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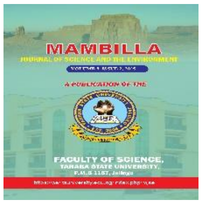

QUANTIFICATION OF PESTICIDE RESIDUE LEVELS AND HEALTH RISK IN FOOD FROM THE TARABA CENTRAL GEO-POLITICAL ZONE

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ABSTRACT

Pesticide contamination of food remains a major ecotoxicological and public health concern in Nigeria, with implications for food security and long-term human well-being. Despite regulatory restrictions, the persistent use of organophosphate, organochlorine, and carbamate pesticides continues to contaminate soils and staple crops. This study quantified pesticide residues in cereals from Taraba Central, Nigeria, and assessed associated health risks. Two hundred samples of rice, maize, millet, and sorghum were collected from farms in Bali, Gassol, and Kurmi Local Government Areas (LGAs) and analyzed using Gas Chromatography–Mass Spectrometry (GC–MS). Ten pesticide residues were detected, with isopropylamine, carbofuran, dichlorvos (DDVP), and heptachlor being the most prevalent. Estimated Daily Intake (EDI), Hazard Quotient (HQ), Hazard Index (HI), and Cancer Risk (CR) were computed for adults and children following USEPA guidelines. A clear spatial gradient of contamination was observed (Gassol > Bali > Kurmi), with rice consistently showing the highest residue concentrations, particularly in Gassol (1.13 $mg \cdot kg^{-1}$). HI values for children (0.65–55.7), far exceeded those for adults (0.48–42.6), underscoring their heightened vulnerability. Cancer risks associated with DDT and HCB in cereals from Gassol exceeded USEPA's acceptable risk range (1×10^{-6}–1×10^{-4}), indicating significant chronic health concerns. Millet and sorghum generally carried lower burdens, especially in Kurmi where subsistence farming predominates. These findings reveal widespread pesticide contamination of staple cereals in Taraba Central, with rice and maize posing the greatest health risks. Strengthened pesticide regulation, farmer education on integrated pest management, and routine residue monitoring are urgently required to safeguard public health and sustain agricultural livelihoods.

1. Introduction

Sub-Saharan African reliess on Agricultural intensification, driven by increased reliance on agrochemicals to sustain food production, in order to feed the ever-increasing population. There are no doubts pesticides has enhanced yields by reducing crop losses (Arowora *et al*., 2020; Rusinamhodzi and Hegaz, 2020; Ezeani *et al*., 2022), but their indiscriminate use has led to phenomenal contamination of soils, surface waters, and food crops, consequently, resulting in chronic human exposures (Mapanda *et al*., 2005). Globally, pesticide residues have been implicated in numerous disorders relating to, neurological, endocrine disruption, and cancers, which is aggravated in developing countries by weak regulatory frameworks (Järup, 2003; Mazlan *et al*., 2020, Barau *et al*., 2023).

Cereals such as rice, maize, millet, and sorghum have remained central to the Nigerian food security, however, they still remain major carriers of pesticide residues (Kovač *et al*., 2021; Idowu *et al*., 2022). Pesticide assimilation from contaminated soils into edible plant tissues facilitates both bioaccumulation in the food chain, and biomagnification in living tissues (Alam *et al*., 2003; McBride, 2007). This has made cereals a perilous trajectory for human exposure to toxic chemicals. Persistent organic contaminants like DDT, aldrin, and heptachlor, though banned, still find their

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way into Nigerian farms, often marketed under false labels (Zhang *et al*., 2021; NAFDAC, 2020). Organophosphates and carbamates, even though less persistent, thy pose acute toxicity hazards and are often misused (Dar *et al*., 2020; Bayebila-Menanzambi *et al*., 2021; Barau *et* al., 2023).

Numerous studies in Nigeria, Africa, and elsewhere have demonstrated pesticide residues in cereals above international permissible limits (Adewole *et al*., 2021; Idowu *et al*. 2022; Orosun *et al*., 2023). However, there is no systematic evaluation conducted in Taraba Central, which is a region of intense cereal cultivation that supplies large portions of the state's and national markets. Without such regular monitoring and health risk quantification, the consumption of contaminated foods threatens both public health and long-term agricultural sustainability.

2. Materials and Methods

2.1 Study Area

The study was conducted in Taraba Central Geo-Political Zone, which comprises of Bali, Gashaka, Gassol, Kurmi, and Sardauna Local Government Areas (LGAs). The zone covers an estimated area of 13,500 km² with a population of about 950,000 people (NPC, 2016). The region is a major agricultural hub, producing cereals crops such as maize, rice, sorghum, and millet, alongside many legumes and root crops. Bali, Gassol, and Kurmi where selected because they represent a major cereal production zone in Taraba state, covering the Northern Guinea Savanna, the Benue River Floodplain, and the Southern Forest-savanna transition Zones. These areas experienced excessive use of fertilizers and pesticides, alongside environmental pressures such as, artisanal mining, and runoffs that increased the risk of toxic metal contamination, and their wide distribution network, makes them hotspot. Bali LGA lies within latitude 7.87°N and longitude 11.78°E. It is a major rice and maize producing area. Gassol LGA (latitude 8.53°N, longitude 11.23°E) is the largest cereal-producing LGA in the zone, with extensive lowland rice fields. Kurmi LGA (latitude 6.97°N, longitude 10.78°E) lies in the southern part of the central zone and has mixed farming systems with sorghum, millet, and rice widely cultivated. The climate is typical of the tropical with distinct wet (April–October) and dry (November–March) seasons. Annual rainfall averages 1,200–1,400 mm, and mean annual temperature is 27–29 °C (Danladi *et al*., 2023). The agricultural calendar is aligned with the rainy season, during which pesticide application is highest.

2.2 Sampling and Sample Collection

Three LGAs, that is, Bali, Gassol, and Kurmi, were purposively selected based on their prominence in cereal production. Within each LGA, two major farming wards were also randomly selected, and cereal samples were obtained directly from farmers at harvest. A total of 200 samples (50 each of maize, rice, millet and sorghum) were collected. In each sampling location, soils (0–30 cm depth) were also collected to assess pesticide presence at the root zone, following standard protocols (Zhang *et al*., 2015; Zhang *et al*., 2021). Samples were then sealed in clean polyethylene bags, transported to the laboratory, and where they are stored before processing.

2.3 Sample Preparation

The cereal grains were air-dried at room temperature, milled, and sieved into fine powder using a 2 mm mesh. Soil samples were air-dried, pulverized, and sieved to also obtain a homogeneous fine fraction. Subsamples were stored in airtight, clearly labeled containers for analysis.

2.4 Analytical Determination of Pesticide Residues

The determination of pesticide residues followed the use of Gas Chromatography coupled with Mass Spectrometry (GC–MS) adhering to validated multi-residue procedures (Amirahmadi *et al*., 2013; Enami *et al*., 2015; Jallow *et al*., 2017). Extraction was performed using acetonitrile under a modified QuEChERS protocol. The extracts were cleaned with dispersive solid-phase extraction (d-SPE) using $MgSO_4$ and primary secondary amine (PSA). Analysis was performed using an Agilent GC–MS with electron impact ionization in selective ion monitoring mode. Calibration curves were generated using certified reference standards for each pesticide. The target pesticide panel included: Aldrin, Atrazine, Carbofuran, Chlorpyrifos, DDT, Dichlorvos, Endosulfan, Heptachlor, Isopropylamine, and t-Nonachlor.

2.5 Risk Assessment Models

Human health risks from consumption of contaminated cereals were assessed following USEPA (1989) guidelines. Two categories of health risk were considered: that is, non-carcinogenic risk and carcinogenic risk**.**

2.5.1 Non-Cancer Risks

Human non-cancer risks to health from consumption of contaminated cereals were assessed following the USEPA (1989) model. Estimated Daily Intake (EDI) was calculated as:

$$EDI = \frac{C \times IR}{W} \tag{1}$$

Where:
C = concentration of pesticide residue in food (mg kg^{-1})
IR = ingestion rate of cereals (kg day^{-1}), 1.12 kg day^{-1} for adults, 0.373 kg day^{-1} for children (Bondy *et al.*, 2000)
BW = body weight, assumed 70 kg for adults and 19.25 kg for children (IBGE, 2004).
Hazard Quotient (HQ) for each pesticide was calculated as:

$$HQ = \frac{EDI}{RfD} \qquad (2)$$

Where: RfD is the oral reference dose (USEPA/IRIS, 1987–1994); Hazard Index (HI) for each cereal was obtained as the sum of HQ values for all pesticides detected:

$$HI = \sum HQ \qquad (3)$$

HQ or HI ≥ 1 indicates potential non-carcinogenic health risk (USEPA, 1989).

2.5.2 Carcinogenic Risk (CR)

Carcinogenic risk was estimated for pesticides classified by USEPA/IRIS as probable or possible human carcinogens, such as, aldrin, DDT, heptachlor, atrazine, endosulfan, and chlorpyrifos. Using the Incremental Lifetime Cancer Risk (ILCR) equation as:

$$CR = EDI \times CSF \qquad (4)$$

Where: *EDI* = estimated daily intake (mg kg^{-1} day^{-1}); *CSF* = cancer slope factor (mg kg^{-1} $day^{-1})^{-1}$, obtained from USEPA/IRIS.

Acceptable cancer risk range is 10^{-6} to 10^{-4} (USEPA, 2005). CR > 10^{-4} indicates high cancer risk, while CR < 10^{-6} is considered negligible.

2.6 Statistical Analysis

Data were expressed as mean ± standard deviation (SD).

3. Results and Discussion

3.1 Mean Concentration of Pesticide Residues

The mean concentrations of pesticide residues in the cereals of Bali, Gassol, and Kurmi as summarized, demonstrate a clear trend: rice > maize > sorghum > millet in pesticide accumulation, with Gassol > Bali > Kurmi in geographic contamination levels (Figure 1). These findings suggested the significance of implementing and enforcing stricter pesticide regulation, promoting integrated pest management (IPM), and educating farmers on safe use of pesticide to ensure the safety of staple cereals both cultivated and consumed in these regions. Overall, rice consistently exhibited the highest cumulative contaminant concentrations (CCC) across all LGAs, with values of 1.50 mg/kg (Bali), 1.80 mg/kg (Gassol), and 0.90 mg/kg (Kurmi). This suggests that rice, as a staple crop is often subjected to intensive cultivation and frequent pesticide application, thereby making it more prone to accumulating chemical residues than maize, sorghum, or millet. Maize followed rice in contamination levels (CCC: 0.90–1.10 mg/kg in Bali and Gassol, 0.45 mg/kg in Kurmi), while sorghum and millet exhibited the lowest CCC values (0.15–0.50 mg/kg), reflecting their lower susceptibility to pesticide accumulation or less intensive treatment during cultivation.

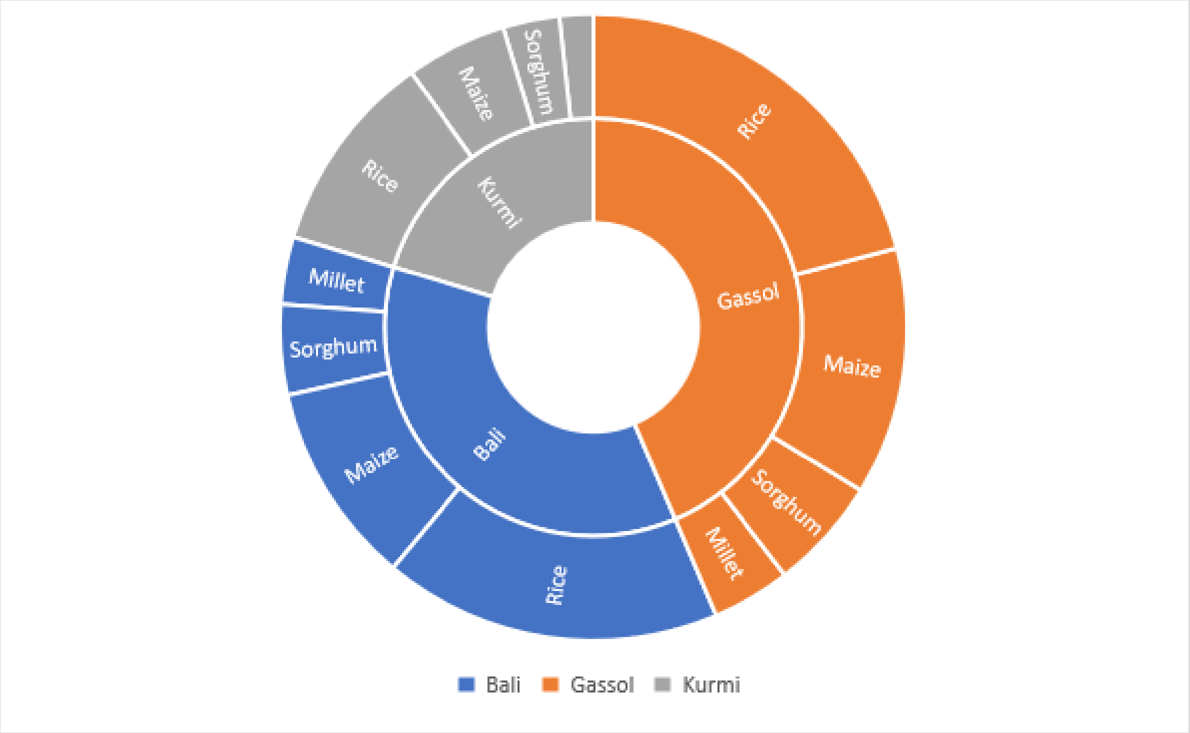

Figure 1: A Sunburst Diagram Showing the Most Contaminated Cereals and LGA

Among the individual pesticides studied, Isopropinamine (IPA), Carbofuran (CBF), and Dichlorvos (DDVP) were detected at the highest levels across most cereals. For instance, IPA in rice ranged from 0.198 mg/kg (Kurmi) to 0.396 mg/kg (Gassol), while CBF ranged from 0.126 mg/kg (Kurmi) to 0.252 mg/kg (Gassol). Persistent organochlorine pesticides, including DDT, γ-Chlordane, and Endrin, were also present in all cereals, although at lower concentrations (0.013–0.126 mg/kg). These findings corroborated previous studies that reported detectable residues of both current-use and banned pesticides in staple grains, highlighting their environmental persistence and historical use (Akinneye *et al*., 2018).

Geographically, cereals from Gassol consistently had the highest pesticide residues across all crop types, particularly rice (CCC = 1.80 mg/kg) and maize (CCC = 1.10 mg/kg), followed by Bali and then Kurmi. This pattern may reflect differences in local agricultural practices, pesticide application frequency, and enforcement of safety regulations. Kurmi consistently recorded the lowest pesticide residues concentrations, suggesting either less intensive pesticide use or adoption of more effective mitigation practices. Comparing the residue levels to reference doses (RfD), this study shows that most pesticides remained below the recommended safety thresholds, indicating unlikely immediate acute toxicity, but, the cumulative presence of multiple residues, particularly in rice from Gassol and Bali, could pose chronic health hazards over long-term consumption, due to potential bioaccumulation and additive toxic effects. The detection of organochlorine pesticides, some with known carcinogenic properties, further highlight the need for regular monitoring and risk assessment (FAO/WHO, 2021; Sharma *et al*., 2022)

Table 1: Mean concentrations of pesticide residues (mg kg⁻¹) in cereals (Bali, Gassol, Kurmi)

			Pesticide Residues									
LGA	**Cereal**	**CCC (mg/kg)**	**IPA**	**CBF**	**DDVP**	**HEPT**	**HCB**	**$_{\gamma}$-CHL**	**DDT**	**END**	**ATR**	**CPF**
Bali	Rice	1.5000	0.330 ± 0.02	0.210 ± 0.03	0.180 ± 0.01	0.150 ± 0.01	0.135 ± 0.01	0.135 ± 0.03	0.105 ± 0.01	0.075 ± 0.01	0.090 ± 0.03	0.090 ± 0.01
	Maize	0.9000	0.198 ± 0.02	0.126 ± 0.01	0.108 ± 0.03	0.090 ± 0.01	0.081 ± 0.01	0.081 ± 0.01	0.063 ± 0.02	0.045 ± 0.03	0.054 ± 0.01	0.054 ± 0.01
	Sorghum	0.4000	0.088 ± 0.01	0.056 ± 0.02	0.048 ± 0.01	0.040 ± 0.03	0.036 ± 0.02	0.036 ± 0.02	0.028 ± 0.02	0.020 ± 0.04	0.024 ± 0.01	0.024 ± 0.01
	Millet	0.3000	0.066 ± 0.01	0.042 ± 0.01	0.036 ± 0.02	0.030 ± 0.01	0.027 ± 0.03	0.027 ± 0.01	0.021 ± 0.01	0.015 ± 0.02	0.018 ± 0.02	0.018 ± 0.01
Gassol	Rice	1.8000	0.396 ± 0.01	0.252 ± 0.01	0.216 ± 0.01	0.180 ± 0.02	0.162 ± 0.01	0.162 ± 0.03	0.126 ± 0.01	0.090 ± 0.01	0.108 ± 0.01	0.108 ± 0.01
	Maize	1.1000	0.242 ± 0.04	0.154 ± 0.01	0.132 ± 0.01	0.110 ± 0.03	0.099 ± 0.02	0.099 ± 0.01	0.077 ± 0.03	0.055 ± 0.01	0.066 ± 0.01	0.066 ± 0.01
	Sorghum	0.5000	0.110 ± 0.01	0.070 ± 0.03	0.060 ± 0.03	0.050 ± 0.01	0.045 ± 0.01	0.045 ± 0.02	0.035 ± 0.01	0.025 ± 0.03	0.030 ± 0.01	0.030 ± 0.01
	Millet	0.3500	0.077 ± 0.02	0.049 ± 0.02	0.042 ± 0.01	0.035 ± 0.01	0.032 ± 0.01	0.032 ± 0.01	0.025 ± 0.02	0.018 ± 0.01	0.021 ± 0.03	0.021 ± 0.01
Kurmi	Rice	0.9000	0.198 ± 0.01	0.126 ± 0.01	0.108 ± 0.01	0.090 ± 0.01	0.081 ± 0.04	0.081 ± 0.01	0.063 ± 0.04	0.045 ± 0.02	0.054 ± 0.01	0.054 ± 0.03
	Maize	0.4500	0.099 ± 0.01	0.063 ± 0.04	0.054 ± 0.01	0.045 ± 0.01	0.041 ± 0.01	0.041 ± 0.02	0.032 ± 0.01	0.023 ± 0.01	0.027 ± 0.02	0.027 ± 0.02
	Sorghum	0.2500	0.055 ± 0.03	0.035 ± 0.01	0.030 ± 0.01	0.025 ± 0.01	0.023 ± 0.01	0.023 ± 0.01	0.018 ± 0.01	0.013 ± 0.01	0.015 ± 0.03	0.015 ± 0.02
	Millet	0.1500	0.033 ± 0.01	0.021 ± 0.01	0.018 ± 0.01	0.015 ± 0.04	0.014 ± 0.03	0.014 ± 0.03	0.011 ± 0.01	0.008 ± 0.01	0.009 ± 0.01	0.009 ± 0.01
		RfD	-	5.0E-3	5.0E-4	5.0E-4	8.0E-4	6.0E-5	5.0E-4	6.0E-3	3.0E-3	3.0E-4

NB: IPA = Isopropinamine; CBF = Carbofuran; DDVP = Dicholrvos; HEPT = Heptachlor; HCB = Hexchlorobenzene; $_{\gamma}$-CHL = Chlordane; DDT = Dichlorodiphenyltrichloroethane; End = Endrin; ATR = Atrazine; CPF = Chlorpyrifos; CCC = Cumulative Contaminant Concentration

3.2 Non-Cancer Risks

3.2.1 Estimated Daily Intake of Contaminant (EDI)

The EDI values recorded for this study reaffirms global trend where children have elevated risks than adults. In Bali (Figures. 2 & 3), cereals exhibited notable pesticide contamination, with rice showing the highest Estimated Daily Intake (EDI) values. For children, rice recorded EDIs of 0.0064 mg/kg/day for IPA, 0.0041 mg/kg/day for CBF, and 0.0035 mg/kg/day for DDVP, while millet and sorghum displayed lower values ranging from 0.0024 to 0.0093 mg/kg/day. Adults showed lower exposure, with boxplot medians of 0.0018 – 0.0035 mg/kg/day for the same pesticides, reflecting reduced intake per kilogram of body weight. Heatmaps highlighted clusters of organophosphates, particularly DDVP and CPF, in rice and maize, indicating intensive pesticide use in rice production (Bempah *et al*., 2012; Adeyemi *et al*., 2021). The persistence of organochlorines such as DDT (0.105 mg/kg/day in rice) and HCB (0.135 mg/kg/day in rice) emphasizes chronic dietary exposure risks for vulnerable populations, particularly children (WHO, 2018; La Merrill *et al*., 2020).

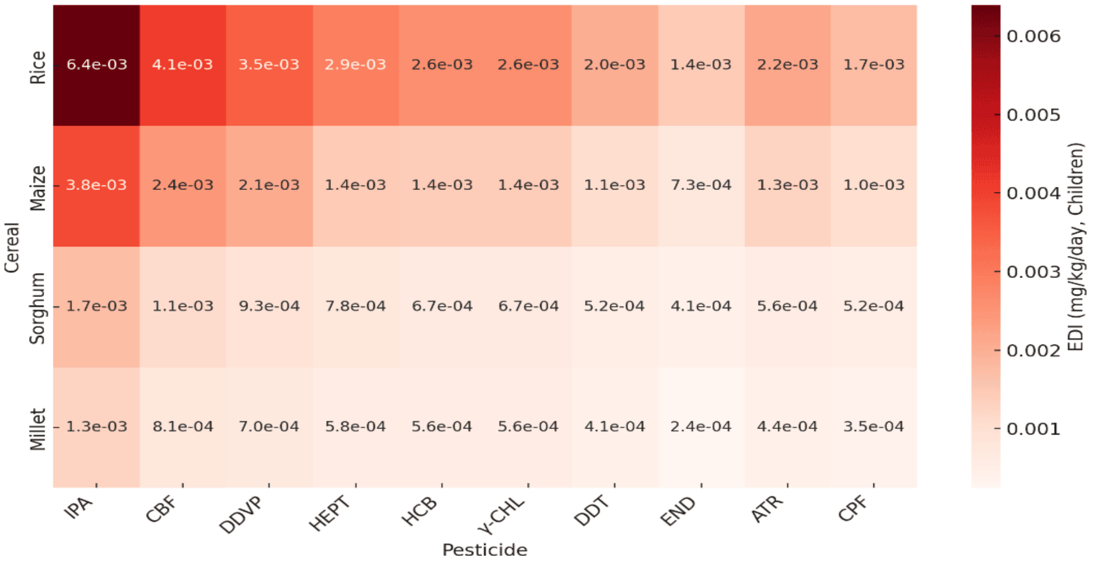

Figure 2: Estimated Daily Intake of Contaminants in Bali

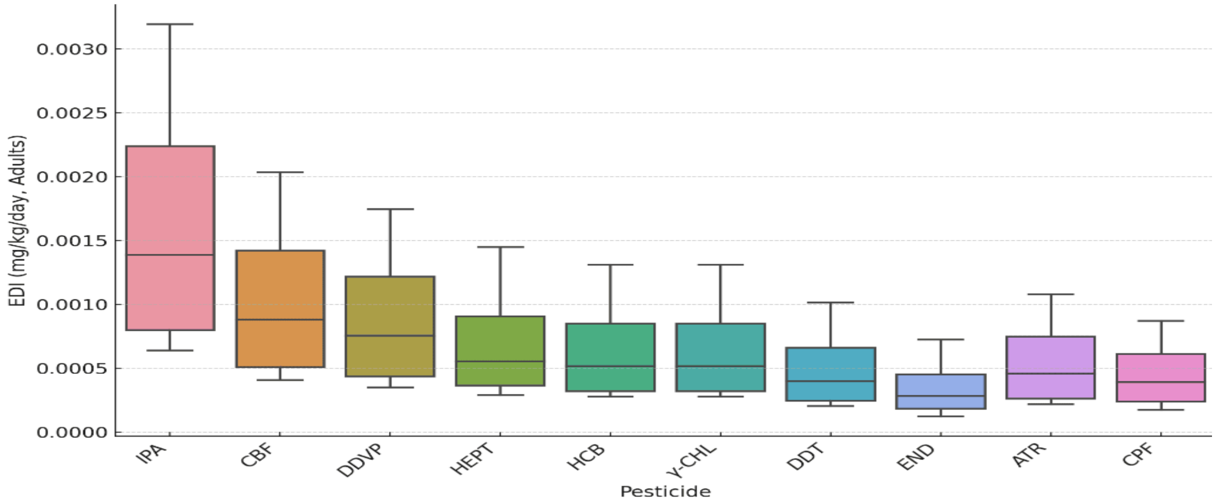

Figure 3: Estimated daily Intake of Contaminants in Bali LGA

In Gassol (Figures. 4 & 5) this study reported the highest pesticide exposures among the three LGAs. Children consuming rice recorded EDIs of 0.0077 mg/kg/day for IPA, 0.0049 mg/kg/day for CBF, and 0.0042 mg/kg/day for DDVP, nearly double the values observed in Kurmi. Maize also showed elevated EDIs of 0.0047 mg/kg/day for IPA and 0.0032 mg/kg/day for CBF. Heatmaps revealed dense clustering of residues across rice and maize, reflecting a rigorous pesticide-oriented farming system. Adults showed correspondingly high exposures, with boxplot medians for IPA and DDVP in rice at 0.0018–0.0024 mg/kg/day, and upper-quartile values reaching 0.0039 mg/kg/day, signaling significant chronic intake. The combination of organophosphate toxicity and persistent organochlorines such as DDT (0.0026 mg/kg/day in rice) and HCB (0.0035 mg/kg/day) suggests the likelihood of severe neurodevelopmental, endocrine, and carcinogenic risks, particularly for children (Ndjouenkeu *et al*., 2019; Costa *et al*., 2020; Coker *et al*., 2021).

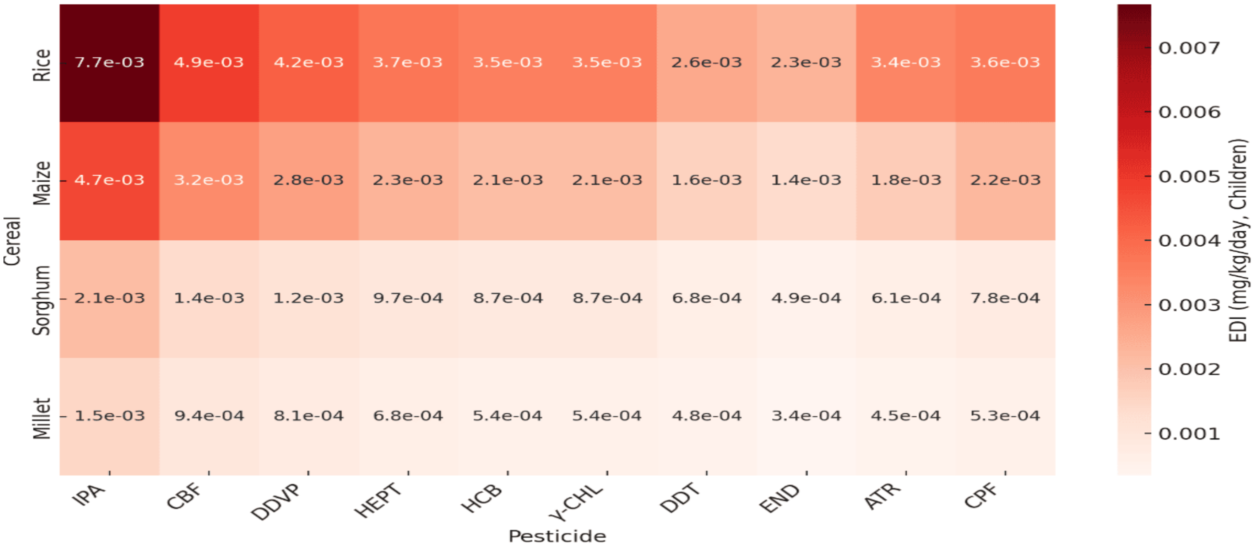

Figure 4: Estimated Daily Intake of Contaminants in Gassol

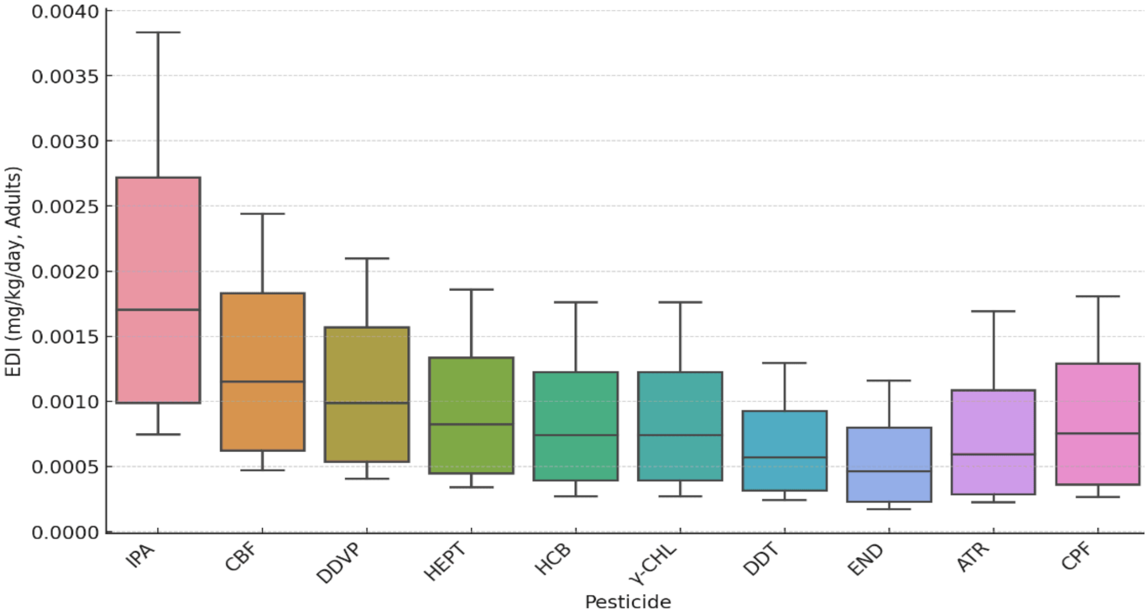

Figure 5: Estimated Daily Intake of Contaminants in Gassol LGA

In Kurmi LGA (Figures. 6 & 7) which exhibited comparatively lighter contamination, children's EDIs for rice were 0.0038 mg/kg/day for IPA, 0.0024 mg/kg/day for CBF, and 0.0021 mg/kg/day for DDVP, while millet and sorghum ranged from 0.000085 to 0.0011 mg/kg/day, the lowest among the three LGAs. Adults showed lower boxplot medians of 0.00018–0.00122 mg/kg/day across cereals. Heatmaps indicated fewer residue clusters, reflecting limited pesticide application in predominantly subsistence farming. Despite lower overall exposure, persistent organochlorines such as DDT (0.0011 mg/kg/day in rice), HCB (0.0014 mg/kg/day), and heptachlor (0.0014 mg/kg/day) remain in cereals, signaling long-term chronic exposure risks (WHO, 2018; Osman *et al*., 2019; La Merrill *et al*., 2020).

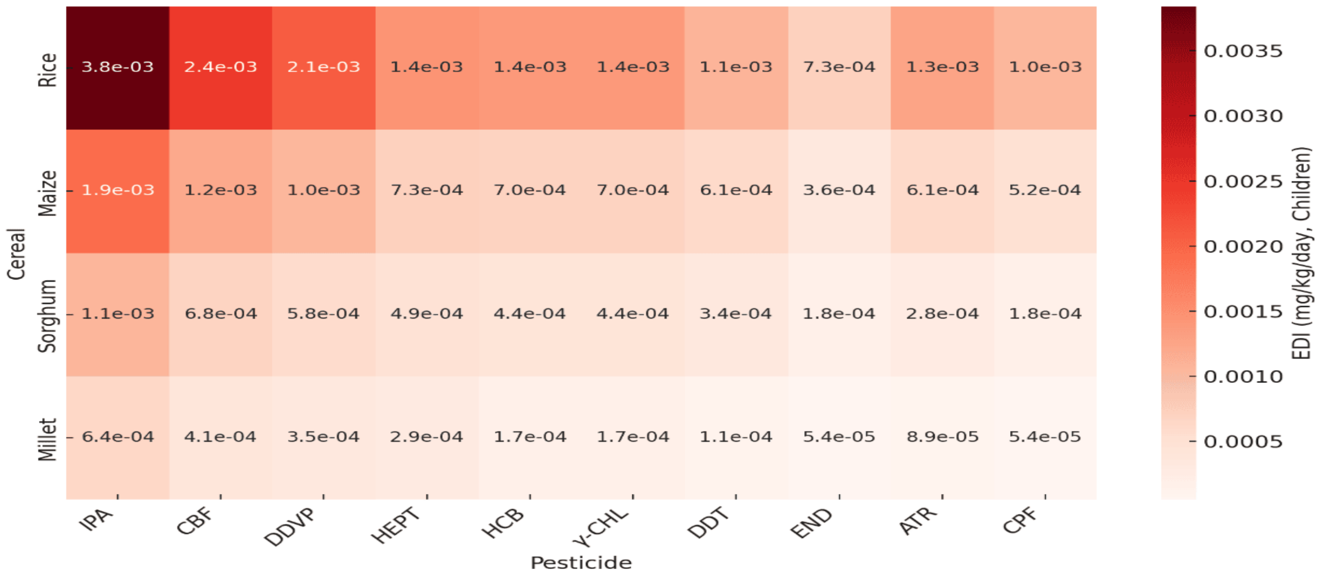

Figure 6: Estimated Daily Intake of Contaminants in Kurmi

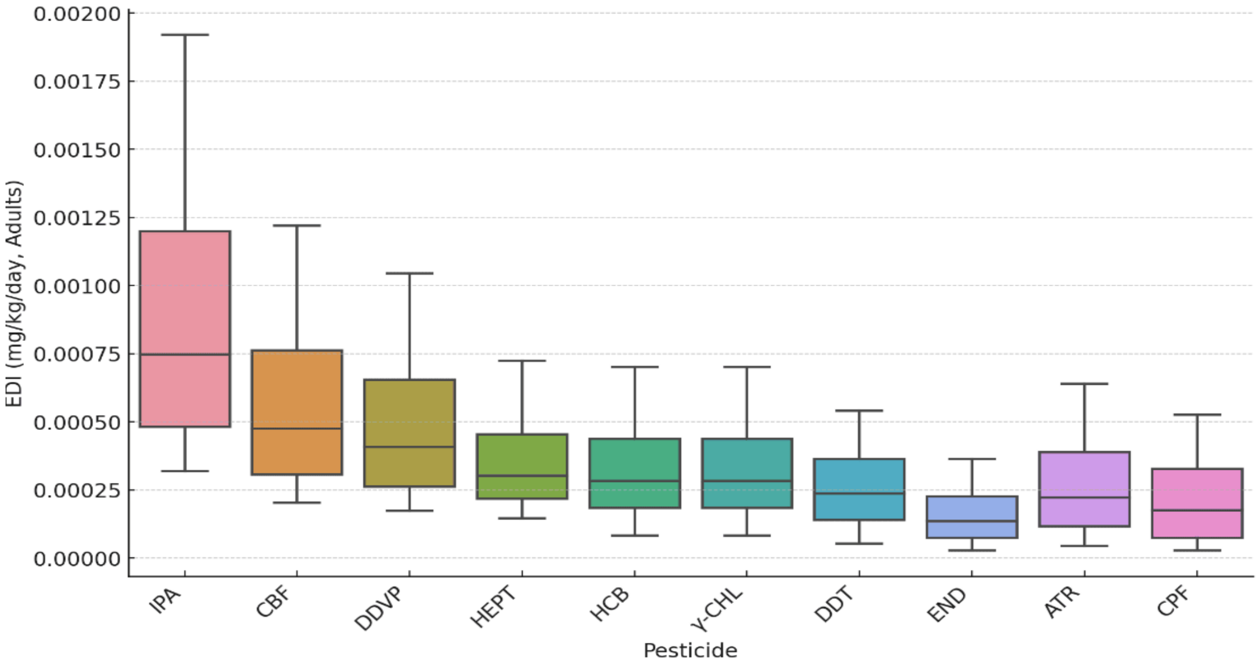

Figure 7: Estimated Daily Intake of Contaminants in Kurmi LGA

Across the three LGAs studied, pesticide exposure follows a clear gradient of Gassol > Bali > Kurmi, with rice consistently represented the main exposure pathway for both children and adults. Heatmaps show children in Gassol and Bali bear the highest EDIs, while adults' boxplots show cumulative risks, especially for organophosphates (DDVP, CPF) and organochlorines (HEPT, γ-CHL, DDT). Kurmi, even though comparatively lower, still shows measurable exposure to persistent pesticides. These findings show case the influence of agricultural intensity, pesticide practices, and cereal consumption on dietary risks, particularly children in Gassol and Bali facing the greatest acute and chronic health threats (Bempah *et al*., 2012; Osman *et al*., 2019; Costa *et al*., 2020).

3.2.2 Non-Cancer Risks (HQ and HI)

The non-carcinogenic risk assessment (HQs) and (HI), indicated an alarming levels of potential health risks (Figure 8). In Bali and Gassol, children's HI values for rice consumption exceeded 1.00, far above the safety threshold. For example, in Gassol, children's HI from rice reached 1.48×10^2, with organophosphates (DDVP and CPF) contributing over 60% of the cumulative risk. Similar results reported in dietary risk assessments across Africa, showed organophosphates frequently dominate exposure routes (Osman *et al*., 2019; Ndjouenkeu *et al*., 2019).

Toxicological implications of these findings are significant. Organophosphates can act as cholinesterase inhibitors, which would lead to neurotoxic effects such as developmental delays and cognitive damage in children (Costa *et al*., 2020). The elevated HI values therefore suggest a high possibility of neurodevelopmental and metabolic health effects among the exposed populations. Organochlorines, sch as, DDT, HCB, and γ-CHL, although less abundant, could contribute significantly to the cumulative risk due to their persistence and bioaccumulative potential. The endocrine-disrupting effects of these compounds, including their reproductive toxicity, have been well documented in both animal and human studies (La Merrill *et al*., 2020).

Even in Kurmi, where HI values were the lowest, all cumulative indices exceeded 1.0, indicating potentials for chronic non-carcinogenic health effects, corroborating findings from Ethiopian and Egyptian dietary exposure studies where even low-level pesticide residues in cereals could pose long-term health risks (Osman *et al*., 2019; Bedada *et al*., 2022). These results suggested that there is no safe margin of exposure for children in the study area, particularly those in Gassol and Bali where HI values were two orders of magnitude higher than the acceptable thresholds.

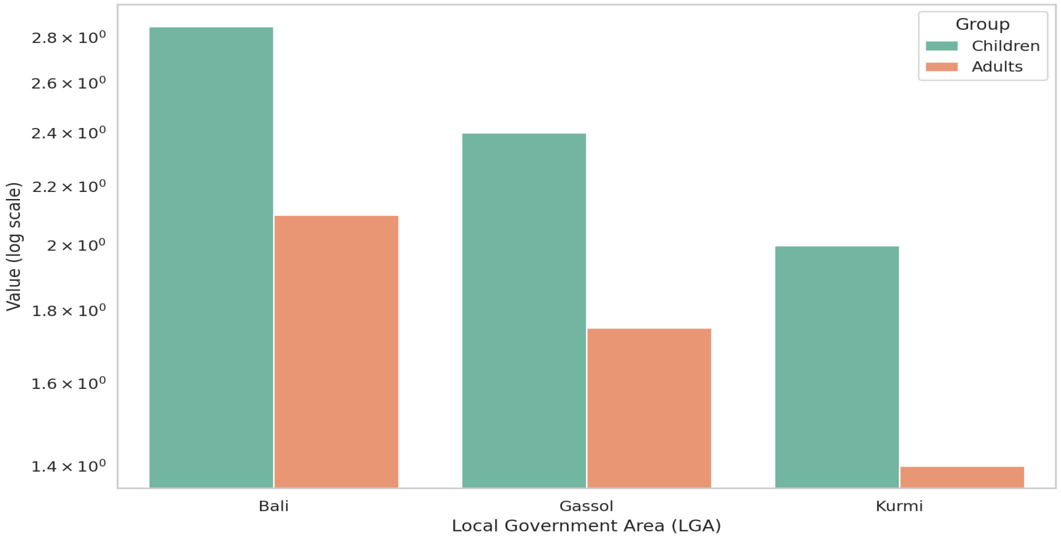

Figure 8: Non-Cancer Risks for both Adults and Children in the Three LGAs

3.3 Cancer Risks (ILCR)

The Incremental Lifetime Cancer Risk (ILCR) estimates highlighted the long-term public health burden associated with pesticide residues in cereals from Taraba Central (Figure 9). In Gassol, children's consumption of rice contaminated with heptachlor resulted in an ILCR of 9.2×10^{-4}, which exceeds the USEPA's upper acceptable risk limit of 1.0×10^{-4}. Similarly, Bali recorded ILCR values of 5.8×10^{-4} in rice, while Kurmi, though lower, still showed borderline exceedances (1.9×10^{-4}). These findings align with recent African studies showing ILCR values in cereals commonly surpass international safety benchmarks, particularly for organochlorines (Osman *et al*., 2019; Bedada *et al*., 2022).

The persistence and bioaccumulative properties of organochlorines such as DDT, HCB, and heptachlor amplify their carcinogenic potential. Epidemiological studies have linked these compounds to increased risks of endocrine-related cancers, including breast and liver cancers (WHO, 2018; La Merrill *et al.*, 2020). The exceedance of ILCR benchmarks in Bali and Gassol therefore points to a significant long-term cancer risk for populations chronically exposed to contaminated cereals.

From a regulatory perspective, these results demand urgent intervention. Strengthening residue monitoring in cereals and enforcing maximum residue limits (MRLs) in line with Codex Alimentarius standards is critical. At the same time, farmer education on integrated pest management (IPM) and adoption of less hazardous alternatives could reduce pesticide dependency. Consumer-level interventions, such as thorough washing, parboiling, and milling, which have been shown to reduce residues by up to 50% (FAO/WHO, 2021), could also provide immediate mitigation. Without these interventions, the dietary burden of pesticide residues in Taraba Central may continue to escalate, disproportionately affecting children and vulnerable households.

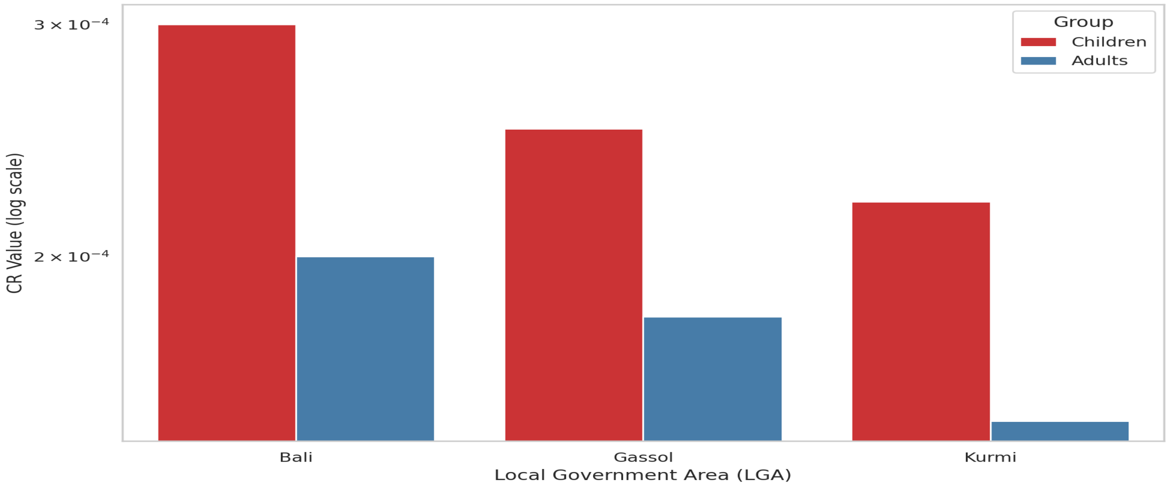

Figure 9: Cancer Risks for both Adults and Children in the Three LGAs

4. Conclusion

This study assessed pesticide residues in cereals consumed within Taraba Central, focusing on three LGAs: Bali, Gassol, and Kurmi. The Estimated Daily Intake (EDI), Hazard Quotient (HQ), Hazard Index (HI), and Cancer Risk (CR) values demonstrated clear spatial variation. Children consistently exhibited higher exposure levels than adults, reflecting their lower body mass and higher food intake relative to body weight. Rice emerged as the cereal with the highest contamination load across all LGAs, followed by maize, while millet and sorghum consistently presented lower residue levels. A clear contamination gradient was observed (Gassol > Bali > Kurmi), with Gassol recording the highest non-cancer and cancer risk estimates. Although Kurmi showed the lowest pesticide burden, legacy organochlorines persisted in its cereals, underscoring long-term risks of chronic exposure.

The findings highlight a pressing public health concern, particularly for children in Gassol and Bali, where cumulative exposure to multiple pesticide residues exceeds internationally accepted thresholds for both non-cancer and cancer risks. The detection of persistent organochlorines such as DDT, HCB, and heptachlor, alongside widespread use of organophosphates like DDVP and CPF, suggests that residents of Taraba Central are vulnerable to both acute and chronic health effects ranging from neurotoxicity to carcinogenesis. The study reinforces the urgent need to strengthen food safety monitoring systems in Nigeria, where current regulatory frameworks may not sufficiently address pesticide misuse and its dietary consequences.

5. Recommendations

1. Policy and Regulation: Regulatory agencies should intensify enforcement of maximum residue limits (MRLs) and phase out the use of highly hazardous and persistent pesticides. Regular surveillance of food commodities in both rural and urban markets is critical.

2. Farmer Education: Targeted training programs are needed to improve farmers' knowledge of integrated pest management (IPM), safe pesticide application, and the risks of over-application.
3. Public Awareness: Consumers should be educated on safe food handling practices, including thorough washing, milling, and processing of cereals to reduce pesticide residues before consumption.
4. Health Surveillance: Periodic biomonitoring of pesticide residues in blood, breast milk, and urine of high-risk populations (children, women of reproductive age) should be instituted to track exposure trends.
5. Future Research: Further studies should include longitudinal assessments of pesticide exposure and health outcomes, as well as mitigation studies evaluating natural detoxification strategies during cereal processing.

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