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Public Health Risks of Toxic Metals in Cattle Skin and Viscera Consumed in Makurdi, Nigeria

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Abstract
The study assessed the levels and public health risks of some toxic metals (Cd, Cr, Cu, Pb, Zn, and Ni) in the skin (ponmo) and viscera (liver) of cattle consumed in Makurdi metropolis, Nigeria. Composite samples were purchased from five markets: Modern (MM), Wadata (WD), High-Level (HL), Wurukum (WK) and North-Bank (NB) in Makurdi, acid-digested and assayed for the toxic metals using atomic absorption spectrophotometry. Human health risk indices viz: chronic daily intake (CDI), estimated daily intake (EDI), target quotient (TGQ), and hazard ratio (HR) were calculated from metal levels and other reference data. The mean concentration (mg/kg) of Cu, Zn and Ni in cattle skin were 25.80±49.053, 26.3±19.967 and 9.00 ±0.707 respectively while those for the viscera were 18.60±19.044, 41.00±17.029 and 2.50± 2.828 respectively. The concentration of Cu in the cattle skin from Wadata Market and viscera samples from Wurukum and North-Bank markets were above USDA permissible level for Cu in meat (20 mg/kg). Viscera samples from North-Bank market also had Zn above the USDA permissible level for Zn in meat (50 mg/kg). Additionally, CDI, THQ, EDI and HR values of these toxic metals were calculated using their respective concentrations. THQ values in adults were < 1 except skin sample from Wadata and viscera from Viscera from Wurukum, while most HR values for Cu, Zn and Ni in children were high or > 1 indicating the existence of potential hazard to health from metal ingestion through the consumption of cattle skin and viscera.

Keywords: Cattle skin/hide, atomic absorption spectrophotometer, viscera

Introduction

Heavy metal is a general collective term, which is applied to the group of metals and metalloids with atomic density greater than 5 g/cm^3 or 5 times greater than water. The most familiar metals are Cadmium, Chromium, Cobalt, and Copper, lead [1]. These metals are toxic in very low concentrations and are also referred to as toxic metals, thus a regular check in the levels of heavy metals in foods consumed by us is necessary to control the human health risk associated with such metals.

All metals are toxic at certain levels of intake, however, in contrast elements such as arsenic, chromium, copper, selenium and zinc that have useful biological functions, cadmium and lead play no useful role and their intake should be limited to avoid organ damage [2]. Metal ions are essential; for functional expression of many proteins in living organisms, while excess leads to issue and organ damage, all organism have developed similar mechanism for utilizing and storing metals as a result of evolutionary process and it is now recognized that there is a relation between the levels of certain trace metals in human tissues and the appearances of certain diseases [3].

Livestock production has a source of supply of animal protein in Makurdi and the world at large. Meat from slaughtered cattle at various abattoirs constitutes the largest source of animal protein for Nigeria populace [4]. Most of the livestock in Nigeria are being raised in commercial quantity in the Northern part of the country, but the enterprise is not known to be associated with the southern part of Nigeria due to the prevalence of trypanosomiasis. These animals are grazed on free range system (open grazing system) during which they eat grass in the surrounding and also drink water nearby streams and stagnant water which could have been contaminated with toxic metals. Contamination with metals is a serious threat because of their potential toxicity, bioaccumulation and biomagnification in the food chain.

Due to increased industrialization and mining activities around livestock farms and most times open grazing activities by the Nomads in the country, there have been many reported cases of poisoning as a result of heavy metals contamination of food and food products as well as the surroundings from where these openly gazed cattle feed. These activities have led to metal dispersion in the environment and consequently, impaired health of the population by ingestion of edible meat contaminated by harmful elements [5].

A number of serious health problems can develop as a result of excessive uptake of dietary toxic metals. Furthermore, consumption of heavy metal- contaminated for can seriously deplete some essential nutrients in a body causing a decrease in immunological defenses, intrauterine growth retardation, impaired psychosocial behaviours, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer [6]. Cadmium, chromium, copper, nickel, lead and zinc are classified as some of the dangerous heavy metals to health and environment. It is therefore necessary to assess the accumulation of such heavy metals, which are public health importance in blood, and tissue of animals used as food regularly.

Materials and Methods

Brief description of the study area

The study was conducted in Makurdi Local government of Benue state, samples were obtained from five major market in Makurdi town (Wurukum, Wadata, North-Bank, High-Level and Modern Markets). The samples were pre-treated in the chemistry laboratory of the college of science, Federal University of Agriculture, Makurdi.

Makurdi town is the capital of Benue state located in the North-central Nigeria. It is situated at 7.73°N latitude, 8.52°E longitude and situated at elevation 104meteres above sea level. Makurdi had a population of 279, 398 inhabitants (2006 census), but recent study reported by the world atlas shows population of 292, 645 inhabitants, making the biggest town in Benue state.

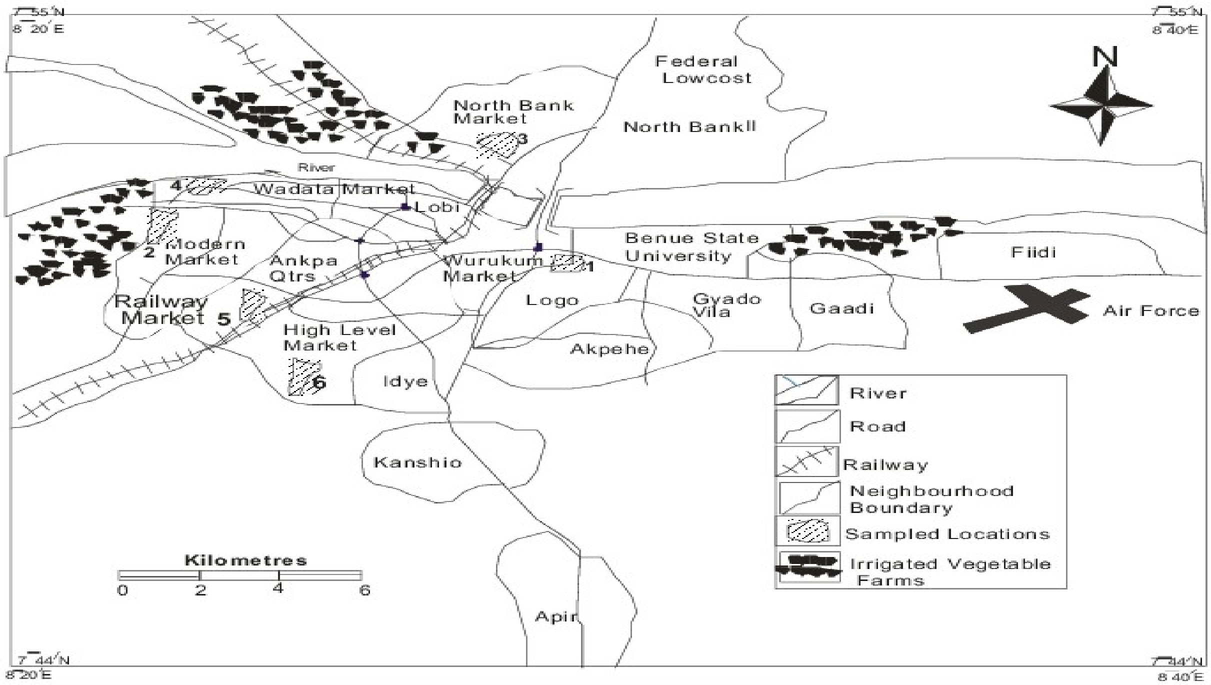

Figure 1: Map of Makurdi showing the study area (Wurukum, Wadata, High-level, Modern and North-Bank Markets)

Sample collection and pretreatment

The samples were obtained from five (5) major markets in Makurdi town, one sample each of cattle skin (Ponmo or Kanda) and viscera (liver) were purchased in each of the markets, making a total of 10 samples (5 fresh cattle skin and 5 fresh cattle viscera samples. The collected samples were washed with distilled water to remove any contaminated particles.

Sample digestion for metal assay

Sample preparation for heavy metal analysis was done using nitric acid (HNO_3) digestion. 1g each of the cattle skin (Ponmo) and viscera were placed in digestion tubes. About 20 mL of conc HNO_3 (analytical grade) was added to the digestion tubes and the digestion apparatus was switched on and allowed to run for about 30 mins. Once the digestion was completed, all samples were completely dissolved in the acid. The mixtures were cooled to room temperature, 50 mL distilled water was added into the tubes to dilute the mixtures.

Human health risk indices for toxic metals

Human exposure to heavy metals occurs through several pathways including direct ingestion, dermal absorption through skin, inhalation through mouth and nose. Ingestion is the most common pathways for meat [7]; [8] Heavy metals can be exposed to humans of polluted air as dermal absorption from contaminated bathing water and occupational exposure to metal contaminated air.

Chronic daily intake (CDI)

The USEPA points out that the human body absorbed pollutant dose is calculated from chronic daily intake (CDI), which means the pollutant dose per kilogram of body weight per day that is absorbed through direct ingestion, dermal absorption or inhalation [9]. We used the direct ingestion as the main exposure pathway.

The CDI of the meat ingestion and dermal adsorption

$$CDI_{in} = \frac{C\ x\ FIR\ x\ ABSg\ X\ EF\ x\ ED}{BW\ x\ AT} \quad (1)$$

Where;
FIR is the metal ingestion rate,
ABSg is the gastrointestinal absorption factor,
EF is the exposure frequency,
ED is the exposure duration,
BW is the body weight of the consumer (70 kg average weight for an adult)
AT is the average time.
CDI_{in} is the exposure does from ingestion of meat ($mgkg^{-1}day^{-1}$), and
C is the average concentration of heavy metals (mg/kg).

Estimated daily intake (EDI)
Heavy metals estimated daily intake (EDI) is dependent on the heavy metal levels the skin and viscera of cattle and the rate of consumption. EDI can be calculated using the formula below [9];

$$EDI = \frac{C\ x\ FIR}{BW} \quad (2)$$

where;
C = concentration of heavy metal in the sample (mg/kg wet weight),
FIR = Skin and viscera ingestion rate (g/day),
BW = body weight of the consumer (70 kg average weight of adult)
The EDI can then be compared with the total daily intakes [10].

Target hazard quotient (THQ)
THQ is used to evaluate health risk accompanied with non-carcinogenic and carcinogenic effect of any toxic metal. Skin and viscera consumption risk of cattle can be evaluated according to THQ. THQ is a relation between the determined pollutant dose and the level of the RFD (reference dose. The reference dose is the daily exposure of a contaminant estimated which the population exposed along a lifetime continually with no significant dose [11]. If this relation is less than one (1), the population has improbable no noticeable bad effects. The equation below is used to determine the risk assessment;

$$THQ = \frac{EF\ X\ ED\ X\ FIR\ X\ C}{RFD\ X\ BW\ X\ AT} X10^{-3} \quad (3)$$

where;
EF = the frequency of exposure (365 days/ year),
ED = the duration of exposure (70 years, average exposure),
FIR = ingestion rate of meat (g/day)
RFD = oral reference dose (mg/kg/day)
At = exposure time average (365 days/ year x exposure years number)
BW = body weight of consumer (70 kg average weight for an adult).
The oral reference dose of Pb, Cd, Zn and Cu is 0.004, 0.001, 0.3 and 0.04 (mg/kg/bw/day) respectively [9].

Hazard ratio index (HR)
The equation used for this study is

$$\text{Hazard Ratio (HR)} = \frac{EDI}{RFD} X10^{-3} \quad (4)$$

The hazard ratios (HRs) can be summed to generate a hard (HI) to estimate the risk of mixed contaminants so HI can be generated using the following equations;

$$HI = \sum HRi \quad (5)$$

Where; I represent each metal, EDI is estimated daily intake, RfD is Reference Dose, A HR and/ or HI of > 1 indicates that there is potential risk to human health, whereas a result of ≤ 1 indicates no risk of adverse health effects.

Results and Discussion

Heavy metal concentrations in cattle skin and viscera from five major markets in Makurdi, Benue, Nigeria.
The concentrations of heavy metals determined using AAS are shown in Table1, the concentration of heavy metals detected are also shown on bar chat.

Table 1: Concentrations of Toxic Metals (mg/kg) in Skin and Viscera Samples from Major Markets in Makurdi, Nigeria.

Sample ID	Cd	Cr	Cu	Pb	Zn	Ni
HL skin	ND	ND	6.000	ND	21.000	ND
WD Skin	ND	ND	113.500	ND	44.000	ND
WK Skin	ND	ND	1.500	ND	48.500	9.500
NB Skin	ND	ND	3.500	ND	18.000	8.500
MM Skin	ND	ND	4.500	ND	DL	ND
HL Viscera	ND	ND	1.000	ND	34.000	ND
WD Viscera	ND	ND	4.000	ND	30.000	ND
WK Viscera	ND	ND	45.500	ND	38.000	4.500
NB Viscera	ND	ND	31.000	ND	71.000	0.500
MM Viscera	ND	ND	11.500	ND	32.000	ND

Note: ND means Not Detected, DL means Detection Limit, NB means North-bank, HL means High-level, MM means Modern Markets, WK means Wurukum and WD means Wadata markets.

Cadmium was detected in all the cattle skin and viscera samples because the concentrations were detention limits. Cadmium concentration was less than (0.001) which conforms to regulatory standards [12 - 16]. This result similarly agrees with Makanjuola and Olakunle [17] who found concentration of cadmium in some meat samples was lower than the detention limits (0.001). However, the results disagree with Chafik [18] who reported the concentration of cadmium in beef, sheep and camel as (0.00, 0.00

and 0.12) mg/kg respectively, it also disagrees with Bendedouche, *et al.,* [19] who found the concentration of cadmium concentration was below the USDA [12] permissible level of Cadmium which is 0.05 mg/kg.

Chromium concentration in all the samples was also below detection limit so they were not detected. The concentration of chromium in the samples was less than USDA [12] permissible limit for chromium which is 1.0 mg/kg

Copper was detected in all samples with concentrations ranging from 1.0 to 45.5 mg/kg for viscera samples and 1.5 to 113.5 mg/kg for cattle skin samples. The highest concentration of copper was detected in the cattle skin sample from Wadata market (113.5 mg/kg), the least for the cattle skin was seen in sample from Wurukum market (1.5mg/kg). Viscera sample from Wurukum market had 45.5 mg/kg of copper which was the highest and 1.0 mg/kg was detected as the least concentration for copper in viscera samples. The concentrations of copper detected were all below USDA [12] permissible limit of 20mg/ kg for copper except cattle skin sample from Wadata with 113.5 mg/kg and Viscera samples from Wurukum and North-bank markets with 45.5 mg/kg and 31.0 mg/kg respectively which indicates that consumers of cattle skin and viscera from these areas are at risk of metal poisoning as a result of continuous intake of copper.

Lead was also detected in all samples due to the fact that its concentration in samples was less than (0.001) which conforms some intentional standards [12 - 16]. These results also agree with Makanjuola and Olakunle [17], who found level of lead in some meat samples was lower than detection limits (0.001). This result disagreed with [20] Amani and Lamia (2012) who reported the level of lead in beef as 7.61 mg/kg. The USDA [12] given permissible limit for lead is 0.1 mg/kg, since lead was below detention limit it is also below permissible limit, thus the sample obtained from all the markets are safe from lead poisoning.

Zinc was detected in all samples with concentrations ranging from 32.0 to 71.0 mg/kg for viscera samples and detention limit (0.003) to 48.5 mg/kg for cattle skin samples. Cattle skin sample from Modern market had the least zinc concentration which was equal to the detention limit used for analysis, while skin samples from Wurukum had highest concentration of 48.5 mg/Kg. The least zinc concentration in viscera was 32.0 mg/kg in viscera sample from Modern market, and the highest was 71.0 mg/kg in sample from North-bank market. The concentrations of Zinc detected were all below USDA [12] permissible limit of 50 mg/kg for Zinc except viscera sample from North-bank market with 71.0 mg/kg of zinc which indicates that consumers of viscera from North-bank market are at risk of metal poisoning due to Zinc.

Nickel was detected in cattle skin and viscera samples from Wurukum and North-bank markets. The rest of the samples had concentrations below detection limit (0.001) which conforms some intentional standards such as [12 - 16]. The concentrations of nickel were within the range of 0.5 to 9.5 mg/kg with the highest concentration in cattle skin sample from Wurukum (9.5 mg/kg) and the lowest concentration in viscera sample from North-bank market. These results show all nickel concentrations below WHO permissible limit of 12.0 mg/kg [21], hence cattle skin and viscera samples from these five markets is safe from nickel poisoning.

Table 2. Mean and standard deviation of Skin and Viscera samples from five major markets in Makurdi, Nigeria.

Samples	Cu	Zn	Ni
Cattle	25.80 ± 49.05	26.30±19.97	9.00±0.71
Viscera	18.60±19.04	41.00±17.03	2.50±2.83

Human health risk indices for toxic metals in cattle skin and viscera from five major markets in Makurdi, Nigeria.

Human health risk indices were calculated for adults and children using the concentrations of all the heavy metals that were detected in the course of this analysis and other reference/ standard data provided by some intentional bodies and other researchers. The following human health risk indices were calculated

Chronic daily intake (CDI)

CDI values of copper, Zinc and Nickel were calculated for both adults and children and are shown in table below, these values are also shown on charts for adults and children in fig1 and 2 respectively.

Table 3: Chronic Daily Intake (CDI) of Toxic Metals in Cattle Skin and Viscera Samples from the Major Markets in Markets in Makurdi, Nigeria.

Adult				Child		
Sample ID	Cu	Zn	Ni	Cu	Zn	Ni
HL skin	1.057	2.466	-	1.973		
WD Skin	19.990	5.166	-	37.315		
WK Skin	0.264	5.695	0.056	0.493		
NB Skin	0.616	2.114	0.049	1.150	3.945	0.093
MM Skin	0.793	0.000	-	1.479	0.000	-
HL Viscera	0.176	3.992	-	0.329	7.452	-
WD Viscera	0.705	3.523	-	1.315	6.575	-
WK Viscera	8.014	4.462	0.027	14.959	8.329	0.049
NB Viscera	5.456	8.337	0.003	10.192	15.562	0.006
MM Viscera	2.025	3.757	-	3.780	7.014	-

Table shows 3 the chronic daily intake (CDI) values of toxic metals in cattle skin and viscera samples. Fig1 and 2 show a plot of the CDI values for adults and children respectively. The CDI values for children were generally higher than those in adults.
Copper: the highest CDI value for Cu in adults was gotten in cattle skin sample from Wadata (19.990), while the lowest value was observed in viscera sample from High- Level (0.176). In children, the highest CDI value was observed in skin sample from Wadata (37.315) and the lowest value in Viscera sample from High-level (0.329).
Zinc: The highest CDI value for Zinc in adults was gotten in viscera sample from Wurukum (8.337), while the lowest value was observed in skin sample from modern market (0.000). in children, the highest CDI value was also observed in viscera sample from North-bank market (15.562) and the lowest value in skin sample from modern market (0.000).
Nickel: the values for CDI for Nickel were calculated for skin and viscera samples from Wurukum and North-bank market only since metal concentration was detected only in these samples. The highest CDI value for adults was 0.056 obtained in skin sample from Wurukum and the lowest was 0.003 obtained in viscera sample from North-bank. For children, the highest CDI value was 0.104 obtained from skin sample from Wurukum and the lowest was 0.005 in viscera sample from North-bank market.

Estimated daily intake (EDI)

EDI values were also calculated for adults and children and are shown in table below and also fig respectively.

Table 4: Estimated Daily Intake (EDI) of Toxic metals in Cattle Skin and Viscera samples from the five Major Markets in Makurdi, Nigeria.

	Adult			Child		
Sample ID	Cu	Zn	Ni	Cu	Zn	Ni
HL skin	8.571	30.000	-	80.000	280.000	-
WD Skin	162.14	62.857	-	1513.333	586.667	-
WK Skin	2.143	69.286	13.571	20.4000	646.667	126.667
NB Skin	5.000	25.714	12.143	46.6667	240.000	113.333
MM Skin	6.429	0.000	-	60.000	0.000	-
HL Viscera	1.429	48.571	-	13.333	453.333	-
WD Viscera	5.714	42.857	-	53.3333	400.000	-
WK Viscera	65.000	54.286	6.429	606.667	506.667	60.000
NB Viscera	44.286	101.429	0.714	413.3333	946.667	6.667
MM Viscera	16.429	45.714	-	153.333	426.667	-

Table 4, shows the estimated daily intake (EDI) values of toxic tals in cattle and viscera samples. EDI values in children are generally higher than those in adults in adults indicating that the children are at higher risk of metal poisoning from copper, Zinc and Nickel. The EDI values of Copper in adults are within the range 2.143 to 162.143 for skin sample and 1.429 to 65.000 for viscera samples. While those for children the range 20.400 to 1513.333 for skin samples and 13.333 to 606.667 for viscera samples
EDI values for Zinc in adults are within the range 0.0000 to 69.2857 for skin samples and 42.857 to 101.429 for viscera samples. While those for children are within the range 0.000 to 646.667 for skin samples and 400.0000 to 946.667 for viscera samples.

The values for EDI for Nickel were calculated for skin and viscera samples from Wurukum and North-bank market only since metal concentration was detected only in these samples. The highest EDI values for adult was 13.571 obtainedin skin sample from Wurukum and the lowest was 0.7143 obtained in viscera sample from North-bank. For Children, the highest EDI value was 126.667 obtained from skin sample from Wurukum and the lowest in viscera sample from North-bank market (6.667).

Target hazard quotient (THQ)

The values of THQ were also calculated and are shown in table below, the values are also shown for adults and children in fig respectively.

Table 5: Target Harzard Quotient (THQ) of toxic metals in cattle skin and viscera samples from five major markets in Makurdi, Nigeria.

	Adult			Child		
Sample ID	Cu	Zn	Ni	Cu	Zn	Ni
HL skin	0.088	0.041	-	0.164	0.077	-
WD Skin	1.666	0.086	-	3.100	0.160	-
WK Skin	0.022	0.095	0.279	0.041	0.177	0.520
NB Skin	0.051	0.035	0.240	0.096	0.066	0.466
MM Skin	0.066	0.000	-	0.123	0.000	-
HL Viscera	0.015	0.067	-	0.027	0.124	-
WD Viscera	0.059	0.059	-	0.100	0.100	-
WK Viscera	0.668	0.074	0.132	1.247	0.139	0.247
NB Viscera	0.455	0.139	0.015	0.849	0.259	0.027
MM Viscera	0.169	0.063	-	0.315	0.117	-

THQ values for children were generally higher than those for adults. The target hazard quotients of copper for adults and were within the range 0.022 to 1.666 for skin samples and 0.015 to 0.668 for viscera samples. Those for Zinc for adults were within the range 0.0000 to 0.095 for skin samples and 0.0587 to 0.1389 for viscera samples. 0.2495 to 0.279 was the range of nickel for skin samples and that of Viscera was 0.015 to 0.132.

For children, THQ values were within the range 0.041 to 3.100 and 0.027 to 1.247; 0.000 to 0.177 and 0.178 and 0.100 to 0.259; 0.466 to 0.520 and 0.027 to 0.247 for cattle skin and viscera samples for copper, Zinc and Nickel respectively.

Skin sample from Wadata and viscera from Wurukum had THQ value > 1 for children, while all other samples were < 1in children. Skin sample from Wadata also had THQ value >1 for adults and all others were <1 for adults. All the samples had THQ values for Zn and Ni < 1 in both children and adults. Generally, THQ and HR values ,1 means that the exposed population is safe from toxic metal risks while THQ and HR values > 1 means the reverse [22]. The population consuming cattle skin from Wadata and Wurukum is therefore at risk of copper poisoning since their THQ values are >1.

Hazard ratio Index (HR)

The values of HR were also calculated and are shown in table and the values are shown on the charts for adults and children in figure

Table 6: Hazard ratio (HR) of toxic metals in cattle skin and viscera samples from the five major markets in Makurdi, Nigeria.

	Adult			Child		
Sample ID	Cu	Zn	Ni	Cu	Zn	Ni
HL skin	0.214	0.100	-	2.000	0.933	-
WD Skin	4.054	0.200	-	0.038	1.956	-
WK Skin	0.054	0.231	0.677	0.500	2.156	6.333
NB Skin	0.125	0.086	0.607	1.667	0.800	5.667
MM Skin	0.160	0.000	-	1.500	0.000	-
HL Viscera	0.036	1.192	-	0.333	1.511	-
WD Viscera	0.143	0.143	-	1.333	1.333	-
WK Viscera	1.6250	0.1809	0.3214	15.1667	1.6889	3.0000
NB Viscera	1.1071	0.3381	0.0357	10.3333	3.1556	0.3333
MM Viscera	0.4107	0.1524	-	3.8333	1.4222	-

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The results of the HR values through the consumption cattle skin and viscera is shown in table. HR values for Copper in skin samples from Wadata and Viscera samples from Wurukum and North-Bank market were >1. HR values of Zinc for adults were all < except viscera sample from High-level market, while those of nickel for were all < 1.

The HR values for copper in Children were all > 1 except skin samples from Wadata and Wurukum market and viscera sample from high-level. HR values of Zinc for children were also >1 except skin samples from High-level, North-Bank and modern market. Nickel had HR values > 1 for children except viscera sample except skin samples from North-bank market.

Generally, THQ and HR values < 1 means that the exposed population is safe from toxic metal risks while THQ and HR values > 1 means the reverse [22] .The population is therefore at greater risk of Zn and Cu poisoning as reported by [23], populations around these markets with HR values > 1 may be at high risk of toxic metal poisoning from contaminated beef on constant consumption. On the other hand, THQ and HR values of <1 are suggestive that the exposed population is assumed to be safe.

Conclusion

The toxicity of heavy metals in living systems and their associated health hazards cannot be overemphasized as they cannot be taken out of such systems easily due to their tendencies of bioaccumulation, bioconcentration, and biomagnification. Most of the HR values of these metals were above 1 which implies that the consumers of cattle skim and viscera in Makurdi are at high risk of potential toxicity as a result of heavy metal (Cu, Zn) poisoning especially children. Children around these areas are also at risk of Ni poisoning but all the HR values of Ni in adult are below 1 implying that they are within safe limits.

Declaration of conflicting interests

The authors declared no potential conflicts of interest.

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