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Full Length Research Article

Assessment of Pesticide Residues in Wild *Clarias gariepinus* AND *Tilapia zilli* from The Argungu River, Northwestern Nigeria, and The Associated Human Health Risks from Their Consumption

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ABSTRACT

Pesticides remain integral to modern agriculture for crop protection but their persistent, bioaccumulative, and toxic nature poses growing ecological and public health concerns. This study evaluate pesticide residue concentrations and associated human health risks from consuming two commonly harvested wild fish species (*Tilapia zilli* and *Clarias gariepinus*) inhabiting Argungu River. A total of 216 specimens (108 per species) were sampled between February and July, 2024 using traditional fishing methods employed by local fishermen. Samples were processed using the QuEChERS extraction method followed by analysis of sixteen pesticides through Gas Chromatographic (GC). *C. gariepinus* exhibited the highest overall pesticide residue of 1.684 µg/kg, with dominant contributions of 0.052, 0.053 and 0.176 µg/kg recorded in DDT, DDE and Alderin respectively. In *T. zilli*, the concentrations of 0.007, 0.047, 0.152, 0.326 and 0.083 were found highest in heptachlor, DDD, alpha-HCH, beta-HCH and dieldrin, respectively. Moreover, the concentrations of many pesticides analyzed in this study were found above the WHO/FAO permissible limit. However, one-way ANOVA revealed no statistically significant variation ($p > 0.05$) between species. Human health risk assessment revealed that Target Hazard Quotient ($THQ \leq 1$) and Carcinogenic Risk ($CR \leq 1 \times 10^{-4}$) for adults and children were below the critical thresholds, suggesting minimal health risks at current exposure levels. Despite the low risk estimates, the detection of pesticides in *T. zilli* and *C. gariepinus* inhabiting Argungu River revealed the deposition of pesticides due the increasing pesticides application, which highlights the need for continuous monitoring. Strengthened

regulation of pesticide use, river quality surveillance, and improved pest management strategies are essential to protect public health and promote the sustainability of Argungu River.
Keywords: River contamination, Pesticide residues, Human health risks, T. *zilli* and *C. gariepinus*

Introduction

Pesticides are widely applied in contemporary agriculture to enhance crop yield and control insect pests. These chemicals include herbicides, insecticides, fungicides, nematicides used during cultivation and post-harvest storage. Despite their agronomic benefits, the indiscriminate or excessive use of pesticides has poses significant environmental and public health threats to non-target organisms across terrestrial and aquatic ecosystems (Olisah *et al*., 2023). Aquatic ecosystems are particularly vulnerable to pesticide contamination via agricultural runoff, leaching, and wind, which can disrupts ecosystem integrity and accelerate biodiversity loss.

Persistent and lipophilic compound, particularly organochlorine pesticides (OCPs) and organophosphorus (OPP), bioaccumulate in fish tissues and biomagnify through the food chains, exposing consumers to long-term toxic effects (Slaby *et al*., 2022; Sabzevari and Hofman, 2022). Health implications associated with chronic exposure include carcinogenesis, endocrine disruption, reproductive impairment, neurological and behavioral effects (Abhilash and Singh, 2009).

Fish are excellent bioindicators of aquatic pollution due to their tendency to accumulate contaminants through skin, gills uptake and ingestion. This process leads to chronic exposure and toxicity to other vertebrate organisms through the food chains, and also affecting ecosystem sustainability and human health (Sultan *et al*., 2023; Sabzevari and Hofman, 2022). The ecological and human health implication of pesticides in aquatic system has attracted the scientific community to evaluate the levels and pesticide residues (Olisah *et al*., 2023; Slaby *et al*., 2022). Studies across Africa and Nigeria have reported OCP_S and OPP_S residues in *Oreochromis niloticus*, *Clarias gariepinus*, *Tilapia zilli, Synodontis budgetti, Hepsetus odoe, Chrysichthys nigrodigitatus* and other freshwater species (Danladi and Akoto, 2021; El-Alfy *et al*., 2019; Osesua *et al*., 2019; Dahshan *et al*., 2016). Despite the bans on several OCP_S their continue detection indicates weak enforcement and persistent usage among the farmers (Williams, 2013). Furthermore, Dichlorodiphenyltrichloroethane (DDT), dieldrin, Alpha-benzene hexachloride (α-BHC), Gamma-benzene hexachloride (γ-BHC), lindane, Endosulfan sulphate, Dichlorodiphenyldichloroethylene (DDE), Dichlorodiphenyldichloroethane (DDD), and aldrin, and other residues has been detected in freshwater fish, particularly *C. gariepinus* and *T. zilli*, with *C. gariepinus* accumulating higher concentrations (Ibrahim, 2023; Akan *et al*., 2014). However, Heptachlor epoxide, Aldrin, Dieldrin, and Endrin concentration above thresholds, poses significant health risk to consumers (Ibrahim, 2023). This

contamination is more prevalent in low- and middle income countries (LMICs) where regulatory frameworks and public awareness are inadequate (Intisar *et al*., 2022).

The Argungu River is a major freshwater body supporting domestic activities, irrigation, fishing, and the internationally renowned Argungu Fishing Festival. Intensified agricultural practices in surrounding farmlands have increased the use of pesticides, including persistent organochlorines and modern herbicides, raising concerns about environmental contamination and human health. Despite the dietary importance of *Clarias gariepinus* and *Tillapia zilli*, limited studies have examined pesticides residues and associated health risks from fish consumption in this riverine system. Most studies focused on water or sediment, neglecting species-specific bioaccumulation, interspecies variation, and exposure in vulnerable population, particularly. This study quantified fifteen pesticides residues in *C. gariepinus* and *T. zilli* across six Argungu River fishing hotspots, evaluated species-specific accumulation, and assessed potential non-carcinogenic and carcinogenic risks to humans; there by providing critical baseline data to inform sustainable fisheries management and evidence-based regulatory interventions.

Materials and Methods

Study Area

The study was conducted in River Argungu (12.45° N, 4.31° E) of Kebbi State, northwestern Nigeria (See Figure 1). The river is originated from Funtua area in Katsina State, flows through Gusau in Zamfara State and then joins River Rima in Sokoto before merging with River through Kebbi State (Obaroh *et al.,* 2015; Umar *et al.,* 2024). Argungu River serves many socioeconomics, cultural and agricultural significance, including domestic uses, recreational activities, fishing, irrigation, and tourism for international fishing festivals (Umar *et al.,* 2024).

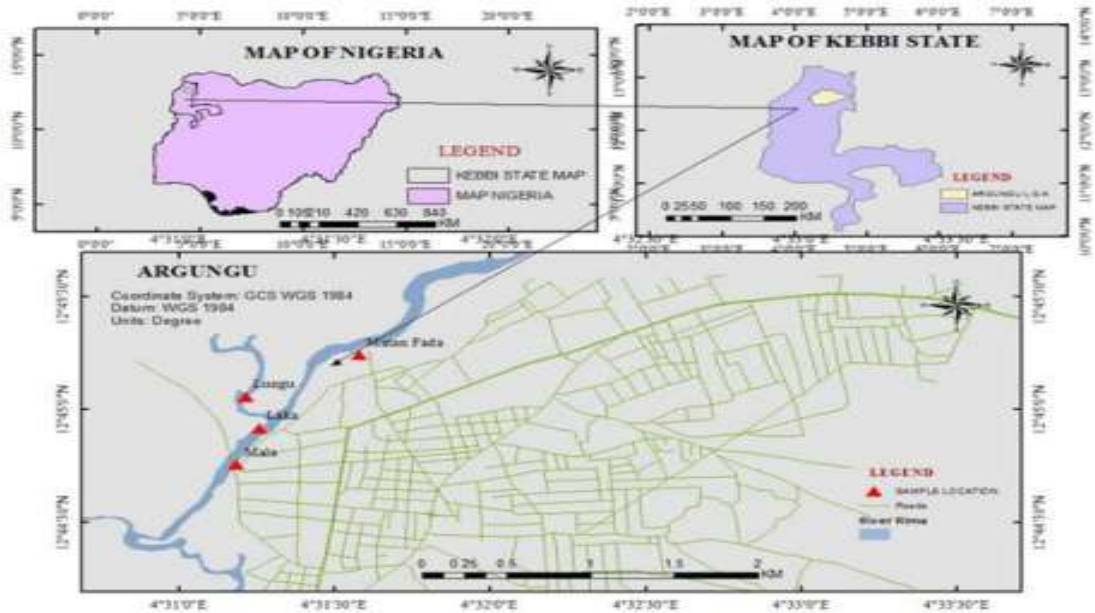


Figure 1: Map of the Study Area Showing the Sampling Locations (Umar *et al.,* 2024).

The area experiences about 800 mm annual rainfall and an average maximum temperature of 40.98°C and 39.62°C in April and March, respectively, making them the hottest months (Salisu *et al.,* 2025). The predominant vegetation type is Sudan savannah with abundance grasses, shrubs and few sparse trees (Salisu *et al.,* 2024). This river support fishing, irrigation, tourist, educational field trip, and domestic activities, experience waste disposal, agricultural runoff, blocks moulding activities for construction, and vehicular and cloth washing (Bawa *et al.,* 2018).

Study design

A cross-sectional study design was employed, combining purposive species selection and random spatial sampling with analytical assessment to evaluate pesticide residue accumulation and associated human health risks in two commonly wild freshwater fish species (*Tilapia zilli* and *Clarias gariepinus*) from the Argungu River, Kebbi State, Nigeria. Sampling was conducted between February and July 2024, covering dry and early rainy seasons. This purposive selection allowed evaluation of species-specific bioaccumulation patterns associated with differences in feeding behavior and habitat.

Ethical Approval

Ethical approval was not required as the study involved no human participants or live experimental animals. Fish specimens were obtained from local commercial fishermen contacted by the researchers, and the study complied with relevant institutional and national guidelines.

Sample Collection

A total of 216 samples (108 of *C. gariepinus* and 108 of *T. zilli*) were collected on monthly basis, from February to July 2024. Fish were captured using traditional methods employed by the local fishermen. Samples were placed in sterile polyethylene bags, transported in icebox and to the General Biology Laboratory, Federal University Birnin Kebbi for preparation in accordance with USEPA Guidelines (2018).

Fish Sample Preparation

Fish length and weight of each specimen were measured with a Vanier caliper and laboratory sensitive weighing scale, respectively. Fish were placed and dissected on Polytetrafluoroethylene (PTFE) cutting board to remove the head, tail, digestive tract, and other internal organs using knife. The muscle tissue was thoroughly washed with running tap water to eliminate attached physical dirt. For analysis, three size-matched fish from the same hotspot were pooled to form a single composite, yielding 36 composite samples per species (72 total), with each composite serving as an independent analytical replicate. Composites were oven-dried at 65°C for 48 h to constant weight and ground into fine powder using laboratory mortar and pestle. Composite sampling minimized individual variability and ensured sufficient tissue for multi-residue pesticide analysis (USEPA, 2017).

Pesticide Extraction in Fish Sample

Pesticides residues were extracted following a modified QuEChERS (Quick-Easy-Cheap-Effective-Rugged-Safe) procedure described by Ibrahim *et al.* (2025). Ten (10.0) g of

each sample was hydrated, extracted with acetonitrile, salted, centrifuged at 5000 rpm for 5 min, cleaned via dSPE ($MgSO_4$, 400 mg PSA and 400 mg C18), and filtered through 0.2 µm PTFE membrane, and finally 2 µL were injected into GC-ECD.

Gas Chromatographic (GC) Analysis

Residues were determined using Shimadzu GC-2010 (ECD) and validated via Varian CP-3800 for confirmation. Column conditions, carrier gas flows, and temperature programming followed established methods (Korteia *et al.,* 2020).

Health Risk Estimation

The assessment of health risks associated with consumption of contaminated fish were determine using the mean pesticides concentration in the tissue of each fish species to compute Estimated Daily Intake (EDI), Hazard Quotient (HQ), and Lifetime Cancer Risk (LCR) in line with WHO (1997), Fianko *et al.* (2011) and USEPA (2017). Per-capita fish consumption was set at 9 kg/year, while body weights for adult and children were set at 70 kg and 15 kg, respectively (FAO, 2011).

Estimated average daily intake (EADI)

The Estimated Daily Intake (EDI) was calculated by adopting equation I below:

$$EDI\ (\mu g/kg/day) = \frac{\text{Residual concentration } (\mu g/ww) \times \text{Food consumption } (Kg/day)}{\text{Body weight } (Kg)} \text{.....Equation I}$$

Target Hazard quotient (THQ)

The THQ was determined using equation II below by dividing the EDI values with the corresponding reference dose (RfD) of the residues:

$$\text{THQ} = \frac{\text{Estimated Daily Intake}}{\text{Reference Dose}} \text{.....Equation II}$$

Cancer Risk Assessment

Lifetime Cancer Risk (LCR) was computed in line with the USEPA (1991), equation III below that measures the elevated lifetime cancer risk associated with chronic exposure to a carcinogenic agent (Buah-Kwofie *et al.,* 2021).

$$LCR = EDI \times CSF \text{.....Equation III}$$

From equation III, CSF refers to cancer slope factor), Cancer risk was deemed acceptable when below 1 in 1,000,000, while a range between 1 in 1,000,000 and 1 in 10,000 raised cancer risk concerns, while LCR values above 1 in 10,000 are indicative of a significantly elevated cancer risk (Buah-Kwofie and Humphries, 2021).

Data Analysis

All data were expressed in mean of pesticides residue concentration per species and analyzed with One-way ANOVA at 5% level of significance ($P \leq 0.05$), to test the interspecies variations using Minitab V. 8.9.

Results

Pesticide Residues in *Clarias gariepinus* and *Tilapia zilli*

The residue concentrations of 16 pesticides were analyzed across the tissues of wild *Tilapia zilli* and *C. gariepinus* collected

from Argungu River, and higher overall residue of 1.684 µg/kg was found in *C. gariepinus* and a lower residue concentration of 1.179 µg/kg was recorded in the tissues of *T. zilli* (Table 1). Moreover, *C. gariepinus* exhibited the highest concentrations of various pesticides residues, including DDT, DDE and Alderin with 0.052, 0.053 and 0.176 µg/kg, respectively, while the concentrations of 0.007, 0.047, 0.152, 0.326 and 0.083 µg/kg recorded in heptachlor, DDD, alpha-HCH, beta-HCH and dieldrin, respectively were found highest in *T. zilli* (Table 1). Pesticides exceeding FAO/WHO limits showed species-specific accumulation patterns; *C. gariepinus* had significantly higher residues of DDE ($p < 0.05$), Aldrin ($p < 0.05$), Atrazine ($p < 0.05$) and Gamma-HCH ($p < 0.05$), whereas *T. zilli* had significantly higher beta-HCH and dieldrin ($p < 0.05$). Other pesticides exceeding limits, including alpha-HCH, glyphosate, and carbofuran, did not differ significantly ($p > 0.05$) between species.

Table 1: Mean±Std.Dev. Pesticides Residue Concentrations in *T. zilli* and *C. gariepinus*

Pesticides Residue	**Pesticides Residue**		**FAO/WHO standard**
	Tilapia zilli	***C. gariepinus***	
DDT (µg/kg)	0.002±0.002	0.052±0.005	0.050
DDE (µg/kg)	0.003±0.002	0.053±0.001	0.050
Alderin (µg/kg)	0.018±0.015	0.176±0.192	0.006
Heptachlor (µg/kg)	0.007±0.006	0.004±0.003	0.006
DDD (µg/kg)	0.047±0.040	0.043±0.001	0.050
Gamma-HCH (µg/kg)	0.068±0.067	0.416±0.055	0.010
Alpha-HCH (µg/kg)	0.152±0.230	0.059±0.005	0.010
Beta-HCH (µg/kg)	0.326±0.520	0.061±0.002	0.010
Dieldrin (µg/kg)	0.083±0.002	0.046±0.003	0.006
Atrazine (µg/kg)	0.081±0.008	0.327±0.030	0.100
Glyphosate (µg/kg)	0.310±0.641	0.256±0.045	0.100
Dimethoate (µg/kg)	0.002±0.001	0.005±0.0003	0.050
Chlorpyrifos (µg/kg)	0.023±0.022	0.061±0.000	0.050
Methylparathion (µg/kg)	0.027±0.000	0.049±0.004	0.050
Carbofuran (µg/kg)	0.029±0.027	0.051±0.027	0.010
Total	**1.179**	**1.684**	

However, across all species, the concentrations of DDT, DDD, dimethoate and methylparathion were found below the WHO/FAO threshold, while the concentration of Alderin (0.018 and 0.176 µg/kg), gamma-HCH (0.068 and 0.41 6µg/kg), beta-HCH (0.326 and 0.061 µg/kg), dieldrin (0.083and 0.046 µg/kg), glyphosphate (0.310 and 0.256 µg/kg) and carboforan (0.029 and 0.05 µg/kg) recorded in *T. zilli* and *C. gariepinus,* respectively, are found above the permissible limit in both species (Table 1).

Non-carcinogenic Risk of Selected Pesticides Residues in Wild *T. zilli*

The potential non-carcinogenic health risk assessment associated with the consumption of wild *T. zilli* in Table 2. Among the 15 detected pesticide residues, beta-HCH recorded the highest EDI value of 3.80E-10 µg/kg/day in children and 1.70E-10 µg/kg/day in adults, whereas dimethoate exhibited the lowest EDI values in both age groups. Children consistently showed approximately two-fold higher EDI values than adults. However, all THQ values were < 1, with maximum THQ value of 2.83E-06 for adults was found in beta-HCH, followed by aldrin, DDD, and dieldrin recorded the THQ

values of 1.31E06, 1.83E06, and 2.02E06, respectively, while DDT showed the lowest contribution (Table 2).

Carcinogenic Risk (CR) of Selected Pesticides Residues in Wild *T. zilli*

For adults, the CR values for six organochlorines were ranged from a minimum of 3.54E-13 in DDT to a maximum of 7.28E-10 in dieldrin, while in children, the CR values ranged from highest value of 8.01E-13 in DDT to the lowest value of 1.62E-09 in dieldrin. However, dieldrin was the dominant carcinogenic contributor, whereas DDT exhibited the lowest CR. Although children exhibited consistently higher CR values, all estimates remained well below the acceptable benchmark of 1.00E-4, indicating low lifetime cancer risk. Of the 15 residue detected, beta-HCH dominated the EDI and THQ values, while dieldrin dominated the CR value of *T. zilli* (Table 2).

Table 2: The EDI, THQ and CR Values of Pesticide Residues in *T. zilli*

Pesticides	Adults EDI	Children EDI	Adults THQ	Children THQ	Adults CR	Children CR
DDT	1.04E-12	2.36E-12	2.08E-09	4.72E-09	3.54E-13	8.01E-13
DDE	1.56E-12	3.52E-12	5.20E-09	1.17E-08	5.30E-13	1.19E-12
Aldrin	9.36E-12	2.10E-11	1.59E-10	1.31E-06	1.59E-10	3.77E-10
Heptachlor	3.64E-12	8.17E-12	7.28E-09	1.63E-08	1.64E-11	3.68E-11
DDD	2.44E-11	5.48E-11	8.15E-07	1.83E-06	5.86E-12	1.32E-11
Dieldrin	4.55E-11	1.01E-10	9.10E-07	2.02E-06	7.28E-10	1.62E-09
γ-HCH	3.54E-11	7.95E-11	1.18E-07	2.65E-07		
Alpha-HCH	7.90E-11	1.77E-10	2.63E-07	5.54E-07		
Beta-HCH	1.70E-10	3.80E-10	2.83E-06	6.35E-06		
Atrazine	4.44E-11	9.90E-11	1.27E-09	2.83E-09		
Glyphosate	1.13E-10	2.52E-10	1.23E-09	2.52E-09		
Dimethoate	7.34E-13	1.69E-12	3.67E-09	8.43E-09		
Chlorpyrifos	8.43E-12	1.94E-11	2.81E-08	6.45E-08		
Methylparathion	9.90E-12	2.27E-11	3.96E-08	9.08E-08		
Carbofuran	1.06E-11	2.45E-11	1.06E-07	2.45E-07		

Key: EDI= Estimated Daily Intake, THQ= Target Hazard Quotient, and CR= Cancer Risk

Human Health Risk Assessment of Pesticide Residue in *C. gariepinus*

The human health risk assessment revealed distinct patterns between exposure magnitude and toxicological potency; gamma-HCH recorded the highest EDI value in both children (4.84E-10) and adults (2.16E-10) as shown in Table 3. However, aldrin residue dominated both non-carcinogenic (THQ) and carcinogenic risk (CR) indices. Additionally, aldrin exhibited the highest THQ value of 1.29E-5 in children and 3.05E-6 in adults. Similarly, carcinogenic risk values ranged from minimum of 5.36E-12 for DDD to a maximum of 1.56E-9 for aldrin in adults, while in children, it has ranged from 1.20E-11 in DDD to 3.71E-9 in aldrin (Table 3). These values remain far below the acceptable lifetime cancer benchmark of 1.00E-4 (Table 3).

Table 3: The EDI, THQ and CR Values of Pesticide Residues in *C. gariepinus*

Pesticides	Adults EDI	Children EDI	Adults THQ	Children THQ	Adults CR	Children CR
DDT	2.70E-11	6.09E-11	5.41E-08	1.22E-07	9.19E-12	2.07E-11
DDE	2.76E-11	6.20E-11	9.19E-08	2.07E-07	9.38E-12	2.10E-11
Aldrin	9.15E-11	2.06E-10	3.05E-06	1.29E-05	1.56E-09	3.71E-09
Heptachlor	2.08E-12	4.68E-12	4.16E-09	9.36E-09	9.36E-12	2.11E-11
DDD	2.24E-11	5.04E-11	7.45E-07	1.67E-06	5.36E-12	1.20E-11
Dieldrin	2.52E-11	5.62E-11	5.04E-07	1.12E-06	4.03E-10	8.99E-10
Gamma-HCH	2.16E-10	4.84E-10	7.21E-07	1.61E-06		
Alpha-HCH	3.07E-11	6.85E-11	1.02E-07	2.28E-07		
Beta-HCH	3.18E-11	7.06E-11	5.29E-07	1.17E-06		
Atrazine	1.79E-10	3.99E-10	5.11E-09	1.14E-08		
Glyphosate	9.33E-11	2.08E-10	9.33E-10	2.08E-09		
Dimethoate	1.83E-12	4.22E-12	9.16E-09	2.11E-08		
Chlorpyrifos	2.23E-11	5.13E-11	7.43E-08	1.71E-07		
Methylparathion	1.80E-11	4.15E-11	7.19E-08	1.66E-07		
Carbofuran	1.86E-11	4.31E-11	1.86E-07	4.31E-07		

Key: EDI= Estimated Daily Intake, THQ= Target Hazard Quotient, and CR= Cancer Risk

A cross-species comparison revealed shared and species-specific patterns in exposure magnitude and toxicological dominance. In *T. zilli*, beta-HCH was the principal driver of dietary exposure and non-carcinogenic risk, recording the highest EDI and THQ values in both adults and children. Conversely, gamma-HCH dominated the EDI value, while aldrin was the leading contributor to the THQ in *C. gariepinus*. However, dieldrin was the primary cancinogenic contributor in *T. zilli*, while aldrin led in *C. gariepinus*. Although THQ and CR values remain within safe limits, children consistently exhibited greater vulnerability than adults which might

be due to their lower body weight and higher intake relative to body mass.

Discussion

Higher pesticides residue accumulation in *C. gariepinus* aligns the findings of Lawrence *et al.* (2015) who reported maximum residue in bottom-dwelling carnivores (5.53-9.98 µg/g wet weight in *C. gariepinus* than 3.49-4.98 µg/g wet weight in *Tilapia zilli*). Their

benthic feeding habits increase contact with contaminated sediment. Moreover, variations might due to life style, age, or species differences. Mwevura *et al*. (2002) reported that feeding mode, age and mobility of the aquatic biota affects the concentrations of pesticide residues. Furthermore, Biego *et al.,* (2010), states that exposure of *Claris gariepinus* to sediments for searching of food materials may likely be a reason for accumulation of higher pesticide residues. The findings of this study are contrary with the result of Osesua *et al.* (2019) who reported lowest total pesticide accumulation in *Tilapia zilli*. The presence of organochlorine pesticides (OCPs) in the fish tissue despite national restrictions suggests continued illegal pesticides application around the riverine area. Exceeded of FAO/WHO limits for aldrin, beta-HCH, dieldrin, and gamma-HCH reflect pesticides deposition from nearby agricultural field. Similar patterns were reported by Ibrahim (2023) and Akoto *et al.* (2016). The Estimated Daily Intake (EDI) is a widely applied metric used to estimate the amount of contaminants ingested on daily basis (Vrhovnik *et al.,* 2013). The EDI of potentially toxic elements (PTEs) directly related to their concentrations in food and the quantity of food consumed. In addition, body weight plays a critical role in determining individual tolerance to contaminant exposure (Vrhovnik *et al.,* 2013). Although THQ and CR values remain within safe limits, children exhibited greater vulnerability which might be due to their lower body weight and higher intake relative to body mass. However, continued detection of persistent pesticides in a culturally and economically significant river like Argungu highlight the risk of chronic exposure. Furthermore, Ibrahim (2023) reported that heptachlor epoxide, aldrin, dieldrin, and endrin concentration above thresholds poses significant health risk to consumers.

Conclusion

Multiple pesticide residues were detected in *C. gariepinus* and *Tilapia zilli* captured from Argungu River, with several concentrations exceeding the permissible limits. Although THQ and CR values were found below the acceptable limit, the findings reveal that children are more vulnerable to health implications of pesticides residue from consumption of contaminated fish. Furthermore, the findings indicated that the level of pesticide contamination in Argungu River is negligible, which is coming from surface runoffs from nearby agricultural land. Regular monitoring, improved regulation and promotion of sustainable pest management practices are urgently needed to protect public health and promote the sustainability of Argungu River.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personnel relationships that could have appeared to influence the work reported in this paper.

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Authors Contribution

Salisu, N. conceived and designed the study, supervised fieldwork and laboratory analysis, interpreted the data, and drafted and revised the manuscript. Abubakar K. M., Umar, J., Abubakar, H. Abubakar, M. contributed to sample collection, laboratory preparation, and pesticide extraction and they also revised the manuscript. Abubakar, S. A. and Mafara, H. M. contributed to data analysis, results interpretation, and manuscript review. All authors read and approved the final manuscript for publication.

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