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Investigation and health risk assessment of heavy metals in cattle from slaughterhouses in Federal Capital Territory (FCT), Abuja, Nigeria

Henrietta Ijeoma Kelle[1*], Emeka Chima Ogoko[1], Prisca Ifeoma Udeozo[2], Adebisi Akinyemi Fagbohun[3], Esther Onoyoche Ngbede[4], Paul Abali Okopi[5], Joseph Adamu[1]

[1]Department of Chemistry, Faculty of Sciences, National Open University of Nigeria, Jabi, Abuja, Nigeria

[2]Department of Industrial Chemistry, Faculty of Natural and Applied Sciences, Enugu State University of Technology, Enugu State, Nigeria

[3]Chemistry Advanced Research Centre, Sheda Science and Technology Complex, Abuja, Nigeria.

[4]Department of Chemistry, School of Science Education, Federal College of Education, (Tech), Asaba, Delta State, Nigeria

[5]Department of Environmental Science and Management, Faculty of Sciences, National Open University of Nigeria, Jabi, Abuja, Nigeria

*Corresponding author E-mail: hkelle@noun.edu.ng

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Summary

Introduction: Heavy metals toxicity in cattle can cause health related issues in humans when they ingest cow meat polluted with heavy metals. The dearth of information regarding the level of heavy metals in cattle meat consumed in the Federal Capital Territory (FCT), Abuja, Nigeria, and its associated health risk to humans led to this study. **Aim:** to determine the level of the heavy metals- nickel, lead, cobalt, cadmium and chromium in cow muscle, intestine and liver from slaughterhouses in Federal Capital Territory (FCT), Abuja, Nigeria, as well as the health risk of consumption of the metals in the meat parts. **Methodology:** The heavy metals were assayed using Atomic Absorption Spectrophotometer Agilent 200 Series A. A. Health risk assessment of exposed adult men and women, adolescent and children to the heavy metals in the meat parts were evaluated via hazard quotient (HQ), hazard index (HI) and incremental lifetime cancer risk (ILCR) calculations. **Results:** The result of the study showed overall mean concentration of the metals in cow muscle, intestine and liver samples ranging from 0.0417 ±0.0226 to 0.690 ±0.0570 mg/kg, fresh weight. HQ and HI values were less than 1, and ILCR values of the carcinogenic heavy metals ranged from 1.07×10^{-7} to 7.50×10^{-5}. **Conclusion:** Consumers of cow muscle, intestine and liver in FCT, Abuja, Nigeria are at low risk of developing chronic non-cancer health related issues, and cancer due to nickel, lead, cobalt, cadmium and chromium in cow meat parts from slaughterhouses in FCT, Abuja, Nigeria.

Keywords: Cattle, Hazard index, Hazard Quotient, Heavy metals and Incremental Lifetime Cancer Risk.

Resumen

Investigación y evaluación de riesgos para la salud de metales pesados en ganado vacuno de mataderos en el Territorio de la Capital Federal (FCT), Abuja, Nigeria

Introducción: La toxicidad por metales pesados en el ganado puede causar problemas de salud en los humanos cuando estos ingieren carne de vaca contaminada con estos metales pesados. La falta de información sobre el nivel de metales pesados en la carne de ganado consumida en el Territorio de la Capital Federal (FCT), Abuja, Nigeria, y el riesgo asociado para la salud de los seres humanos llevó a este estudio. **Objetivo:** determinar el nivel de metales pesados: níquel, plomo, cobalto, cadmio y cromo en el músculo, el intestino y el hígado de las vacas procedentes de mataderos en el Territorio de la Capital Federal (FCT), Abuja, Nigeria, así como el nivel de riesgo en la salud por el consumo de metales en las partes cárnicas. **Metodología:** Los metales pesados se analizaron utilizando un espectrofotómetro de absorción atómica Agilent 200 Serie A. A. La evaluación de riesgos para la salud de hombres y mujeres adultos, adolescentes y niños expuestos a los metales pesados en las diferentes partes de la carne se evaluó mediante el cociente de peligro (HQ), el índice de peligro (HI) y cálculos de riesgo incremental de cáncer de por vida (ILCR). **Resultados:** El estudio mostró una concentración media general de metales en muestras de músculo, intestino e hígado de vaca que oscilaba entre 0,0417 ±0,0226 y 0,690 ±0,0570 mg/kg de peso fresco. Los valores de HQ y HI fueron inferiores a 1, y los valores de ILCR de los metales pesados cancerígenos oscilaron entre $1{,}07 \times 10^{-7}$ y $7{,}50 \times 10^{-5}$. **Conclusión:** Los consumidores de músculo, intestino e hígado de vaca en FCT, Abuja, Nigeria, tienen un riesgo bajo de desarrollar problemas de salud crónicos no relacionados con el cáncer, además de cáncer propiamente dicho, debido al níquel, plomo, cobalto, cadmio y cromo en las partes de carne de vaca de los mataderos en FCT, Abuya, Nigeria.

Palabras clave: Bovinos, índice de peligrosidad, cociente de peligrosidad, metales pesados y riesgo incremental de cáncer a lo largo de la vida.

Resumo

Investigação e avaliação do risco sanitário de metais pesados em bovinos provenientes de matadouros no Território da Capital Federal (FCT), Abuja, Nigéria

Introdução: A toxicidade de metais pesados em bovinos pode causar problemas de saúde em humanos quando estes ingerem carne de vaca poluída com metais pesados. A escassez de informações sobre o nível de metais pesados na carne bovina consumida no Território da Capital Federal (FCT), Abuja, Nigéria, e o risco associado à saúde humana levou a este estudo. **Objetivo:** determinar o nível de metais pesados - níquel, chumbo, cobalto, cádmio e cromo no músculo, intestino e fígado de vacas de matadouros no Território da Capital Federal (FCT), Abuja, Nigéria, bem como a saúde risco de consumo dos metais nas partes da carne. **Metodologia:** Os metais pesados foram dosados usando Espectrofotômetro de Absorção Atômica Agilent 200 Série A. A. A avaliação do risco à saúde de homens e mulheres adultos expostos, adolescentes e crianças aos metais pesados nas partes da carne foi avaliada através do quociente de perigo (HQ), índice de perigo (HI) e cálculos incrementais de risco de câncer ao longo da vida (ILCR). **Resultados:** O resultado do estudo mostrou concentração média global dos metais em amostras de músculo, intestino e fígado de vaca variando de 0,0417 ±0,0226 a 0,690 ±0,0570 mg/kg, peso fresco. Os valores de HQ e HI foram inferiores a 1, e os valores de ILCR dos metais pesados cancerígenos variaram de $1{,}07 \times 10^{-7}$ a $7{,}50 \times 10^{-5}$. **Conclusão:** Os consumidores de músculo, intestino e fígado de vaca na FCT, Abuja, Nigéria, apresentam baixo risco de desenvolver problemas crónicos não cancerígenos relacionados com a saúde e cancro devido ao níquel, chumbo, cobalto, cádmio e crómio em partes de carne de vaca provenientes de matadouros em FCT, Abuja, Nigéria.

Palavras-chave: Bovinos, Índice de Perigo, Quociente de Perigo, Metais Pesados e Risco Incremental de Câncer ao Longo da Vida.

Introduction

The muscle and edible offal of cow are the meat that are mainly consumed in Nigeria, because they are cheaper compared to that of goat, sheep and chicken. On the other hand, pig muscle and edible offal are avoided by some citizens of Nigeria due to religious and traditional beliefs. Cow muscle and edible offal provide cheap source of meat protein to the Nigerian people. Cattle rearing is highest among other domestic animals reared for meat consumption in Nigeria; cow meat account for 45% of the total meat eaten in Nigeria while meat from goat and sheep account for 35% [1]. Cow meat in Nigeria is mostly supplied by the Fulani tribe of Northern Nigeria whose occupation is cattle rearing. These Fulanis are nomads; moving from one region of the country to another in search of grazing for their cattle. As they move, wherever they find pasture and water (stream, ponds etc) they settle for their cattle to feed and or drink. Their movement from place to place may expose the cattle to heavy metal pollution.

Cows are herbivores; they feed on green plants (grasses). Green plants grow on soil. The problem that may arise from consumption of plants by cows reared in Nigeria is ingestion of heavy metal polluted plants, because some Nigeria soils are polluted with heavy metals [2-6], arising from dumping of scrap metals on soils [3], metal recycling activities [4], mining operations [6], power plant station emissions [7], vehicular exhaust emissions [8-10], oil spill [11-13], industrial effluent discharge [14-16], improper solid waste disposal [17, 18], auto mechanic and auto panel workshop activities [18, 19], application of fertilizers and pesticides etc. Some plants grown on heavy metal polluted soil have the ability to absorb heavy metal from soil through their root to other plant parts [16, 20], also, by atmospheric deposition heavy metals emitted into the atmosphere are deposited on plants and absorbed by plant parts [21, 22]. Apart from pollution of soil with heavy metals, heavy metals also pollute water.

Federal Capital Territory (FCT), Abuja, Nigeria is the capital city of Nigeria, with high population density, traffic and vehicular emission, which contributes to heavy metal pollution. Cattle consumed in the capital city are reared within and outside the capital city, majorly Zamfara, Sokoto and Niger states all within the Northern Nigeria. Zamfara, Sokoto and Niger states are rich in gold deposit. Among other metals, gold bearing ore contains minerals of cadmium, lead, nickel, and cobalt [23-26]. Artisanal gold mining in Zamfara, Sokoto and Niger states release heavy metals into the environment from gold mining tailings, Zamfara state reported lead poisoning in this state due to artisanal gold mining. Gold mine tailings are characterized by high levels of arsenic, cadmium, nickel, lead, copper, zinc, cobalt and mercury [27]. Studies have shown that soil, vegetables and livestock (chicken, goat, sheep and cattle) around some goldmine areas in Zamfara state, Nigeria are polluted with heavy metals [28, 29]. When grazing animals such as cow eat and drink heavy metal polluted grasses and surface soil, and water, they can be exposed to heavy metal pollution [30].

Exposure of humans to heavy metals through ingestion of cow meat polluted with heavy metals can affect human health despite the nutritional benefits of meat. Heavy metals such as iron, zinc, copper, manganese, molybdenum, cobalt, chromium (Cr III), magnesium, selenium and nickel are essential mineral nutrients required for proper functioning of the human body [31]. However, excess amount of these heavy metal mineral nutrients causes adverse health effects in humans [32]. Non-essential heavy metals are not useful biologically in humans [20], they include cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), and chromium (Cr (VI)) [20]. These metals are toxic even at low concentrations [32]. Cadmium can cause osteoporosis, kidney, breast, lung, prostrate, nasopharynx and pancreas cancer [33]. Chromium VI is a human carcinogen [34]. Lead in the body can cause high blood pressure, neurological problems, kidney and brain damage as well as miscarriage, low birth weight, stillbirth, premature birth in pregnant women [35]. High concentrations of cobalt may cause cancer [36]. Nickel pollution is associated with lung fibrosis, cardiovascular disease, lung cancer, kidney diseases and nasal cancer [37]. Previous studies conducted in Nigeria on some meat samples from different regions in Nigeria showed pollution of the meat samples with heavy metals [38-41].

The objectives of this study are to evaluate levels of heavy metals – nickel (Ni), lead (Pb), cobalt (Co), cadmium (Cd) and chromium (Cr) in cow muscle, intestine and liver from slaughterhouses in FCT, Abuja, Nigeria and to determine the health risk of consumption of the heavy metals in cow meat parts by consumers in FCT, Abuja, Nigeria. The data generated will be a useful aid for policy formulation by relevant health and environmental regulatory agencies in FCT, Abuja and Nigeria in general.

Materials and methods

Study area and sampling

Federal capital territory (FCT), Abuja is the capital of Nigeria, it is found in longitudes 6° 46′ and 7° 37′ E and latitudes 8° 21′ and 9° 18′ N. It is situated in the center of Nigeria and located in the North Central geopolitical region of Nigeria. The vegetation in Abuja is a blend of savannah grassland and tropical rain forest. It has agricultural rich soil hence the local people of the area are farmers and livestock animal farmers. The weather conditions in the FCT are of two types; rainy season (similar to winter) and dry season (similar to summer). The raining season last for six months beginning from April to October. Annual precipitation in the FCT range from 1100 mm to 1600 mm, while monthly mean temperature ranges from 25 °C to 30 °C. The savannah grassland, tropical rain forest and agricultural rich soil produce lots of plant and grasses for grazing animals such as cattle. There are four slaughterhouses in Federal Capital Territory (FCT), Abuja, Nigeria, namely Deidei, Gwagwalada, Karu and Kubwa slaughterhouses. Meat samples comprising of cow muscle, liver and intestine were randomly collected from 10 cows in each slaughterhouse located in FCT, making a total of 120 meat parts samples. The age of the cows ranged from three to four years. Each cow meat part of a cow was enclosed in a clean polyethylene bag, labelled and preserved in an ice box. The meat samples were taken to the laboratory and preserved in refrigerator preset at -18 °C, prepared and analyzed within five days.

Sample preparation and analysis

All glass wares and sample bottles used for sample preparation and storage were washed with detergent and rinsed with tap water, afterwards they were soaked overnight in 50% HNO_3 at room temperature, rinsed again in deionized water and air dried [42]. The meat part samples were washed with deionized water and cut into pieces with stainless-steel knife precleaned with detergent and rinsed with distilled water. 2 g each of meat sample was weighed into a beaker, 20 mL of aqua regia (3:1 ratio of HCl and HNO_3) prepared from 37% HCl and 69% HNO_3 from Merck, Darmstadt, Germany was added to the content in the beaker and heated on a hot plate in a fume cupboard for 50 minutes. The beaker was brought down from the hot plate and allowed to cool. The content in the beaker was filtered through a 110 mm filter paper into a 100 mL volumetric flask and made to the mark with deionized water and transferred into properly labelled sample bottle and assayed for heavy metal using atomic absorption spectrophotometer Agilent 200 Series A. A. Calibration curve of nickel was prepared with 3 mg/L, 6 mg/L, 9 mg/L and 12 mg/L standard solutions of nickel from 1000 mg/L stock solution of nickel, that of cadmium was prepared with 2 mg/L, 4 mg/L, 6 mg/L and 8 mg/L of standard solutions of cadmium from 1000 mg/L stock solution of cadmium, while that of lead was prepared with 1 mg/L, 1.5 mg/L, 2 mg/L and 2.5 mg/L of standard solutions of lead from 1000 mg/L stock solution of lead, calibration curve of cobalt was prepared with 2 mg/L, 4 mg/L, 6 mg/L and 8 mg/L of standard solutions of cobalt from 1000 mg/L stock solution of cobalt, that of chromium was prepared with 1 mg/L, 2 mg/L, 3 mg/L and 4 mg/L of chromium from 1000 mg/L stock solution of chromium. The heavy metals were determined at their wavelength 232.0 nm (nickel), 217.0 nm (lead), 240.7 (cobalt), 228 (cadmium) and 357.9 (chromium) 357.9. The limit of detection (LOD) of the metals was 0.00001 mg/kg, calculated as the concentration corresponding to three times the standard deviation (SD) of reagent blank, while the limit of quantification (LOQ) 0.000033 mg/kg was calculated as 10 times the standard deviation of reagent blank.

Quality control

Reagents used in the study were of analytical grade. Accuracy of the analysis was achieved by triplicate determination of the concentration of the heavy metals in the meat samples. Reagent blank was prepared and analyzed before each measurement.

Method and instrument validation

Recovery study of each heavy metal was determined so as to validate the digestion method and the spectrophotometer of the analysis. Recovery study for each metal was performed by weighing 2 g of muscle in two places, one of the 2 g was spiked with 1 mL standard solution of heavy metal (Ni (3 mg/L), Pb (0.5 mg/L), Co (2 mg/L), Cd (2 mg/L), Cr (1 mg/L), while the other 2 g was unspiked. Both spiked and unspiked muscle samples were digested with *aqua regia* and assayed for heavy metal.

The % recovery was calculated using equation:

$$\% \text{ recovery} = \frac{A_1 - A_2}{B} \tag{1}$$

A_1 = Concentration of spiked meat sample

A_2 = Concentration of unspiked meat sample

B = Concentration of standard solution added to the spiked sample.

Health risk assessment

Carcinogenic and non–carcinogenic health risk assessment of pollutant(s) or toxicant(s) can be evaluated by determining hazard quotient, hazard index and incremental lifetime cancer risk of the pollutant(s) or toxicant(s) [43-45]. To obtain hazard quotient, estimated daily intake (EDI) or average daily dose (ADD) of the pollutant(s) or toxicant(s) will have to be determined first. Hazard quotient and hazard index estimates non-carcinogenic chronic and adverse health effects, while, incremental lifetime cancer risk estimates carcinogenic risk due to exposure to carcinogenic pollutant(s) or toxicant(s) [43-45].

Estimation of Daily Intake (EDI) of nickel, lead, cobalt, cadmium and chromium in muscle and edible offal (intestine and liver) from slaughterhouses in FCT, Abuja, Nigeria.

This was calculated as shown in Eq. 2. [46-48]:

$$\text{EDI} = \frac{C \times IR}{BW} \tag{2}$$

where C is mean concentration (mg/kg) of heavy metals in muscle, intestine and liver of cow samples, IR is the daily ingestion rate (mg/day) of the meat parts, and BW is body weight (kg) of adult men, adult women, adolescent and children. There is no available data on daily consumption/ingestion rate of cow muscle and edible offal by Nigerians in food consumption database by international organization such as Food and Agricultural Organization of the United Nations (FAO) and World Health Organization (WHO), but, Ihedioha *et al.* (2014) [40] determined daily ingestion rate of cow muscle and edible offal by Nigeria adult men and women, adolescent and children. This was used to estimate the daily intake of the metals in the cow meat parts. Daily ingestion rates of cow muscle by adult men, adult women, adolescent and children are 25.54 g/day, 22.96 g/day, 26.27 g/day and 19.13 g/day respectively, while, ingestion rates of cow liver are 17.31 g/day, 21.47 g/day, 22.01 g/day, and 22.31 g/day respectively, and ingestion rates of cow intestine are 32.58 g/day, 23.50 g/day, 25.89 g/day and 21.67 g/day respectively. The ingestion rates were converted to mg/day to keep the unit consistent. Body weight of Nigeria adult men, adult women, adolescent and children, are 70, 63, 65 and 35 kg respectively [40].

Non–carcinogenic Risk Assessment

Hazard quotient is used to determine non-cancer risks due to exposure to a single pollutant or toxicant, while, hazard index evaluates non-cancer risks due to exposure of person(s) to more than one pollutant or toxicant that affect the same target organ or system and, or exposure of person(s) to same toxicant or pollutant via different exposure route [43, 45]. To obtain hazard quotient, the estimated daily intake of a chemical toxicant is compared to an acceptable level of exposure of the chemical toxicant. The expression used to calculate hazard quotient (HQ) is Eq. 3 [46, 48]:

$$HQ = \frac{EDI}{RfD} \quad (3)$$

Where RfD is oral reference dose (mg/kg/day). Oral reference dose is defined as the highest level at which no adverse health effects are expected on human population through daily exposure to a chemical toxicant. Value of HQ < 1 indicates that there is no significant health related illness envisaged from a toxicant, while HQ > 1 implies that possibility of non-carcinogenic health issues is likely. Hazard index (HI) is estimated from Eq. 4 [47, 49]:

$$HI = \Sigma HQ \quad (4)$$

HI < 1 implies non probability of chronic non-carcinogenic health issues or adverse risk and HI > 1 indicates possibility of chronic risk or adverse non-carcinogenic health effects [43-45].

Nickel, lead, cobalt, cadmium and chromium affect the same target organ (kidney and central nervous system); hence their HQ were summed up to derive HI.

Carcinogenic risks Assessment

The possibility of developing cancer by person(s) exposed from lifetime to carcinogenic heavy metals nickel, cadmium and chromium in cow muscle and edible offal samples from the study area was computed using incremental lifetime cancer risk (ILCR) Eq. 5 [46, 50]:

$$ILCR = CDI \times CSF \tag{5}$$

Where CDI is chronic daily intake of chemical carcinogen (mg/kg bw/day) calculated with Eq. (6) and CSF is the cancer slope factor.

$$CDI = \frac{EDI \times EF \times ED}{AT} \tag{6}$$

Where, EDI is the estimated daily intake (mg/kg bw/day), EF is the exposure frequency (days/year and 365 days/year), ED is the exposure duration (years) (in this study, exposure duration is 25 years for adult men and women, 16 years for adolescent, and 6 years for children), AT is the averaging time (days). AT is the period over which exposure is averaged, it is calculated as exposure frequency (days/years) multiplied by exposure duration (years). AT is of two types, namely, for carcinogens and non-carcinogens. For carcinogens AT is based on a lifetime exposure. The life expectancy of Nigerians is 53 years [51]. In this study, AT is 19345 (365 days/year multiplied by 53 years). ILCR between 1×10^{-6} and 1×10^{-4} is acceptable by United States Environment Protection Agency (EPA) [43].

Results and discussion

Table 1 shows the result of percentage recovery of Ni, Pb, Co, Cd and Cr in muscle of cow sample. The percentage recovery ranged from 83 to 101%.

Table 1. Percentage Recovery of Ni, Pb, Co, Cd and Cr from cow muscle.

Heavy metals	Added concentration (mg/L)	Concentration of spiked sample (mg/L)	Concentration of unspiked sample (mg/L)	% recovery
Nickel	3.00	2.917	0.042	96
Lead	0.50	0.446	0.030	83
Cobalt	2.00	2.115	0.098	101
Cadmium	2.00	2.013	0.002	101
Chromium	1.00	1.001	0.097	90

The mean concentrations (mg/kg, fresh weight) and range of Ni, Pb, Co, Cd and Cr in samples of muscle, intestine and liver of cattle from Deidei, Gwagwalada, Karu and Kubwa slaughterhouses in FCT, Abuja, Nigeria are presented in Table 2. Nickel in muscle, intestine and liver of cattle samples ranged from -0.63 ±0.005 to 0.614 ±0.004 mg/kg fresh weight, from 0.007 ±0.005 to 0.414 ±0.030 mg/kg fresh weight, and from -0.070 ±0.008 to 0.509 ±0.009 mg/kg fresh weight, respectively. Lead, cobalt, cadmium and chromium in the meat parts ranged as follows: from 0.01 ±0.072 to 0.34 ±0.006 mg/kg fresh weight (muscle), from 0.02 ±0.043 to 0.68 ±0.009 mg/kg fresh weight (intestine), from 0.010 ±0.007 to 0.280 ±0.004 mg/kg fresh weight (liver) for lead; from -0.225 ±0.003 to 0.673 ±0.008 mg/kg fresh weight (muscle), from -0.583 ±0.002 to 2.845 ±0.005 mg/kg fresh weight (intestine), and from -0.650 ±0.008 to 0.699 ±0.008 mg/kg fresh weight (liver) for cobalt; from 0.021 ±0.007 to 0.092 ±0.064 mg/kg fresh weight (muscle), from 0.018 ±0.004 to 0.239 ±0.042 mg/kg fresh weight (intestine), and from 0.018 ±0.002 to 0.120 ±0.061 mg/kg fresh weight (liver) for cadmium; from 0.545 ±0.005 to 0.789 ±0.006 mg/kg fresh weight (muscle), from 0.497 ±0.072 to 0.799 ±0.021 mg/kg fresh weight (intestine), and from 0.509 ±0.004 to 0.772 ±0.087 mg/kg fresh weight (liver) for chromium. Mean concentration of nickel in muscle is 0.194 ±0.158 mg/kg fresh weight, in intestine it is 0.167 ±0.125 mg/kg fresh weight and 0.169 ±0.139 mg/kg fresh weight in liver. The result shows that the highest concentration of Ni is in cow muscle. The order of concentration of Ni in the cow meat parts is: muscle > liver > intestine. Similar trend was observed in some previous studies, these studies showed that the concentration of Ni is higher in muscle than liver [40, 41, 52]. When ingested into humans and animals, the cell lining the small intestine absorb small quantity of ingested nickel [53]; the absorbed nickel is transported to other parts (tissue and organs), and accumulates majorly in the kidney [53, 54], but less in the liver [54]. The mean concentrations of Ni in all the meat parts were below the maximum limit of 0.5 mg/kg nickel in meat and meat products set by Russia [55]; Food and Agricultural Organization (FAO) of the United Nations and World Health Organization (WHO) does not have maximum limit for nickel in meat and meat products. Low levels of Ni in liver and kidney (from 0.04 to 0.3 mg/kg) of cattle from Southern Nigeria [56], and in muscle, kidney, liver, intestine and tripe, (from 0.25 to 0.36 µg/g fresh weight) of cow consumed in an Urban Nigeria [40] was reported. Nickel is used in the industries to manufacture electrical appliances, coins, jewelry, alloys, as a component of stainless steel it is used to manufacture household utensils, it finds application in pigment, food processing and metallurgical industries, etc. [37]. Nigeria is not an industrialized nation, however, it has very few industries which include food processing and metallurgical industries. Release of nickel from industrial sources may be low because of few industries in the country. Release of nickel into the environment in Nigeria from other sources may be due to indiscriminate disposal of nickel containing waste (e.g., electronic waste) and combustion of fossil fuel (vehicular emission). The levels of nickel in the meat parts below recommended maximum limit suggest that they are not polluted with nickel and that the cows may have grazed on grasses, drank water and were exposed to air with low levels of nickel. Mean concentration of Pb in cow muscle is 0.101 ±0.084 mg/kg fresh weight, it is 0.127 ±0.134 mg/kg fresh weight in intestine and 0.118 ±0.09 mg/kg fresh weight in liver. The trend of concentration of Pb in the meat parts is: intestine > liver > muscle. Similar trend was observed in cow meat parts in some studies [52, 57], in these studies, the trend was kidney > liver > muscle (0.052 ±0.002 mg/kg in kidney, 0.036 ±0.018 mg/kg in liver and 0.013 ±0.010 mg/kg in muscle), and kidney > liver > muscle (109.42 µg/kg in kidney, 42.70 µg/kg in liver and 8.77 µg/kg in muscle) respectively. These studies and the present study showed that Pb accumulates in liver than muscle of cow**.** Maximum level of Pb permitted in cattle muscle and edible offal is 0.2 mg/kg [58], none of the concentrations of Pb in the meat parts exceeded the recommended maximum level of Pb in muscle and edible offal, meaning that the meat parts are not polluted with Pb, suggesting that the cows were exposed to low levels of Pb. The level of Pb in muscle and edible offal (from 0.013 ±0.010 to 0.052 ±0.002 mg/kg) of cow obtained from Benin City, Nigeria, from a previous studies, and (from 0.01 to 0.26 mg/kg) of Pb in meat parts from southern Nigeria were below FAO/WHO stipulated maximum level (57; 56), except in liver from Sapele, Nigeria (0.26 mg/kg) which was slightly above the maximum level, but, high levels of Pb was found in meat parts from Kaduna, Nigeria (41). Sources of Pb in the environment include smelting of Pb, battery manufacture and recycling, use of Pb in car repair, Pb based paints and pigments etc. [59]. In Nigeria, automobile mechanic makes up a large proportion of the informal sector; their activities include car body work (which involves panel beating and metal cutting), car spray painting (which uses paint), battery charging etc. The activities of the automobile mechanics release lead in the environment [60], other sources of lead in the environment in Nigeria are battery recycling activities, lead and gold mining activities and indiscriminate disposal of waste battery and other lead containing waste. Mean concentration of Cobalt in cow muscle, intestine and liver samples are: 0.256 ±0.255 mg/

kg fresh weight in muscle, 0.179 ±0.584 mg/kg fresh weight in intestine and 0.096 ±0.237 mg/kg fresh weight in liver. The trend of concentration of Co in muscle and edible offal of cow samples is muscle > intestine > liver, however, the work of Ogbomida *et al.* (2018) [57] showed a contrary trend of cobalt concentration in cow meat parts: liver > kidney > muscle. There is no maximum level for cobalt, but minimal risk level (MRL) [61], MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure [61]. The MRL oral exposure for cobalt is 0.03 mg/kg/day [61], Mean concentrations of Co in cow muscle, intestine and liver are higher than the recommended MRL oral exposure for Co. These concentrations indicates that the cow meat parts are polluted with Co and that the cows may have grazed on grasses, and or drank water and or were exposed to air with high levels of Co. Sources of Co include both natural and anthropogenic activities. Co is a natural component of soil, rock and air, and can be leached from soil and rock by rainwater and surface runoff into water bodies [62]. Anthropogenic activities such as mining and ore smelting activities releases Co from ore deposits and phosphate rocks into the environment [62]. Cobalt is among the heavy metals released into the environment during gold mining, High Co concentration ranging from 0.275 ±0.053 to 2.200 ±0.011 µg/g (mg/kg) in liver and muscle of goat, sheep and cattle reared in the gold-mining areas of Zamfara state in Nigeria was reported [29]. Significant levels of cobalt in soil, vegetables and livestock around some gold mine areas in Zamfara state, Nigeria was also reported [28]. Zamfara state is one of the states from which cattle is brought into FCT slaughterhouses. Other sources of cobalt include, airport and highway traffic, coal fired power plants, colored glass and ceramics and cobalt containing alloys [62]. In Nigeria, mining and ore smelting activities are among non-oil sector economic activities of the country and may have contributed to release and pollution of the environment with Co in addition to indiscriminate disposal of colored glass and ceramics and Co containing alloy substances and gold mining. FCT, Abuja being the capital city of Nigeria experience highway and airport traffic due to the population density and landing of local and international aircrafts, these too may have added Co to the environment. Co can cause neurological problem such as hearing and visual impairment, endocrine and cardiovascular health effects [63]. Mean concentrations of Cd in the meat parts samples are 0.040 ±0.0153 mg/kg fresh weight (muscle), 0.0475 ±0.041 mg/kg fresh weight (intestine) and 0.0417 ±0.0226 mg/kg fresh weight (liver). This result shows that the trend of the concentration of Cd in the cow meat parts is: intestine > liver > muscle. This result compares well with the result from previous studies which showed the trend, kidney > liver > muscle (0.890 ±1.035 mg/kg in kidney, 0.044 ±0.013 mg/kg in liver and 0.001 ±0.000 mg/kg in muscle) [57], and kidney > liver > muscle (62.56 µg/kg in kidney, 14.16 µg/kg in liver and 1.40 µg/kg in muscle) [52]. This suggest that, may be Cd concentrates more in the liver of cow than in the muscle. According to Agency for Toxic Substances and Disease Registry [64], Cd concentration is highest in the kidney and liver. The maximum level of Cd in muscle and liver of cattle are 0.050 m/kg wet weight and 0.50 mg/kg wet weight respectively [65]. The levels of Cd in muscle and liver of the cow meat parts samples are lower compared to the approved maximum level of Cd in muscle and liver, also, the level of Cd in intestine is lower compared to recommended maximum level of Cd in both muscle and liver. This indicates that the meat parts are not polluted with Cd. Usman *et al.* (2022) [41] reported 0.05 μg/g (mg/kg) and 0.31 μg/g (mg/kg) of Cd in muscle and liver respectively and 0.16 μg/g (mg/kg) and 0.22 μg/g (mg/kg) of Cd in tripe and intestine of cow from Kaduna State, Nigeria. These levels of Cd in the meat parts are within the recommended maximum level of Cd in muscle and liver of cattle. Also, Cd levels in the work of Ogbomidia *et al.* (2018) [57] showed low level of cadmium in muscle (0.001 ±0.000mg/kg) and liver (0.044± 0.013 mg/kg) of cows from Benin, Nigeria. Cd can be released into the environment from mining and smelting, burning of fossil fuels, burning of plastics and nickel cadmium batteries [66], recycling of cadmium-containing steel scrap and electronic waste. The mean concentrations of Cr in cow muscle, intestine and liver samples are: 0.690 ±0.0570 mg/kg in fresh weight in muscle, 0.698 ±0.0680 mg/kg in fresh weight in intestine, and 0.687 ±0.062 mg/kg in fresh weight in liver; i.e. intestine > muscle > liver. Ogbomida *et al.* (2018) [57] reported more concentration of Cr in muscle (0.261 ± 0.216 mg/kg) of cattle than in liver (0.064 ±0.014 mg/kg) of cattle, as reported in the present study. Food and Agricultural Organization of the United Nations, World Health Organization and other international regulatory bodies have not recommended standards for Cr in meat and meat products in food, however, China set maximum limit of 1.0 mg/kg of Cr in meat and meat products [67]. The mean concentrations of Cr in the different meat parts are less than the recommended 1.0 mg/kg in meat and meat parts by China, this implies that the muscle and edible offal of the cattle samples are not polluted with Cr.

Table 2. Mean concentrations (mg/kg, fresh weight) of Ni, Pb, Co, Cd and Cr in muscle and edible offal of cattle from slaughterhouses in Federal Capital Territory (FCT), Abuja, Nigeria.

Cow meat parts	Statistics	Nickel	Lead	Cobalt	Cadmium	Chromium
Muscle	Min	-0.63	0.01	-0.225	0.021	0.545
	Max	0.614	0.34	0.673	0.092	0.789
	Median	0.157	0.08	0.284	0.039	0.696
	Range	0.677	0.33	0.898	0.071	0.244
	Mean ±SD	0.194 ±0.158	0.101 ±0.084	0.256 ±0.255	0.040 ±0.015	0.690 ±0.057

(*Continued*)

Table 2. *Continuation.*

Cow meat parts	Statistics	Nickel	Lead	Cobalt	Cadmium	Chromium
Intestine	Min	0.007	0.02	-0.583	0.018	0.497
	Max	0.414	0.680	2.845	0.239	0.799
	Median	0.119	0.08	0.172	0.039	0.709
	Range	0.407	0.66	3.428	0.221	0.302
	Mean ±SD	0.167 ±0.125	0.127 ±0.134	0.179 ±0.584	0.048 ±0.041	0.698 ±0.068
Liver	Min	-0.070	0.010	-0.650	0.018	0.509
	Max	0.509	0.280	0.699	0.120	0.772
	Median	0.144	0.09	0.106	0.034	0.705
	Range	0.579	0.27	1.349	0.102	0.263
	Mean ±SD	0.169 ±0.139	0.118 ±0.090	0.096 ±0.0237	0.042 ±0.023	0.687 ±0.062

The ingestion rate of muscle, intestine and liver, and the result of estimated daily intake (EDI, mg/kg bw/day) of Ni, Pb, Co, Cd and Cr in muscle, liver and intestine of cow meat samples are presented in Tables 3 and 4 respectively. The EDI of nickel in the meat parts was: i) for adult men: 7.00×10^{-5} mg/kg bw/day (muscle), 7.70×10^{-5} mg/kg bw/day (intestine) and 4.10×10^{-5} mg/kg bw/day (liver), ii) for adult women, it was 7.00×10^{-5} mg/kg bw/day (muscle), 6.20×10^{-5} mg/kg bw/day (intestine) and 5.70×10^{-5} mg/kg bw/day (liver), iii) for adolescent, it was, 7.80×10^{-5} mg/kg bw/day (muscle), 6.60×10^{-5} mg/kg bw/day (intestine) and 5.70×10^{-5} mg/kg bw/day (liver), and iv) for children, it was, 1.05×10^{-4} mg/kg bw/day (muscle), 1.03×10^{-4} mg/kg bw/day (intestine) and 1.07×10^{-5} mg/kg bw/day (liver). The tolerable daily intake (TDI) derived for nickel in food is 3 μg/kg bw/day [68], which is equivalent to 0.013 mg/kg bw/day. According to European Food Safety Authority (EFSA), TDI is an estimate of the amount of a substance in food or drinking water which is not added deliberately (e.g. contaminants) and which can be consumed over a lifetime without presenting an appreciable risk to health. EDI values of nickel in the meat parts obtained in this study for different groups (adult men and women, adolescent and children) are lower than the TDI set by EFSA. This indicates no risk to health over lifetime from consumption of the level of Ni in the meat parts. EDI of the other heavy metals in muscle and edible offal of the cow samples ranged from 2.90×10^{-5} to 7.80×10^{-5} mg/kg bw/day of Pb in muscle, intestine and liver for all the groups (adult men and women, adolescent and children). For Co, it ranged from 2.30×10^{-5} to 1.39×10^{-4} mg/kg bw/day of Co in muscle, intestine and liver for all the groups, while, for Cd, it ranged from 1.03×10^{-5} to 2.90×10^{-5} mg/kg bw/day of Cd in the meat parts for all the groups. For Cr, it ranged from 2.16×10^{-4} to 4.37×10^{-4} mg/kg bw/day of Cr in muscle and edible offal for all the groups. There is no stipulated tolerable or acceptable daily intake for cobalt in muscle and edible offal or food substances by Food and Agricultural Organization of the United Nations (FAO), World Health Organization (WHO) and United States Protection Agency (USEPA) etc., However, French Food Safety Agency (Agence Francaise De Securite Sanitaire Des Aliments) set tolerable daily intake of cobalt in food between 1.6 and 8 μg/kg bw/day [69], equivalent to 0.0016 and 0.008 mg/kg bw/day. From the result of the study, EDI of cobalt in the muscle and edible offal of the cow samples are lower than the TDI of cobalt set by AFSSA. This suggest that there may be no risk to health over lifetime from consumption of the level of Co in the meat parts. FAO/WHO does not have TDI for lead but provisional tolerable weekly intake (PTWI) which is 0.025 mg/kg bw [70], conversion of this value to daily basis gives 0.0036 mg/kg bw, The EDI of Pb in the meat parts is lower than 0.0036 mg/kg bw, which implies that ingestion of the concentrations of Pb in the meat parts may not pose risk to health over lifetime from consumption of the meat parts. Acceptable daily intake (ADI) or TDI is not provided by relevant regulatory authorities for cadmium, however, Provisional Tolerable Monthly Intake (PTMI) of cadmium is 25 mg/kg/month [71], by converting the PTMI to daily intake, using 30 days in a month, gives the Provisional Tolerable Daily Intake (PTDI) 0.83 mg/kg/day [72], which when converted to mg/kg/day gives 0.00083 mg/kg/day. EDI of cadmium in muscle, intestine and liver of the cows by the groups are less than 0.00083 mg/kg/day. This suggests that there may be no risk to health to adult men and women, adolescent and children, due to consumption of the level of cadmium in the cow meat parts. There are no intake values for chromium (VI). The intake value available for chromium III is adequate intake (AI) [73]. Adequate Intake is the intake assumed to ensure nutritional adequacy; established when evidence is insufficient to develop a recommended dietary allowance (RDA) [73]. Adequate intake for children between the ages of 4 to 8 is 15 μg (male and female) (0.015 mg), 9 to 13 years are 25 μg (male) (0.025 mg) and 21 μg (female) (0.021 mg), 14 to 18 years are 35 μg (male) (0.035 mg) and 24 μg (female) (0.024 mg), 19 to 50 years 35 μg (male) (0.035 mg) and 25 μg (female) (0.025 mg), and 51 years and above 30 μg (male) (0.03 mg) and 20 μg (female) (0.02 mg) (73). The estimated daily intake of chromium in muscle, intestine and liver of the cow samples (from 2.16×10^{-4} to 4.37×10^{-4} mg/kg bw/day) by adult men and women, adolescent and children residing in FCT, Abuja, Nigeria, are lower than the recommended adequate intakes, indicating that health risk is unlikely to happen over lifetime from consumption of the level of Cr in the cow meat parts.

Table 3. Ingestion rate of Cow Muscle, Liver and Intestine in Nigeria

Group	Age (years)	Body weight (kg)	Daily meat consumption (g/day)		
			Muscle	Liver	Intestine
Adult men	25 – 55	70 ±10.4	25.54 ±2.20	17.31 ±2.86	32.58 ±6.10
Adult women	25 – 55	63 ±10.8	22.96 ±2.44	21.47 ±3.38	23.50 ±3.03
Adolescent	16 – 25	65 ±10.8	26.27 ±2.93	22.01 ±4.46	25.89 ±5.78
Children	6 – 15	35 ±5.9	19.13 ±1.83	22.31 ±3.76	21.67 ±4.16

Table 4. Estimated daily intake (mg/kg bw/day) of muscle and edible offal consumed by adult men, adult women, adolescent and children in FCT, Abuja, Nigeria.

Group	Cow meat part	Nickel	Lead	Cobalt	Cadmium	Chromium
Adult men	Muscle	7.00×10^{-5}	3.60×10^{-5}	9.30×10^{-5}	1.40×10^{-5}	2.51×10^{-4}
	Intestine	7.70×10^{-5}	5.90×10^{-5}	8.30×10^{-5}	2.20×10^{-5}	3.24×10^{-4}
	Liver	4.10×10^{-5}	2.90×10^{-5}	2.30×10^{-5}	1.03×10^{-5}	2.10×10^{-4}
Adult women	Muscle	7.00×10^{-5}	3.60×10^{-5}	9.30×10^{-5}	1.40×10^{-5}	2.51×10^{-4}
	Intestine	6.20×10^{-5}	4.70×10^{-5}	6.60×10^{-5}	1.76×10^{-5}	2.60×10^{-4}
	Liver	5.70×10^{-5}	4.00×10^{-5}	3.30×10^{-5}	1.42×10^{-5}	2.33×10^{-4}
Adolescent	Muscle	7.80×10^{-5}	4.00×10^{-5}	1.03×10^{-4}	1.60×10^{-5}	2.78×10^{-4}
	Intestine	6.60×10^{-5}	5.00×10^{-5}	7.10×10^{-5}	1.87×10^{-5}	2.78×10^{-4}
	Liver	5.70×10^{-5}	3.90×10^{-5}	3.20×10^{-5}	1.41×10^{-5}	2.32×10^{-4}
Children	Muscle	1.05×10^{-4}	5.50×10^{-5}	1.39×10^{-4}	2.17×10^{-5}	3.76×10^{-4}
	Intestine	1.03×10^{-4}	7.80×10^{-5}	1.10×10^{-4}	2.90×10^{-5}	2.32×10^{-4}
	Liver	1.07×10^{-4}	7.50×10^{-5}	6.10×10^{-5}	2.65×10^{-5}	4.37×10^{-4}

Table 5 shows the hazard quotient (HQ) and hazard index (HI) of nickel in the meat parts. Hazard quotient of nickel for adult men is 3.50×10^{-3} (muscle), 3.85×10^{-3} (intestine) and 2.05×10^{-3} (liver), for adult women it is, 3.50×10^{-3} (muscle), 3.10×10^{-3} (intestine) and 2.85×10^{-3} (liver), while for adolescent it is, 3.90×10^{-3} (muscle), 3.30×10^{-3} (intestine) and 2.85×10^{-3} (liver), and for children it is, 5.25×10^{-3} (muscle), 5.15×10^{-3} (intestine) and 5.35×10^{-3} (liver). HQs of nickel in the meat parts are less than 1. This suggest that the level of nickel in the meat parts do not pose potential health risk to its consumers. HQ of lead, cobalt, cadmium and chromium in muscle, intestine and liver of the cow meat parts consumed by all the groups range as follows: from 1.45×10^{-2} to 3.90×10^{-2} for lead, from 7.66×10^{-2} to 4.63×10^{-1} for cobalt, from 3.40×10^{-3} to 9.60×10^{-3} for cadmium, and 7.00×10^{-2} to 1.45×10^{-1} for chromium. Values of the HQs are less than 1, implying non likelihood of potential health risks to the groups due to consumption of the metals in the meat parts. Likewise, hazard index (HI) values of all the metals in muscle, intestine and liver consumed by the different groups are less than 1 (1.66×10^{-1} to 6.20×10^{-1}). This suggest that chronic non-cancer health risk is not likely to happen.

The result of incremental lifetime cancer risk (ILCR) is presented in Table 6. The range of the ILCR values of the carcinogenic metals (nickel, lead, cadmium and chromium) in the meat parts, for all the groups are as follows: from 1.07×10^{-7} to 3.23×10^{-5} for nickel, from 9.15×10^{-7} to 3.87×10^{-6} for cadmium, from 1.28×10^{-5} to 7.50×10^{-5} for chromium, and from 6.2×10^{-6} to 2.78×10^{-5} for lead. These values are below and within the recommended cancer risk values, namely from 1×10^{-6} to 1×10^{-4}, stipulated by United States Environmental Protection Agency [43]. This suggest that the possibility of adult men and women, adolescent and children who consume the carcinogenic metals in muscle, intestine and liver of cows' from FCT, Abuja, Nigeria, developing cancer is low.

Table 5. Hazard quotient and Hazard index of lead, cobalt, cadmium and chromium in muscle and edible offal consumed by adult men, adult women, adolescent and children in FCT, Abuja, Nigeria

Group	Cow meat parts	Nickel	Lead	Cobalt	Cadmium	Chromium	ΣHI
Adult men	Muscle	3.50×10^{-3}	1.80×10^{-2}	3.10×10^{-1}	4.60×10^{-3}	8.30×10^{-2}	4.19×10^{-1}
	Intestine	3.85×10^{-3}	2.95×10^{-2}	2.70×10^{-1}	7.30×10^{-3}	1.08×10^{-1}	4.24×10^{-1}
	Liver	2.05×10^{-3}	1.45×10^{-2}	7.66×10^{-2}	3.40×10^{-3}	7.00×10^{-2}	1.66×10^{-1}
Adult women	Muscle	3.50×10^{-3}	1.80×10^{-2}	3.10×10^{-1}	4.60×10^{-3}	8.36×10^{-2}	4.19×10^{-1}
	Intestine	3.10×10^{-3}	2.35×10^{-2}	2.20×10^{-1}	5.80×10^{-3}	8.60×10^{-2}	3.38×10^{-1}
	Liver	2.85×10^{-3}	2.00×10^{-2}	1.10×10^{-1}	4.70×10^{-3}	7.70×10^{-2}	2.15×10^{-1}
Adolescent	Muscle	3.90×10^{-3}	2.00×10^{-2}	3.43×10^{-1}	5.30×10^{-3}	9.26×10^{-2}	4.64×10^{-1}
	Intestine	3.30×10^{-3}	2.50×10^{-2}	2.36×10^{-1}	6.10×10^{-3}	9.26×10^{-2}	3.63×10^{-1}
	Liver	2.85×10^{-3}	1.95×10^{-2}	1.06×10^{-1}	4.70×10^{-3}	7.70×10^{-2}	2.10×10^{-1}
Children	Muscle	5.25×10^{-3}	2.75×10^{-2}	4.63×10^{-1}	7.20×10^{-3}	1.25×10^{-1}	6.20×10^{-1}
	Intestine	5.15×10^{-3}	3.90×10^{-2}	3.66×10^{-1}	9.60×10^{-3}	7.73×10^{-2}	4.97×10^{-1}
	Liver	5.35×10^{-3}	3.75×10^{-2}	2.03×10^{-1}	8.80×10^{-3}	1.45×10^{-1}	3.99×10^{-1}

RfD: Ni = 0.02 mg/kg/day (USEPA), Pd = 0.002 mg/kg/day (USEPA), Co = 0.0003 mg/kg/day (USEPA), Cd = 0.003 mg/kg/day (USEPA), Cr = 0.003 mg/kg/day (USEPA)

Table 6. Incremental Lifetime Cancer Risk of nickel, cobalt, cadmium and chromium in muscle and edible offal consumed by adult men, adult women, adolescent and children in Abuja, Nigeria.

Group	Cow meat parts	Nickel	Cadmium	Chromium	Lead
Adult men	Muscle	2.94×10^{-5}	2.46×10^{-6}	5.81×10^{-5}	1.69×10^{-5}
	Intestine	3.23×10^{-5}	3.87×10^{-6}	7.50×10^{-5}	2.78×10^{-5}
	Liver	1.71×10^{-5}	1.81×10^{-6}	4.86×10^{-5}	1.36×10^{-5}

(*Continued*)

Table 6. *Continuation.*

Group	Cow meat parts	Nickel	Cadmium	Chromium	Lead
Adult women	Muscle	3.09×10^{-5}	2.46×10^{-6}	5.81×10^{-5}	1.69×10^{-5}
	Intestine	2.61×10^{-5}	3.09×10^{-6}	6.01×10^{-5}	2.22×10^{-5}
	Liver	2.39×10^{-5}	2.49×10^{-6}	5.39×10^{-5}	1.88×10^{-5}
Adolescent	Muscle	2.10×10^{-5}	1.80×10^{-6}	4.11×10^{-5}	1.21×10^{-5}
	Intestine	1.61×10^{-5}	2.10×10^{-6}	4.11×10^{-5}	1.53×10^{-5}
	Liver	1.52×10^{-5}	1.58×10^{-6}	3.43×10^{-5}	1.11×10^{-5}
Children	Muscle	1.05×10^{-5}	9.16×10^{-7}	2.08×10^{-5}	6.2×10^{-6}
	Intestine	1.03×10^{-5}	1.22×10^{-6}	1.28×10^{-5}	8.8×10^{-6}
	Liver	1.07×10^{-7}	1.11×10^{-6}	2.42×10^{-5}	8.9×10^{-6}

CSF: Ni = 0.91 mg/kg/day (EPD, Georgia), 2020), Cd = 0.38 mg/kg/day (USDOE), Cr = 0.5 mg/kg/day (USDOE), Pb = 0.0083 mg/kg/day.

Conclusion

Cow muscle, intestine and liver from slaughter houses in FCT, Abuja, Nigeria are not polluted with nickel, lead, cobalt, cadmium and chromium. Human population viz adult men and women, adolescent and children are at low risk of developing potential non-cancer health related issues, chronic non-cancer health related issues, and cancer due to consumption of nickel, lead, cobalt, cadmium and chromium in cow muscle, intestine and liver from at slaughter houses within FCT, Abuja, Nigeria.

Conflict of interest

All authors report that they do not have any conflicts of interest.

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