Research Article

Human Exposure to Arsenic and Toxic Metals Through Meat Consumption in Africa: A Review of the Scientific Literature

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While meat consumption is decreasing in high-income countries, significant increases are observed elsewhere. Although this includes African nations, average meat consumption is generally lower in Africa than in other continents. Meat provides essential nutrients, but inadequate consumption can lead to health problems, with exposure to environmental contaminants being a concern. This review focuses on recent scientific literature regarding human exposure to toxic metals/metalloids through meat consumption in Africa, particularly non-essential elements like As, Cd, Hg, and Pb, as well as Cr(VI) and Ni. PubMed and Scopus databases indicate limited information on this topic in Africa, primarily from Nigeria. Concentrations of toxic metals/metalloids in meat, and estimated intakes, vary significantly. Similar to organic and inorganic pollutants in other continents, meat is not the primary contributor to human dietary exposure to toxic trace elements in African countries.

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Introduction

Meat consumption has increased remarkably since the 20th century[1]. However, this global increase varies across continents[2]. In high-income countries like those in the European Union, the USA, and Canada, meat consumption is decreasing. Conversely, many countries worldwide are experiencing significant increases[3]. China, accounting for 27% of global consumption, is the largest meat consumer, although its per capita consumption lags behind that of Western countries[4][5].

Regular meat consumption offers advantages and disadvantages[6][7]. Benefits include high nutritional value, with meat being a complete source of proteins, B-vitamins, and essential trace elements (Fe, Co, P, Se, and Zn), along with saturated and unsaturated fats. However, regular consumption of large amounts of certain meats can pose health risks. The high saturated fat content of red and processed meats is linked to increased risks of heart disease, stroke, and diabetes[8][9][10][11]. In 2015, the IARC classified red and processed meat consumption as "probably carcinogenic to humans" and "carcinogenic to humans," respectively, increasing the risk of cancers, especially colorectal cancer[12][13][14][15][16]. Furthermore, antibiotic resistance is a potential risk due to antibiotic overuse in livestock[17][18].

Like other food groups, meat consumption can result in exposure to environmental pollutants. Regarding metals/metalloids, toxic elements such as arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg), as well as chromium-VI (CrVI) and nickel (Ni), are frequently detected in food alongside essential trace elements. However, based on previous reviews, meat is generally not the primary source of environmental inorganic and organic contaminants[19][7][20]. Fish and seafood typically contribute the most to human dietary exposure to toxic trace elements[21][22][23].

Organizations like WHO/FAO, US EPA, and EFSA have established recommended intakes for trace elements. However, rigorous control of toxic element levels is lacking in many countries, including those where meat consumption is increasing. A recent review examined toxic trace element levels (As, Cd, Hg, and Pb) and potentially carcinogenic metals (Cr(VI) and Ni) in meat in Asian countries, along with exposure through meat consumption[24]. Levels varied significantly, and meat was not the primary contributor to dietary exposure.

Meat consumption in Africa varies widely due to cultural, economic, and environmental factors. Overall, consumption is lower than in other regions, but demand is growing, with access and preferences varying based on local resources and economic conditions[3][25][26][27][28]. Contamination of meat by pollutants, particularly toxic metals/metalloids, is a growing concern due to the presence of elements like As, Cd, Hg, and Pb in animals[29][30][31]. Sources of contamination include mining, urban waste, industrial activities, agricultural practices, contaminated water, and contaminated feed[32][33][34][35]. Considering the current interest in this topic, this review examines scientific studies on human exposure to toxic trace elements through meat consumption in African countries. The search strategy is detailed below.

Search strategy

PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) and Scopus (https://www.scopus.com) databases were used to search for information (only articles published in English were considered). Search terms included: 'meat and meat products', 'dietary exposure', 'human intake', 'metals', 'metalloids', 'human health risks', and 'Africa'. The search period was from January 1, 2000, to December 31, 2024. Information from the reviewed studies is summarized below by country, in chronological order.

Concentrations of toxic trace elements in African countries

Nigeria

Nigeria has the most data available regarding toxic metal/metalloid levels in meat. While most studies focused on Cd and Pb, data for other elements were also found. Ihedioha and Okoye[36] measured Cd and Pb concentrations in muscle and edible offal (kidney, intestine, and tripe) of cows in Enugu State. Mean Cd levels ranged from 0.24 to 0.44 μg/g, detected in 43% of muscle samples and varying percentages of offal samples (100% of kidney, 95% of liver, 70% of intestine, and 50% of tripe). Mean Pb levels ranged from 0.09 to 0.26 μg/g, detected in 70% of muscle and 100% of offal samples. Cd concentrations were relatively high, while Pb concentrations were moderate.

In a subsequent study, Ihedioha and Okoye[37] assessed Cd and Pb exposure through consumption of cow tissues by the Enugu State population. Mean Cd levels were 0.35±0.27, 0.44±0.27, 0.24±0.26, 0.29±0.33, and 0.41±0.33 µg/g (dry weight, dw) for muscle, kidney, liver, intestine, and tripe, respectively. Cd intakes for adult men were 0.23, 0.45, 0.15, 0.55, and 0.50 µg/kg body weight (bw)/week, respectively. Mean Pb concentrations were 0.09±0.16, 0.13±0.07, 0.26±0.25, 0.17±0.12, and 0.17±0.16 µg/g dw for muscle, kidney, liver, intestine, and tripe, respectively, with intakes of 0.89, 0.42, 0.50, 0.94, and 1.21 µg/kg bw/week for adult men. Target hazard quotients (THQ) ranged from 0.42 to 0.90 for Cd and 0.05 to 0.10 for Pb, all < 1, indicating no significant health risks for consumers in that region. Olusola et al.[38] analyzed frozen chicken (thighs and wings) from markets in Lagos and Ibadan for Cd and Pb content. Mean concentrations were 0.0065 and 0.0078 µg/dL for Cd, and 0.0207 and 0.0227 µg/dL for Pb, for Lagos and Ibadan, respectively, within maximum residue levels. There were minimal differences between thigh and wing samples. Adetunji et al.[39] measured Cd and Pb concentrations in cattle samples (muscles, liver, and kidney) from Ogun State. Mean Cd concentrations in muscle, liver, and kidney were 0.156, 0.172, and 0.197

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μg/g, respectively. Mean Pb levels were 0.721, 0.809, and 0.908 μg/g, respectively. Cd concentrations were within Nigerian standards, while Pb levels exceeded standards in all tissues.

Ihedioha et al. (2014) also assessed health risks from Zn, Cr, and Ni derived from cow meat consumption, having previously measured Cd and Pb concentrations. Minimum and maximum mean levels (μg/g fresh weight, fw) were: 91.10 (intestine) and 132.33 (liver) for Zn; 1.24 (muscle) and 4.28 (liver) for Cr, and 0.20 (liver) and 0.36 (kidney) for Ni. Estimated daily intakes (EDIs) were 10,496-13,459 μg/person/day for Zn; 310.90-393.73 for Cr, and 26.72-34.87 for Ni, with mean EDIs of 299, 88.9, and 0.76 μg/kg bw/day for Zn, Cr, and Ni, respectively. Only Cr intake exceeded the recommended daily intake (RDI). Adejumo et al. [40] measured Cd, Cr, Ni, and Pb in cured meat products from markets/supermarkets and fast-food restaurants in South-West Nigeria. Pb, Cr, and Ni were not detected, while Cd levels ranged from 0.35 to 1.20 μg/g in corned beef and meaty sausage, with a mean of 0.76 μg/g, exceeding the maximum allowable limit in Nigeria (0.005 μg Cd/g). Orisakwe et al.[41] conducted a study around a Pb-polluted goldmine in Dareta and Abare (Zamfara State), measuring metal levels in farm produce and livestock (goat, sheep, cattle, and chicken). The highest mean levels of Pb and Cd were found in goat and chicken blood (7.75 and 0.32 μg/g, respectively), with the authors noting concern about Cd and Pb levels in meats. In turn, Ogbomida et al.[42] assessed health risks of trace elements (As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn) by consumption of tissues (muscle, liver, kidney, and gizzard) of free-range animals (chicken, cattle, and goats) from municipal solid waste sites in Benin City. As concentrations ranged from 0.040 to 0.081 μg/g ww in chicken, and 0.007 to 0.008 μg/g ww in goat and cattle. Cd ranged between 0.890 μg/g ww in chicken kidney and 0.001 μg/g in muscle of cattle and goat, while Pb ranged between 0.588 μg/g ww in chicken kidney and 0.009 μg/g ww in goat muscle. The highest Hg levels were in chicken liver (0.034 μg/g ww) and kidney (0.030 μg/g ww), and the lowest in cattle liver (0.001 μg/g ww) and goat muscle (0.0010 μg/g). Although THQs were < 1, Cd and As values suggested potential health risks for continuous exposure through contaminated meats, particularly prolonged consumption of chicken livers with high Cd levels.

On the other hand, Njoga et al.[43] evaluated As, Cd, and Pb in goat carcasses processed for consumption in Enugu State, assessing health risks for consumers. The ranges of the mean concentrations (μg/g) were: As, 0.45 (muscle)-0.57 (liver); Cd, 0.02 (muscle and liver)-0.06 (kidney), and Pb, 0.45 (liver)-0.82 (muscle). EDIs were above recommended limits for children and adults, but the hazard index (HI) was < 1 for As, Cd, and Pb. Okoye et al.[44][45] reported results of studies determining As and metal levels (Cd, Cu, Hg, Pb, V, and Zn) in edible samples of goat, chicken, and cow (also fish) from six areas of the Niger Delta, evaluating health risks for consumers. Human exposure from Nigerian food (fish and meats) did not indicate potential hazards for Hg and V, but Pb exposure in children and seniors was above (or close) to the BMDL0.1 for neurotoxicity and nephrotoxicity due to goat and cow meat intake. Consumption of meats contributed to dietary As intake (especially for children, exceeding the BMDL0.1) and Cd intake (especially in adolescents)[44][45].

A summary of the results of the above studies conducted in Nigeria is presented in Table 1.

Region/City	Analyzed meat/meat products	Results for the analyzed toxic elements	Remarks	References
Enugu State	muscle and edible offal (kidney, intestine and tripe) of cows	Mean Cd levels (range): 0.24-0.44 μg/g. Mean Pb levels (range) 0.09-0.26 μg/g	The highest intakes of Cd and Pb were 0.55 μg/kg bw/week (intestine), and 1.21 μg/kg bw/week (tripe), respectively.	Ihedioha and Okoye[36] [37]
Lagos and Abadan	frozen chicken (thighs and wings)	Mean concentrations: 0.0065 and 0.0078 μg/dL for Cd, and 0.0207 and 0.0227 μg/dL for Pb	The Cd and Pb concentrations were within the maximum residue levels allowed in the country.	Olusola et al.[38]
Ogun State	cattle (muscles, liver and kidney)	The mean levels of Cd in muscle, liver and kidney were: 0.156, 0.172 and 0.197 μg/g, respectively. For Pb, the mean levels were: 0.721, 0.809 and 0.908 μg/g, for muscle, liver and kidney, respectively.	The levels of Pb were higher than the standards in all bovine tissues.	Adetunji et al.[39]
Nigeria (area/region not specified)	muscle and edible offal of cows	The minimum and maximum mean levels (μg/g fw) were: 1.24 (muscle) and 4.28 (liver) for Cr, and 0.20 (liver) and 0.36 (kidney) for Ni.	The mean EDIs were 88.9 and 0.76 μg/kg bw/day, for Cr and Ni, respectively. Only the intake of Cr was higher than the recommended daily intake.	Ihedioha et al. (2014)
South-West of the country	cured meat products (ham, bacon, sausages, corned beef, and luncheon)	Pb, Cr and Ni were not detected in any sample, while Cd levels ranged between 0.35 and 1.20 μg/g, in samples of corned beef and meaty sausage,	Cd concentrations exceeded the maximum allowable limit in the country	Adejumo et al.[40]

Region/City	Analyzed meat/meat products	Results for the analyzed toxic elements	Remarks	References
		respectively, being 0.76 μg/g its mean level.		
Dareta and Abare, Zamfara State (around a lead-polluted goldmine)	goat, sheep, cattle, and chicken	The highest mean levels of Pb and Cd were found in samples of goat and chicken (blood), with values of 7.75 and 0.32 μg/g, respectively.	According to the authors, the levels of Cd and Pb in meats of the examined area would be of concern.	Orisakwe et al.[41]
Benin City (near municipal solid waste sites)	muscle, liver, kidney and gizzard of free-range animals (chicken, cattle and goats)	The highest concentrations were 0.081 μg/g ww for As in chicken muscle, and 0.890 and 0.588 μg/g ww for Cd and Pb, respectively. The highest Hg levels corresponded to chicken liver (0.034 μg/g ww) and kidney (0.030 μg/g ww),	Potential health risks were suggested for those individuals with continuous exposure to As and Cd by consumption of contaminated meats.	Ogbomida et al.[42]
Enugu State	muscle, liver and kidney from goat carcasses	The ranges of the mean concentrations (μg/g) were the following: As, 0.45 (muscle)-0.57 (liver); Cd, 0.02 (muscle and liver)-0.06 (kidney), and Pb, 0.45 (liver)-0.82 (muscle)	The hazard index (HI) was < 1 for As, Cd and Pb	Njoga et al. [43]
Six areas of the Niger Delta	goat, chicken and cow	As and various metals (Cd, Cu, Hg, Pb, V and Zn) were measured in meat samples of the indicated animals'	No potential health hazards were found for Hg and V. The risk for Pb exposure was above (or close) to $BMDL_{0.1}$ for developmental	Okoye et al. [44][45]

Region/City	Analyzed meat/meat products	Results for the analyzed toxic elements	Remarks	References
		species. Numerous data were obtained and classified by age groups of the population	neurotoxicity and nephrotoxicity (intake of meats of goat and cow, respectively) in children and seniors, in the six areas included in the survey. Meat consumption also contributed to the dietary intake of As (especially for children, exceeding the $BMDL_{0.1}$) and Cd (especially in the group of adolescents)	

Table 1. A summary of studies conducted in the current century in Nigeria on the levels of toxic trace elements in edible meat and meat products.

Egypt

Kamaly and Sharkawy[46] measured essential and non-essential elements (Al, Ba, Bi, Cd, Co, Cr, Cu, Fe, Ni, Pb, Se and Zn) in chicken samples from markets in Assiut city, evaluating health risks. Cd concentrations ranged from 0.014–0.054 µg/g in chest samples, 0.015–0.088 µg/g in thigh samples, and 0.027–0.104 µg/g in liver samples. Pb levels ranged from 2.560–5.552, 0.334–1.082, and 0.146–0.952 µg/g in chest, thigh and liver samples, respectively. Cd EDIs ranged from 0.008 to 0.049 µg/kg bw for chicken meat consumption, and Pb EDIs ranged from 0.188 to 3.13 µg/kg bw, with liver consumption being negligible. Mohamed et al. [47] determined As, Cd, Hg and Pb levels in chilled and frozen beef from Sharkia Governorate. Average concentrations in chilled samples (µg/g) were 4.66, 0.02, ND, and 0.64, for As, Cd, Hg and Pb, respectively. In frozen samples, mean levels were 5.32, 0.02, 0.08 and 0.89 µg/g, respectively. EDIs of Cd, Hg and Pb were below the oral reference dose (RfD), while the As RfD was exceeded by 46.7% and 60% for chilled and frozen beef, respectively.

Ghana

Adei and Forson-Adaboh[48] collected fresh livers of various animal species in markets of Accra and Kumasi, measuring Cd, Cu, Fe, Hg, Mn, Pb and Zn concentrations. Over 50% of samples exceeded the allowable Cd limit of 0.5 µg/g, and Pb concentrations (range 1.3-13.8 µg/g) also exceeded the limit of 0.5 µg/g. Hg levels were below the tolerable limit of 0.5 µg/g. Bortey-San et al.[49] assessed health risks from metals/metalloids due to meat consumption near gold mines in Tarkwa, determining levels of As, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb and Zn in muscle and offal of free-range animals. As concentrations ranged from non-detected (ND) to 0.14 µg/g ww in goat muscle and chicken kidney. The mean Cd level in chicken kidney (0.73 µg/g ww) was higher than in goat and sheep kidney, but within the tolerable residual level (0.5-1.0 µg/g ww) in offal. Cadmium was detected in 14% of muscles, 100% of liver and kidney, and 90% of chicken gizzard. The highest Hg concentrations were found in chicken kidney (0.12 µg/g ww) and liver (0.11 µg/g ww), followed by sheep kidney (0.07 µg/g ww), with the authors noting concern about high Hg concentrations in free-range chicken, exceeding allowable maximum values in Ghana (0.01-0.05 µg/g).

Uganda

Kasozi et al.[50] measured essential (Cu, Fe and Zn) and non-essential metal levels (Cd and Pb) in beef samples and evaluated consumption safety. Cd was not detected, while the mean Pb concentration was 18.90 µg/g. The EDI of Pb was acceptable for adults but not safe for children, with a high THQ indicating an elevated HI. The authors emphasized caution regarding beef consumption by children. More recently, Kasozi et al.[51] carried out another study. The means (ranges) were the following: 0.41 (0.11-0.98), 19.37 (6.94-35.84), 14.96 (5.97-26.58) and 5.42 (2.41-10.94) µg/g for Cd, Cr, Ni and Pb, respectively. For these four elements, the EDIs followed the order: Cr > Ni > Pb > Cd, being (excepting Cd), higher than the tolerable daily intake (TDI) recommended by the WHO. A third survey[52] found the following: The mean levels of the 4 potentially most toxic analyzed elements in 40 beef samples were the following: 0.4, 19, 15 and 5.5 µg/g for Cd, Cr, Ni and Pb, respectively. According to the authors, it could be explained by the presence of Cr or Ni in all beef samples.

Other African countries

Mengistu[53] published a systematic review of 21 studies conducted in Ethiopia, determining health implications from heavy metal exposure in food and drinking water between 2016-2020. Mean concentrations of As, Cr, Cd, and Pb in meat and milk were 0.79-2.96, 1.032-2.72, 0.233-0.72, and 1.32-3.15

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μg/g, respectively. Toxic element levels in foods were higher than allowable limits, posing potential health risks.

Hassan Emami et al.[54] reviewed studies on metal concentrations in red meat in Middle Eastern countries, including As, Cd, Pb, Ni, and Hg. Variations depended on the element, meat product, and country, with most studies showing concentrations exceeding WHO/FAO and US EPA tolerable values. Benamirouche et al.[55] measured Hg, Pb, and Fe in broiler parts in Algeria. The lowest Hg and Pb concentrations were in gizzard samples (0.004 and 0.185 μg/g, respectively), and the highest in breast (0.007 μg/g) and liver (0.480 μg/g), respectively. EDIs of Hg and Pb exceeded the tolerable daily intake. Incremental lifetime cancer risk levels for Pb suggested potential carcinogenic risks for adults and children.

Missohou et al.[56] assessed the impact of a landfill in Senegal, finding Hg contamination of poultry meat from well water, with 68% of samples containing Hg and 20% having high concentrations (> 0.011 μg/g). Ambushe et al.[57] measured essential and non-essential elements in bovine meat from mining areas of South Africa, with metal concentrations varying by organ/tissue. The highest Cd (1.35 μg/g), Pb (0.62 μg/g), and U (0.009 μg/g) concentrations were found in bone, while Cd and Pb levels were also high in kidney and liver, with notable differences among samples. Ahmed et al.[58] collected dromedary meat samples in Mauritania, measuring trace elements. The mean levels of the toxic elements were: 0.055, 0.064, 0.027, and 0.040 μg/g, for As, Cd, Hg, and Pb, respectively. The authors suggested measuring toxic element concentrations in edible parts of camels and dromedaries due to potential concerns for frequent consumers.

Discussion

Meat consumption varies considerably between countries depending on various factors. Africa is no exception, as meat consumption varies significantly based on income levels, cultural practices, urbanization, and the availability of meat. Africa has a lower per capita meat consumption compared to other regions, but demand has increased in recent decades due to population growth, economic development, and urbanization[59][60]. The animal species most consumed in African countries are beef, goat, sheep, poultry, pork, and bushmeat.

Various pollution sources can contaminate meat with environmental pollutants[19][61][62][54]. Toxic trace elements such as As, Cd, Hg, and Pb can accumulate in animals, affecting the meat consumed by humans[63][64][54]. This paper reviewed studies on toxic trace element levels in meats published in English in international journals indexed in PubMed and/or Scopus. The analytical techniques and results were not discussed, assuming they were rigorously reviewed by the journals.

Most studies focused on Cd and Pb, although As and Hg, as well as Cr(VI) and Ni, were also determined. Results varied depending on the country/region, meat characteristics, and the specific metal/metalloid. Some authors expressed concern regarding the consumption of certain meats in specific areas due to toxic element concentrations, which were generally higher in edible viscera and internal organs.

Conclusion

Based on the reviewed studies, drawing conclusions on the health risks for regular meat consumers in Africa due to dietary exposure to As and heavy metals is challenging due to limited studies in scientific databases for most African countries. Additionally, the studies varied too significantly to allow for specific recommendations. However, some general points apply to most countries: toxic trace element content in muscle tissues is generally lower than in other tissues and organs, and toxic metal levels in meat are usually less significant than in other food groups like fish and seafood[22][7]. Furthermore, the environmental presence of some metals (e.g., Pb) has been notably reduced in recent years, affecting their content in food groups, including meats, and Africa should be no exception.

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Conflicts of Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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