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Determination of Heavy Metal Levels of some Cereals and Vegetables sold in Eke-Awka Market Awka, Anambra State, Nigeria

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Abstract

A field survey was conducted to investigate heavy metals present in three vegetables (cucumber, cabbage and carrot) and three cereals (rice, maize and millet) from Eke Awka market, Awka, Anambra State, Nigeria and also evaluate possible health risks to local population through food chain transfer. Atomic Absorption Spectrophotometer (AAS) was used to estimate the levels of Cadmium (Cd), Lead (Pb), Cobalt (Co), Chromium (Cr), Nickel (Ni) and Iron (Fe) in the vegetables and cereals. The levels of the metals obtained in $mgkg^{-1}$ were as follows: Cucumber: Pb (0.126), Cd (0.084), Cr (0.032), Ni (0.080), Co(0.016) and Fe (0.985). Cabbage: Pb (0), Cd (0.140), Cr (0.144), Ni (0.142), Co (0.032) and Fe (0.360). Carrot: Pb (0.026), Cd (0.004), Cr (0.024), Ni (0.248), Co (0.188) and Fe (0.445). Maize: Pb (0.100), Cd (0.022), Cr (0.012), Ni (0.192), Co (0.046) and Fe (0.590). Local rice: Pb (0.082), Cd (0.020), Cr (0.014), Ni (0.202), Co (0.042) and Fe (0.405). Imported rice: Pb (0.012), Cd (0.006), Cr (0), Ni (0.042), Co (0.008) and Fe (0.365). Millet: Pb (0.080), Cd (0.028), Cr (0.038), Ni (0.038), Co (0.022) and Fe (0.320). The estimated daily oral intake of the metals (DIM) for the vegetables and cereals were analyzed. Pb was in all samples except cabbage and carrot; Cd was in all samples except carrot; Ni was in all samples except cucumber; and Co was in carrot, local rice and millet were all higher than their corresponding reference dosage (RfD_0). Hazard quotient (HQ) and hazard index (HI) were all less than one except for local rice. These results showed that in all, only local rice posed heavy metal health risks in a long term. Balanced diet and continual monitoring of food crops were recommended to help check heavy metal intake.

Keywords: Vegetables, Cereals, Heavy Metals, Ingestion, Potentially toxic element, Daily Intake, Hazard Quotient, Hazard Index

1. Introduction

Heavy metals are natural constituents of the earth crust. They are well known for their persistence in nature (Chen and Chen, 2001). This is caused by their inability to degrade into harmless end products on impact by agents of denudation. Heavy metals hence accumulate in the environment or a host and by so doing cause harm to them. As a result, heavy metals are considered as both contaminants and pollutants (Chen and Chen, 2001).

Heavy metals usually stream from industries where they have found major usefulness e.g. electronics, machines, mining, painting, tannery, jewellery, agricultural chemicals, car manufacturing etc. (Ladigbolu and Balogun, 2011).They find their way into our environment via sewage disposal or dust emissions. They are also found naturally in rock-forming and ore minerals from where they leach into our water bodies and agricultural soils (Jiaping, 2012). They are taken up from the soil into our food crops or accumulate into leaves used in processing foods like in *"moi moi"* and many other Nigerian local foods from where they enter into the food and ultimately into man.

Heavy metal toxicity has revealed its deadly nature in many forms. They can cause major diseases that can destroy man, upset the natural concentration of the environment and make the environment uninhabitable for plant and animals. They usually cause very severe illnesses and in very extreme cases death. In Nigeria, many reports on the analysis of heavy metals in many parts of our environment (involving food crops, soils and water bodies) have revealed how prone our environment is to the dangers of heavy metals and how deadly they can be. For example, it was reported that Pb toxicity claimed 28 lives with 44 others hospitalized in Niger Delta (Sahara reporters, 2015). Another report in 2010 recorded the death of more than 500 individuals in a community located in Zamfara state on account of same Pb poisoning (Galadima and Garba, 2012). In both cases the heavy metal concentration in the blood was above the recommended dosage.

In an effort to ensure that our environment is safe from heavy metal toxicity we should be on guard by continuously monitoring our environment. Therefore, we have studied the presence of heavy metals in some vegetables and cereals sold in Eke-Awka market, Awka, Anambra state of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study area (Eke-Awka, largest market in Awka) is situated along Arthur Eze road (near Zik Avenue), heading towards Amawbia near Awka, capital of Anambra state in Nigeria. It has the coordinates: 6.207175, 7.068868 (latitude and longitude respectively), and is ~94.76 ft above sea level. The food crops sold in the market stream from major food source in Nigeria, namely, Jos and Kano, in the Northern part of Nigeria. The local rice was obtained from Otuocha, a popular rice market in Anambra state. To check the health risks of these food crops coming into the market, the selected food crop samples were collected from every corner of the market and analyzed to estimate the intake of heavy metals by local populace.

2.2 Collection and Preparation of Sample

The vegetables, namely, cucumber, cabbage, and carrot and the cereals, namely, rice, millet and maize used for the work were bought from the market, with sizes not less than 100g. The sample preparation was carried out in accordance with steps outlined by Thanat and John (1982). The samples were washed with distilled water to remove dust particles. The vegetables were chopped into smaller pieces (roughly 1cm^3 sizes), and the cereals were ground using mortar and pestle. The samples were air dried and oven dried at 65˚C till constant weight was achieved. The dried samples were finally ground into fine powder using an electric blender. The procedure was performed five times for each set of food sample during the period September, 2014 to July, 2015 to help achieve a more representative report as well as cover the different season in the country.

2.3 Analytical Procedures

Using the AOAC (1980) standard implemented by Thanat and John, (1982), each sample (3.0g) was weighed and put into a 100ml beaker containing a mixture of 2ml of concentrated sulphuric acid, 4ml of concentrated perchloric acid and 30ml of concentrated nitric acid in the ratio 1:2:12.5 by volume respectively. The mixture was heated at 70°C for 35min. The digestion was complete when a colourless solution was formed. The digest was diluted with 20ml of distilled water and boiled for 15min for the evolution of white fumes of $HClO_4$. Each solution was allowed to cool and was transferred into 250ml volumetric flask and diluted to the mark with distilled water. The solutions were then used for the determination of the metals. The concentrations of Pb, Cd, Ni, Co, Mn and Fe were determined by first running a blank. This was achieved by aspirating the solvent (water) into the atomic absorption spectrophotometer (AAS) and passing light on the atomized solvent in order to calibrate the AAS machine. Hallow cathode lamps of desired metal were installed for each metal analysis and the concentration of the heavy metal samples were computed by extrapolating the absorbance of the metals in the food samples with respect to that of the metal standards in the AAS. The process was performed five (5) times for each sample and for each heavy metal analyzed. The mean of each value was determined, the standard deviation calculated and rejection quotient test carried to check wrong data due to any determinate error.

2.4 Statistical Analysis

The data were statistically analyzed using Microsoft excel, 2007. Comparison of the Statistical mean and statistical significance of heavy metal concentration between the crop samples was computed by one-way analysis of variance (One-way ANOVA) and Kruskal-Wallis test for the non-parametric analysis and the procedures employed were in accordance with the steps outlined by Shiv (1978). The level of significance was also set at $P < 0.05$.

2.5 Data Analysis

2.5.1 Determination of oral intake of metals, (DIM) (mg day^{-1}) for the vegetables and cereals

This is an estimated heavy metal quantity in mg taken from the consumption of a food crop by an individual per day. This was determined with the help of the daily vegetable and cereal intake (DIV) of individuals obtained through a survey of opinion conducted in the studied area. To estimating the DIV, A head-to-head interview of a 400 sample persons (S), estimated from Yamane (1967) equation (1) for Awka population (N), within 17-70years age bracket was conducted at the market site. Their weight, sample food quantity consumed per day and frequency of consumption in days/week were inquired. The average intake of each vegetable or cereal per person per day was estimated for the samples studied. Daily oral intake of heavy metals, (DIM) in mg/day, fresh weight was estimated using equation (2) (Geetanjali and Chauhan, 2014; Sapana et al., 2013; and Yu-jing et al., 2004):

$$S = N \div (1 + N e^2) \qquad (1)$$

e is margin error (0.05)

$$DIM = \underset{(DIV)\ (kg\ person^{-1} day^{-1})}{\text{Daily vegetable or cereal intake}} \times \underset{(mg/kg)}{\text{Mean heavy metal concentration,}} \qquad (2)$$

2.5.2 Calculation of Hazard Quotient (HQ) for the heavy metal contamination

This is a quantity used to describe a heavy metal intake risk over a lifetime of exposure and is defined as the ratio of determined oral intake of metals (DIM) to the reference dose (RfD_0). Hazard quotient was calculated using equation (3). (Sapana et al., 2013; Iosif and Monica, 2012):

$$HQ = \frac{DIM}{RfD_0} \times \text{Adjustment factor} \qquad (3)$$

$$\text{Adjustment factor} = \frac{EF \times ED}{W \times T} \qquad (4)$$

RfD_0 is the oral reference dose for the metal (mg kg^{-1} day^{-1}), **W** is the human body mass (kg), **EF** is the exposure frequency (days/week), **ED** is the exposure duration (weeks) and **T** is the time an individual will spend in an area (days).

The reference dosage, RfD_0, as noted by Sapana *et al,* (2014), is an estimated daily exposure to which the human population is likely to be without any appreciable risk of deleterious effects during a lifetime. The values of RfD_0 for heavy metals were largely taken from EPA Integrated Risk Information System (2015) and FOA/WHO, (2013). The Health Quotient is believed to be highly conservative and a relative index. When HQ is < 1, there is no obvious risk from the substance over a lifetime of exposure. However, when HQ is > 1, the hazardous metals may produce an adverse effect. Hence, the probability of experiencing long-term carcinogenic effects and other toxic changes increases with the HQ value. Here also, the adjustment factors in equation (4) were applied to help achieve more accurate results.

2.5.3 Hazard Index (Health risk index) HI

Assuming there are no apparent risks when considering the hazardous quotient of each metal analyzed, the potential risk could be multiplied when considering all hazardous metals in the system; this could be referenced as hazard index, HI. Hazard index could be deduced using equation (5) (Geetanjali and Chauhan, 2014; Sapana *et al.*, 2013):

$$HI = \sum HQ \qquad (5)$$

3. RESULTS AND DISCUSSION

Table 1 shows the average heavy metal concentration (mg/kg) for the vegetables and cereals and there mean standard deviations.

Table 1: The average metal concentration (mg/kg) of the vegetables and cereals

sample/ metals	Cucumber	Cabbage	Carrot	Maize	Local rice	Imported Rice	Millet	RfDo (mg/kg/day)
Pb	0.126 ± 0.1	0 ±0.00	0.026 ±0.04	0.100 ± 0.10	0.082 ± 0.04	0.012 ± 0.01	0.08 ± 0.08	**0.004**[a]
Cd	0.084 ±0.12	0.140 ± 0.23	0.004 ± 0.01	0.022 ± 0.02	0.020 ± 0.02	0.006 ± 0.01	0.028 ± 0.02	**0.001**[b]
Cr	0.032 ± 0.07	0.144 ±0.28	0.024 ± 0.03	0.012 ± 0.02	0.014 ± 0.02	0 ± 0.00	0.038 ± 0.03	**1.500**[b]
Ni	0.080 ± 0.09	0.142 ±0.10	0.248 ± 0.15	0.192 ± 0.17	0.202 ± 0.17	0.042 ± 0.04	0.038 ± 0.03	**0.020**[b]
Co	0.016 ± 0.02	0.032 ± 0.01	0.188 ± 0.26	0.046 ± 0.08	0.042 ± 0.06	0.008 ± 0.02	0.022 ± 0.02	**0.012**[c]
Fe	0.985 ± 0.60	0.360 ± 0.23	0.445 ±0.24	0.590 ± 0.36	0.405 ± 0.22	0.365 ± 0.21	0.32 ± 0.23	**7.000**[a]

RfD_0 = Reference of Oral Dosage

a) FAO/WHO-Codex Alimentarious commission, 2013
b) US EPA -Integrated risk information, 2015
c) MAFF, 2000

From the results, moderate variations in the mean heavy metal concentration levels were observed among the vegetables and cereals (Table.1). These variations may be due to the differences in plant's morphology and physiology for heavy metal uptake (i.e. different plant species and their tissue's heavy metal selectivity). It could be related to the fact that plants' heavy metal contents are directly proportional to the metal concentration in a growth solution or soil where they were grown (Kabata-Pendias et al., 1998; Sapana et al., 2013). From the table, the concentration of Fe in cucumber was highest at 0.985 mg/kg while the concentration of Co was lowest at 0.016mg/kg. In cabbage, the concentration of Fe was highest at 0.36 mg/kg. Pb was absent. In carrot, Fe had the highest concentration at 0.445 mg/kg , while Cd had the lowest at 0.004 mg/kg. Amongst the cereals, Fe was found to be highest in maize at 0.59 mg/kg, while Cr was lowest at 0.012mg/kg. In local rice, Fe was highest at 0.405 mg/kg and Cr was lowest at 0.014mg/kg. In imported Rice, Fe was highest at 0.365 mg/kg and Cr was absent. In millet, Fe had the highest concentration at 0.32 mg/kg while Co was least at 0.022mg/kg. In general the concentration of Fe remained predominantly highest amongst the metals while Cr and Pb were absent in both imported rice and cabbage respectively.
In addition, the result in Table 1 revealed heavy metal levels to be above the recommended standard dosage (except for Cr and Fe). Furthermore, the sample standard deviation revealed a relatively high dispersion level of heavy metals in the food samples in relation to the metals' mean. However, Rejection quotient (Q) test values calculated for the metals were all less than the table value. This revealed that errors were as a result of indeterminate errors at 99% confidence level.

Heavy metal concentration evaluation across all food samples

Iron (Fe) had its highest concentration in cucumber (0.985mgkg-1) and lowest concentration in millet (0.32mgkg-1). Both limits remained below the RfD_0 (7.0mgkg-1). Fe accumulation in the samples in relation to RfD_0 followed the order: **RfD_0** > cucumber > maize > carrot > local rice > imported rice > cabbage > millet.
Lead (Pb), a nonessential toxic heavy metal, showed highest concentration in cucumber (*0.126*mgkg^{-1}) and lowest in cabbage

(0 $mgkg^{-1}$). The upper limit exceeded the RfD_0 (0.004 $mgkg^{-1}$). Pb accumulation in the samples in relation to RfD_0 was in the following order: cucumber > maize > local rice > millet > carrot > imported rice > $\mathbf{RfD_0}$ > cabbage.

Cadmium (Cd), a nonessential toxic heavy metal, showed highest concentration in cabbage (0.14 $mgkg^{-1}$) and lowest concentration in carrot (0.004 $mgkg^{-1}$). Both limits exceeded the RfD_0 (0.001 $mgkg^{-1}$). Cd accumulation in the samples in relation to RfD_0 was in the following order: cabbage > cucumber > millet > maize > local rice > imported rice > carrot > $\mathbf{RfD_0}$.

Chromium (Cr) showed the highest concentration in cabbage (0.144mgkg-1) and lowest in imported rice (0 $mgkg^{-1}$). Both limits were below the $\mathbf{RfD_0}$ (1.50$mgkg^{-1}$). Cr accumulation in the samples in relation to RfD_0 was in the following order: $\mathbf{RfD_0}$ > cabbage > millet > cucumber > carrot > local rice > maize > imported rice.

Nickel (Ni) showed its highest concentration in carrot (0.248$mgkg^{-1}$) and lowest concentration in millet (0.038$mgkg^{-1}$). Both limits were above the RfD_0 (0.02$mgkg^{-1}$). Ni accumulation in the samples in relation to RfD_0 was in the following order: carrot > local rice > maize > cabbage > cucumber > imported rice > millet > $\mathbf{RfD_0}$.

Maximum concentration of **Cobalt** (Co) was found in carrot (0.188$mgkg^{-1}$) and lowest in imported rice (0.008$mgkg^{-1}$). The upper limit exceeded the RfD_0 (0.012 $mgkg^{-1}$). Co accumulation in the samples in relation to RfD_0 was in the following order: Carrot > Maize > Local rice > Cabbage > Millet > Cucumber > $\mathbf{RfD_0}$ > Imported rice.

Data significance

Table 2 shows ANOVA f-values and P-values for the normally distributed metals. From the statistical analysis, the f-values for Pb and Ni heavy metals were all below table values ($f < 2.69$) and in addition, their P values were all greater than the critical level / level of significance ($p > 0.05$) as follows:

Table 2: f-values and P-values for the heavy metals

Metals	Pb	Ni
F-values	0.90	1.49
P-values	0.48	0.23

Table 3 shows Kruskal-Wallis test for non-normal heavy metals. The statistical analysis revealed that the calculated Chi Square values were lower than their corresponding table values at $p > 0.05$. This implies that the Null hypothesis made on account of the study was acceptable.

Table 3: Kruskal-Wallis test for non-normal heavy metals

Metals	Chi Square $(H)_{calc}$	Chi Square $(H)_{table}$
Fe	1.179592	3.841459149
Cd	2.736054	9.487729037
Cr	5.844218	9.487729037
Co	3.714966	9.487729037

Estimation of the average daily oral intake of heavy metals

Estimated average daily vegetable and cereal intake (DIV) by an individual for each food crop determined from survey of opinion which was carried out in the sample region are shown in Table 4.

Table 4: Estimated average daily food crop intake for an individual on vegetable and cereals from Eke-Awka market

Samples	DIV ($kgperson^{-1}$ day^{-1}, fresh weight)
Cucumber	0.14290
Cabbage	0.20346
Carrot	0.19154
Maize	0.16338
Local rice	0.94644
Imported rice	0.94644

Estimation of the daily oral intake of heavy metals

The daily metal intake (DIM) from each food crop was estimated using equation (2) and the results are presented in Table 5.

Table 5: Estimated daily metal intake for both vegetable and cereals (mg day^{-1}, fresh weight).

Sample/ metals	Cucumber	Cabbage	Carrot	Maize	Local rice	Imported rice	Millet	RfD_0 (mg/kg/day)	UL (mg/day)
Pb	**0.0256**	0.0000	0.0037	**0.0163**	**0.0776**	**0.0114**	**0.0055**	0.004[a]	0.240[d]
Cd	**0.0171**	**0.0268**	0.0006	**0.0036**	**0.0189**	**0.0057**	**0.0019**	0.001[b]	0.064[d]
Cr	0.0065	0.0276	0.0034	0.0020	0.0133	0.0000	0.0026	1.500[b]	15.00[e]
Ni	0.0163	**0.0272**	**0.0354**	**0.0314**	**0.1912**	**0.0398**	**0.0026**	0.020[b]	1.000[d]
Co	0.0033	0.0061	**0.0269**	0.0075	**0.0398**	0.0076	0.0015	0.012[c]	-
Fe	0.2004	0.0690	0.0636	0.0964	0.3833	0.3455	0.0219	7.000[a]	45.000[d]

RfD_0 = Reference of Oral Dosage; **UL** = Upper tolerable limits

a) FAO/WHO-Codex Alimentarious commission, 2013
b) US EPA -Integrated risk information, 2015
c) MAFF, 2000
d) Geetanjali and Chauhan, 2014
e) Garcia-Rico *et al.*, 2007

From Table 5 it could be deduced that some heavy metal concentrations are higher than their reference dosage. As a result, these heavy metals have probable capability of causing hazard to health.

Estimated levels of the daily Pb intake from the food samples were in the order: local rice > cucumber > maize > imported rice > millet > carrot > cabbage. Local rice, cucumber, imported rice, maize and millet had Pb content higher than the RfD_0 but in all, the values are within the upper tolerable limits, UL.

Estimated level of the daily Cd intake from the food samples were in the order: cabbage > local rice > cucumber > imported rice > maize > millet > carrot. Cucumber, cabbage, maize, local rice, imported rice and millet had Cd level higher than the RfD_0. All the food samples had Cd quantity lower than UL.

Level of the daily Cr intake from the food samples had estimated results in the order: cabbage > local rice > cucumber > carrot > millet > maize > imported rice. In general, all the food samples had Cr levels below the RfD_0 and UL.

Level of the daily Ni intake from the food samples had estimated values in the order: local rice > imported rice > carrot > maize > cabbage > millet > cucumber. Only cucumber had Ni level lower than the RfD_0 while the rest were higher. All food samples were lower than the UL.

The estimated levels of the daily Co intake from the food samples were in the order: local rice > carrot > cucumber > imported rice > maize > cabbage > millet. Only millet, local rice and carrot had Co level higher than the RfD_0. All food samples had Co level lower than the UL.

The estimated Level of the daily Fe intake for the food samples were in the order: local rice > imported rice > cucumber > maize > cabbage > carrot > millet. In all, the food samples had Fe level below the RfD_0 and UL.

Estimated average exposure frequency and exposure duration

Estimated average exposure frequency (EF), which is the number of days food sample is consumed in days/week, and exposure duration (ED), which is number of weeks/year food sample from Eke-Awka is consumed throughout the stay of an individual in Awka, Nigeria is shown in Table 6.

Table 6: Estimated average exposure frequency and exposure duration to heavy metal from food sample consumption.

Samples	EF (days/week)	ED (weeks/year)
Cucumber	1.52	52
Cabbage	1.04	52
Carrot	2.00	52
Maize	2.65	52
Local rice	3.66	52
Imported rice	3.66	52
Millet	1.28	52

Health risks in consuming sampled food crops

To compute the hazard quotient, average weight, W for individuals surveyed was set at 60.19kg average, and the period, T being 54 years, the average life expectancy of an average Nigerian (WHO, 2016). The method established in equations 3 and 4 was used to compute the Hazard Quotient (HQ). Table 7 shows the results of the Hazard Quotients (HQ).

Table 7: Estimated Hazard Quotient, HQ in adults, 18 -70 years and their corresponding hazard Index (HI)

Samples/ Metals	Cucumber	Cabbage	Carrot	Maize	Local Rice	Imported Rice	Millet
Pb	1.56E-01	0.00E+00	2.97E-02	1.73E-01	1.13E+00	1.66E-01	2.80E-02
Cd	4.17E-01	4.45E-01	1.82E-02	1.52E-01	1.11E+00	3.32E-01	3.92E-02
Cr	1.06E-04	3.05E-04	7.30E-05	5.54E-05	5.17E-04	0.00E+00	3.54E-05
Ni	1.98E-02	2.26E-02	5.66E-02	6.64E-02	5.59E-01	1.16E-01	2.66E-03
Co	6.61E-03	8.47E-03	7.15E-02	2.65E-02	1.94E-01	3.69E-02	2.56E-03
Fe	6.98E-04	1.63E-04	2.90E-04	5.83E-04	3.20E-03	2.89E-03	6.39E-05
∑ HI:	**6.00E-01**	**4.76E-01**	**1.76E-01**	**4.19E-01**	**3.00E+00**	**6.54E-01**	**7.25E-02**

Generally, except for Cd and Pb in local rice, the hazard quotients (HQ) for all the heavy metals contained in the individual food samples have values lower than unity (i.e. 1). Thus, local rice is the only food sample posing an inherent metal hazard risk to individuals or the public residing in Awka in a long term with respect to Cd and Pb content.

Although the HQ-based risk assessment method does not provide a quantitative estimate for the probability of an exposed population experiencing a negative health effect, it does provide an indication of the risk level due to exposure to pollutants (Sapana et al., 2013; and Chary et al., 2008). According to Sapana et al., (2013) researchers consider the risk estimation method reliable and it has been proven to be valid and useful.

This HQ method considers only exposure to heavy metals via consumption, without taking into account other routes like dermal contact, soil ingestion, and other factors such as the presence of agrochemicals and herbicide molecules (Sapana et al., 2013).

From Table 7, the hazard index was deduced as an aggregate sum of all individual hazard quotients of different heavy metals in a food sample, ∑ **HQ,** (equation 5) and pictorially presented in Fig 1**.**

The aggregate sum of each sample hazard index is less than unity except for local rice having an index value of 3. Therefore, local rice is not safe for consumption and would accumulate to a toxic level after 54years of a life time. On the other hand, the rest of the food samples are safe.

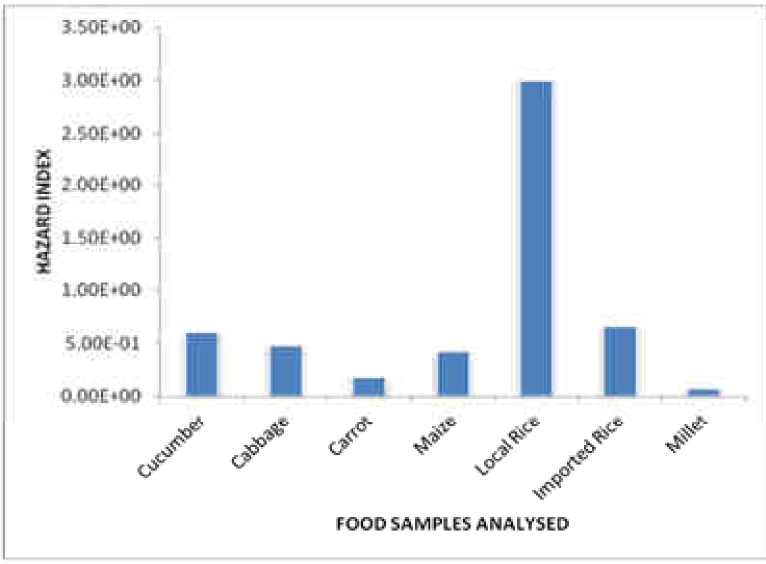

Fig 1: Hazard index for the individual food samples

4. CONCLUSION

Results obtained for the average heavy metal concentrations via AAS (Table 1) revealed that Pb in all samples (except for cabbage), Cd in all samples, Ni in all samples, Co in all samples (except for imported rice), had quantities higher than their corresponding reference dosage, RfD_0 hence implying a possible presence of heavy metal toxicity in them.

Fe is the predominant heavy metal, occurring in higher concentration in the whole food samples.

In the analysis of variance for the mean heavy metal levels in the food samples, the calculated f-values for normal distributed Ni and Pb were all below their corresponding table values, and their P-values were higher than the critical level. Likewise, metals not normally distributed (Fe, Cd, Co, Cr) revealed that the calculated Chi Squre values were all less than their corresponding table values. Hence, there is no significant difference in the mean metal data. These results tend to imply that the food samples containing these metals are grown from the same environment or that the soil/growth media from which food samples were grown had the same background concentration level of the heavy metals.

Result obtained for the daily metal intake from vegetables and cereals (mg day^{-1}, fresh weight) (DIM) revealed that Pb in all samples except cabbage and carrot; Cd in all samples except carrot; Ni in all samples except cucumber; and Co in carrot, local rice and millet were all higher than their corresponding reference dosage (RfD_0). Although the samples are all below the upper tolerable limits, the foregoing implies that these food samples having concentrations above the reference dosage could have an implicit potential to cause harm to individuals in a long term. People more exposed to the hazard risk are those who consume the food all day round.

On the estimation made for the hazard quotient and the hazard index and considering the necessary adjustments made, it could be inferred that, except for local rice, none of the food samples posed any heavy metal toxicity risk after a given period.

Finally, from the above considerations one can conclude that except for local rice, the food samples studied were generally safe for human consumption at the time of study.

5. RECOMMENDATION

The study recommends having a balanced diet and moderate intake of food crops as excessive intake could raise the hazard quotient thereby increasing the heavy metal toxicity. It recommends further analysis at various parts of Otuocha, Anambra State where local rice in Awka are grown, to reaffirm toxicity. It also recommends regular monitoring of food crops in the environment to ensure that heavy metal hazards from food crops do not go out of hand.

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