesium content of fertilizers used during cultivation and its absorption from the soil solution. These crops may have absorbed more magnesium as a means to improve tolerance to various stresses and to increase yield and quality parameters.

V. CONCLUSION

It was concluded that the fruits and vegetables sold in these markets exceeds daily dietary intake of heavy metals and are of health risk for human consumption since they are polluted with copper, zinc, iron and magnesium in high concentrations as they exceed recommended limit of the Food and Agricultural Organization except for cobalt.

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