***Original Research Article***

**Assessing the profile and health risk associated with organochlorine residue contaminants in marketed packaged spices in Abuja, Nigeria**

**ABSTRACT**

**Study Design**: Experimental in laboratory study.

**Place and Duration of Study:** This study was conducted at Advanced Chemistry Laboratory – SHESTCO in Sheda-Abuja and Analytical Laboratory, Port Harcourt, Rivers State, Nigeria

**Aim:** This study determine the occurrence of organochlorine pesticide (OCP) residues in marketed and consumed spices in the Federal Capital Territory, Abuja, and assessed their human health risks.

**Methodology:** The eleven sampled brands of spices procured from the Abuja markets were extracted and cleaned up using the Quick, Easy, Cheap, Efficient, Rugged, and Safe (QuEChERS) method. Organochlorine pesticide residue (OCPs) in the extracts were quantified using Gas Chromatography-Mass Spectrometry (GC-MS). Health risk assessment involved computing Estimated Daily Intake (EDI) and Hazard Quotient (HQ). The derived HQ values were compared to a threshold limit of 100%. Potential health hazards are indicated with HQ values higher than 100%.

**Result:** Nine out of the 11 samples (81.08%) were contaminated with the 20 OCPs, while nutmeg and chicken seasoning spices had 19 OCPs residue each as the PP’ DDD residue was below the detected level in them. Residual concentration of Delta-BHC (2.009 µg kg⁻¹) was the highest in Nutmeg (exceeding the EU standard of 0.010 µg kg⁻¹). Aldrin residual concentration was 1.743 µg kg⁻¹, and that of Beta-BHC in yellow pepper (0.686 µg kg⁻¹) exceeded the EU MRL limits. Gamma-Chlordane showed high levels in chicken seasoning (0.79 µg kg⁻¹) exceeding the 0.05 µg kg⁻¹ EU limit. Health risk assessment indicated that the EDI and HQ values for all OCPs residues remained below the individual Acceptable Daily Intake (ADI) and the HQ threshold of 100 respectively, suggesting no long-term consumption risk. However, the HQ values for Heptachlor (65.06) and Aldrin (63.34) were relatively high, thus requiring attention.

**Conclusion:** Regulatory agencies need to intensify close monitoring of food commodities in Abuja, Nigeria to ensure food safety.

**Keywords:** Contaminants, QuEChERS, Gas-Chromatography Spectrophotometry, Organochlorin, Residue, Regulation.

**Introduction**

Spices play a crucial role in culinary practices, offering both flavour enhancement and preservative properties. In addition to their ability to enrich the taste and complexity of dishes, spices also contain phytochemicals that provide potential health benefits and therapeutic properties (De La Torre *et al*., 2017; Majid *et al*., 2018). These products are typically packaged in convenient containers, making a wide range of flavors and bioactive compounds easily accessible to consumers. However, during cultivation, processing, packaging, and transportation, spices are susceptible to contamination by various harmful substances, including pesticides and heavy metals, which pose significant health risks to consumers (Nollet *et al.*, 2023; Balan *et al*., 2024).

One of the major contaminants of concern in food products, including packaged spices, is organochlorine pesticides (OCPs). These insecticides have been extensively used in crop protection to control insect pests in the field and post-harvest storage facilities due to their high effectiveness (Olisah *et al.,* 2020; Anjorin *et al*., 2025). However, OCPs are known to be persistent organic pollutants (POPs) that could accumulate in food chain or human tissues and leading to serious health risks (Fagotto, 2014). Chronic exposure to OCPs such as DDT, aldrin, dieldrin, heptachlor, and lindane has been linked to neurotoxicity, endocrine disruption, reproductive disorders, and carcinogenic effects (Webb, 2015; Randhawa *et al*., 2018; Chandra *et al*., 2021). These compounds can impair the nervous system, disrupt hormonal balance, and increase the risk of various cancers. Due to their toxicity and persistence, many OCPs have been banned or restricted globally (Thompson *et al*., 2019).

Despite regulatory bans, residues of OCPs continue to be detected in food matrices and water in Nigeria, including the Federal Capital Territory (FCT), Abuja (Fagbohun *et al*., 2023; Fagbohun *et al*., 2024). In food products such as packaged spices, these residues can pose severe health risks, including endocrine disruption, neurotoxicity, and carcinogenicity (Mina & Ljilja, 2025). To address these risks, international regulatory bodies such as the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the CODEX Alimentarius Commission (CODEX) have established Maximum Residue Limits (MRLs) and Acceptable Daily Intake (ADI) thresholds for pesticides in various foods, including spices (WHO, 2021). These regulatory limits are based on scientific assessments to ensure that contamination levels in food remain within safety thresholds. This study aims to assess the profile and health risks associated with organochlorine pesticide residue contaminants in packaged spices available in Abuja. Ensuring the safety of these products is essential due to their widespread use in cooking and potential exposure to harmful substances. By quantifying OCP residues in retail packaged spices, this study seeks to assess the level of risk posed to consumers.

**Materials and Methods**

From grocery stores in three selected Area Councils (AMAC, Kuje and Gwagwalada) of the FCT, Abuja. Bulked samples of 11 brands of spices were collected. The samples were labelled, swiftly transported to the Chemistry Advanced Research Centre, Sheda Science and Technology Complex (SHESTCO), Abuja, and kept in a -20 oC refrigerator pending analytical determination. Reagents used and sample preparation were done in the SHESTCO laboratory. The chemicals used were organochlorine pesticides (OCPs) standard, acetonitrile, acetone, and methanol, distilled deionized water. Sodium sulphate (Na₂SO4), Magnesium sulphate anhydrous fine powder (MgSO4), graphitized carbon black (GCB), primary secondary amine (PSA), disodium hydrogen citrate sesquihydrate (C6H6Na2O71.5H2O), trisodium citrate dehydrate (C6H2Na3O7.2H2O), sodium chloride (NaCl). All solvents are 99.90 % HPLC grade and purchased from Sigma-Aldrich USA. Solid phase extraction tubes (SPE tubes), ceramic discs, were purchased from Biocommune Limited, Hong Kong.

Sample preparation began by removing foreign matters such as stone and admixtures by handpicking. The samples were later pulverized with a laboratory blender (MasterChef) and then extracted and analyzed for the presence of OCPs in Spices. The Quick, Easy, Cheap, Efficient, Rapid, and Safe (QuEChERS) method and dispersive liquid-liquid micro-extraction (DLLME) were used for sample extraction. As previously described by Anastassiades *et al*. (2003), AOAC Official method (2007-01) was used for the extraction of the samples as follows.

Ten (10) grams of finely pulverized sub-sample was transferred into a polypropylene centrifuge tube (50 mL), and 10 mL of water was added to hydrate the samples. This was followed by the addition of 15 mL acetonitrile and the mixture was vortexed vigorously for 5 minutes using a vortex mixer. Further, 0.5 g disodium hydrogencitrate sesquihydrate, 1g trisodium citrate dihydrate, 4 g anhydrous magnesium sulphate, and 1 g sodium chloride were added, and the mixture was immediately vortexed for another five minutes, then centrifuged at 4500rpm for 5 min. At this stage, an optional low-temperature clean step was performed before dispersive-SPE for the most complex matrices, such as the spices. For this, an aliquot of the supernatant was transferred into a glass test tube and stored for at least 2 hours in a freezer (−20 oC). The extract was then separated from the precipitates by simple decantation. An aliquot of the extract was transferred into a solid-phase extraction tube containing 100 mg anhydrous magnesium sulphate, 75 mg graphitized carbon black (GCB), and 20 mg PSA per mL acetonitrile extract. The extract was eluted into a GC vial by the gravity method and acidified by adding 15µL of 5 % (v/v) formic acid in acetonitrile per mL of extract and kept in a freezer (- 20 o C) pending GC-MS analysis.

**Gas Chromatography-Mass Spectrophotometry**

Instruments and equipment for GC-MS determination: The 20 OCPs residue concentrations in the sample extracts were determined using an Agilent HP-5-60 to 325 oC GC column (30 m × 320 m x 0.25 m film thickness) attached to a gas chromatograph (6890N Agilent technologies) and a mass selective detector (Agilent 5975B) (GC-MS). The volume of the sample injected in the splitless mode was 1µL. The initial oven temperature was maintained at 100 oC for 2 minutes, then increased to 180 oC at a rate of 15 oC/minute, ramped up to 300 oC at a rate of 3 oC/minute, and held for 9 minutes. The carrier gas was helium with a flow rate of 0.8 mL/min. The operation mode of the mass spectrometer was electron impact ionisation with the use of automatic gain control. The storage window was programmed at full scan mode in the range of m/z 200–500, and the selected ion monitoring (SIM) mode was employed in acquiring data by Agilent Chemstation software.

**Analytical Method Validation Quality Control**

The glassware used was washed and rinsed with Milli-Q water and further with acetone before use. The effectiveness of the analytical procedure for the extraction of the OCs was evaluated by employing method blanks and matrix-spiked samples. Known standards of the OC compounds were added to selected sample aliquots that had been previously analysed and reanalyzed. The concentrations of OCs in the samples were quantified using the external calibration method.

Linearity of the Standard Curves: Calibration curves was produced for quantification. Linearity was observed all along the area of concentration studied, depending on the target pesticide chemicals. These ranges of concentrations were selected in function of the sensitivity of the gas chromatography towards each pesticide from the correlation coefficient (R2) of the linear regression. The calibration curves were obtained by injecting eight different concentrations of the pesticide standards in a range of 4-300 ng/ml. The R2 values obtained from the plot of known concentrations of OCs against their peak areas ranged between 0.9997 and 0.9999.

**Limits of Detection and Limits of Quantification**

The limit of determination (LODs) of the OC compound ranged from 0.03 to 0.20 ng g-1. Limits of detection (LOD) and limits of quantification (LOQ) of the method were measured by spiked serial dilution of working standards prepared for calibration curves and calculated by considering a value 3 and 10 times of background noise, respectively. LOD was determined considering it as 3 times the signal-to-noise ratio, while LOQ was determined as 10 times the signal-to-noise ratio. This means that LOD and LOQ were determined as the lowest concentrations yielding a signal-to-noise (S/N) ratio of 3 and 10, respectively.

**Recovery Studies**

The spice sample was spiked with a solution containing a mixture of the 20 OC pesticide standards. A pesticide standard was spiked into a laboratory blank sample to give 0.25 mg/g, and recovery was based on 4 replicates. The spiked samples were left for 1 hour before extraction to allow the OCP residue to partition into the matrices, and the percentage recovery was obtained according to the following formula adapted from (Liao *et al*., 2018; Barriga- Vélez *et al*., 2023)

X 100

**Human health risk assessment**

An assessment of health risks was performed by comparing mean levels of contaminants with international guidelines (US EPA, 2000). The daily intake (EDI) of the 20 OCs pesticides and their mean concentration of the residues in the spices were estimated. The food supply value of spices in Nigeria used was 3.650 kg/capita/year according to the Food and Agriculture Organisation (FAO), 2000. The food supply value was divided by the number of days in the year (365 days). The result obtained was an intake of 0.01 kg/capita/day, which is the food ingestion rate (FIR) of spice in Nigeria. However, these assessments do not consider variables such as consumption rates and eating habits. Equation 1 was used for the calculation of the EDI (Antoine *et al.*, 2017).

…….Eqn. I

where

C = the dry weight concentration of the organochlorine pesticides in the spice in mg kg-1,

FIR = the daily FIR in kg/day, and BW is the reference body weight of 60 kg for an adult human of ≤20 years.

The hazard quotient (HQ) was regarded as the probable risk of undesirable health effects from pesticide mixtures to specify the long-term assessment of risk and was computed by dividing the EDI by the pertinent acceptable daily intake (ADI) and multiplying by 100, as shown in equation ii. (Silipunyo *et al*., 2017; Elgueta *et al*., 2020).

……….. Eqn. ii

It should be noted that ADI is the quantity of a specific chemical that can be ingested daily throughout a human's lifespan without substantial health risks (Verger, 2013).

**Statistical analysis**

The results obtained from the matrices were statistically analyzed through MS Excel and SPSS version 21. The elements of descriptive statistics of samples generated included mean, range, minimum, maximum, and standard deviation. The concentration of OC pesticide residues in spice samples was compared with the MRLs recommended by the European Union (2011). The MRLs of a food contaminant are the maximum concentration of its residue that is legally permitted to remain in food (FAO, 2002).

**Results and Discussion**

**3.1 Recoveries of Organochlorine Compounds**

**Table 1 shows the** percentage recoveries of each organochlorine compound for the recoveries. This ranged from 96.01 % (Alpha-Chlordane) to 99.15 % (Endosulfan II) while the mean was 98.14 ± 0.67, confirming how appropriate and suitable the separation protocol and the GC-MS analyses used. The amount of fortification used was 25 µg/kg. The linear regression's coefficient (R2) values were obtained from the plot of known concentrations of OCPs against their peak areas, which ranged between 0.9996 and 0.9998.

**Table 1. Percentage recovery of OCPs in herbal tea from Abuja, Nigeria**

|  |  |  |  |
| --- | --- | --- | --- |
| **Compound** | **Fortification concentration (µg/Kg)** | **Residue concentration (µg/Kg)** | **% Recovery** |
| Alpha-BHC | 25 | 24.02 | 96.58 |
| Beta-BHC | 25 | 24.13 | 96.82 |
| Gamma-BHC | 25 | 24.20 | 97.30 |
| Delta-BHC | 25 | 24.37 | 97.98 |
| Heptachlor | 25 | 24.32 | 97.78 |
| Heptachlor Epoxide | 25 | 24.43 | 98.22 |
| Gamma- Chlordane | 25 | 24.48 | 98.42 |
| Alpha-Chlordane | 25 | 24.02 | 96.14 |
| Endosulfan I | 25 | 24.54 | 98.66 |
| Endsulfan II | 25 | 24.71 | 99.34 |
| Endosulfan sulfate | 25 | 24.60 | 98.90 |
| P p'-DDE | 25 | 24.57 | 98.78 |
| P P'-DDD | 25 | 24.66 | 99.14 |
| P P'-DDT | 25 | 24.48 | 98.42 |
| Aldrin | 25 | 24.40 | 98.10 |
| Dieldrin | 25 | 24.57 | 98.78 |
| Endrin | 25 | 24.59 | 98.86 |
| Endrin aldehyde | 25 | 24.30 | 97.70 |
| Endrin ketone | 25 | 24.66 | 99.14 |
| Methoxychlor | 25 | 24.65 | 99.10 |

**Occurrence of the OCPs Residue in the Spices**

Table 2 presents the result of residual concentrations of organochlorine pesticides (OCPs) in various food spices sold in FCT, Abuja, highlighting widespread contamination as all the samples were contaminated at various levels of contamination with several compounds exceeding EU regulatory limits. The highest detected OCP concentration was Delta-BHC in nutmeg spice (2.009 µg kg⁻¹), surpassing the EU standard of 0.01 µg kg⁻¹ by a wide margin. These chemicals’ persistence and toxicity raise concerns about contamination from historical or ongoing illegal pesticide use in food production. Chronic exposure to Delta-BHC has been linked to neurological and endocrine disruptions. Conversely, the lowest detectable concentration was Endosulfan sulfate in garlic powder (0.001 µg kg⁻¹), well below the EU limit of 0.05 µg kg⁻¹, though its presence still indicates trace contamination. These findings emphasize the necessity for continuous monitoring, as even low pesticide residues can accumulate over time and pose health risks, particularly given the excessive Delta-BHC levels in nutmeg.

Among the detected OCPs, Beta-BHC concentration was relatively high in yellow pepper (0.686 µg kg⁻¹), black pepper (0.592 µg kg⁻¹), and cayenne pepper (0.589 µg kg⁻¹), all exceeding the EU standard of 0.01 µg kg⁻¹. Heptachlor epoxide was notably high in turmeric powder (0.851 µg kg⁻¹) and thyme leaves (0.582 µg kg⁻¹), exceeding the EU permissible limit of 0.02 µg kg⁻¹.

Aldrin contamination was particularly of concern in black pepper (1.743 µg kg⁻¹) and yellow pepper (0.86 µg kg⁻¹), both exceeding the permissible limit of 0.05 µg kg⁻¹. Gamma-Chlordane shows significant contamination across multiple spices, with the highest concentrations observed in fried rice seasoning (0.544 µg kg⁻¹), turmeric powder (0.66 µg kg⁻¹), and chicken seasoning (0.79 µg kg⁻¹), all surpassing the EU standard of 0.01 µg kg⁻¹. P, P’-DDE, a degradation product of DDT, was most concentrated in ginger powder (0.418 µg kg⁻¹), exceeding the EU threshold of 0.05 µg kg⁻¹. Dichlorodiphenyltrichloroethane was found highest in nutmeg seasoning at 0.054 µg kg⁻¹ violating the MRL of 0.05 µg kg⁻, ¹and lowest in turmeric and fried rice seasoning at 0.020 µg kg¹ within the MRL.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 2: Concentration of Organochlorine Pesticides Residue in food spices sold in FCT, Abuja** | | | | | | | | | | | | |
| **Target Compound (µg kg-1)** | **Garlic powder** | **Turmeric powder** | **Thyme leaves** | **Ginger powder** | **Curry powder** | **Chicken seasoning** | **Yellow pepper** | **Fried rice seasoning** | **Black pepper** | **Cayenne pepper** | **Nutmeg** | **EU Standard** |
| Alpha-BHC | 0.015 | 0.165 | 0.082 | 0.139 | 0.115 | 0.103 | 0.035 | 0.058 | 0.017 | 0.092 | 0.011 | 0.01 |
| Beta-BHC | 0.131 | 0.387 | 0.331 | 0.329 | 0.067 | 0.121 | 0.686 | 0.341 | 0.592 | 0.589 | 0.478 | 0.01 |
| Gamma-BHC | 0.007 | 0.096 | 0.002 | 0.038 | 0.02 | 0.016 | 0.02 | 0.009 | 0.034 | 0.01 | 0.027 | 0.01 |
| Heptachlor | 0.036 | 0.204 | 0.174 | 0.05 | 0.03 | 0.233 | 0.122 | 0.200 | 0.188 | 0.019 | 0.09 | 0.02 |
| Delta-BHC | 0.034 | 0.235 | 0.104 | 0.128 | 0.188 | 0.13 | 0.478 | 0.09 | 0.184 | 0.243 | 2.009 | 0.01 |
| Aldrin | 0.058 | 0.03 | 0.819 | 0.077 | 0.413 | 0.078 | 0.86 | 0.042 | 1.743 | 0.081 | 0.026 | 0.05 |
| Heptachlor Epoxide | 0.059 | 0.851 | 0.582 | 0.763 | 0.832 | 0.207 | 0.597 | 0.095 | 0.15 | 0.685 | 0.189 | 0.02 |
| Gamma-Chlordane | 0.44 | 0.66 | 0.526 | 0.721 | 0.048 | 0.79 | 0.046 | 0.544 | 0.423 | 0.585 | 0.292 | 0.01 |
| Alpha Chlordane | 0.038 | 0.02 | 0.028 | 0.182 | 0.039 | 0.129 | 0.022 | 0.037 | 0.044 | 0.363 | 0.175 | 0.01 |
| Endosulfan I | 0.221 | 0.236 | 0.208 | 0.038 | 0.24 | 0.197 | 0.16 | 0.021 | 0.038 | 0.061 | 0.085 | 0.05 |
| P,P’-DDE | 0.004 | 0.004 | 0.002 | 0.418 | 0.005 | 0.01 | 0.016 | 0.019 | 0.008 | 0.016 | 0.288 | 0.05 |
| Dieldrin | 0.002 | 0.001 | 0.006 | 0.051 | 0.016 | 0.024 | 0.014 | 0.011 | 0.009 | 0.053 | 0.191 | 0.05 |
| Endrin | 0.012 | 0.079 | 0.039 | 0.007 | 0.024 | 0.045 | 0.045 | 0.031 | 0.413 | 0.02 | 0.743 | 0.05 |
| P, P’-DDD | 0.08 | 0.105 | 0.002 | 0.01 | 0.016 | ND | 0.008 | 0.011 | 0.048 | 0.044 | ND | 0.05 |
| Endosulfan II | 0.157 | 0.006 | 0.061 | 0.083 | 0.011 | 0.019 | 0.047 | 0.01 | 0.008 | 0.131 | 0.39 | 0.05 |
| P, P’-DDT | 0.013 | 0.02 | 0.031 | 0.022 | 0.03 | 0.018 | 0.024 | 0.02 | 0.035 | 0.023 | 0.054 | 0.05 |
| Endrin aldehyde | 0.027 | 0.011 | 0.024 | 0.018 | 0.23 | 0.008 | 0.019 | 0.036 | 0.021 | 0.022 | 0.028 | 0.05 |
| Endosulfan sulphate | 0.001 | 0.002 | 0.004 | 0.003 | 0.004 | 0.012 | 0.006 | 0.004 | 0.002 | 0.017 | 0.005 | 0.05 |
| Methoxychlor | 0.021 | 0.022 | 0.025 | 0.007 | 0.022 | 0.02 | 0.04 | 0.008 | 0.064 | 0.066 | 0.017 | 0.01 |
| Endrin ketone | 0.042 | 0.027 | 0.045 | 0.02 | 0.045 | 0.021 | 0.048 | 0.057 | 0.058 | 0.042 | 0.024 | 0.05 |
| \*ND= Below detectable level | | |  |  |  |  |  |  |  |  |  |  |

Alpha-BHC, Beta-BHC, Heptachlor and Alpha-chlordane OCPs residue detected were above the EU MRL in all the eleven brands of the spices (100%) (Figure II). Endosulfan I was above the EU Limit in 10 out 11 spices i. e 81.81%, while the PP’-DDD, PP ’-DDT and Methoxychlor residues was above the MRL in just one out of the eleven spices analysed (9.09%). However, the Endosulfan sulphate residue was below the EU MRL level in all the 11 spices.

**Fig. 1: Percentage of brand of spices in Abuja, Nigeria with OCP residues above EU Maximum Residue Limit (MRL)**

Endrin and Endosulfan II concentrations were particularly high in nutmeg 0.743 µg kg⁻¹ and (0.39 µg kg⁻¹ respectively. Dieldrin was also most prominent in nutmeg (0.191 µg kg⁻¹). All these level exceeded the EU standards. Methoxychlor contamination surpasses EU permissible levels of 0.01 µg kg⁻¹ in black pepper (0.064 µg kg⁻¹) and cayenne pepper (0.066 µg kg⁻¹), This contamination level might be due to the using of OCPs during cultivation or in storage, The presence of the aforementioned chemical residues in the spices in Abuja, Nigeria raised concerns about the possible long-term exposure risks.

Figures 2 gave an overview at a glance of contamination burden and frequency in the 11 spices. The stalk bar-charts revealed that Gamma-Chlordane (5.070 µg/kg) and Heptachlor Epoxide (5.010 µg kg⁻¹) exhibited the highest cumulative concentrations among all OCPs analyzed. Together with Endosulfan I and Endosulfan II, these compounds accounted for more than 70% of the total OCP burden, highlighting their dominant presence in the spice samples. Endosulfan sulpate recorded the lowest concentration at 0.06 µg kg⁻¹, indicating minimal prevalence. Other OCPs such as Dieldrin, p,p'-DDE, Gamma-BHC, and p,p'-DDT also contributed marginally to the total contamination. The Pareto distribution emphasizes that a limited number of high-risk OCPs are responsible for the majority of contamination in seasoning spices within the region. This finding underscores the urgent need for focused regulatory interventions and continuous surveillance targeting these predominant contaminants to ensure food safety and public health protection.

**Figure 2: Contamination burden of 20 OCPs in different brands of spices sold in FCT, Nigeria**

Fagbohun *et* *al*. (2024) reported 100% of 20 OCPs contamination in cowpea grains sold in Abuja FCT. They reported high concentration of heptachlor epoxide (0.0554 µg kg-1) and endrin ketone (0.1574 µg kg-1) residue in the marketed cowpeas. These values corroborate with what was obtained in this current study. Another research conducted in Lagos State, South-West Nigeria, also confirmed the presence of banned organochlorine pesticide (OCP) such as DDT residues in herbal samples, with concentrations exceeding the established maximum residue limits (Ajoke, 2024). She reported heptachlor-epoxide residues in all herbal liquid samples, with concentration values ranging from 0.11 – 0.28 mg kg-1, which were above its EU MRL of 0.01mg/kg. Heptachlor ranged from non-detected to 0.67 mg kg-1. Aldrin ranged 0.12–0.99 mg/kg. These results obtained corroborate what was found in Abuja.

Adenuga *et al*. (2022) detected DDE, a Group 2B probable human carcinogen, in herbal tea in South West Nigeria at a concentration of 2.44 µL⁻¹. Furthermore, α-BHC was recorded at concentrations ranging from 0 to 4.64 µL⁻¹. Heptachlor and its isomers were detected at significantly higher concentrations, ranging from 12.11 to 24.70 µL⁻¹, exceeding the levels observed in the present study. Solid herbal medicines showed higher concentrations and health risk indices compared to liquid forms, indicating a need for improved processing techniques (Ajoke, 2024).

**Health Risk assessment**

The analysis of Estimated Daily Intake (EDI), Acceptable Daily Intake (ADI), and Hazard Quotient (HQ) for the detected organochlorine pesticides (OCPs) in food spices sold in FCT, Abuja, confirms that all EDI values remain below their respective ADI limits, ensuring that the estimated intake does not exceed permissible exposure levels. The HQ values for all detected OCPs are well below the threshold of 100, indicating that none of the analyzed pesticides pose an immediate or acute health risk at the current exposure levels.

Among the detected compounds, Gamma-BHC, Heptachlor, Aldrin, Heptachlor Epoxide, Endrin, p, p’-DDD, Endosulfan sulfate, and Endrin ketone exhibit relatively elevated HQ values. However, despite their higher values, none reach the critical threshold of 100, implying that while these compounds contribute to potential chronic exposure concerns, they do not pose an immediate toxicological hazard under normal dietary intake. For instance, in order of hierarchy, Heptachlor recorded the highest HQ value of 65.06, followed by Aldrin (63.33), indicating that while these values indicate a potential for long-term exposure risks, they do not exceed the critical hazard threshold. Endrin ketone and Endosulfan sulfate also showed HQ values of 17.72 and 17.99, respectively, reinforcing the need for continued monitoring. Conversely, OCPs such as Dieldrin, Endrin aldehyde, Methoxychlor, and P, P’-DDT exhibited relatively low HQ values, confirming that its toxicological concern remains low compared to other persistent OCPs.

**Table 3: Mean Concentration, and Health Risk Assessment of 20 organochlorine residues in Herbal teas in Abuja, Nigeria**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **OCPS** | **Burden (µg kg-1)** | **Mean (µg kg-1)** | **EDI** | **ADI** | **HQ** |
| Alpha-BHC | 1.356 | 0.071 | 3.34E-05 | 0.005 | 0.67 |
| Beta-BHC | 1.383 | 0.072 | 3.4E-05 | 0.003 | 1.13 |
| Gamma-BHC | 2.65 | 0.139 | 6.52E-05 | 0.0003 | 21.74 |
| Heptachlor | 2.643 | 0.146 | 6.51E-05 | 0.0001 | 65.06 |
| Delta-BHC | 2.607 | 0.153 | 6.42E-05 | 0.005 | 1.28 |
| Aldrin | 2.573 | 0.160 | 6.33E-05 | 0.0001 | 63.34 |
| Heptachlor Epoxide | 2.515 | 0.167 | 6.19E-05 | 0.0001 | 61.91 |
| Gamma-Chlorodane | 2.456 | 0.175 | 6.05E-05 | 0.0005 | 12.09 |
| α-Chlorodane | 2.016 | 0.097 | 4.96E-05 | 0.0005 | 9.92 |
| Endosulfan I | 1.978 | 0.164 | 4.87E-05 | 0.0005 | 9.74 |
| P,P’-DDE | 1.757 | 0.159 | 4.32E-05 | 0.005 | 0.86 |
| Dieldrin | 1.753 | 0.175 | 4.32E-05 | 0.02 | 0.22 |
| Endrin | 1.751 | 0.194 | 4.31E-05 | 0.0001 | 43.10 |
| P,P’-DDD | 1.739 | 0.217 | 4.28E-05 | 0.0002 | 21.40 |
| Endosulfan II | 1.659 | 0.237 | 4.08E-05 | 0.02 | 0.20 |
| P, P’-DDT | 1.502 | 0.250 | 3.7E-05 | 0.008 | 0.46 |
| Endrin aldehyde | 1.489 | 0.297 | 3.67E-05 | 0.02 | 0.18 |
| Endosulfan sulfate | 1.462 | 0.365 | 3.6E-05 | 0.0002 | 17.99 |
| Methoxychlor | 1.461 | 0.487 | 3.6E-05 | 0.006 | 0.599 |
| Endrin ketone | 1.44 | 0.72 | 3.54E-05 | 0.0002 | 17.723 |

The findings highlight the necessity for continued regulatory oversight and food safety interventions. While none of the detected OCPs exceed ADI or pose an immediate toxicological threat (HQ < 100), the presence of multiple OCPs with HQ values above 50 suggests the potential for cumulative long-term effects, necessitating stricter pesticide control measures in food spices sold in FCT, Abuja.

**Conclusion**

The findings revealed a substantial contamination burden, particularly for benzene hexachloride (BHC) isomers, cyclodiene pesticides, and chlordane compounds, which demonstrate high occurrence across various species. The lower contamination rate of DDT metabolites suggests a decline in their use or environmental degradation over time. However, the widespread presence of multiple OCPs highlights the need for stringent regulatory enforcement and continuous monitoring to mitigate health risks associated with chronic pesticide exposure. The study indicates that spices such as black pepper, yellow pepper, turmeric powder, nutmeg, and cayenne pepper contain notably high contamination levels for various OCPs, with most of them exceeding regulatory limits. This underscores the urgent need for stricter monitoring and regulatory enforcement to minimize pesticide contamination in food spices available in FCT, Abuja. The findings from this work are expected to give base information to policymakers, regulatory bodies, and future researchers.

## **Disclaimer (Artificial Intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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