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Seasonal Dynamics of Organochlorine Pesticide Residues in Fruits and Vegetables and Associated Health Risks in North-Western Nigeria

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ABSTRACT

The persistence of banned organochlorine pesticides (OCPs) in agricultural systems remains a major concern for food safety, environmental sustainability, and public health in developing countries. This study assessed the seasonal variation and health risks associated with organochlorine pesticide residues in selected fruits and vegetables sold in Kaura Namoda, Zamfara State, North-western Nigeria. A total of 120 fruit and vegetable samples (watermelon, pineapple, cucumber, cabbage, and lettuce) were randomly collected from local markets across four quarters between December 2024 and October 2025, representing both dry and wet seasons. Pesticide residues were extracted using the QuEChERS method and quantified using gas chromatography–mass spectrometry (GC–MS). The results revealed that multiple OCPs, including lindane isomers, DDT and its metabolites, heptachlor, aldrin, and dieldrin, were detected in most samples. Residue concentrations were significantly higher during the dry season compared to the wet season ($p < 0.05$), indicating a strong seasonal influence on pesticide persistence and accumulation. A health risk assessment based on estimated daily intake, target hazard quotient (THQ), and hazard index (HI) revealed that children were more vulnerable, with THQ values for DDT and HCH exceeding unity during the wet season. The hazard index values for both children and adults were greater than one in both seasons, indicating potential non-carcinogenic health risks associated with long-term dietary exposure. Although most detected residues were below established maximum residue limits, the combined exposure poses environmental and public health concerns. The findings highlight the continued use or environmental persistence of banned pesticides and emphasise the need for strengthened regulatory enforcement, farmer education, and sustainable pest management practices to reduce contamination of food crops and protect ecosystem and human health.

Keywords: Pesticides; Residues; Fruit and Vegetable; Seasonal Variation; Food Safety; Health Risk Assessment; QuEChERS; Maximum Residual Limit; Hazard index; Kaura Namoda; GC-MS.

1. Introduction

The global demand for fruits and vegetables has increased significantly due to rapid population growth and rising awareness of their nutritional benefits. However, agricultural productivity continues to be constrained by pest infestations that cause substantial losses during cultivation and post-harvest handling (Adeolowa *et al*., 2019). To address these losses and ensure adequate yields that meet food demand, farmers worldwide rely heavily on pesticides as a key pest management strategy. Among these, organochlorine pesticides (OCPs) have historically been widely used because of their broad-spectrum efficacy, low cost, and ready availability (Shaibu et al., 2020). Common examples include dichlorodiphenyltrichloroethane (DDT) and hexachlorocyclohexane (HCH). Despite their effectiveness, the use of organochlorine pesticides has been prohibited or restricted in many countries due to their high environmental persistence, resistance to degradation, and strong tendency to bioaccumulate in living organisms. Regulatory agencies responsible for agrochemical control have banned OCPs for several years because of their documented adverse effects on human health, including carcinogenicity, endocrine disruption, and developmental abnormalities (Basal *et al*., 2025). Nonetheless, their continued detection in environmental and food matrices suggests ongoing or residual use.

Several studies have provided quantitative evidence of organochlorine pesticide residues in Nigeria, confirming their presence in farmland soils, water bodies, fruits, vegetables, and other food commodities across different regions of the country (Adeolowa *et al.*, 2019; Olayinka *et al.*, 2025; Shaibu *et al*., 2020; Shaibu *et al*., 2021; Salihu *et al*., 2025). These residues pose serious public health concerns because of their lipophilic nature and slow degradation rates, which facilitate accumulation along the food chain and prolonged human exposure (USEPA, 2020). Fruits are consumed daily by a large segment of the Nigerian population due to their dietary and health importance. The fruit supply chain in Nigeria often involves long-distance transportation from farmers to wholesalers and retailers before reaching consumers. As a result, fruits produced in southern Nigeria are frequently transported and sold in northern regions of the country (Santino *et al.*, 2025). This extensive distribution network increases the likelihood of pesticide residue transfer across regions and complicates traceability of contamination sources.

Zamfara State, located in north western Nigeria, includes Kaura Namoda as one of its major local government areas with a vibrant fruit market. A wide variety of fruits are sold by vendors in the main market, many of which are sourced from outside the state, including southern Nigeria. Consequently, consumers in this region may be exposed to pesticide residues originating from diverse agricultural zones.

Seasonal variation plays a critical role in pesticide application patterns, degradation rates, and residue levels in agricultural produce. Farmers may adopt different farming practices during the wet and dry seasons to meet market demand and manage varying levels of pest pressure, thereby influencing the type and quantity of pesticides applied (Samuel *et al.*, 2018). The two major seasons, wet and dry, are therefore crucial determinants of crop productivity, pest incidence, and chemical usage in agriculture (Sivakumar, 2023).

Previous studies have reported the presence of organochlorine pesticide residues in fruits and other foodstuffs in Nigeria (Salihu *et al*., 2025; Samuel *et al*., 2018; Santino et al., 2025). However, most of these studies focused on single-season assessments or general residue levels without detailed consideration of seasonal dynamics. Despite existing evidence of organochlorine pesticide contamination in food matrices, there remains a notable lack of data on the seasonal variation and dynamic changes in residue concentrations in fruits, particularly in northern Nigeria. This gap limits comprehensive risk assessment and the formulation of effective regulatory and mitigation strategies.

The present study aimed to assess the concentrations of organochlorine pesticide residues in selected fruits sold in Kaura Namoda, Zamfara State, Nigeria, and to compare residue levels between the rainy and dry seasons. The scope of the study included the evaluation of seasonal trends in pesticide contamination in fruits to provide insight into patterns of pesticide application and potential consumer exposure risks in the study area. It was hypothesized that the concentrations of organochlorine pesticide residues in fruits differed significantly between the rainy and dry seasons, reflecting variations in agricultural practices, pest pressure, and environmental degradation processes.

1.1. Study Objective

The objectives of this study are as follows:

1) Determine the seasonal dynamic concentration of organochlorine pesticide residues OCP in fruit and vegetable samples from Kaura Namoda, Zamfara, Nigeria.

2) Estimation of health risk from the concentration of organochlorine pesticide residues in the fruit and vegetables.

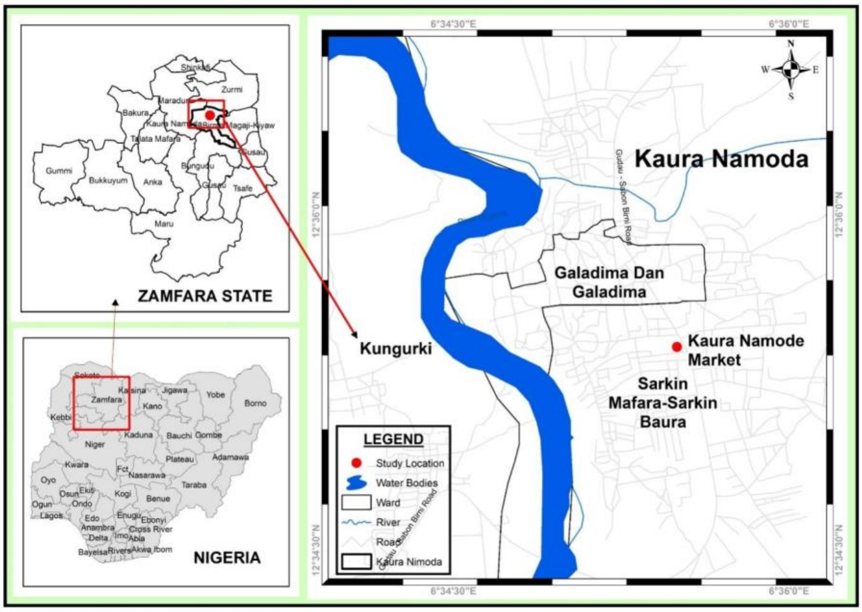
3) Comparison of the concentration of organochlorine pesticide residues in fruit and vegetables between the wet and dry seasons.

4) Comparison of organochlorine pesticide residues in the fruits and vegetable samples with the WHO maximum residual limit MRL.

2. Materials and Methods

2.1. Study Area and Sample Collection

Kaura Namoda, located in Zamfara North, is the capital of the state. The town is the commercial hub of that zone; it comprises five local governments. Other local governments within the zone obtained goods and services from the Kaura Namoda central market. The fruit and vegetables were collected randomly from Kaura Namoda central market from the different fruit and vegetable vendors (watermelon, pineapple, lettuce, cucumber, and cabbage). The total number of samples of fruits collected from the January to October 2025 was 120 samples. The five selected fruits are watermelon, pineapple, cabbage, cucumber, and lettuce were randomly collected quarterly, starting from December 2024 to October 2025. In both seasons, 60 samples were collected each (N=60). Each sample collected was placed in a clear polythene bag and labelled properly. the laboratory for analysis.



Map of Zamfara state, showing Kaura Namoda

2.2. Chemicals and Reagents

All the chemicals and Reagents, organochlorine pesticides standard, used were analytical grade. All the solvents were used as purchased from Sigma and CO. The laboratory precautions, such as washing of glassware and prevention of interference for quality control, were maintained.

2.3. Sample Preparation

All the samples were first rinsed with distilled water; thereafter, the samples were peeled to obtain the edible parts of the fruits, while the vegetables were blended without any peel. The homogeneous fruit and vegetable samples were stored for extraction.

2.4. Extraction of pesticide residues

Quick Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) Techniques were used for the extraction of pesticide residues from the sample's matrix. Acetonitrile, magnesium sulphate, and sodium hydroxide were used for the extractions. Magnesium sulphate was used to remove water, while the sodium hydroxide was used to increase its polarity (Shaibu et al., 2020).

2.5. Clean up of the extract

The sample extract was cleaned up to remove unwanted interference using primary and secondary Amin (PSA) (Shaibu et al., 2021). The extract was loaded in a pesticide cartridge and eluted with acetonitrile solvent, then evaporated to dryness with the aid of an evaporator. Thereafter, the extract was dissolved in acetonitrile solvent for Gas Chromatograph coupled with Mass spectrometer (GC-MS) for Analysis.

2.6. Instrumentation and condition of GC-MS.

GC-MS is an analytical instrument generally used for the identification and quantification. The Agilent technologist model of GC-MS used in the present experiment is an autosampler with a capillary column (HP5ms) with 30 mm length, 0.320 mm internal diameter, and 0.25 micrometre thickness. The program temperature was from 60 degrees and held at 5-minute intervals, and finally at 300 ^{O}C. A splitless injector was used for the sample injector; one microliter was purged, and a flow of 3.0 ml per minute was maintained while the pressure was also held at 150 degrees. The same procedure was used for the pesticide standard.

2.7. Health Risk Assessment

The health risk potential of the residues was estimated using the daily intake estimate, Hazard Quotient, and hazard index (HI) according to USEPA (2020).

The calculation: Estimate daily intake EDI = Mean Concentration of the residues (mg/kg) multiplied by food ingestion rate (Kg/day). EDI (mg/kg/bw/day) = (C×IR)/BW, where BW is body weight. Taking 0.345 kg/day for the injection rate for a 70 kg weight adult, and 0.232 kg/day and 15 kg for the injection rate and body weight, respectively.

Calculation of target Hazard Quotient (THQ) = $\frac{EDI}{RfD}$ where RfD is the reference dose in mg/kg/day of the residues, and EDI is estimated daily intake. If THQ > 1 signified a non-carcinogenic risk.

Hazard index (HI) = ∑THQ is the summation of THQs of pesticide residues; if the HI >1, it signifies a potential health risk (WHO, 2011).

2.8. Statistical Analysis

A random sampling method was used during the sample collection to ensure proper representation. ANOVA was also used to test for the significant difference. The results of the samples were expressed in mean ± standard deviation.

3. Results

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Table 1. Concentrations (mg/kg) of organochlorine pesticide residues in fruit and vegetables obtained from Kaura Namoda, Zamfara state

Sample	Quarters	α lindane	β lindane	Gamma lindane	Heptachlor	Aldrin	Dieldrin	DDT	p.p' DDE	p.p' DDT	PP' DDD
	Q1	0.0023± 0.002	0.005 ±0.001	0.202 ±0.002	0.233±0.013	0.125±0.005	0.231±0.011	0.079 ± 0.002	0.023±0.112	0.031±0.0021	0.025±0.0021
Watermelon	Q2	0.0033± 0.004	0.016±0.008	0.336±0.00	0.244±0.002	0.135±0.009	0.312±0.009	0.087 ±0.004	0.0110±0.005	0.041±0.013	0.035±0.007
	Q3	0.002±0.005	ND	0.005±0.031	0.048±0.006	0.045±0.046	0.030±0.008	0.009±0.131	0.002±0.0021	ND	0.007±0.0021
	Q4	ND	0.003±0.005	0.006±0.001	0.032±0.039	0.014±0.001	0.004±0.009	0.012±0.013	0.001±0.0032	ND	ND
	Q1	0.08±0.004	0.031±0.004	0.146±0.005	0. 193±0.002	0.197±0.0013	0.018±0.004	0.029±0.002	0.003±0.0O32	0.012±0.008	0.014±0.001
Pineapple	Q2	0.005±0.003	0.012±0.001	0.222±0.004	0.162±0.003	0.213±0.054	ND	0.073±0.006	0.002±0.0021	0.021±0.009	0.051±0.023
	Q3	0.002±0.002	ND	ND	0.032±0.012	0.034±0.003	ND	ND	ND	ND	ND
	Q4	0.001±0.004	0.003±0.001	0.001±0.003	0.011±0.003	0.001±0.017	0.011±0.001	0.231±0.0021	0.001±0.003	0.023±0.0021	ND
	Q1	0.026±0.004	0.021±0.003	0.123±0.002	0.182±0.005	0.411±0.002	0.115±0.006	0.136±0.0115	0.051±0.026	0.062±0.0034	0.023±0.005
Cucumber	Q2	0.031 ± 0.002	0.011±0.004	0.131±0.002	0.411± 0.011	0.171 ± 0.0012	0.251±0.0020	0.105± 0.014	0.038±0.008	ND	0.067±0.009
	Q3	0.007±0.002	ND	0.035±0.032	0.028±0.014	0.055±0.0017	0.040±0.006	0.013±0.023	0.006±0.004	0.005±0.0032	0.002±0.003
	Q4	ND	0.004±0.007	0.007±0.006	0.012±0.009	0.024±0.023	0.074±0.013	0.0046±0.007	ND	0,0035±0.006	0.0011±0.006
Cabbage	Q1	0.18±0.001	0.023±0.006	0.46±0.004	0. 13±0.002	0.47±0.041	0.17±0.002	0.077±0.007	0.018±0.006	0.028±0.0034	0.031±0.0023
	Q2	0.170±0.002	0.12±0.007	0.12±0.001	0.42±0.004	0.13±0.002	ND	0.095±0.008	0.023±0.008	0.031±0.009	0.041±0.006
	Q3	0.07±0.003	ND	0.011±0.003	0.03±0.005	0.04±0.051	ND	0.147±0.114	0.041±0.005	0.045±0.0012	0.061±0.0021
	Q4	0.03±0.003	0.003±0.003	0.001±0.001	0.21±0.004	0.11±0.014	0.011±0.002	0.067±0.011	0.036±0.021	0.031±0.001	ND
Lettuces	Q1	0.036±0.007	0.205 ±0.001	0.112 ±0.001	0.223±0.007	0.035±0.005	0.051±0.002	0.144±0.005	0.061±0.002	0.038±0.0023	0.045±0.001
	Q2	0.217±0.005	0.115±0.002	0.226 ±0.008	0.154±0.002	0.000±0.00	0.000±0.00	0.064±0.001	0.026±0.007	0.017±0.0116	0.021±0.003
	Q3	ND	0.021±0.008	0.005±0.032	0.248±0.004	0.255±0.046	0.040±0.004	0.049±0.009	ND	0.026±0.008	0.023±0.002
	Q4	ND	ND	0.007±0.001	0.232±0.009	0.224±0.001	0.054±0.005	0.034±0.002	ND	0.002±0.004	0.032±0.0023

Key: ND = not detected.

The table above shows the concentration of organochlorine pesticide residue in mg/kg and mean ± standard deviation using a statistical tool. Each quarter of the seasons were evaluated for the pesticide residues, for each sample after every three months starting from November 2024 to October 2025. Each samples of the quarters were treated independently for the pesticide residues and wet and dry seasons inclusively.

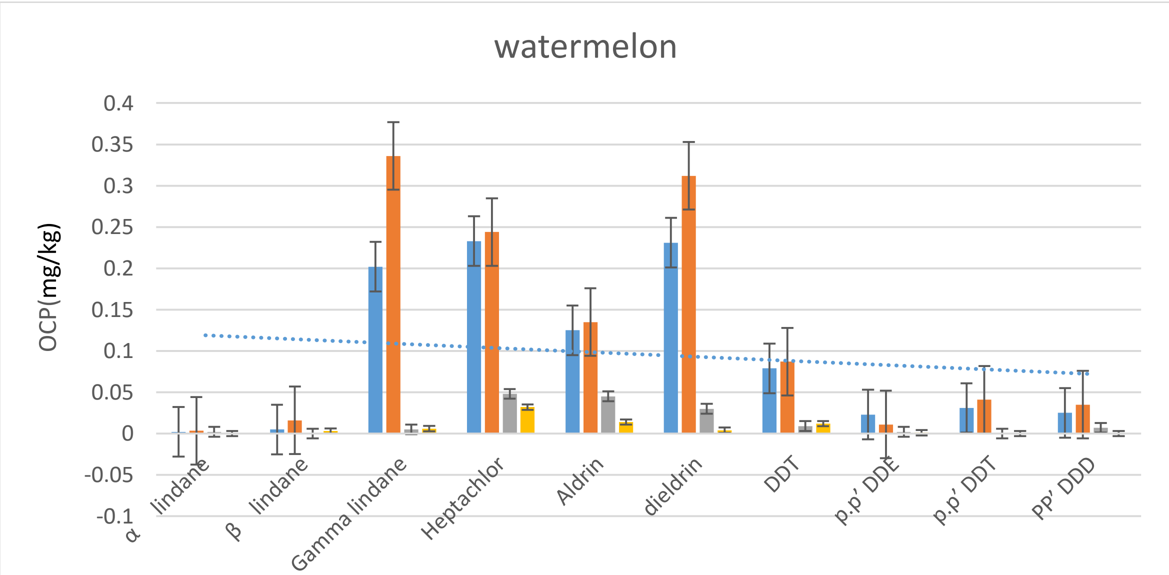

Figure 1. Seasonal variation in the concentration of OCP residues in watermelon samples in quarterly distribution

From the figure above, alpha lindane and beta lindane in each quarter have very low concentrations compared to gamma lindane, in the first and second quarters, which are dry seasons. Heptachlor, Aldine, and dieldrin showed a trend of higher concentration in the first and second quarters.

The trend in concentration indicated higher levels in the first and second quarters, which are mostly dry seasons. This may be some factors that determined the degradation of the pesticide residues, such as temperature and rainfall. This was reported by Fidelia *et al. (*2024). The seasonal determination of organochlorine pesticide residues in Lagos farmland.

The same trend of concentrations was observed in the other samples (Koleayo *et al.*, 2025). The low concentrations of alpha lindane in watermelon, maybe a result of the slow degradation, while the beta lindane degrades faster in the soil and is absorbed faster. Hexachlorocyclohexane (α-HCH), is an organochlorine pesticide residue that has been identified as a persistent organic pollutant POP and banned by the WHO because of its adverse effects on humans (Momta *et al*., 2024).

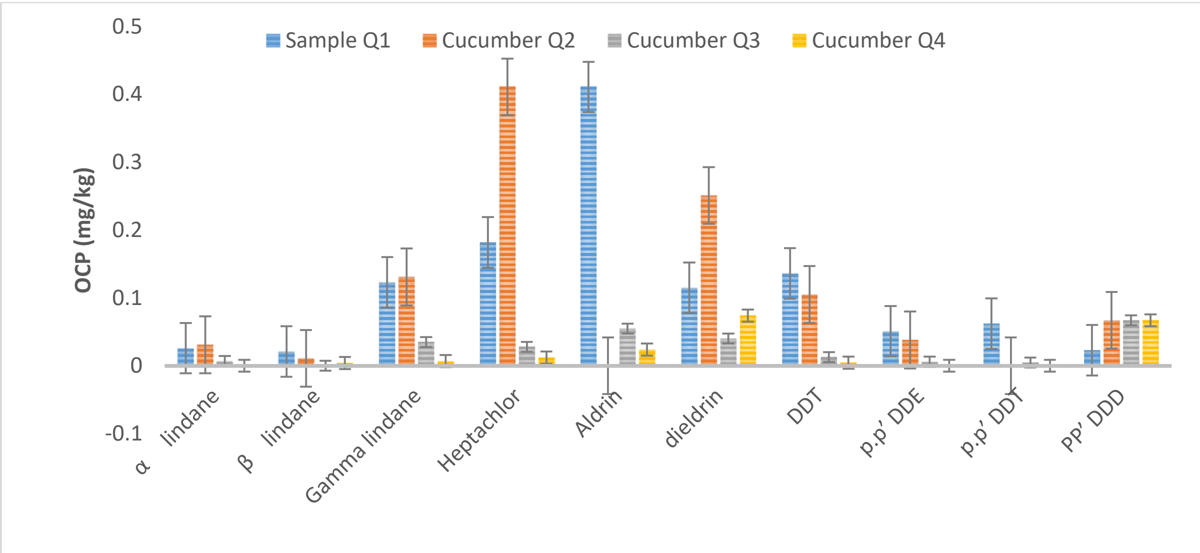

Figure 2. Seasonal variation of OCP concentration in the pineapple samples for quarterly distribution

From the chat above, it was reviewed that the trend of the concentration of the organochlorine pesticide residues is higher in the first and second quarter samples of pineapple than in the third and fourth quarters. But beta lindane has shown a lower concentration in all the quarters, while heptachlor shows demonstrated a higher concentration in the first and second quarters. Only pp' DDD tend to increase in concentration in the second, third, and fourth quarters. P, P'DDD is one of the products of DDT, especially when it breaks down in water or soil. It is always an indication that DDT has been used for pest protection (Madukasi & Azaka, 2025). These residues have a very slow degradation time and are highly persistent in the soil. DDT shows a high concentration in the first quarter and second quarter only, like the P, P'DDE, and P, P' DDD.

This trend of quarterly concentration of other fruit samples shows that the concentration of the organochlorine pesticide residues tended to be high in the first and second quarters, which are mostly the dry season, from January to May 2025. Several factors can be attributed to the high concentration of the residues in dry seasons. Among others, lack of rainfall tends to reduce the leaching of the pesticide residues in the soil and the low degradation rate.

The period encourages higher volatilisation because of an increase in heat, and the vapour may be redeposited on the plant (Fidelia *et al.*, 2024).

Sunlight is another factor that the absorption of organochlorine pesticides may depend on, this is because volatilisation depends on high temperature to vaporise from the plant surface. Organochlorine pesticides a fat-soluble compound called lipophilic; therefore, they accumulate more and persist longer in fatty tissues. Alpha lindane residue concentration (0.054 ± 0.001) in dry tends to be higher than the value obtained in the wet season (0.024 ± 0.021). alpha hexachlorocyclohexane may enter the body through direct eaten the contaminated fruit and vegetables, which may not undergo any processing and are eaten directly. It is fat-soluble residues that accumulate in the tissue, brain, and liver. Therefore, causes neurological effects, endocrine and carcinogenic effects (Omotehinwa *et al.*, 2025).

Table 2. Health Risk Assessment of OCP in Fruit and Vegetable Samples

	Seasons	**THQ (DDT)**	**THQ (HCH)**	**THQ (Heptachlor)**	**HI**
Children	Wet	1.44	1.23	0.86	3.53
	Dried	0.62	0.87	0.17	1.66
Adult	Wet	0.98	0.85	0.72	2.58
	Dried	0.86	0.76	0.23	1.85

THQ = target hazard Quotient, HI = Hazard index.

Table 2 shows the estimated health risk of organochlorine pesticide residue in the fruits for children and adults during the wet and dry seasons deduced from the quarterly samples collection of the fruit. In the wet season, the average DDT calculated is 1.44, and in the dry season is 0.62 in children. The target hazard quotient (THQ) is greater than 1 for DDT, which indicates its potential health risk if it is exposed for a long time in children, and the hazard index (HI) in both children and adults for DDT and HCL are 3.53 and 1.66, respectively. The hazard index is the sum of THQ of organochlorine pesticide residues in the fruit sample. Therefore, if the value is less than 1, it indicates that the contamination level is still safe and cannot pose a potential health risk to the consumers (WHO, 2011). On the other hand, if the HI is greater than 1 or equal to 1, it means that the combined pesticide residue contamination can possibly have advanced health effects on the consumer.

Therefore, the target hazard quotient of adults in both the wet and dry seasons is all below 1 (THQ<1). While only true in children where DDT target hazard quotients are above 1 in the wet season. Since DDT THQ is above 1, these indicate that the organochlorine pesticide residues in the fruit samples pose a health risk to the consumers (WHO, 2011).Organochlorine pesticide residues are named persistent compounds that accumulate in fat and cause various health issues, such as hormone imbalance, liver problems, reproductive defects, and nervous system damage (WHO, 2013).

3.1. Discussion

Organochlorine pesticide residues have been named as the most toxic and most persistent in the soil; only 1% is utilised when applied to the target plants. This indicated that the remaining 99% of the pesticide may be washed away by the rain, some evaporated by the sunlight, and others remain in the soil and subsequently absorbed by the plant. The degradation process of this pesticide takes a long time and thereafter releases its metabolites that are dangerous to humans (Praise *et al.,* 2025).

This compound is unique because of the high bonding dissociation energy between the chlorine atom and the carbon atom. This makes the organochlorine pesticide more persistent in the environment than other pesticides. Organochlorine pesticide structures are usually in three different structures, namely, aromatic rings, the DDT group, and HCH lindane. Polycyclic structures, Aldrin, dieldrin, and chlordane, and when chlorine is attached at multiple positions.

Researchers around the globe have identified organochlorine pesticide residues in water, soil, and other environmental matrices. The presence in food and other ecological matrices has been attributed to the indiscriminate use by the farmers despite the ban by regulatory agents such as the WHO and NAFDAC in Nigeria.

These organochlorine pesticide residues are lipophilic in nature; therefore, they are absorbed more in the fatty tissue and are subjected to biodegradation, hydrolysis, and oxidation processes. Direct exposure above the maximum residual limit MRL results in various health disorders, such as convulsions in children, liver damage, birth defects, and cancer (Gabriel *et al.*, 2025).

It has been identified that watermelon may retain residues from organochlorine pesticides such as alpha and beta lindane, DDT, and dieldrin. Despite the high water content in the watermelon, the results have shown that OCPs can still accumulate in the edible portion. The present research shows that from the first quarter to the fourth quarter, the edible portion of watermelon was contaminated with OCP residues. These results confirmed the work of Fidelia *et al*. (2024) that watermelon can absorb this persistent compound. The concentration of organochlorine pesticide residues is lower than the WHO maximum residual limit (MRL); continued exposure can have long-term health effects such as endocrine hormone disruption, weakness of the immune system, and weight loss in children and adults (WHO, 2013).

On the other hand, pineapple and cucumber were among the fruit samples analysed for the OCP residues. It was found that the edible parts of both fruits were contaminated with the OCP residues with DDT, Aldrin, dieldrin, and heptachlor, from the sources of OCP, maybe soil, irrigation water, and spray drift from farmers (Praise *et al.,* 2025). Pineapple tends to have a higher sugar content and a little fat content, which may support the absorption of OCP since lipophilic compound. Lettuce and cabbage were also contaminated with the OCP residues; they are very vulnerable to organochlorine pesticide residue, either from the soil, water or irrigated water. it is more vulnerable when the vegetable farmer sprays directly indiscriminately and is trapped by the leaf surface. Exposure to this vegetable can be dangerous, especially when the vegetables are eaten raw without processing. Some of the advanced health effects are long-term liver and kidney stress (WHO, 2011).

4. Conclusion

The concentration of organochlorine pesticide residues differed significantly across seasons and within each quarter. The concentration is higher during dry seasons, mostly in the first and second quarters. The fruit and vegetable samples obtained from Kaura Namoda showed the organochlorine pesticide residue concentration across the season, but mostly below the maximum residual limit MRL. Present finding points out that the presence of these residues in the fruit and vegetables shows the level of contamination of this pesticide in the environment and the fact that farmers are still using it despite the ban due to its persistence in the environment and the health effects.

5. Recommendations

1. Regulatory agencies, such as the National Food and Drugs Administration (NAFDAC) should create more awareness on the safe use of pesticides

2. There should be more routine monitoring of pesticide residues in fruit and vegetables during the rainy season in the other part of the country.

3. Farmers should be educated on the use of pesticides, when to use them, and how to use them.

Declarations

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Competing Interests Statement

Author has declared no competing interests.

Consent for publication

The author declares that he/she consented to the publication of this study.

Authors' contributions

Author's independent contribution.

Institutional Review Board Statement

Not applicable for this study.

Informed Consent

Not applicable for this study.

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References

Adeleye, A.O., Sosan, M.B., & Oyekunle, J.A.O. (2019). Dietary exposure assessment of organochlorine pesticides in two commonly grown leafy vegetables in South-western Nigeria. Heliyon, 5(6): e01895. https://doi.org/10.1016/j.heliyon.2019.e01895.

Akinlotan, O.O., Odika, I.M., & Okoye, C.O.B. (2025). Levels and health risk assessment of organochlorine residues in vegetables from the confluence in Lokoja, North Central, Nigeria. Discover Public Health, 22(1). https://doi.org/10.1186/s12982-025-00530-9.

Bansal, O.P. (2025). Pesticide residues in vegetables and fruit: A review. International Journal of Current Science Research and Review, 8(4). https://doi.org/10.47191/ijcsrr/V8-i4-18.

Gabriel, K.O., Ahmad, T.M., & Patience, B.U. (2025). Consumer awareness regarding pesticide residue in selected markets in Ilorin, Kwara State. Research Square. https://doi.org/10.21203/rs.3.rs-6820432/v1.

Fidelia, I.O., Olamide, F.H., Miriam, N.I., Arnold, G.U., Iyanuoluwa, A., Mojeed, F., Precious, A., Azeemah, J., & Olufunke, O. (2024). Occurrence and seasonal variation of organochlorine pesticides in selected vegetable farmlands in Lagos State, Nigeria. Environmental Analysis, Health and Toxicology, 39(2). https://doi.org/10.5620/eaht.2024013.

Koleayo, O.O., Amos, L.O., & Adebayo, L.O. (2025). Organochlorine pesticide residues and associated health risks in Nigerian rice samples: Implications for food safety and environmental policy. Global Journal of Environmental Science and Sustainability, 2(1): 84–98. https://doi.org/10.69798/62628184.

Madukasi, E.I., & Azaka, L.K. (2025). Sustainable food security: Pesticide residues and heavy metals accumulation in Ugu vegetable grown in Atani, Anambra State. In Charting a Resilient Future: Climate Change as a Catalyst for Sustainable National Development Proceedings of the 5th International Conference (FESCON 2025).

Mosudi, B.S., Adeoluwa, A.O., John, U., Onehireba, M.O., Philemon, O.D., Miracle, T.S., & Waidi. (2020). Dietary risk assessment of organochlorine pesticide residues in maize-based complementary breakfast food products in Nigeria. Heliyon. https://doi.org/10.1016/j.heliyon.2020.e05803.

Momta, P.N., Marcus, A.C., & Uzamere, O. (2024). Risk assessment of pesticide residues in vegetables cultivated in selected farmlands in Kaa Community, Ogoni, Rivers State, Niger-Delta. Faculty of Natural and Applied Sciences Journal of Scientific Innovations, 5(3).

Omotehinwa, F.H., Aremu, M.O., & Onwuka, J.C. (2025). Pesticide handling practices and residue levels in yams and cassava across Nasarawa South, Nigeria.

Praise, E.I., Obemeata, E.O., Helen, I., & Aroloye, O.N. (2025). Pesticide residue in cucumber-exposed plants and its associated effects on soil nematode population. Advances in Modern Agriculture, 6(2). https://doi.org/10.24294/ama3196.

Salihu, A.M., Okotubu, W., Shaba, E.Y., Idris, S., Gwadabe, N.K., & Adedokun, K.A. (2025). Determination of organochlorine and synthetic pyrethroid pesticide residues in fresh pepper from selected farmlands in Edozhigi, Gbako L.G.A., Niger State, Nigeria. Journal of the Chemical Society of Nigeria, 50(3): 584–592.

Samuel, O.A., Samuel, S.A., Olayinka, A.I., Joshua, I.O., Mayowa, A.A., & Abiodun, F.A. (2018). Multi-residue levels of persistent organochlorine pesticides in edible vegetables: A human health risk assessment. Journal of Agricultural Chemistry and Environment, 2.

Santino, O., Diana, A., Giuseppe, D.A., Salvatore, B., Francesca, D.G., & Silvia, O. (2025). Quantification of pesticide residues in fruit and vegetable samples in Sicily (Italy) and assessment of health risk. Journal of Food Composition and Analysis. https://doi.org/10.1016/j.jfca.2025.108573.

Shaibu, M., Suleiman, M.A.T., Lafia-Araga, R.A., & Salihu, S.O. (2020). Study of organochlorine pesticide residue levels in fresh and dried tomatoes from selected farmlands in Zamfara State, Nigeria. International Journal of Engineering Applied Sciences and Technology, 5(8): 91–96.

Shaibu, M., Sunday, M., & Zayyanu, I. (2021). Assessment of hazard index of organochlorine pesticide residues in soil and fresh tomatoes from selected farmlands in Gusau, Zamfara State, Nigeria. International Journal of Advanced Research in Biological Sciences, 8(12). https://doi.org/10.22192/ijarbs.2021.08.12.013.

Sivakumar, J. (2023). Rejuvenation of pesticide polluted soil from the isolated microbial FloDra of an agricultural field. Asian Journal of Science and Applied Technology, 12(1): 25–37. https://doi.org/10.51983/ajsat-2023.12.1.3421.

USEPA (2020). Hexythiazox human health risk assessment.

WHO (2011). Generic risk assessment model for indoor and outdoor space spraying of insecticides.

WHO (2013). Consolidated ARV guidelines 2013. https://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/.

World Health Organization (2005). Fruit and vegetables for health: Report of the Joint FAO/WHO workshop on fruit and vegetables for health, 1–3 September 2004, Kobe, Japan. World Health Organization. https://iris.who.int/handle/10665/43143.