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ORGAN-SPECIFIC DISTRIBUTION OF PESTICIDE RESIDUES IN MAXWELL'S DUIKER (Cephalophus Maxwellii)

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Abstract

Pesticide contamination of wildlife poses significant risks to biodiversity conservation and food safety. This study assessed pesticide residue levels in the flesh, liver, and kidney of Maxwell's duiker (Cephalophus maxwellii) obtained from Akwa Ibom, Nasarawa, and Oyo States, Nigeria. Samples were analyzed for common organochlorine and organophosphate pesticides using validated residue detection methods. Results showed that pesticide concentrations in muscle tissues were largely below detectable limits, indicating minimal direct risk to consumers of duiker meat. However, detectable residues of dichlorodiphenyltrichloroethane (DDT) and its metabolites were found in the liver and kidney, with higher accumulation in lipid-rich organs. These findings suggest organ-specific bioaccumulation of persistent pesticides and highlight the continued presence of banned chemicals in Nigerian ecosystems. The persistence of such residues, despite regulatory restrictions, underscores the need for strengthened pesticide control measures, routine wildlife monitoring, and awareness campaigns to reduce ecological and human health risks.

Keywords: Pesticide residues, Maxwell's duiker, Accumulation, Metabolites, Safety, Wildlife toxicology.

Introduction

The global use of pesticides has increased significantly in recent decades, largely driven by the growing human population, expansion of agricultural land, and intensification of animal husbandry (Chrustek *et al.*, 2018; Del Prado-Lu, 2014; Bradberry *et al.*, 2005; Soderlund, 2012). Although pesticides are intentionally applied to control agricultural pests, they are inherently toxic and may pose substantial risks to humans and non-target organisms (Ademoroti, 1996). Alarmingly, it has been estimated that only 0.1% of applied pesticides reach the intended pest species, while as much as 99% disperse into the environment where they bioaccumulate and biomagnify across ecosystems and food webs (Pimentel, 1995; Passuello *et al.*, 2010; Volschenk *et al.*, 2019; Zikankuba *et al.*, 2019). Consequently, pesticide application in agriculture often leaves measurable residues in environmental matrices and food products, with potential adverse ecological and health implications (Omonona *et al.*, 2015).

These measurable quantities of pesticides, commonly referred to as residues, may persist in agricultural commodities long after their intended protective role has ceased (IUPAC, 1997). Such residues contaminate soils, surface and groundwater, crops, and ultimately enter the human diet through consumption of contaminated food and water (Taylor *et al.*, 2003). Due to their persistence and lipophilic properties, pesticide residues have been detected in a wide range of foodstuffs, including

meat, milk, fish, fruits, and vegetables (Stephen *et al*., 2011). Their tendency to persist and magnify through trophic levels highlights the long-term risks associated with chronic, low-dose exposures.
Over time, pesticide usage patterns have shifted from organochlorines, carbamates, and organophosphates to pyrethroids, which are widely favoured due to their greater efficacy at lower concentrations, as well as their relatively lower persistence and reduced photostability (Urkude *et al*., 2019). Pyrethroids are synthetic derivatives of pyrethrins; naturally occurring insecticidal compounds extracted from *Chrysanthemum* flowers (Sogorb and Vilanova, 2002; Evans and Evans, 2009). Chemically, they are esters of chrysanthemic acid (ethyl 2,2-dimethyl-3-(1-isobutenyl) cyclopropane-1-carboxylate) (Soderlund, 2012). Despite their comparatively lower acute toxicity, pyrethroids remain intrinsically hazardous to both human health and biodiversity due to their neurotoxic properties and persistence in the environment (Soderlund, 2020).

Beyond agricultural use, reports suggest that certain chemical agents have been misused for hunting purposes, resulting in the contamination of bushmeat and, in some cases, mortality among consumers (Mensah, 2003). This underscores the dual threat these compounds pose directly to wildlife and indirectly to humans through the food chain. Animal tissues, particularly meat and other edible products, are critical sources of dietary protein, yet multiple pesticide residues have been detected in such products globally (Glynn *et al*., 2000; Manirakiza *et al*., 2002). The persistence of these contaminants in the environment exacerbates the vulnerability of both humans and wildlife, contributing to ecological degradation and long-term health risks (Forget, 1991).

In Nigeria, where bushmeat consumption remains widespread and contributes significantly to household nutrition and food security, the risk of pesticide contamination in wild animal species cannot be overlooked. Agricultural intensification, coupled with weak regulatory enforcement, increases the likelihood of contamination in terrestrial and aquatic ecosystems, with residues subsequently entering the food chain. Given these concerns, the present study was designed to evaluate pesticide residue levels including organochlorines, pyrethroids, triazines, and organophosphates in the tissues of *Cephalophus maxwellii* (Maxwell's duiker) harvested from selected ecological zones in Nigeria.

Materials and Methods

Sampling Technique

The research was conducted using multistage sampling technique considering the ecological zones. Three ecological zones were purposively selected from the seven ecological zones available in Nigeria. One state from each ecological area was chosen on the basis of: availability and high concentration of wildlife species, trade in wildlife products and population of wildlife sellers in the area. The States were Akwa Ibom, Oyo and Nasarawa in Mangrove, Rainforest and Guinea Savanna ecological zones, respectively. Five markets were purposively selected from five local government areas (LGAs) of each state. Figure 1 shows the chosen ecological zones of Nigeria.

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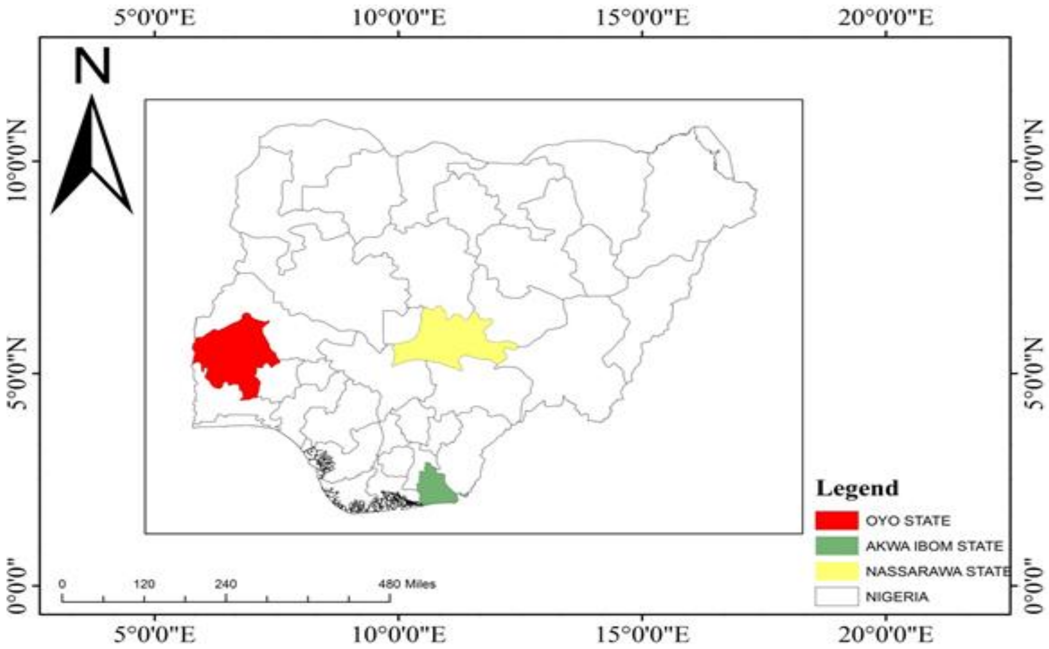

Figure 1: Nigeria map showing the ecological zones selected for assessment of pesticide residues in wildlife. Source: Field survey

Animal Sampling and Handling

The wild animal species sampled were picked on animals' accessibility in the selected area. Tissue samples collected from *Cephalophus maxwellii* (Maxwell's duiker) were preserved in frozen ice packs. They were conveyed to the laboratory pending when analysis on pesticide residues were conducted.

Pesticide Residues Assessment and Evaluation

In all, 90 samples (30 each of liver, kidney and flesh) were collected from 15 carcasses of *Cephalophus maxwellii* (Maxwell's duiker). Samples were analyzed for the detection of 19 compounds: alpha (α) BHC, beta(β) BHC, gamma (ϒ)-HCH (Lindane), Chlorothalonil, delta (Δ) BHC, Heptachlor, Aldrin, Heptachlor epoxide (B), o,p'-DDE, Endosulfan I, o,p'-DDE, Deldrin, Endosulfan II, PCB 153, p,p'-DDT, alpha (α) cypermethrin, beta (β) cypermethrin, atrazine and glyphosate.

Experimental Analysis for Pesticide Residues

Experimental Chemicals

All analytical solvents were bought from Merck, Germany and were distillated over the packaged column (Schwarzbauer, 2006). The chromatographical analyses were conducted for the solvent purity. The standard and PCB external standard containing 27 congeners were bought from Restek United States.

Analytical Procedure and Method

Four main stages were involved in the analysis: extraction, cleaning up of animal samples, quality control and data analyses.

In sample groups of 6-8, all necessary QA/QC samples were extracted, including those specified by the protocol used for the work. The pesticide quality with grade was applied as the solvents. Three grams of tissue was weighed, sterilized and combined with 20g of anhydrous sodium sulphate previously dried overnight by heat at 140°C. Fortification and standard solutions were prepared by analytical standards (>98 percent pureness). The samples obtained were identified/quantified by Gas Chromatography (GC). The compounds were evaluated with an electron capture apparatus from the Hewlett Packard GC 5890

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series 11. The apparatus was operated splitless mode and a temperature program of the oven was initiated at 90°C (2 minutes) to 130°C (15°C/minute, then at 290°C (4°C/minutes). The temperature of the injector and the detector was 250 and 300°C. The flow rate was 3ml per minute through the column. Quantification of each compound was done with the operation of the calibration curve.
Approved reference values were applied for the tool calibration and quantification from Accustandards USA for pesticide residues. The sample extracts have recognized residues by relating the exact withholding time of the standard formulation and quantified by reaction variables from the standards 5-level calibration curves. The analysis was carried out of appropriate quality assurance and quality control (QA/QC) including investigation of procedural blanks to check the pureness of mixtures, possible laboratory impurity and inferences of standard. The testing of the accuracy of the device was performed using random identical samples (standard deviation <5). To quantify the residues, five standardization curves and an r^2 value of 0.999 was used.

Statistical Analysis

Descriptive statistics (frequencies and percentages) and inferential analysis was conducted using IBM SPSS Version 20.0, with significance considered at $p < 0.05$.

Results and Discussion

Residues of 19 pesticide compounds were detected in the liver tissues of *Cephalophus maxwellii* collected from Akwa Ibom, Nasarawa, and Oyo States, representing three distinct ecological zones of Nigeria (Table 1). Concentrations varied widely across compounds and ecological zones, reflecting differences in environmental exposure, pesticide usage, and potential sources of contamination.
In the rainforest zone (Akwa Ibom), liver samples exhibited relatively high mean concentrations of several organochlorines compared with the other two regions. Among the highest values recorded were ΔBHC (2.40µg/kg), heptachlor (2.76µg/kg), deldrin (2.50µg/kg), and p,p′-DDT (2.20µg/kg). These results highlight the persistence of organochlorines despite regulatory restrictions, suggesting either ongoing use or long-term environmental retention in soils, water, and vegetation, from which they may bioaccumulate in wildlife. The humid climate of this zone, combined with intensive agricultural activity, likely contributes to enhanced pesticide application and subsequent mobilization. High rainfall, characteristic of this region, facilitates the transport of agrochemicals through runoff and leaching, promoting wider environmental dispersion. As Albert and Benitez (2005) reported, pesticides can travel through air and water either freely or bound to particulates, resulting in deposition across diverse ecological landscapes. Runoff from agricultural fields is a major entry point for pesticides into the ecosystem (Olisah *et al.*, 2020), while long-range transport processes contribute to contamination of soils, water, crops, and the atmosphere (Boonupara *et al.*, 2020).

Beyond climatic factors, anthropogenic pressures in the Niger Delta may further explain the elevated residues in Akwa Ibom. The region is heavily impacted by frequent oil spills, pipeline vandalism, fuel diversion, and sabotage, which have caused extensive ecological degradation (Baird, 2010; Anderson, 2005). The combined effects of poorly maintained pipelines, weak enforcement of environmental regulations, and unsustainable industrial activities exacerbate environmental contamination. Anthropogenic pollution, including airborne pollutants, is already recognized as a major global health risk, contributing to an estimated nine million deaths annually (Fuller *et al.*, 2022).

In the Guinea savannah zone (Nasarawa), residue levels were comparatively lower, though detectable concentrations of o,p′-DDE (1.58µg/kg), βBHC (1.10µg/kg), and γHCH (1.10µg/kg) were observed. βBHC is known to be the most stable HCH isomer, with slow elimination and strong bioaccumulation potential in animal tissues (Pardio *et al.*, 2012), which may explain its persistence. Glyphosate was detected only

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in trace amounts (0.01μg/kg) in this zone, possibly reflecting its use in large-scale cereal and legume production common in the savannah. Atrazine was not detected in any of the samples, consistent with previous findings by Anzene *et al*. (2014), who reported organochlorine residues such as aldrin, dieldrin, endrin, lindane, and DDT in grains from Nasarawa State.
In the derived savannah zone (Oyo), higher pesticide concentrations were recorded compared to Nasarawa. The highest concentration of o,p′-DDE (2.40μg/kg) was observed here, alongside elevated levels of endosulfan I (2.10μg/kg) and p,p′-DDT (2.00μg/kg). These results align with Adeola *et al*. (2025), who reported greater insecticide use in Oyo compared to other southwestern states. Furthermore, Oyo farmers have been noted for their relatively higher use of herbicides such as glyphosate, paraquat, diuron, and atrazine (Babarinsa *et al*., 2018), which likely contributes to the contamination profiles observed in wildlife from this region.

Overall, the presence of both parent and degradation products of DDT and endosulfan suggests historical use as well as possible ongoing inputs, underlining their persistence and environmental stability. Organochlorines, including BHC isomers, aldrin, heptachlor, DDT and its metabolites, and endosulfan, dominated the contaminant profile across all zones. Their persistence is consistent with their lipophilic nature, resistance to degradation, and tendency to biomagnify through food webs. The additional detection of fungicides (chlorothalonil), pyrethroids (cypermethrins), and trace glyphosate reflects exposure to a broad spectrum of chemical classes. According to Adeola *et al*. (2025), cypermethrins are less frequently used by Nigerian farmers, possibly due to cost, availability, or perceived lower efficacy. Glyphosate, however, remains the most widely applied herbicide nationwide, particularly in Oyo, where paraquat and atrazine are also commonly used.

The variation in residue levels between ecological zones can be attributed to differences in land use, cropping systems, pest pressures, and pesticide application practices. The rainforest zone's higher residue levels likely reflect intensive pesticide use in perennial cropping systems, coupled with high rainfall and moist soils that promote pesticide runoff and accumulation. In contrast, the savannah zones, dominated by annual cropping systems, are associated with more seasonal pesticide inputs and consequently lower residue loads. This observation agrees with Oyenpemi *et al*. (2023), who emphasized the influence of regional characteristics on agricultural technology adoption. Similarly, Olita *et al*. (2024) and Demi and Sicchia (2021) demonstrated that ecological, cultural, and agricultural factors significantly shape pesticide usage patterns across West Africa.

From a conservation and public health perspective, the detection of these residues is of significant concern. The liver is a primary site for xenobiotic metabolism and storage, and its contamination with persistent organic pollutants poses risks to wildlife health, including potential effects on reproduction, immunity, and survival. Tongo and Ezemonye (2015) observed higher αHCH concentrations in liver compared to other tissues, while Khalid *et al*. (2013) attributed such accumulation to the liver's central role in detoxification processes. Furthermore, in communities where bushmeat is consumed, these contaminants present a potential route of human exposure, particularly to compounds with carcinogenic, neurotoxic, and endocrine-disrupting effects.

The findings emphasize the importance of continuous environmental monitoring using sentinel species such as *C. maxwellii*. Strengthening the enforcement of pesticide regulations, alongside the promotion of integrated pest management strategies and public awareness campaigns, will be crucial in reducing hazardous pesticide burdens and safeguarding ecological and human health.

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Table 1: Concentrations in mean (µg/kg) of Residues of Pesticide in the Liver of Antelopes (*Cephalophus maxwellii*) in the Three Ecological Zones in Nigeria

Pesticide residue	CMLAK	CMLNA	CMLOY
αBHC	0.86 ± 0.92^{ab}	0.51 ± 0.29^{abcd}	0.50 ± 0.00^{abc}
βBHC	1.80 ± 2.02^{ab}	1.10 ± 0.65^{bcde}	1.48 ± 2.04^{abcd}
ϒHCH	1.70 ± 1.99^{ab}	1.10 ± 0.82^{bcde}	1.50 ± 0.79^{abcd}
Chloro	1.50 ± 1.87^{ab}	0.50 ± 0.71^{abcd}	1.60 ± 1.47^{abcd}
ΔBHC	2.40 ± 2.41^{ab}	1.50 ± 1.06^{de}	0.90 ± 1.02^{abcd}
Heptac	2.76 ± 2.14^{b}	1.01 ± 0.97^{abcde}	1.90 ± 0.42^{cd}
Aldrin	1.60 ± 1.75^{ab}	1.20 ± 0.27^{cde}	1.80 ± 1.25^{bcd}
Heptac	0.96 ± 0.83^{ab}	0.74 ± 0.72^{abcde}	1.60 ± 2.04^{abcd}
oDDE	1.80 ± 1.89^{ab}	1.58 ± 1.27^{e}	2.40 ± 1.92^{d}
Endosul	2.10 ± 1.47^{ab}	0.90 ± 1.02^{abcde}	2.10 ± 1.52^{cd}
pDDE	0.76 ± 0.60^{ab}	0.60 ± 1.08^{abcde}	0.88 ± 0.97^{abcd}
Deldr	2.50 ± 1.58^{b}	1.00 ± 1.17^{abcde}	1.60 ± 0.89^{abcd}
Endosu	1.70 ± 0.27^{ab}	0.10 ± 0.22^{ab}	0.90 ± 1.08^{abcd}
PCB	0.90 ± 2.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
pDDT	2.20 ± 1.44^{ab}	0.20 ± 0.27^{abc}	2.00 ± 1.84^{cd}
α cyper	1.12 ± 1.61^{ab}	0.00 ± 0.00^{a}	0.06 ± 0.13^{ab}
β cyper	0.90 ± 2.01^{ab}	0.00 ± 0.00^{a}	0.05 ± 0.11^{ab}
ATRZ	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
GLYS	0.00 ± 0.00^{a}	0.01 ± 0.03^{a}	0.01 ± 0.02^{a}

NB: Means with the same superscript alphabets in the same column are not significantly different at $p<0.05$

CMLAK – *Cephalophus maxwellii* Liver from Akwa Ibom state

CMLNA – *Cephalophus maxwellii* Liver from Nasarawa state

CMLOY – *Cephalophus maxwellii* Liver from Oyo state

KEY: **αBHC** – Alpha(α)BHC; **βBHC** – beta(β)BHC; **ϒHCH** – Gamma (ϒ)HCH (Lindane); **Chloro** – Chlorothalonil; **ΔBHC** – Delta (Δ) BHC; **Heptac** – Heptachlor); **Aldrin** – Aldrin; **Heptac** – Heptachlor epoxide (B); **oDDE** – o,p'-DDE; **Endosul** – Endosulfan I; **pDDE** – p,p'-DDE; **Deldr** – Deldrin; **Endosu** - Endosulfan II; **PCB** – PCB 153; **pDDT** – p,p'-DDT; **α cyper** – alpha (α) cypermethrin; **β cyper** – beta (β) cypermethrin; **ATRZ** – Atrazine; **GLYS** – Glyphosate

Residues of 16 pesticide compounds were detected in the kidney tissues of *Cephalophus maxwellii* from Akwa Ibom, Nasarawa, and Oyo States, spanning three ecological zones of Nigeria (Table 2). Concentrations varied considerably across compounds and locations, indicating ecological differences in contamination patterns as well as potential organ-specific bioaccumulation. Interestingly, kidney concentrations were in several cases slightly higher than those observed in the liver, a trend that may be associated with the lipid and water content of renal tissues, which influences xenobiotic storage and elimination (Tongo and Ezemonye, 2015; Boonupara *et al*., 2023).

In the rainforest zone (Akwa Ibom), elevated residues were recorded for several organochlorines, including γ-HCH (3.70µg/kg), aldrin (3.30µg/kg), p,p′-DDT (3.50µg/kg), and endosulfan I (2.90µg/kg). Chlorothalonil was also relatively high at 2.50µg/kg, reflecting exposure to both insecticides and fungicides. The consistent occurrence of persistent organic pollutants (POPs) in this zone mirrors the contamination profile observed in liver samples, suggesting widespread environmental distribution. Such trends align with earlier reports that POPs may not always originate locally but can be introduced

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through long-range atmospheric transport (Lichota *et al*., 2004). Although comparable studies from Ghana (Blankson-Arthur *et al*., 2011) reported lower mean concentrations of aldrin, γ-HCH, and DDT following pesticide bans since 1985, residues in the present study were notably higher. Nevertheless, the concentrations detected in Nigerian antelope kidneys were lower than those reported for chicken kidney samples from Tanzania by Mahugija *et al*. (2018), suggesting interspecies and agroecological differences.

In the Guinea savannah (Nasarawa), residues were generally lower but still included relatively high concentrations of Δ-BHC (2.70µg/kg) and heptachlor (3.30µg/kg). The presence of these legacy compounds highlights their environmental persistence and possible continued application in agriculture. Glyphosate was only detected at trace levels (0.01µg/kg), while atrazine was entirely absent. In the derived savannah zone (Oyo), residues were moderate to high, with heptachlor reaching the highest recorded value for this compound across all zones (3.80µg/kg), alongside Δ-BHC (2.70µg/kg), endosulfan I (1.70µg/kg), and o,p′-DDE (1.49µg/kg). Notably, p,p′-DDT was absent in Oyo kidney samples despite its detection in Akwa Ibom and Nasarawa, suggesting possible differences in pesticide use or environmental fate across ecological contexts.

Across the three zones, organochlorines; including BHC isomers, aldrin, heptachlor, DDT and its metabolites, endosulfan, and deldrin, were consistently dominant. Their persistence reflects their lipophilic properties, environmental stability, and strong potential for bioaccumulation. Detection of chlorothalonil in the rainforest zone suggests relatively recent fungicide use, while the consistent absence of pyrethroid residues (α- and β-cypermethrin), glyphosate, and atrazine in kidney samples indicates limited renal accumulation of these compounds. This finding contrasts with previous reports that glyphosate and atrazine remain among the most widely used herbicides in Nigeria, particularly in Oyo State, due to cost-effectiveness and broad-spectrum weed control efficacy (Adeola *et al*., 2025; Otorkpa, 2017; Otabor *et al*., 2022).

The kidney serves as a primary excretory organ for xenobiotics, yet the persistence of measurable pesticide residues highlights their resistance to metabolic breakdown and tendency to accumulate over time. This persistence poses ecological risks, as chronic exposure may impair renal function, disrupt physiological processes, and contribute to systemic toxicity in wildlife populations. From a human health perspective, the presence of banned or restricted pesticides in antelope kidneys is concerning, especially where bushmeat consumption forms part of local diets. Such exposures carry potential risks of carcinogenesis, endocrine disruption, and neurotoxicity (Olisah *et al*., 2020; Sallam and Morshedy, 2018). Furthermore, the persistence of these residues has implications for both local consumers and international trade in wildlife products (Tao *et al*., 2009). Ecological differences across zones also appear to influence residue patterns. Higher concentrations in Akwa Ibom may be linked to intensive crop production, heavy pesticide application, and greater chemical runoff retention in the humid rainforest environment, while comparatively lower levels in Nasarawa reflect seasonal pesticide inputs tied to annual cropping cycles.

Table 2: Concentrations in mean (µg/kg) of Residues of Pesticide in the Kidney of Antelopes (*Cephalophus maxwellii*) in the Three Ecological Zones in Nigeria

Pesticide residue	CMKAK	CMKNA	CMKOY
αBHC	0.80 ± 0.45^{abc}	0.39 ± 0.22^{a}	1.51 ± 2.01^{ab}
βBHC	1.80 ± 1.89^{abcdef}	0.50 ± 0.61^{a}	2.20 ± 1.79^{abc}
ϒHCH	3.70 ± 1.60^{g}	1.70 ± 1.25^{ab}	2.30 ± 2.17^{abc}
Chloro	2.50 ± 1.17^{cdefg}	0.90 ± 0.82^{a}	0.16 ± 0.23a
ΔBHC	2.20 ± 1.68^{bcdefg}	2.70 ± 2.17^{bc}	2.70 ± 1.72^{bc}

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Heptac	2.10 ± 0.65^{bcdefg}	3.30 ± 2.11^{c}	3.80 ± 1.44^{bc}
Aldrin	3.30 ± 1.79^{efg}	1.40 ± 1.39^{ab}	1.00 ± 1.00^{ab}
Heptac	1.58 ± 1.27^{abcde}	1.50 ± 1.27^{ab}	2.10 ± 2.66^{abc}
oDDE	1.76 ± 1.86^{abcdef}	0.29 ± 0.27^{a}	1.49 ± 1.88^{ab}
Endosul	2.90 ± 1.85^{defg}	1.60 ± 1.02^{ab}	1.70 ± 1.15^{abc}
pDDE	0.57 ± 0.24^{ab}	0.60 ± 0.89^{a}	1.50 ± 2.12^{ab}
Deldr	2.20 ± 1.25^{bcdefg}	1.00 ± 1.17^{a}	1.30 ± 1.86^{ab}
Endosu	1.20 ± 0.76^{abcd}	1.50 ± 1.73^{ab}	1.10 ± 1.60^{ab}
PCB	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.30 ± 0.45^{ab}
pDDT	3.50 ± 2.06^{fg}	0.60 ± 1.34^{a}	0.00 ± 0.00^{a}
α cyper	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
β cyper	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
ATRZ	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
GLYS	0.00 ± 0.00^{a}	0.00 ± 0.01^{a}	0.00 ± 0.00^{a}

NB: Means with the same superscript alphabets in the same column are not significantly different at $p<0.05$

CMKAK – *Cephalophus maxwellii* Kidney from Akwa Ibom state

CMKNA – *Cephalophus maxwellii* Kidney from Nasarawa state

CMKOY – *Cephalophus maxwellii* Kidney from Oyo state

KEY: **αBHC** – Alpha(α)BHC; **βBHC** – beta(β)BHC; **ϒHCH** – Gamma(ϒ)HCH (Lindane); **Chloro** – Chlorothalonil; **ΔBHC** – Delta (Δ) BHC; **Heptac** – Heptachlor); **Aldrin** – Aldrin; **Heptac** – Heptachlor epoxide (B); **oDDE** – o,p'-DDE; **Endosul** – Endosulfan I; **pDDE** – p,p'-DDE; **Deldr** – Deldrin; **Endosu** - Endosulfan II; **PCB** – PCB 153; **pDDT** – p,p'-DDT; **α cyper** – alpha (α) cypermethrin; **β cyper** – beta (β) cypermethrin; **ATRZ** – Atrazine; **GLYS** – Glyphosate

The analysis of *Cephalophus maxwellii* flesh samples collected from Akwa Ibom, Nasarawa, and Oyo States indicated an almost complete absence of detectable pesticide contamination (Table 3). Out of the 19 compounds screened, the majority recorded zero values across all ecological zones, with only trace levels of o,p′-DDE, p,p′-DDE, and p,p′-DDT being detected. These concentrations were extremely low, with o,p′-DDE reaching just 0.01µg/kg in Akwa Ibom and Oyo, while p,p′-DDE and p,p′-DDT exhibited similarly negligible values. No residues were detected for other organochlorines (α-BHC, β-BHC, γ-HCH, aldrin, heptachlor, or endosulfan), nor for fungicides, pyrethroids, atrazine, or glyphosate.

Compared to the elevated concentrations observed in the liver and kidney (Tables 1 and 2), residue levels in flesh were significantly lower. This aligns with the lipophilic nature of many persistent organic pollutants (POPs), which tend to bioaccumulate in lipid-rich and metabolically active organs such as the liver, and to a lesser extent, the kidney, rather than in muscle tissue. Since muscle generally contains less fat and has a reduced capacity for xenobiotic storage, the pesticide burden detected here was minimal. Visceral organs such as the liver, kidney, and heart typically retain higher pesticide residues because their fat stores act as sinks for persistent compounds (Kraybill, undated). Tongo and Ezemonye (2015) similarly observed that in edible cattle tissues from Benin City, Nigeria, residue concentrations followed the order: liver > tongue > muscle > kidney. Likewise, Darko and Acquaah (2007) reported that pesticide residues in muscle were consistently lower than those in organ tissues.

From a toxicological standpoint, the negligible levels in flesh suggest a comparatively low dietary risk from muscle consumption relative to organ meats. Nevertheless, the presence of trace amounts of DDT metabolites is of concern, as it reflects the persistence of such compounds in the environment and their

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potential to bioaccumulate through the food chain. Despite being minimal, these residues are noteworthy due to the long half-life and chronic health risks associated with persistent pesticides.

The uniformity of results across the three ecological zones further suggests that muscle tissue is not a significant site of pesticide accumulation, regardless of external environmental contamination. This highlights organ-specific storage dynamics as the key determinant of pesticide distribution in *C. maxwellii*. Consistent with findings elsewhere (Kariyanna *et al*., 2024), flesh was the least affected tissue. Nonetheless, the detection of even trace residues underscores the importance of continuous monitoring and strict enforcement of pesticide regulation to safeguard wildlife health and prevent potential risks to human consumers.

Table 3: Concentrations in mean (µg/kg) of Residues of Pesticide in the Flesh of Antelopes (*Cephalophus maxwellii*) in the Three Ecological Zones in Nigeria

Pesticide residue	CMFAK	CMFNA	CMFOY
αBHC	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
βBHC	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
ϒHCH	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Chloro	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
ΔBHC	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Heptac	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Aldrin	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Heptac	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
oDDE	0.01 ± 0.02^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.01^{ab}
Endosul	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Pdde	0.00 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{ab}
Deldr	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Endosu	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
PCB	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
pDDT	0.00 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{ab}
α cyper	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
β cyper	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
ATRZ	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
GLYS	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

NB: Means with the same superscript alphabets in the same column are not significantly different at $p<0.05$

CMFAK – *Cephalophus maxwellii* Flesh from Akwa Ibom state

CMFNA – *Cephalophus maxwellii* Flesh from Nasarawa state

CMFOY – *Cephalophus maxwellii* Flesh from Oyo state

KEY: **αBHC** – Alpha(α)BHC; **βBHC** – beta(β)BHC; **ϒHCH** – Gamma (ϒ)HCH (Lindane); **Chloro** – Chlorothalonil; **ΔBHC** – Delta (Δ) BHC; **Heptac** – Heptachlor); **Aldrin** – Aldrin; **Heptac** – Heptachlor epoxide (B); **oDDE** – o,p'-DDE; **Endosul** – Endosulfan I; **pDDE** – p,p'-DDE; **Deldr** – Deldrin; **Endosu** - Endosulfan II; **PCB** – PCB 153; **pDDT** – p,p'-DDT; **α cyper** – alpha (α) cypermethrin; **β cyper** – beta (β) cypermethrin; **ATRZ** – Atrazine; **GLYS** – Glyphosate

The comparison of pesticide residues in the liver and kidney of *Cephalophus maxwellii* across the three ecological zones with international Maximum Residue Limits (MRLs) established by FAO/WHO, the European Union Pesticide Database (EUPDB), and the Japan Food Chemical Research Foundation (JFCRF) revealed that all detected concentrations were well below permissible thresholds (Table 4).

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Organochlorine residues, including α-BHC, β-BHC, γ-HCH, Δ-BHC, aldrin, dieldrin, and their metabolites (o,p′-DDE, p,p′-DDE, and p,p′-DDT), were detected at varying concentrations but none exceeded established regulatory limits. For example, γ-HCH concentrations ranged from 1.1μg/kg in Nasarawa liver to 3.7μg/kg in Akwa Ibom kidney, remaining substantially below the lowest permissible limit of 20μg/kg set by the EU. Likewise, aldrin and dieldrin, although detected in all ecological zones, were well within the 200μg/kg threshold defined by FAO/WHO, EU, and JFCRF (FAO and WHO, 2022).

Cyclodiene insecticides, notably heptachlor and heptachlor epoxide, were consistently detected in both liver and kidney tissues, with the highest concentration observed in Oyo kidney (3.8μg/kg for heptachlor). Nevertheless, these levels were negligible compared to the 200μg/kg MRL. DDT metabolites were also recorded at low concentrations, with p,p′-DDE ranging between 0.57 and 1.5μg/kg, while p,p′-DDT peaked at 3.5μg/kg in Akwa Ibom kidney. All of these values were far below the allowable 500–2000μg/kg limits across regulatory agencies. Other pesticide classes, including endosulfan I and II, chlorothalonil, PCBs, and cypermethrins, were present in small quantities or entirely absent. Endosulfan I reached its highest concentration in Akwa Ibom kidney (2.9μg/kg), yet this was still well below the accepted 50–200μg/kg MRL. Atrazine and glyphosate were undetected in all samples.
The overarching observation across all ecological zones is that residues in both liver and kidney fell within safe consumption limits as defined by international food safety standards. This pattern suggests minimal recent exposure of *C. maxwellii* populations to these pesticides. However, the detection of persistent organic pollutants (POPs), including aldrin, DDT metabolites, and PCBs even at low levels, confirms their continued environmental presence decades after restrictions or bans. While the immediate toxicological risk to consumers appears low, the co-occurrence of multiple residues within single tissue samples raises concerns about potential cumulative and synergistic effects, particularly among populations with high bushmeat consumption rates.

Comparable findings were reported by Anzene *et al*. (2014), who noted that while most pesticide residues in food samples were below FAO/WHO MRLs, some exceeded permissible levels. Such contamination, even when rare, poses potential public health risks, underscoring the importance of continuous surveillance. Bhanti and Taneja (2007) similarly highlighted that pesticide residues in food commodities may still present dangers to human health, particularly where monitoring and regulatory enforcement are weak. Thus, although current residue levels in *C. maxwellii* organs appear safe, the persistence of POPs and the potential for bioaccumulation in lipid-rich tissues necessitate sustained monitoring programs to ensure both wildlife conservation and human food safety.

Table 4: Pesticide Residues in the Liver and Kidney of Antelopes (*Cephalophus maxwellii*) in Average Concentrations (μg/kg) from Three Ecological Zones of Nigeria with Recommended Maximum Residual Levels (MRL)

Pesticide residue	AKCML	AKCMK	NACML	NACMK	OYCML	OYCMK	FAO/WHO	EUPDB	JFCRF
αBHC	0.86	0.8	0.51	0.39	0.5	1.51	-	-	-
βBHC	1.8	1.8	1.1	0.5	1.48	2.2	-	-	-
ϒHCH	1.7	3.7	1.1	1.7	1.5	2.3	-	20	1000
Chloro	1.5	2.5	0.5	0.9	1.6	0.16	-	-	-
ΔBHC	2.4	2.2	1.5	2.7	0.9	2.7	-	-	-
Heptac	2.76	2.1	1.01	3.3	1.9	3.8	200	200	200
Aldrin	1.6	3.3	1.2	1.4	1.8	1	200	200	200

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Heptac	0.96	1.58	0.74	1.5	1.6	2.1	200	200	200
oDDE	1.8	1.76	1.58	0.29	2.4	1.49	-	-	200
Endosul	2.1	2.9	0.9	1.6	2.1	1.7	100	50	200
pDDE	0.76	0.57	0.6	0.6	0.88	1.5	500	-	2000
Deldr	2.5	2.2	1	1	1.6	1.3	200	200	200
Endosu	1.7	1.2	0.1	1.5	0.9	1.1	100	50	200
PCB	0.9	0	0	0	0	0.3	-	-	-
pDDT	2.2	3.5	0.2	0.6	2	0	500	-	2000
α cyper	1.12	0	0	0	0.06	0	-	-	-
β cyper	0.9	0	0	0	0.05	0	-	-	-
ATRZ	0	0	0	0	0	0			
GLYS	0								

NB: MRL adapted from FAO/WHO, Japan Food Chemical Research Foundation (JFCRF) and European Union Pesticide Data Base (EUPDB)
AKCMK - *Cephalophus maxwellii* Kidney from Akwa Ibom
NACMK - *Cephalophus maxwellii* Kidney from Nasarawa
OYCMK - *Cephalophus maxwellii* Kidney from Oyo
KEY: **αBHC** – Alpha(α)BHC; **βBHC** – beta(β)BHC; **ϒHCH** – Gamma(ϒ)HCH (Lindane); **Chloro** – Chlorothalonil; **ΔBHC** – Delta (Δ) BHC; **Heptac** – Heptachlor); **Aldrin** – Aldrin; **Heptac** – Heptachlor epoxide (B); **oDDE** – o,p'-DDE; **Endosul** – Endosulfan I; **pDDE** – p,p'-DDE; **Deldr** – Deldrin; **Endosu** - Endosulfan II; **PCB** – PCB 153; **pDDT** – p,p'-DDT; **α cyper** – alpha (α) cypermethrin; **β cyper** – beta (β) cypermethrin; **ATRZ** – Atrazine; **GLYS** – Glyphosate

Conclusion

The present study revealed that pesticide residues in the flesh of *Cephalophus maxwellii* across Akwa Ibom, Nasarawa, and Oyo States were largely undetectable, with only trace concentrations of DDT metabolites observed. In contrast, higher residue levels were recorded in the liver and kidney, confirming that pesticide accumulation in wildlife is organ-specific and strongly influenced by lipid content and metabolic activity. The negligible residue burden in muscle tissue suggests a relatively lower dietary risk to consumers of antelope meat compared to organ consumption. However, the persistence of DDT derivatives, despite global restrictions, points to their continued presence in the environment and potential long-term ecological and health implications. These findings emphasizes the importance of sustained residue monitoring in bushmeat species and stricter enforcement of pesticide regulation to safeguard both wildlife populations and public health.

References

1) Adeola, A., van Gestel, C.A.M., Doherty, V.F., Aneyo, I.A., Ajagbe, F. and Kasule, F. (2025). Regional variations and determinants of pesticide use among farmers in Southwestern Nigeria: implications for sustainable agriculture. Front. Agron. 7:1503899. doi:10.3389/fagro.2025.1503899
2) Albert, A. and Benitez, A. (2005). Environmental impact of pesticides on coastal ecosystems. In Gulf of Mexico Pollution and Environmental Impact: Diagnostic and Tendencies, 2nd edition; Botello, J.A.V., Osten, R., Gold-Bouchot, G., Agraz-Hernandez, C., Eds.; Univ.Auton. de Campeche, Univ. Nal. Auton.de Mexico, Instituto Nacional de Ecologia: Campeche, Mexico, pp. 237 – 248 (In Spanish).
3) Anderson, I. (2005). Niger River Basin: Vision for Sustainable Development. The World Bank Washington D.C. Pp. 1 – 131.
4) Anzene, J. S., Tyohemba, R. L., Ahile, U. J. and Emezi, K. S. A. (2014). Organochlorine pesticide residues analysis of postharvest cereal grains in Nasarawa State, Nigeria. International Journal

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2025-14-1-04 African Multidisciplinary Journal of Development (AMJD)

of Agronomy and Agricultural Research 5(5): 59-64. ISSN: 2223-7054 (Print) 2225-3610 (Online) http://www.innspub.net

5) Babarinsa, S., Ayoola, O., Fayinminnu, O. and Adedapo, A. (2018). Assessment of the pesticides usage in selected local government areas in Oyo State, Nigeria. J. Exp. Agric. Int. 21, 1– 13. doi: 10.9734/JEAI/2018/3957
6) Baird, J. (2010). Oil's Shame in Africa. Newsweek: 27. Pp. 32.
7) Bhanti, M. and Taneja, A. (2007). Contamination of Vegetables of Different Seasons with Organ Phosphorus Pesticides and Related Health Assessment in Northern India. Chemosphere, 69, 63-68. https://doi.org/10.1016/j.chemosphere.2007.04.071
8) Blankson-Arthur, S., Yeboah, O., Golow, A., Osei Tutu, A. and Denutsui, D. (2011). Levels of Organochlorine Pesticide Residues in Grasscutter (Thryonomys swinderianus) Tissues. Research Journal of Environmental and Earth Sciences 3(4): 350-357, 2011
9) Boonupara, T., Udomkun, P., Khan, E. and Kajitvichyanukul, P. (2023). Airborne Pesticides from Agricultural Practices: A Critical Review of Pathways, Influencing Factors, and Human Health Implications. Toxics, 11, 858. https://doi.org/10.3390/ toxics11100858
10) Bradberry, S.M., Cage, S.A., Proudfoot, A.T. and Vale, J.A. (2005). Poisoning due to Pyrethroids. Toxicol. Rev.; 24:93–106.
11) Chrustek A., Hołyńska-Iwan, I., Dziembowska, I., Bogusiewicz, J., Wróblewski, M., Cwynar, A. and Olszewska-Słonina, D. (2018). Current Research on the Safety of Pyrethroids Used as Insecticides. Medicina; 54:61.
12) Darko, G. and Acquaah, S.O. (2007). Levels of organochlorine pesticides residues in meat. Int. J. Environ. Sci. Tech., 4 (4), 521-524.
13) Del Prado-Lu J.L. (2014). Insecticide Residues in Soil, Water, and Eggplant Fruits and Farmers' Health Effects Due to Exposure to Pesticides. Environ. Health Prev. Med.; 20:53–62.
14) Demi, S. M. and Sicchia, S. R. (2021). Agrochemicals use practices and health challenges of smallholder farmers in Ghana. Environ. Health Insights 15, 117863022110430333. doi: 10.1177/11786302211043033
15) Eta, H., Eremi, E., Idiku, F. and Eta, J. (2023). Pesticide use, management practices and perceived effects on the health of cocoa farmers in Cross River State, Nigeria. Afr. J. Food Agric. Nutr. Dev. 23, 23558–23575. doi: 10.18697/ajfand.121.22785
16) Evans, W.C. and Evans, D (2009). Pesticides of natural origin. Trease Evans' Pharmacogn., pp. 533-536.
17) FAO and WHO. (2022). Report 2021 - Pesticide residues in food - Joint FAO/WHO Meeting on Pesticide Residues. Rome. https://doi.org/10.4060/cb8313en
18) Forget, G. (1991). Pesticides and the third world. Journal of Toxicology and Environmental Health, 32: 1131 – 1137.
19) Fuller, R, Landrigan, P J, Balakrishnan, K, Bathan, G, Bose-O'Reilly, S, Brauer, M, Caravanos, J, Chiles, T, Cohen, A, Corra, L, Cropper, M, Ferraro, G, Hanna, J, Hanrahan, D, Hu, H, Hunter, D, Janata, G, Kupka, R, Lanphear, B, Lichtveld, M, Martin, K, Mustapha, A, Triana, S, Sandilya, K, Schaefli, L, Shaw, J, Seddon, J, Suk, W, Téllez-Rojo, M M, Yan, C. (2022). Pollution and health: A progress update. Lancet Planet. Health, 6, e535–e547. Lancet Planet Health; 6: e535–47 Published Online May 17, 2022 https://doi.org/10.1016/ S2542-5196(22)00090-0
20) Glynn, A. W., Wolk, A., Aune, M., Atuma, S., Zettermark, S., Maehle Schmid, M., Darnerud, P. O., Becker, W., Vessby, B. and Adami, H. O. (2000). Serum concentrations of organochlorines in men: a search for markers of exposure. Science of the Total Environment, 263, (1-3), 197-208.

21) IUPAC (1997). International Union of Pure and Applied Chemistry. Compendium of Chemical Terminology, 2nd edition (the "Gold Book").Usepa. P. 116.
22) Kariyanna, B., Senthil-Nathan, S., Vasantha-Srinivasan, P., Reddy, B. V. S., Krishnaiah, A., Meenakshi, N. H., Han, Y. S., Karthi, S., Chakravarthy A. K. and Park, K. B. (2024). Comprehensive insights into pesticide residue dynamics: unraveling impact and management. Chemical and Biological Technologies in Agriculture 11(182)1-18. https://doi.org/10.1186/s40538-024-00708-4
23) Khalid, H.G., Nada, K.A., Qasim, M.A., Mona, N.A. and Ali, H.A. (2013). The effects of organophosphorus insecticides on liver of male mice, J. Babylon Univ./Pure Appl. Sci. 21 7.
24) Kraybill, H. F. (Undated). Pesticide residues in mammalian tissues, problems, incidence, and controls. U. S. A. public health service d. Washington. C. Presented by: Howard Bofld U. S. Public Health Service Pages: 190-213
25) Lichota, G.B., McAdie, M. and Ross, P.S. (2004). Endangered Vancouver Island marmots (Marmota vancouverensis): Sentinels of atmospheric delivered contaminants to British Columbia, Canada. Environ. Toxicol. Chem., 23, 402–407.
26) Mahugija, J. A. M., Chibura, P. E. and Lugwisha, E. H. J. (2018). Residues of pesticides and metabolites in chicken kidney, liver and muscle samples from poultry farms in Dar es Salaam and Pwani, Tanzania. Chemosphere 193 (2018) 869e874
27) Manirakiza, P., Akimbamijo, O., Covaci, A., Adediran, S. A., Cisse, I. and Fallc, S. T. (2002). Persistent chlorinated pesticides in fish and cattle fat and their implications for human serum concentrations from the Sene-Gambian region. Journal of Environmental Monitoring, 4: 609 – 617.
28) Mensah, J. (2003). Grasscutter: the most preferred bushmeat in Ghana. A daily Guide Report-Accra January 2003 Ghana National Implementation Plan, 2007. P. 72.
29) Olisah, C., Okoh, O. O. and Okoh, A. I. (2020). Occurrence of organochlorine pesticide residues in biological and environmental matrices in Africa: A two-decade review. Heliyon 6 e03518
30) Olita, T., Stankovic, M., Sung, B., Jones, M. and Gibberd, M. (2024). Growers' perceptions and attitudes towards fungicide resistance extension services. Sci. Rep. 14, 6821. doi: 10.1038/s41598-024-57530-z
31) Olughu, F. C., Asadu, A. N., Okoro, J. C. and Ozioko, R. I. (2019). Use of herbicides among rural women farmers in Abia State, Nigeria. J. Agric. Ext. 23, 171–171. doi: 10.4314/jae.v23i1.15
32) Omonona, A.O., Jarikre, T.A. and Adetuga, A.T. (2015). Clinico-pathological effects of single oral dose of cypermethrin in guinea pigs. Sokoto Journal of Veterinary Sciences, 13 (1): 1 – 8.
33) Otabor, I. J., Okrikata, E. and Bulus, S. (2022). Comparative lethal impact of glyphosate and paraquat on African mound-building termites (Macrotermes bellicosus Smeathman). Fudma J. Sci. 6, 20–24. doi: 10.33003/fjs-2022-0604-1053
34) Otorkpa, O. J. (2017). Health impact of the indiscriminate use of herbicides in Nigeria. Texila Int. J. Public Health 5, 33–40. doi: 10.21522/TIJPH.2013.05.01.Art004
35) Oyenpemi, L. O., Tijani, A. A. and Kehinde, A. D. (2023). What determines a sustained use of approved pesticides for cleaner production and its impact on yield? Evidence from the cocoa industry in Osun State, Nigeria. Clean. Responsible Consumption 9, 100113. doi: 10.1016/j.clrc.2023.100113
36) Pardio, V., Martinez, D., Flores, A., Romero, D., Suarez, V., Lopez, K. and Uscanga, R. (2012). Human health risk of dietary intake of organochlorine pesticide residues in bovine meat and tissues from Vera Cruz, Mexico, Food Chem. 135: 1873–1893.
37) Passuello, A., Mari, M., Nadal, M., Schuhmacher, M. and Domingo, J. L. (2010). POP accumulation in the food chain: integrated risk model for sewage sludge application in agricultural soils. Environment international, 36, (6), 577-583.

38) Pimentel, D. (1995). Amounts of pesticides reaching target pests: environmental impacts and ethics. Journal of Agricultural and environmental Ethics, 8, (1), 17-29.
39) Sallam, K. I. and Morshedy, A. E. M. A. (2018). Organochlorine pesticide residues in camel, cattle and sheep carcasses slaughtered in Sharkia Province, Egypt. Food Chemistry 108 (2008) 154–164
40) Schwarzbauer, J. (2006). Organic contaminants in riverine and groundwater systems: aspects of anthropogenic contribution. Berlin: Springer-Verlag Berlin Heidelberg. P.464.
41) Soderlund D.M. (2012). Molecular mechanisms of pyrethroid insecticide neurotoxicity: Recent advances. Arch. Toxicol.; 86:165–181.
42) Soderlund, D.M. (2020). Neurotoxicology of pyrethroid insecticides. Advances in Neurotoxicology, 4, Academic Press, pp. 113-165.
43) Sogorb, M.A. and Vilanova, E. (2002). Enzymes involved in the detoxification of organophosphorus, carbamate and pyrethroid insecticides through hydrolysis. Toxicol. Lett., 128 (1–3) (2002), pp. 215-228
44) Stephen W.C., Chung, B. and Chen, L.S. (2011). Determination of organochlorine pesticide residues in fatty foods: A critical review on the analytical methods and their testing capabilities. Journal of Chromatography A. 1218 (33): 5555 – 5567.
45) Tao, S., Liu, W.X., Li, X.Q., Zhou, D.X., Li, X., Yang, Y.F., Yue, D.P. and Coveney, R.M. (2009). Organochlorine pesticide residuals in chickens and eggs at a poultry farm in Beijing, China. Environ. Pollut. 157, 497e502.
46) Taylor, M., Klaine, S., Carvalho, F.P., Barcelo, D. and Everaarts, J. (2003). Pesticide Residues in Coastal Tropical Ecosystems. Distribution, Fate and Effects. Taylor and Francis, London. P. 576.
47) Tongo, I. and Ezemonye, L. (2015). Human health risks associated with residual pesticide levels in edible tissues of slaughtered cattle in Benin City, Southern Nigeria. Toxicology Reports 2 1117–1135.
48) Urkude, R., Dhurvey, V. and Kochhar, S. (2019). Pesticide residues in beverages Qual. Control Beverage Ind., pp. 529-560.
49) Volschenk, C., Gerber, R., Mkhonto, M., Ikenaka, Y., Yohannes, Y., Nakayama, S., Ishizuka, M., van Vuren, J., Wepener, V. and Smit, N. (2019). Bioaccumulation of persistent organic pollutants and their trophic transfer through the food web: Human health risks to the rural communities reliant on fish from South Africa's largest floodplain. The Science of the total environment, 685, 1116.
50) Zikankuba, V. L., Mwanyika, G., Ntwenya, J. E. and James, A. (2019). Pesticide regulations and their malpractice implications on food and environment safety. Cogent Food Agr. 5, (1).

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2025-14-1-04 African Multidisciplinary Journal of Development (AMJD)