Ethiopian Journal of Environmental Studies & Management 18(4): 485 – 495, 2025
ISSN:1998-0507 doi: https://ejesm.org/doi/v18i4.5
Submitted: September 12, 2025 Accepted: November 3, 2025

HEAVY METAL CONTAMINATION IN BUSHMEAT: THE IMPLICATIONS FOR WILDLIFE CONSERVATION AND ECOSYSTEM HEALTH

***ODEBIYI, B.R.,[1] ADEWALE, R.O.,[1] ODEBIYI, M.O.,[2] ADEBAYO, B.O.[1] AND OYELEYE, D.O.[3]**

[1]Department of Forestry, Wildlife and Fisheries, College of Agricultural Sciences, Olabisi Onabanjo University. P.M.B. 0012, Ayetoro, Ogun State, Nigeria
[2]Department of Science Laboratory Technology, Gateway ICT Polytechnic, Saapade, Ogun State, Nigeria
[3]Department of Wildlife and Ecotourism Management, Ladoke Akintola University of Technology, Oyo State, Nigeria
*Corresponding author: jideodebiyi@oouagoiwoye.edu.ng

Abstract

Bushmeat remains a critical protein source in sub-Saharan Africa but poses risks when contaminated with toxic heavy metals. This study investigated concentrations of mercury (Hg), lead (Pb), arsenic (As), cadmium (Cd), and chromium (Cr) in smoked bushmeat samples from three major markets (Brewery, Ishara, and Ajura) in Ogun State, Nigeria, using atomic absorption spectrometry. Samples analyzed included duikers, grasscutters, pythons, civets, and monitor lizards. Results revealed widespread contamination, with Hg levels (0.04–0.09 mg/kg) consistently exceeding the FAO/WHO (2011) limit of 0.05 mg/kg. Cd concentrations were especially high, ranging from 0.17 to 0.81 mg/kg across species, far surpassing permissible thresholds. Pb and As were detected at lower concentrations (0.01–0.03 mg/kg and 0.00–0.01 mg/kg, respectively), within regulatory limits but still of concern due to risks of bioaccumulation and chronic toxicity. Cr was not detected in any sample. These findings highlight heavy metal pollution as a regional environmental issue rather than an isolated occurrence, with implications for both consumer safety and ecosystem health. Elevated Hg and Cd levels are linked to reproductive impairment, kidney dysfunction, and reduced survival in wildlife, while contamination across trophic guilds signals potential biomagnification and ecosystem-wide disruption. The study concludes that heavy metal contamination in bushmeat represents a dual threat to public health and biodiversity. Strengthening environmental monitoring, regulating bushmeat trade, and mitigating anthropogenic pollution sources are essential steps to safeguard both human communities and wildlife populations.

Keywords: *Heavy metal toxicity, Food safety risks, Ecosystem health, Wildlife conservation*

Introduction

Bush meat, also referred to as wild meat, encompasses the flesh of wild animals hunted for food, primarily in tropical regions (Nasi *et al.,* 2008). Bush meat refers to wild animals hunted and consumed by humans. It serves as a critical protein source for millions of people in rural and urban areas, particularly in sub-Saharan Africa, Southeast Asia, and parts of Latin America (Wilkie *et al*., 2011). This practice is particularly prevalent in forested regions where alternative sources of animal protein are scarce or expensive (Nasi *et al.,* 2008). For some communities, bush meat also holds cultural and social significance, often featured in rituals or traditional dishes (van Vliet and Nasi, 2008). However, the increasing demand for bush meat, driven by urbanization and market commercialization, has transformed what was once a subsistence activity into a large-scale industry (Fa *et al*., 2002). In addition to biodiversity loss, the bush meat trade poses serious legal and governance challenges, as much of it is conducted illegally in protected areas or without appropriate regulation (Lindsey *et al*., 2013). Despite its cultural and nutritional importance, bush meat hunting has raised concerns due to its implications for biodiversity and the sustainability of wildlife populations (Cawthorn and Hoffman, 2015).

Heavy metals are naturally occurring elements that have a high atomic weight and density, at least five times greater than that of water. While some heavy metals, such as zinc (Zn), iron (Fe), and copper (Cu), are essential for biological functions in trace amounts, others, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), are toxic even at low concentrations (Tchounwou *et al.,* 2012). These metals enter the environment through natural processes like volcanic eruptions, weathering of rocks, and anthropogenic activities, including industrial discharges, mining, and agricultural practices (Singh *et al.,* 2011). Heavy metals, such as lead (Pb), mercury (Hg), and cadmium (Cd), are non-biodegradable and can accumulate in animal tissues, posing serious health risks to consumers. The bioaccumulation of heavy metals in soil, water, and air has significant ecological and human health implications. For instance, cadmium and lead can accumulate in crops irrigated with contaminated water, leading to human exposure through dietary intake (Sharma and Agrawal, 2005). The toxicity of heavy metals depends on their concentration, chemical form, and exposure route. For example, lead exposure, even at low levels, is associated with neurobehavioral deficits, particularly in children, where it can impair cognitive and motor development (Needleman, 2004). Similarly, prolonged exposure to cadmium is linked to kidney dysfunction, bone demineralization, and lung cancer (Jarup, 2003.)

This study was conducted to investigate the levels of heavy metal contamination in commonly consumed bush meat species in Ogun state, Southwestern part of Nigeria. The outcome of this study is expected to provide insights on the implications for wildlife conservation and ecosystem health in order facilitate a well informed and holistic policy decisions and actions.

Materials and Methods

Study Area

The research was conducted across three prominent bush meat markets (Brewery, Ishara Remo, and Ajura

Market) in Ogun State, Nigeria. These markets were strategically selected due to their active involvement in the bush meat trade and their accessibility to a variety of wildlife species. These markets are situated within ecological zones characterized by derived savannah and secondary forest vegetation, providing suitable habitats for various wildlife species.

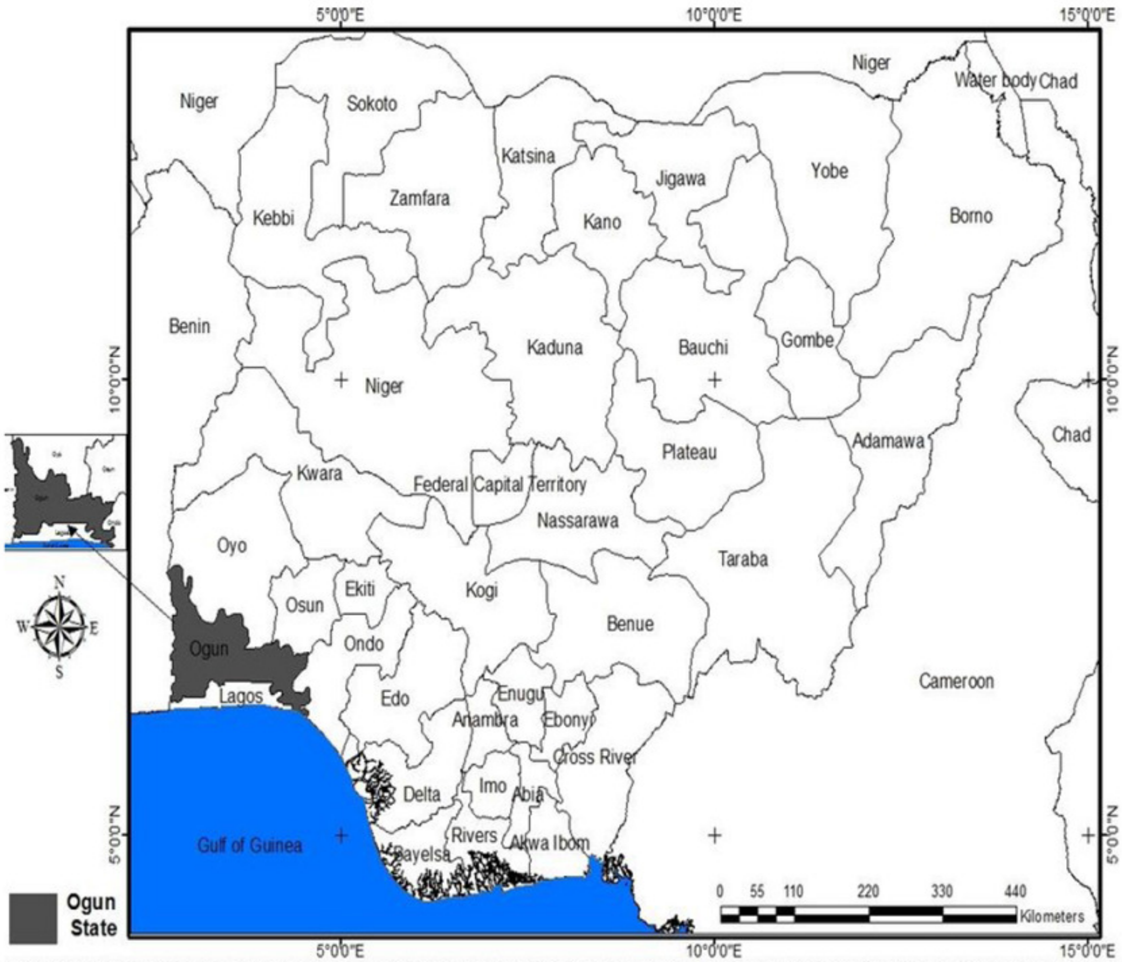

Fig. 1: Map of Nigeria showing Ogun state

Sample Collection and Preparation

Samples of smoked bushmeat sold by bushmeat sellers in the study area were collected. Each species of smoked bush meat was separately packed in sterile, labelled Ziploc plastic bags and transported to the laboratory in ice boxes at 4°C to prevent microbial growth or deterioration within 24 hours of collection to maintain sample integrity. The method for analysis of heavy metals in processed bush meat involved a two-stage procedure.

Nitric–perchloric Acid Digestion

Ten grams of sample was placed in a 250 ml digestion tube followed by the addition of 4ml of concentrated H_2SO_4, 20ml HNO_3, and 5ml of perchloric acid ($HClO_4$). The mixture was left to stand at room temperature for 30 min before being heated at 250 ºC for 30 minutes. Afterwards, the digestion tube was removed from the heating mantle and allowed to cool. Once the solution was clear after cooling, it was filtered through Whatman No. 42 filter paper and < 0.45 millipore filter paper and transferred quantitatively to a 25ml volumetric flask by adding distilled water.

The Use of Atomic Absorption Spectrometer (AAS)

The concentrations of each of the heavy metals – Mercury (Hg), Lead (Pb), Arsenic (As), Cadmium (Cd) and Chromium (Cr) in the final solutions of 25 ml volumetric flask were determined by an atomic absorption spectrometer (AAS) (Hitachi Z-8100, Japan). AOAC (1990).

Table 1: Permissible Limits of Heavy Metals in Bush meat (FAO/WHO Codex, 2011)

Heavy metals	Permissible Limits (FAO/WHO Codex, 2011)
Mercury (Hg)	0.05 mg/kg
Lead (Pb)	0.1 mg/kg
Arsenic (As)	0.01 mg/kg
Cadium (Cd)	0.05 mg/kg
Chromium (Cr)	0.05–0.1 mg/kg (depending on oxidation state)

Results and Discussion

The analysis of heavy metals in bushmeat samples collected from Brewery, Ishara, and Ajura markets in Ogun State, Nigeria reveals concerning patterns of contamination with mercury (Hg), lead (Pb), arsenic (As), cadmium (Cd), and chromium (Cr). These findings highlight potential risks to food safety, environmental health, and wildlife conservation.

Mercury (Hg)

Mercury was consistently detected in all three markets, with concentrations exceeding the FAO/WHO (2011) permissible limit of 0.05 mg/kg. At Brewery market, Red Flanked duiker (*Cephalophus rufilatus*) exhibited the highest Hg concentration at 0.09 mg/kg, while other species also showed elevated levels (0.05–0.09 mg/kg). At Ishara market, monitor lizard (*Varanus niloticus*) recorded 0.07 mg/kg, followed by grasscutter (*Thryonomys swinderianus*) at 0.06 mg/kg, and Maxwell's duiker (*Philantomba maxwelli*) at 0.04 mg/kg. In Ajura market, the highest levels were observed in ball python (*Python regius*) and Maxwell's duiker, both at 0.08 mg/kg, and grasscutter at 0.07 mg/kg.

The widespread presence of Hg across species and locations is concerning given its toxicity and tendency to bioaccumulate. Mercury exposure is linked to neurological disorders and kidney damage Its presence in bushmeat has been attributed to environmental pollution from industrial activities, mining, and contaminated soils or water bodies (Auta et al., 2017). Comparable elevated Hg levels have been reported in bushmeat from Epe, Southwest Nigeria (Adewuyi *et al.*, 2020). This indicates that mercury contamination is not an isolated occurrence but part of a broader environmental issue affecting terrestrial wildlife.

Lead (Pb)

Lead was detected in all markets but at levels below the maximum permissible limit of 0.1 mg/kg (WHO, 2010). At Brewery, Pb was present in all samples but within safe thresholds, while Ishara and Ajura markets showed concentrations ranging from 0.01 to 0.03 mg/kg. Although these concentrations appear low, chronic exposure to Pb can still lead to bioaccumulation and toxicity, affecting the nervous and hematopoietic systems (Jarup, 2003).

The prevalence of Pb in bushmeat may be linked to atmospheric deposition from fuel combustion, vehicle emissions, paint residues, and industrial activities (Ogundiran *et al.*, 2015). Similar findings of Pb residues in bushmeat have been reported by Iwegbue *et al.* (2013) and Ipeaiyeda and Adegbesan (2015). This suggests that even low Pb levels in bushmeat represent a potential long-term health risk to consumers.

Arsenic (As)

Arsenic was detected at low concentrations in all three markets, generally within the permissible limit. At Brewery, As was present at 0.01 mg/kg in Red Flanked duiker and rabbit (*Oryctolagus cuniculus*), while at Ishara, levels ranged from 0.00–0.01 mg/kg. At Ajura, grasscutter and civet cat (*Civettictis civetta*) contained 0.01 mg/kg each.

Though concentrations were low, arsenic is a carcinogen linked to skin, lung, and bladder cancers (Smith *et al.*, 2002). Chronic exposure through repeated consumption could pose health risks (Rahman *et al.*, 2018). Sources of As contamination include ingestion of contaminated plants, exposure to agrochemicals such as pesticides and herbicides, and runoff from farmlands (ATSDR, 2007). Nwani *et al.* (2010) similarly reported low but detectable arsenic levels in bushmeat from farmland-adjacent areas.

Cadmium (Cd)

Cadmium contamination was a major concern across all three markets, with concentrations far exceeding the FAO/WHO limit of 0.05 mg/kg. At Brewery, Cd ranged from 0.17 to 0.78 mg/kg, with all species except Red Flanked duiker testing positive. At Ishara, grasscutter and Maxwell's duiker recorded 0.81 mg/kg and 0.80 mg/kg, respectively, while monitor lizard had 0.52 mg/kg. At Ajura, ball python showed 0.60 mg/kg, Maxwell's duiker 0.53 mg/kg, grasscutter 0.38 mg/kg, and civet cat 0.26 mg/kg.

These findings indicate cadmium contamination is widespread and severe. Cadmium is highly toxic even at low levels, associated with kidney dysfunction, skeletal damage, and other systemic effects (Godt *et al.*, 2006). The elevated levels may be linked to contamination of grazing environments by industrial waste, phosphate fertilizers, and other anthropogenic pollutants (Alloway, 2013). Similar elevated Cd levels in bushmeat have been reported in New Bussa and southwestern Nigeria (Adelegan *et al.*, 2019; Akinboro *et al.*, 2018). The significant cadmium burden observed in this study represents a critical public health concern requiring urgent monitoring and intervention.

Chromium (Cr)

In contrast to other metals, chromium was not detected in any of the samples from Brewery, Ishara, or Ajura markets (0.00 mg/kg). This contrasts with previous studies that found trace Cr levels in bushmeat near tannery and industrial sites (Bamgbose *et al.*, 2015; Tchounwou *et al.*, 2012). Chromium exists in two forms: trivalent (Cr III), which is essential at trace levels, and hexavalent (Cr VI), which is toxic (ATSDR, 2012). Its absence in the present study may reflect minimal industrial activity in the sampled areas or levels below detection thresholds.

Findings from this study are more than a food-safety issue; they signal ecosystem-level stress with direct consequences for wildlife populations, ecological processes, and long-term conservation outcomes. For instance, heavy metals affect reproduction and survival of some wild animals. Mercury, especially as methylmercury, is strongly linked to reduced hatching success, impaired chick growth, and behavioral deficits in birds—key bio indicators for terrestrial contamination. These sub lethal effects reduce recruitment and can depress populations over time, even where outright mortality is rare. (Ackerman *et al.*, 2024; Doughty, 2024).

There is risk of organ damage when wild animals are exposed to heavy metals. Cadmium accumulates in kidneys and bone across taxa, causing renal dysfunction, osteomalacia/osteoporosis, and compromised physiological performance. In wildlife, such chronic burdens reduce survival prospects, weaken dispersal capacity, and heighten vulnerability to other stressors (e.g., drought, disease). (Davidova *et al.,* 2024; Qu and Zheng*,* 2024; He and Zhang, 2025.).

The species in trade—duikers, grasscutters, pythons, civets, and monitor lizards—span different trophic guilds. Detectable metals across these guilds indicate landscape-scale contamination rather than isolated point sources, increasing the likelihood of biomagnification into predators and scavengers and threatening community stability. Comparable Nigerian studies (e.g., Epe, New Bussa) report similar patterns, reinforcing that these are regional pressures likely affecting free-ranging populations beyond the markets. (Adelakun *et al*., 2020; Ogungbile *et al*., 2023).

Disruption of keystone ecosystem functions such as pollination and plant reproduction, soil fertility and nutrient cycling and food-web stability are likely to occur with heavy metal contamination. Heavy metals impair pollinator cognition, foraging, and reproduction; exposure has been tied to reduced learning, altered morphology, and lower visitation rates - outcomes that can depress fruit/seed set in native flora and agroecosystems. In landscapes that mix farms, settlements, and forest patches - as in Ogun - this threatens crop yields and forest regeneration. (Musah, 2024; Zavrtnik, *et al.,* 2024; Luo *et al.,* 2024).

Cadmium suppresses soil microbial diversity and key N-cycling processes, reducing ammonium/nitrate availability and altering microbial community structure; climate stress can further mobilize Cd in acidic tropical soils. Diminished microbial function slows litter decomposition and nutrient turnover, weakening primary productivity and habitat quality for herbivores and detritivores. (Luo *et al.,* 2024).

Sublethal Pb and As exposures - even below regulatory thresholds - can accumulate and impair behavior and immunity, subtly shifting predator-prey dynamics and raising disease susceptibility. Lead loads from road corridors and combustion sources remain a persistent diffuse input in West African landscapes, with wildlife acting as sentinels of exposure. (Al-Sabbagh *et al*., 2025).

Detection of heavy metals in the bushmeat sold in the study area has implications for wildlife conservation. Some of the direct consequences are decline in wildlife population, genetic erosion and edge effects. Reproductive and behavioral effects from Hg and Cd can drive slow, undetected declines in small mammals and birds, especially low-fecundity species (e.g., duikers), undermining bushmeat "sustainability" claims. (Ackerman *et al.,* 2024). Chronic toxicant stress truncates lifespan and fecundity, reducing effective population sizes and adaptive potential under climate change. (Marinaro *et al.,* 2025). As contamination sources (industry, roads, farms) cluster near forest edges, metals amplify edge-related biodiversity loss - critical for a state where many wildlife populations persist in fragmented mosaics. (Miner *et al.,* 2024).

Table 2: Levels of Heavy Metals in Smoked - Processed Bush Meat at Brewery Market Abeokuta

S/N	Species (Common name/ Scientific name)	Mercury (Hg)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)
1	Red Flanked duiker (*Cephalophus rufilatus*)	0.09	0.02	0.01	0.00	0.00
2	Grasscutter *(Thrynomys swinderianus)*	0.08	0.01	0.00	0.61	0.00
3	Mongoose *(Mungos gambianus*),	0.05	0.02	0.00	0.64	0.00
4	Guinea fowl *(Numida melagris)*	0.07	0.01	0.00	0.78	0.00
5	Ball python *(Python reguis)*	0.06	0.03	0.00	0.17	0.00
6	Crocodile *(Crocodylus niloticus)*	0.05	0.01	0.00	0.52	0.00
7	Rabbit *(Oryctolagus cuniculus)*	0.06	0.02	0.01	0.43	0.00
8	Civet cat (*Civettictis civetta*)	0.07	0.03	0.00	0.21	0.00

Table 3: Levels of Heavy Metals in Smoked - Processed Bush Meat at Ishara Remo

S/N	Species	Mercury (Hg)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)
1	Maxwell`s duiker *(Philantomba maxwelli)*	0.04	0.03	0.01	0.80	0.00
2	Monitor lizard *(Varanus niloticus*)	0.07	0.02	0.00	0.52	0.00
3	Grasscutter (*Thryonomys swinderianus*)	0.06	0.01	0.00	0.81	0.00

Table 4: Levels of Heavy Metals in Smoked - Processed Bush Meat at Ajura, Siun

S/N	Species	Mercury (Hg)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)
1	Ball python *(Python reguis)*	0.08	0.01	0.00	0.60	0.00
2	Maxwell`s duiker *(Philantomba maxwelli)*	0.08	0.03	0.00	0.53	0.00
3	Grasscutter (*Thryonomys swinderianus*),	0.07	0.02	0.01	0.38	0.00
4	Civet cat (*Civettictis civetta*)	0.05	0.03	0.01	0.26	0.00

Conclusion

This study demonstrates widespread contamination of bushmeat with toxic heavy metals in Ogun State, with cadmium and mercury posing the greatest risks due to their consistently elevated concentrations across multiple species and markets. Lead and arsenic were present at lower levels but remain concerning due to potential bioaccumulation and long-term exposure risks. Chromium was not detected, suggesting limited industrial input in the sampled areas.

The findings highlight the urgent need for stricter monitoring of environmental pollution sources, regulation of bushmeat processing and trade, and increased public awareness of the health risks associated with consuming contaminated wildlife. Addressing heavy metal contamination in bushmeat is essential not only for protecting public health but also for ensuring wildlife conservation and ecosystem integrity.

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