Organochlorine Pesticide Residues (OCPs) in Agricultural Soils in Nigeria and Associated Health Risk Assessment: A Systematic Review

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ABSTRACT

Purpose: Soil is a major sink for contaminants, including organochlorine pesticide residues (OCPs) from anthropogenic activities. Despite global concerns over their health risks, Nigerian farmers continue to rely on OCPs to increase crop yield.

Methods: This study reviewed eight research articles on OCPs in Nigerian soils and their health risk assessment, covering Abuja FCT, Adamawa, Akwa Ibom, Lagos, Ondo, and Plateau states, published between 2012 and 2025. The review focused on extraction procedures, analytical methods, results, and conclusions. PRISMA 2020 guidelines were followed. Databases searched included Scopus, Web of Science, PubMed, ScienceDirect and AJOL (2012-2025) plus manual reference search. After duplicate removal (n=186 screened), 32 full-texts were assessed and 8 studies meeting inclusion criteria (Nigeria, soil, OCP quantification, 2012-2025) were included.

Results: All reviewed studies detected varying levels of OCP residues in soil and assessed associated health risks from consumption of crops grown on contaminated soils. Most concentrations were within EU/WHO Maximum Residue Limits (MRLs), indicating minimal immediate health risk. Mean concentrations were generally higher in the dry season than in the rainy season, except for dieldrin and heptachlor epoxide.

Conclusion: While OCP levels were largely below MRLs, long-term bioaccumulation could pose health problems. The authors recommend farmer education on proper pesticide application and promotion of environmentally friendly farming practices.

Keywords: Organochlorine pesticide residues, Soil, Risk assessment, Health quotient, Review, Nigeria.

INTRODUCTION

Organochlorine pesticides (OCPs) are a type of non-polar toxic chemicals that include carbon, hydrogen, and chlorine. These chemicals exhibit high levels of toxicity, volatility, persistence, and bioaccumulation (Maia et al. 2017; Zhao et al. 2021; Said et al. 2024). Being ubiquitous, hydrophobic, and resistant to degradation, they have a large potential to accumulate in soil, plants, and the fatty tissues of organisms (Kamalesh et al. 2023; Qu et al. 2015; Sharm et al. 2019). Organochlorine pesticides (OCPs), a widespread environmental danger, have also been classified among Persistent Organic Pollutants (POPs) due to their

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inability to break down in the environment. Originally created in 1884, these long-lasting chlorinated hydrocarbons were widely employed in agriculture from 1940s to 1960s (Kiran et al. 2019). Pesticide residues are deposits of pesticide's active ingredient, metabolites, or breakdown products that are left in an environment after application, spillage, or disposal. (Wondimu and Geletu, 2023). They are members of a class of agrochemicals that are frequently utilized in agriculture, families, and public health initiatives (Gereslassie et al. 2019; Wang et al. 2023). Organochlorine pesticides are among the most widely used pesticide compounds due to their effectiveness (Ajima, 2019; Gbarakoro, 2017). The widespread use of these chemicals increases the likelihood of their bioavailability. Since its introduction in the 1950s, especially in 1957 when Lindane was launched and advised for use due to the prevalence of cocoa pests and diseases in the country, the usage of organochlorine has increased in Nigeria (Adegbola et al. 2012).

The organochlorine pesticide residues include the following o,p' dichlorodiphenyldichloroethylene (o,p-DDE), p,p′ dichlorodiphenyldichloroethylene (p,p-DDE) 4,4'- dichlorodiphenyldichloroethane (p,p'-DDD),2,4'dichlorodiphenyldichloroethan (o,p'-DDD), 2,4'-dichlorodiphenyltrichloroethane(o,p'-DDT), 4,4'dichlorodiphenyltrichloroethane (p,p' DDT), dieldrin, endrin, aldrin, lindane, α-lindane, β-lindane, methoxychlor, endosulfan, endosulfan I, endosulfan II, endosulfan sulphate, heptachlor, heptachlor epoxide, α- chlordane, γ- chlordane, chlordecone, α- hexachlorocyclohexane (α-HCH), β-hexachlorocyclohexane (β-HCH), γ-hexachlorocyclohexane (γ-HCH), δ-hexachlorocyclohexane (δ-HCH), Hexachlorobenzene (HCB) and pentachlorobenzene. Air and water exchange, as well as post-depositional processes are impacted by various microenvironmental conditions present in soils and sediments. Soil contamination increases concerns about food security, biodiversity, and soil utilities as well as the off-site transport of contaminants through erosion brought on by wind and water. Such off-site transportation may have a detrimental effect on sink ecosystems and correlates to extra exposure pathways to soil toxins for humans and other non-target animals (Silva et al. 2019). The main environmental compartment that is exposed to various poisons, primarily due to human activities, is soil. These contaminants include organochlorine pesticides (OCPs), organophosphates, (OP) polycyclic aromatic hydrocarbons, (PAHs), heavy metals etc. which are detrimental to human health. In particular, compared to comparable interactions of pesticides and/or other matrices, OCPs develop strong interactions with soil because of their physical characteristics and this prevent them from being degraded, volatilized, or even leached but instead bind to soil organic matter (SOM) (Ibadov et al. 2017).

Nigeria, formally known as the Federal Republic of Nigeria, is a West African nation situated between the Atlantic Ocean's Gulf of Guinea to the south and Sahel to the north. It is 923,769 square kilometers (356,669 square miles) in size. It is the most populous nation in Africa and the sixth most populated nation in the world, with a population of over 236 million. It shares borders with Benin in the west, Cameroon in the east, Niger in the north, and Chad in the northeast. Nigeria is a federal republic made up of 36 states, six geopolitical zones, and the Federal capital Territory is located at Abuja. According to reports, Nigeria uses between 125,000 and 130,000 metric tons of pesticides annually to increase agricultural output and fight disease-transmitting vectors (Asogwa and Dongo, 2009). Residues are mostly found in the soil as a result of the careless and uncontrolled usage of these pesticides. (Masumbuko et al. 2024; Williamson et al. 2008; Addo et al. 2002; Crissman et al. 1994; Dinham 2003; Sibanda et al. 2000). Chemical pesticides are widely used by Nigerian farmers. (Madak et al. 2024; Bouwman et al. 2021).

Reliance on pesticides is difficult to sustain because of the unanticipated long-term detrimental effects on the ecosystem and human health in particular. Pesticide residues in food products provide direct health risks, whereas pesticide residues in soils can be eroded and leached, contaminating water in wells, rivers, and ponds (Chauhan et al. 2013). The US Environmental Protection Agency (US EPA) conducts human health risk assessments to examine potential health issues related to exposure to OCPs. (US EPA, 2002) The four steps of the EPA's risk assessment process are risk characterization, exposure assessment, dose-response assessment, and hazard identification.

This process helps the organization to develop guidelines for safe exposure levels and identify potential health risks associated with OCP exposure. (He et al., 2023) The Hazard Index (HI) is a numerical value used to assess potential health concerns related to exposure to one or more hazardous substances by

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quantifying the level of risk offered by a particular substance or combination of substances. The predicted exposure level to a chemical is typically compared to a toxicity threshold or reference dose (RfD) to determine HI. (US EPA, 2002).

The exposure level is deemed safe and the risk of negative health consequences is minimal if the HRI is less than 1, but the risk is deemed high if it is greater than 1. OCP contamination has consequently become a significant national and international issue due to its toxicity and long-term risks to human health and environment. Chemical pollutants can be inhaled, ingested, or come in touch with the skin (Abbasnia et al. 2018; Lv et al. 2024). Pesticide exposure can occur through non-dietary methods such unintentional soil ingestion, dust inhalation, and skin contact, or through dietary methods like consuming pesticide-contaminated food (Ogbeide et al. 2016). Among other non-carcinogenic and carcinogenic effects, these exposures may result in endocrine system disruption, immune system suppression, neurological damage, cancer, and mortality in both adults and children. (Sharma et al.; Taiwo 2019). Brain, kidney, leukemia, lymphoma, and breast cancers have all been linked to exposure to OCPs (Infante and Weichenthal, 2007; Arrebola et al. 2025; Attaullah et al. 2018). Certain organochlorine pesticides are categorized as likely human carcinogens, including dichlorodiphenyltrichloroethane (DDT) and its metabolites, aldrin, and heptachlor and its metabolite (US EPA, 2014). There have been reports of severe health effects, including headache, vertigo, nausea, vomiting, seizures, reproductive problems, neurotoxicity, hypertension, cardiovascular illnesses, and cancer. (ATSDR, 2007; Mittal et al. 2013) Additionally, research has indicated that extended exposure to metals and pesticides raises the risk of Parkinson's disease in persons with a family history of the illness (Ratner et al. 2014). Additionally, a study that assessed plasma concentrations in both men and women found that those with high levels of OCPs were almost three times more likely to experience cognitive impairment in the future than those with low concentrations (Lee et al., 2016). Recent studies have reported OCPs in vegetables (Akinlotan et al. 2025; Osuala et al 2024; Daniel et al. 2021) water, soil, sediment,(Mica et al. 2025; Udoekpo et al. 2024; Dan-kihiya et al. 2023; Adetunji et al. 2020; Abiola et al. 2019; Aiyesanmi and Idowu, 2012) plant, fish, and animal samples (Essumang et al. 2009; Idowu, 2013; Akan et al. 2014; Nwankwo et al. 2025). The aim of this study is to review the organochlorine pesticides residues in Nigerian Soils and their potential health risks.

Organochlorine Pesticide Residues, OCPs

OCPs are synthetic materials with limitless chemical stability. They are considered serious environmental contaminants that lead to ecological instability globally. (Aikpokpodion et al. 2012). Due to their hydrophobic nature and exceptionally high adsorption coefficients, several OCPs can be adsorbed and firmly attached to soil particles through agricultural processes (Egbe et al. 2021). After adsorption, they remain in the soil's surface layers without descending the soil profile, and their half-lives range from months to years (Joseph et al. 2020). According to Taiwo (2019), they belong to the following chemical classes: cyclohexanes, chlorinated cyclodienes, chlorodiphenylethanes, and chlorinated benzenes. These substances belong to the class of persistent organic pollutants (POPs) with significant environmental persistence because of their long half-lives (DT50), which range from 60 days to 12 years in soils and sediments (Jayaraji et al. 2016; Aktar et al. 2009). They can cling to fatty tissues in both human and animal bodies due to their lipophilic nature. OCPs may be found at higher concentrations in specific tissues, such as the liver or kidney, due to their lipophilic nature, which results in bioconcentration (Sparaling et al., 2016). Another way that their lipophilicity enhances their environmental persistence is by their capacity to accumulate in soil, plants, and sediment.

Soil

The main environmental compartment that is exposed to various poisons, primarily due to human activities, is soil. Among these, organochlorine pesticides (OCPs) pose a serious threat. Soil is often the main source of contaminants released into other media since it is a medium of direct contact exposure. The amount, location, and kind of soil sample collection will consequently have a major influence on the risk assessment. Within that depth range, the sample depth should be carefully chosen and suitable for the exposure pathways and pollutant transport routes that are of concern.(EPA, 1987a) If a depth interval is deliberately selected, a

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random procedure for selecting a sampling point can be created. An evaluation of surface exposures will be more accurate if samples are taken from the shallowest depth that is practically feasible rather than, say, zero to two feet. Subsurface soil samples, however, are essential if the site has agricultural uses now or in the future, if chemical leaching to ground water is a concern, or if there is a chance of soil disturbance.

The fact that soil (or other solid materials) is usually diverse makes representative sample collecting difficult and sample compositing almost impossible. This is one of the main obstacles in sampling soil. As a result, obtaining sufficient data to calculate an exposure concentration may require collecting a large number of soil samples. Composite samples can be used to hide hotspots for contamination as well as areas with low concentrations of contaminants. They are sometimes obtained to provide a more homogenous sample of a particular area.

Summarized monitoring data can be used to predict current exposure concentrations in soil if concentrations are assumed to remain constant over time. Such an assumption could not be appropriate for some chemicals and places where leaching, volatilization, photolysis, biodegradation, wind erosion, and surface runoff may finally reduce chemical concentrations. Soil monitoring data and site parameters should be carefully examined in order to identify situations when considerable source depletion is anticipated. Generally speaking, data from random sampling programs or samples from grid networks with equal spacing can be considered indicative of concentrations across the site. Nevertheless, sampling procedures at many sites are restricted to identifying hotspot regions or soils that are obviously polluted. Samples from places where direct contact is impracticable (e.g., where a steep hill or dense vegetation prohibits current access) should not be considered when determining current exposure concentrations for direct contact pathways. Similarly, the depth of the sample should be considered and surface soil samples should be evaluated separately from subsurface samples if direct contact with surface soil or breathing in dust carried by the wind are potential exposure pathways at the site. When contamination is dispersed unevenly throughout a site, hotspots—areas of elevated contamination in comparison to other parts of the site—may develop. If a hotspot is near an area that is used or visited more frequently due to site or demographic considerations, exposure to that region should be assessed separately. The area across which the activity is expected to occur should be considered when averaging the monitoring data for a hot spot. (EPA, 1987a)

Extraction Techniques used for soil samples

Various extraction and clean-up techniques for pesticide residues from soils have been reported in the literature since the 1990s. Some of them include;

Solvent Extraction;

Numerous studies have used solid-liquid extraction, which is the solvent extraction of organic analytes from solid materials, such as environmental soil and sediment matrices, prior to solvent evaporation. Conventional sample preparation techniques include solvent extraction methods including mechanical agitation through shaking (Vig et al. 2001; Garimella et al. 2000). Soxhlet extraction (Wobst et al. 1999; Fatoki et al. 2003) and ultrasonic solvent extraction (Banjoo et al. 2005) Mao et al. (2012) evaluated this extraction method almost ten years ago. They extracted DDT pesticides from soil matrices using five different organic solvents: 1-propanol, ethanol, and three petroleum ether fractions. Temperature, mixing speed, wash time, organic solvent concentration, and solution-to-soil ratio were found to have a significant effect on the extraction process. Ye et al. (2013) found that 100 mL of petroleum ether (60–90 °C), a washing period of 180 minutes, a mixing speed of 100 r min−1, a solution-to-soil ratio of 10:1, and a washing temperature of 50 °C were the optimal parameters for removing DDTs from soil.

Soxhlet Extraction, (SE)

Soxhlet extraction (SE) is still recommended as a second effective conventional extraction method for volatiles and semi-volatile analytes from solid matrices by the US Environment Protection Agency (EPA), Food and Drug Administration (FDA), and Association of Official Analytical Chemists (AOAC) Standards Methods (Well et al. 1999). The target chemical is concentrated in the distillation flask after multiple cycles

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

and significant solvent consumption in regular SE, which usually takes at least 8 hours. SE is performed with either a single solvent, usually toluene or dichloromethane (DCM), or a mixture of solvents, such as hexane/acetone, pentane/DCM, etc.

Because the sediment and soil sample contains sulfur, cleanup frequently involves the use of silica gel, Florisil ($MgSiO_3$), and a reaction with Cu or tetrabutylammonium sulfite to eliminate the sulfur (Luque et al. 2014). Twenty-five years ago, Lopez-Aviala et al. were among the first to evaluate the SE approach for identifying several OCPs in soil and sediment samples (Lopez et al. 1994). Specifically, 250 mL of DCM:acetone (1:1) exchanged by 50 mL of hexane were selected as the extraction solvents following a 24-hour extraction interval prior to GC–ECD analysis with GC/MS confirmation. Additionally, individual OCPs were cleaned from specific interferants using silica gel (SG) (Ibadov et al. 2017). Since then, the SE extraction method has been used in many studies, including comparisons with alternative extraction methods. Despite being time-consuming, requiring a lot of organic solvents, and difficult to alter and automate, SE is nevertheless utilized in this field today—possibly due to the device's simplicity and the lack of specialist training required (Lu et al. 2020; Tesi et al. 2020). For example, Xing et al. successfully extracted several HCHs (like α-HCH, β-HCH, γ-HCH, and δ-HCH) and other DDTs (like o,p′-DDE, p,p′-DDE, o,p′-DDD, p,p′-DDD, o,p′-DDT, and p,p′-DDT) from surface soils prior to GC–ECD analysis using 150 mL of DCM as the extraction solvent in a 24-hour SE extraction procedure (Xing et al. 2019).

Ultrasonic Extraction (USE)

Ultrasonic extraction (USE) is another common extraction method that can be used to remove pesticides from soil samples instead of shaking flask extraction and regular SE. Since the extraction temperature and pressure are lower than usual, it is recommended for the detection of thermolabile analytes from soil samples. However, in general, USE requires a lot of solvent and an extra step for extraction and residue separation using filtration or centrifugation. Torr et al. identified OCPs and their metabolites from real soil samples using this technique in 2006 (Tor et al. 2006). The solvent's kind, amount, and sonication duration were all tuned. It was recommended that the soil matrices be extracted twice using 25 mL of a 1/1 v/v mixture of petroleum ether and acetone in addition to 20 minutes of sonication in order to obtain an adequate extraction efficiency. Pesticide recoveries from enriched soil samples ranged from 88% to 92%, with relative standard deviations frequently less than 6%. The time consumption was reduced by over 75% and 82%, respectively, when compared to the shake flask and SE procedures. Additionally, the solvent drop was more than 67% as compared to SE. Although USE is not frequently used to determine OCP extraction in soils, the results clearly demonstrated that USE could be used to extract OCPs from soils with solvent and time extraction to be scientifically reduced. Additionally, Ozcan et al. (2009) successfully developed a miniaturized ultrasonic extraction method for determining several OCPs in soil.

QuEChERS Extraction

The QuEChERS method was initially applied to remove pesticides from soils by Lesueur et al. (2008). Two years later, a QuEChERS-based technique was developed to identify nineteen OCPs in soil samples with different physicochemical properties. Recovery results showed significant agreement when the proposed method was compared with a tried-and-true procedure based on Soxhlet extraction. Because the extraction was cleaner, QuEChERS exhibited lower detection limits (Rashid et al. 2010).

The QuEChERS method has been used to extract pesticides from soils, either with or without sorbent cleanup. (Coldas et al. 2011; Correia-sa et al. 2012) Nineteen (19) OCPs in wet soil samples were successfully recovered using acetonitrile and liquid-liquid partition into n-hexane (Rashid et al. 2010). Yang et al. used this technique that same year to identify 38 pesticides in freeze-dried soil and sediment samples from a Chinese vegetable-growing region, including endosulfan I and II. They were successful in achieving good repeatability and low detection limits (Yang et al. 2010).

Modified Focused Ultrasound Liquid Extraction, FUSLE

Modified focused ultrasound liquid extraction, or FUSLE, applies high-power focused ultrasonic waves by

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submerging a micro-tip directly in the extraction mixture. FUSE has been successfully optimized for the simultaneous investigation of several pesticides, including POPs, in diverse matrices, including soils and sediments. During the optimization phase, the percentage of maximum power, extraction duration, number of cycles, extraction solvent, and sample volume were all evaluated (Wang et al. 2007). The FUSE method for calculating OCPs in soils was first mentioned in the literature by Flores-Ramírez et al. (2015). This team successfully validated FUSE by determining 13 OCPs using gas chromatography–electron impact–mass spectrometry (GC-EI-MS). Under optimum conditions, FUSE was carried out in triplicate for one minute at 60% irradiation power at 20 °C on a 1 g sample using 10 mL of hexane: DCM (75:25, v/v) as an extraction solvent. Florisil-filled columns were also utilized in a cleaning procedure. The results showed that FUSE was a useful and approachable technique for detecting POPs in soil (Flores-Ramirez et al. 2015). It might be regarded as an appropriate strategy even though there aren't many studies on the extraction of POPs from soils.

Analytical Method

Gas chromatography tandem mass spectrometry (GC–MS/MS) has become more popular in pesticide analysis in recent years. For the analysis of pesticide residues in different environmental media, a number of GC-MS multi-residue analytical approaches have been published. OCPs as volatile or semi-volatile compounds are usually determined by GC equipped with either electron-capture detection (ECD) or mass spectrometry (MS) detection, in contrast to the analysis of other POPs, which usually uses GC–MS/MS or liquid chromatography tandem mass spectrometry (LC–MS/MS) (Tor et al. 2009; Vera et al. 2013; Kim et al. 2019). In any case, it is challenging to extract many pesticides, including OCPs, from complex environmental matrices such soils due to their diverse physiochemical properties (Yang et al. 2010). Because of its superior sensitivity and resolution, low operating costs, and the fact that it requires less technical expertise to obtain reliable findings, GC-ECD is widely employed to detect OCPs. However, due to soil interferences and previously mentioned complicated matrices, GC-ECD usually yields false positive results. More selective methods, such as GC–MS or even GC–MS/MS, have been developed for the determination of OCPs in complex matrices in order to confirm and further determine the identity of pesticides. (Fatoki et al. 2003; Sanchez et al. 2004) For example, Liu et al. (2014) evaluated and compared two analytical methods for measuring 26 organochlorine pesticides: GC–ECD and GC–MS with negative chemical ionization (NCI). Although GC-ECD sensitivities for most of the compounds analyzed were higher than those observed with the GC-NCI-MS technique, the matrix interferences were clearly visible with GC-ECD. GC-ECD should be used cautiously in actual environmental sample analysis due to the possibility of false positives associated with these methods, which could result in an overestimation of the levels of these illegal compounds in the environment (Liu et al. 2014).

In particular, the LC method is less frequently used to detect OCP residues in soil matrices. In a 2006 article, Moreno et al. refined MAME in conjunction with SPME-HPLC-UV to determine OCPs in agricultural soil samples (Moreno et al. 2003). In order to quantify a small number of OCPs, rapid bioanalytic techniques such as enzyme-linked immunosorbent assays (ELISA) have been tested separately, referring to alternative methods to avoid or reduce the required clean-up steps, expensive instrumentation, and the use of large amounts of solvents (Muir et al. 2006).

This method was used by Shivaramaiah et al. (2002) to monitor DDT/DDE residues in soil samples. The ELISA result and the GC instrumental technique findings were contrasted. According to the findings, the suggested test might be a different analytical method for tracking DDE (Shivaramaiah et al. 2002; Hongsibsong et al. 2011). The recovery values calculated with the ELISA approach matched the GC results.

Health Risk Assessment for Organochlorine Pesticide Residue

Human Health Risk Assessment

Exposure Assessment: Calculates Average Daily Dose (ADD) in mg/kg/day for three pathways:

- ADDing: incidental soil ingestion (especially critical for children)

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- ADDderm: dermal contact with contaminated soil

- ADDinh: inhalation of soil particles and volatilized residues

Non-Carcinogenic Risk

Hazard Quotient (HQ) = ADD / RfD (Reference Dose)

Hazard Index (HI) = ΣHQ

If HQ or HI < 1, no appreciable non-cancer risk; if >1, adverse effects likely.

A health assessment includes a preliminary assessment of the potential threats that individual sites and facilities pose to human health. (ATSRD) The US Environmental Protection Agency (US EPA) conducts human health risk assessments to examine potential health issues related to exposure to OCPs. (US EPA) The four steps of the EPA's risk assessment process are risk characterization, exposure assessment, dose-response assessment, and hazard identification. This process helps the organization develop guidelines for safe exposure levels and identify potential health risks associated with OCP exposure. (He et al., 2023) The Hazard Index (HI) is a numerical value used to assess the potential health effects of exposure to one or more hazardous substances by quantifying the level of danger posed by a particular material. The hazard risk index (HRI) is a technique for assessing and conveying the level of danger associated with environmental pollutants such chemicals, pesticides, and heavy metals. (US EPA, 2002). When assessing the health hazards related to OCPs, both potential non-carcinogenic and carcinogenic health concerns were taken into account. These were computed using three basic standard indices: Estimated Daily Intake (EDI), Cancer Benchmark Concentration (CBC), and Health Risk Index (HRI). Estimated daily intakes (EDIs) of a pesticide residue and food consumption assumptions were used to evaluate long-term health risks to consumers. The EDI was computed by dividing the result by body weight after calculating the food consumption rate (kg/d) by the mean residual pesticide content (mg/kg) in the food of interest (Sosan and Oyekunle, 2017; Forkuoh et al. 2018). Each person consumes 46.4 g of vegetables daily. (WHO, 2012a; WHO, 2012b).

EDI = (F x Cr)⁄mean body weight (BW) (2)

where F is the food consumption data and Cr is the residue concentration in the food sample.

Health risk index (HRI) was calculated using Equation 3.

HRI = EDI⁄ADI (3)

This was done in accordance with the levels of OCP residues found in the food samples. A comparison was made between the estimated daily intake (EDI) and the established appropriate daily intake (ADI) (Wang et al. 2011; Lozowicka et al. 2013). The estimated daily intake was calculated by multiplying the residual pesticide content (mg/kg) by the food consumption rate (kg/day) and dividing the result by body weight. The Hazard Ratio (HR) for carcinogenic effects was calculated using the following formula, (Forkuo et al. 2018; Aamir et al. 2018).

Estimated Daily Intake⁄Cancer Benchmark Concentration (4)

The Cancer Benchmark Concentration (CBC) for carcinogenic effect is derived by setting the risk to one in one million due to lifetime exposure. The Oral Slope Factors (OSFs), 1 mg/ kg-day for the pesticides were obtained from USEPA (2014).

CBC = Risk × Body Weight⁄Consumption rate × Oral Slope Factor (5)

Where Risk is the maximum acceptable risk level (1×10^{-6}). The average body weight of Nigerian adults equals 60 kg while the Average body weight of Nigerian child equals 15 kg.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

Carcinogenic Risk

Incremental Lifetime Cancer Risk (ILCR) = ADD × CSF (Cancer Slope Factor)

USEPA acceptable range is 1×10^{-6} to 1×10^{-4}. Values $>1\times10^{-4}$ indicate high risk.

The likelihood that a person will get cancer as a result of lifetime exposure to a carcinogenic substance is represented by the incremental lifetime cancer risk (ILCR). Equations 7-8 were used to determine the ILCR, while equations 9–10 were used to calculate the ILCR for oral, dermal, and inhalation exposure pathways in accordance with the U.S. Environmental Protection Agency's standard models (US EPA 1997; Inam et al. 2016).

$$ILCR=ADD\times CSF \quad (7)$$

$$ILCR_{ingest}= C_{soil} \times (CSF_{ingest} \times 3\sqrt{BW/70}) \times IR_{soil} \times EF \times ED / BW\times AT \times CF \quad (8)$$

$$ILCR_{dermal}= C_{soil} \times (CSF_{dermal} \times 3\sqrt{BW/70}) \times SA \times FE \times AF \times ABS \times EF \times ED / BW \times AT \times CF \quad (9)$$

$$ILCR_{inhale}=C_{soil} \times (CSF_{inhale} \times 3\sqrt{BW/70}) \times IR_{air} \times EF \times ED / BW \times AT \times PEF \quad (10)$$

where, C_{soil} is the concentration of OCP in soil (µg/kg), ADD is the Average Daily Dose and CSF is the cancer slope factor. The predicted risks were ranked using the following ILCR classification: values.

Ecological Risk Assessment

Uses risk quotient (RQ) based on Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC):

TEC-HQ = Concentration / TEC

PEC-HQ = Concentration / PEC

TEC-HQ >1 indicates potential adverse effects; PEC-HQ >1 indicates frequent adverse effects on soil biota, earthworms and microorganisms.

Review of Organochlorine Pesticide Residues in Nigeria

The study "Assessment of organochlorine pesticide residues in agricultural soils of southern Nigeria and analysis of potential health risks" by Udoekpo et al 2024 revealed the presence of 13 organochlorine pesticide residues (including α-hexachlorocyclohexane (α-HCH), β-hexachlorocyclohexane (β-HCH), γ-hexachlorocyclohexane (γ-HCH), δ-hexachlorocyclohexane (δ-HCH), Hexachlorobenzene (HCB), o,p' and p,p' dichlorodiphenyldichloroethane (DDD), o,p′ and p,p′ dichlorodiphenyldichloroethylene (DDE), o,p′ and p,p′ dichlorodiphenyltrichloroethane (DDT), as well as α-chlordane and γ-chlordane) in soil samples from .Akwa Ibom state in Southern Nigeria. Thirty (30) composite samples totaling 150 grad samples (0.5 cm3 depth) were gathered, and 486 farmers were interviewed. Data was gathered via a structured questionnaire, in-person interviews with farmers, and soil sample. OCPs were extracted using a Soxhlet extractor and analyzed using gas chromatography combined with a mass spectrometer (GC-MS). The study's findings showed that OCP concentrations in the Oron agricultural zone varied from below detection limits (BDLs) for HCB, o,p'-DDE, α-chlordane, and γ-chlordane to 18.35 ± 13.83 µg/kg for α-HCH

With the exception of α-HCH in Oron and β-HCH in Etinan, where mean concentrations (± SD) were 18.35 ± 13.83 µg/kg, exceeding the 7.4 µg/kg MRL, all targeted OCPs were below the minimum risk levels (MRL) set by the US Agency for Toxic Substances and Disease Registry (ATSDR, 2021). For eating, dermal absorption, and inhalation, the Hazard Indexes (HIs) and Hazard Quotients (HQs) were all less than one (1), indicating typically modest hazards. According to the United States Agency for Toxic Substances and Disease Registry (US ATSDR), the carcinogenic risk assessment showed that the Incremental Lifetime

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

Cancer Risk (ILCR) values varied from 10^{-10} to 10^{-4}. The results of the source apportionment indicated that very few OCP congeners indicated recent use, while the majority came from the past. The majority of the organochlorine pesticide residues in the farms under study came from historical rather than recent use, and the scientists came to the conclusion that these residues posed very little health risk.

Abiola et al. (2019) found a significant concentration of pesticide residues on top soil samples in a study conducted in Ogbomoso, Ondo state, in western Nigeria, to evaluate the levels of contamination in soil samples from Wazo market. Incremental Lifetime Cancer Risk (ILCR) values ranged from 10−10 to 10−4, indicating a very low to low risk level. The study evaluated the impact of market activities on pesticide residues in Wazo market soil, including the sale and storage of agricultural products. In 2015, sampling was conducted in five distinct market sections during the rainy and dry seasons. Soxhlet extractor and GC-ECD were used for extraction and analysis, respectively. The study's findings showed that the top soil sample contained the following OCPs: α-BHC, β-BHC, heptachlor, Aldrin, γ-BHC, δ-BHC heptachlor epoxide, endosulfan I, p'p-DDE, dieldrin, endrin, p, p'-DDD, endosulfan II, p, p'-DDT, endrin aldehyde, endosulfan sulfate, and methoxychlor. The concentrations of α-BHC, β-BHC, γ-BHC, methoxychlor, and endosulfan sulfate were found to be above the allowable limit, with respective values of -0.0074, 0.0006, 0.8710, 0.01, and 0.008 mg/kg. The study found that, with the exception of dieldrin and heptachlor epoxide, the mean concentrations of pesticides were higher during dry season than during the wet season. The authors attributed this variation to the strong positive correlation observed between the pesticides and soil pH.

Another study carried out by Aiyesanmi and Idowu (2012) targeted at examining the contamination of farm soils by organochlorine pesticides sprayed on cocoa fields within the Central Senatorial District of Ondo State, Nigeria. 45 topsoil samples were taken from three distinct local government districts' cocoa farms. Organochlorine pesticide residues were extracted from soil samples using a Soxhlet extractor, and GC-MS was utilized for analysis. A few soil physicochemical properties, including pH, particle size, and organic matter, were also found to have the potential to influence the dynamics of the pollutants. Endosulfan I and Endosulfan II had the largest quantities of 350.10 mg/kg and 3.55 mg/kg, respectively, according to the study. . Heptachlor, Heptachlor epoxide, Aldrin, Deldrin, and the isomers of benzene hexachloride, α-BHC, β-BHC, δ-BHC, and ₌-BHC (lindane), were among the other organochlorine chemicals found. Only the organic matter content and the OCP measured in the soil over the entire study region showed a high significant ($p<0.05$) link, according to the correlation coefficients between soil physico-chemical parameters and the mean total organochlorine pesticide residues.

Findings from this research thus, provide information on the current and health risk residue levels of organochlorine pesticides in soil from this region with which future environmental performance on the use of pesticides on cocoa farms could be progressively monitored. The authors attributed the high occurrence of endosulfan I to its high content in the technical manufacture of endosulfan and its thermal stability unlike endosulfan II which is unstable and may slowly be converted to endosulfan I. They concluded that the high concentrations and frequency of occurrence of endosulfan I, endosulfan II, heptachlor epoxide and aldrin in the soil samples are of serious concern and may pose potential danger to human and soil organisms.

Dan-Kishiya et al. (2023) evaluated organochlorine pesticide residues in a field in Abuja, Nigeria, and found that the concentration levels of pesticides (Alpha Lindane, Beta Lindane, Heptachlor, Aldrin, DDT, and Endrin Aldehyde) varied significantly throughout the test period. 36 surface soil samples were collected from a farm in the Gwagwalada Area Council in Abuja, Nigeria, between January and September of 2020. Three subsamples were obtained from each quadrant and homogenized in order to obtain one sample per quadrant at depths of 0–15 cm. Organochlorine pesticide residues were extracted from soil samples using a Soxhlet extractor, and GC-MS was utilized for analysis. According to the study's results, month of May had the highest Endrin Aldehyde concentrations (45.932 mg/kg), while January had the lowest Aldrin concentrations (0.33 mg/kg). The maximum allowable limit of 0.05 mg/kg is well below the measured DDT levels. By revealing the presence and levels of organochlorine pesticide residues in Abuja's agricultural soils, this study emphasized the urgent need for efficient pesticide management and control techniques in the region. The authors recommended that less harmful replacements be employed and that the spread of these

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

dangerous compounds be promptly stopped in order to prevent further harm to the environment and human life.

Adetunji et al.' s 2020 study, "Organochlorine Pesticide Residues in Soil and its Potential Health Risk Assessment in Vegetables from Iyana-Iba Farm Settlement, Lagos State, Nigeria," measured the amounts of OCP residues in the soil and evaluated the potential health risk in vegetables from a Nigerian farm settlement. While vegetable samples of smooth pigweed (Amaranthus hybridus) and jute mallow (Corchorus olitorious) were taken seven and twenty-one days following pesticide application, twenty-four (24) soil samples were taken at top-soil and sub-soil depths. OCPs were extracted using Soxhlet extraction and analyzed by GC-ECD, respectively. After being cleaned up, the soil and vegetable extracts of jute mallow (Corchorus olitorious) and smooth pigweed (Amaranthus hybridus) were examined for 17 OCPs. A total of 3.66±3.47 µg/kg of organochlorine residues were found in the top soil and 1.83±1.56 µg/kg in the subsoil 7 DAPA. The OCP residues in the soil ranged from BDL to 3.46±3.38 µg/kg. Organochlorine residues were found in the top soil and 1.83±1.56 µg/kg in the subsoil 7 DAPA, with OCP residues ranging from BDL to 3.46±3.38 µg/kg and a total of 3.66±3.47 µg/kg. The amount of OCP residue found in the soil samples collected on 21 DAPA ranged from BDL to 3.41±0.45 µg/kg, with a total of 3.61±0.55 µg/kg in the top soil and 2.04±0.54 µg/kg in the sub soil. Seven and twenty-one days following OCP application, the soil samples' lower depth (sub soil) decreased in comparison to their upper depth (top soil). The top soil had larger levels of organochlorine residue than the subsoil, according to the results. A total of 3.46±3.15 µg/kg and 0.44±0.57 µg/kg were found seven and twenty-one days after pesticide treatment, respectively. The residues in jute mallow varied from below detection limit (BDL) to 3.18±2.94 µg/kg. Organochlorine residues in smooth pigweed varied from BDL to 1.75±1.59 µg/kg, with a total of 2.02±1.87 µg/kg and 0.73±0.94 µg/kg found seven and twenty-one days after pesticide treatment, respectively. The United States Environmental Protection Agency's (USEPA) approved guidelines were used to calculate the hazard risk index. The study's findings showed that some OCP residues were found in the soil and vegetable samples, and that the veggies' Hazard harm Index of less than one (1) suggested that there was no harm to human health. Long-term ingestion of jute mallow and smooth pigweed from the agricultural settlement may provide a public health risk due to the high content of Endosulfan 2 that was found. The authors suggested that public education, campaigns, and farmer compliance monitoring be used to enforce the ban on organochlorine pesticides

The study "Occurrence and seasonal variation of organochlorine pesticides in selected vegetable farmlands in Lagos State, Nigeria," conducted by Osuala et al. in 2024, looked into the occurrence and seasonal changes of organochlorine pesticide residues in vegetable farmlands in particular Lagos State regions. The Lagos State Agricultural Development Agency identified the sampling areas based on Lagos State's three zonal agricultural divisions. From each zone, three vegetable-growing blocks were selected. Sixty-three (63) soil samples were gathered from various locations, including the control sites. For each season in each zone, seven (7) composite samples were analyzed in triplicate. The authors also analyzed carcinogenic and non carcinogenic risk assessment.

Sonicator and Gas chromatography coupled with an Agilent mass spectrometer were used respectively to extract and analyze organochlorine pesticide residues (α-lindane, lindane, δ-lindane, aldrin, heptachlor epoxide, α.-endosulfan, p,p'-dichlorodiphenyldichloroethylene (p,p'-DDE), endrin, endosulfan, m,p'-dichlorodiphenyldichloroethane (m,p'-DDD), endosulfan sulfate, o,p'-dichlorodiphenyltrichloroethane (o,p'-DDT) and endrin ketone) in soil. The study unveiled maximum concentration of Heptachlor epoxide with 43.03 mg/kg , m,p'-DDD and endosulfan each having minimum value of 0.004 mg/kg in different stations . Far Eastern zone: Heptachlor epoxide had the highest HQ of 5.34×10^{7}, 4.91×10^{14} and 1.76 while endosulfan sulfate had the lowest HQ with values of 1.89×10^{2}, 1.73×10^{9} and 6.22×10^{-6} in children for ingestion, inhalation and dermal exposure routes respectively.

Eastern zone: For ingestion, inhalation, and dermal exposure routes, heptachlor epoxide had the highest HQ (4.31 × 106, 3.96 × 1013, and 1.42 × 10-1), while p,p'-DDE had the lowest HQ (5.29 × 101, 4.86 × 108, and 1.74 × 10-6) in children. Also, heptachlor epoxide had the highest HQ in adults with values of 9.76 × 10-2, 9.51 × 1012 and 3.71 × 106 for ingestion, inhalation and dermal routes respectively while p,p'-DDE had the

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

lowest HQ with values of 1.2 × 10-6 and 1.17 × 108; 4.56 × 101 for ingestion, inhalation and dermal exposure routes respectively.

In the Western zone, endosulfan sulfate had the lowest HQ of 1.11 × 102, 1.02 × 109, and 3.66 × 10-6 for ingestion, inhalation, and cutaneous exposure routes, respectively, while heptachlor epoxide had the highest HQ of 3.57 × 107, 3.28 × 1014, and 1.18. Heptachlor epoxide had the highest HQ in adults (8.09 × 10-1, 7.89 × 1013, and 3.08 × 107), but endosulfan sulfate had the lowest HQ (2.52 × 10-6, 2.45 × 108, and 9.57 × 101) for ingestion, inhalation, and cutaneous exposure, respectively.

The authors came to the conclusion that certain of the vegetable farmlands in particular parts of Lagos State are contaminated with organochlorine pesticides, suggesting that these prohibited pesticides are still in use despite their persistence in the environment and may pose a risk to public health. Based on this, they recommended more stringent monitoring program such as restriction on pesticide usage.

A study titled "Assessment of Heavy Metals and Pesticide Residues in Soils in Adamawa State, Nigeria" by Mica et al. (2025) assessed and monitored the levels of heavy metals and pesticide residues in soils from various agricultural areas in Adamawa State, Nigeria. A total of twenty samples were collected from four villages; four soil samples were collected at a depth of 0 to 20 cm at four cardinal sites on each farm. Pesticide residues, especially those containing organochlorine and organophosphate compounds, were identified and measured using gas chromatography-mass spectrometry (GC-MS). Organochlorine pesticides discovered in the soil included Lindane (2.136 mg/kg), Aldrin (1.022 mg/kg), Heptachlor (0.358 mg/kg), and Dieldrin (0.167 mg/kg), all of which above the Codex Maximum Residue Limits (MRLs). Organophosphate pesticides were also found, including Diazinon (6.133 mg/kg), Dichlorvos (0.848 mg/kg), and Chlorpyrifos (0.215 mg/kg), with Diazinon and Dichlorvos surpassing MRLs. Additionally, heavy metals such as copper (0.630–16.77 mg/kg), zinc (12.183–246 mg/kg), lead (3.648–9.056 mg/kg), cadmium (0.563–3.842 mg/kg), and chromium (1.784–5.378 mg/kg) were found in the soil. There are several locations with cadmium amounts exceeding permissible limits, indicating localized contamination. The results of the investigation showed that the amounts of organophosphate and organochlorine pesticides in a number of soil samples were either slightly higher or lower than the EU/WHO MRLS.

Risk Assessment of Organochlorine Residues in Agricultural Crops Cultivated [2020] on/around Abandoned Tin Mine Areas in Jos South LGA, Plateau State, Nigeria: Daniel et al. (2021) investigated the levels and associated risks of eighteen organochlorine residues in water, soil, sediment, and five vegetables cultivated on abandoned mine areas. Soil samples were collected in triplicate from the agricultural sections of the abandoned tin mine at three depths (0–10 cm, 11–20 cm, and 21–30 cm). Following that, each of the soil samples of soil samples of soil samples of soil samples of soil samples of soil samples of soil, and so on were chosen from each depth. Sediments were collected from ponds and streams in the areas where water samples were collected. Ten locations on the deserted sites were chosen at random to collect one kilogram each of green beans (Phaseolus vulgaris), potatoes (Solamun tuberosum), tomatoes (Lycopersicon esculentum L), and green peppers (Capsicum annuum L. cv. Lady Bell). The study employed the USEPA method 3510 to extract pesticide residues from vegetable samples in non-fatty crops using ethyl acetate as the solvent, the Soxhlet extractor to extract soil and sediment, and the liquid-liquid extractions method to extract pesticide residues from water. Each sample's organochlorine residues were measured using GC/MS.

The investigation found methoxychlor I, p,p-DDD, and β-endosulfan in water. The DDD recorded in this study was above the WHO MRL of 2.00µg/l for drinking water, β-endosulfan was higher than the WHO MRL of 0.01µg/l for drinking water. The study reported the mean concentrations of OCPs in soil samples as follows : α-BHC, β-BHC, γ–BHC and δ BHC range between ND and 72µg/kg; ND and 176µg/kg; ND and 1076µg/kg and ND and 8µg/kg respectively with most of the highest values in the subsoil of 11 – 20cm. γ – BHC was detected in almost all the locations with higher concentrations than with α– BHC and β- BHC. Also, the highest concentrations were in 11 – 20cm soil. Aldrin and dieldrin presented the range of ND – 84µg/kg and ND - 60µg/kg respectively. The mean concentrations were above the WHO MRL of 0.03µg/g for drinking water and agricultural soils. Concentration levels of endrin ranged from ND - 284µg/kg, endrin aldehyde was ND – 72µg/kg and endrin ketone ND - 388µg/kg. The levels of α- endosulfan, β-endosulfan

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

and endosulfan sulfate were at the range of ND – 140µg/kg, 4 – 112µg/kg and ND – 12µg/kg accordingly. DDD, DDE and DDT presented the values of 4– 942µg/kg, ND – 492µg/kg, ND – 20µg/kg in that order. Methoxychlor presented the values range of 4 - 396µg/kg.

This study also examined the concentrations of OCPs in five vegetables from abandoned mine sampling locations. The ranges of BHC isomer residue levels were as follows: α-BHC, ND-60µgkg; β-BHC, ND-88µgkg; and γ-BHC, 4-1020µgkg. All crops had quantities of 4–44µg/kg of heptachlor, while only potatoes and cabbage had concentrations of 24µgkg and 16µgkg of hept epoxide, respectively. Tomato accumulated the highest levels of aldrin and dieldrin, which ranged from 6 to 128µg/kg and 4 to 180µg/kg, respectively. The amounts of α–endosulfan and β–endosulfan sulfate ranged from ND–272 µg/kg, 10–88 µg/kg, and 2–36 µg/kg, respectively; tomatoes had the highest values for α–endosulfan and β–endosulfan. The values of endrin, endrin aldehyde, endrin sulphate, and endrin ketone ranged from ND–196µg/kg, ND–300µg/kg, 2–36µg/kg, and ND–733932µg/kg, respectively. DDD, DDE and DDT level were from ND - 68µg/kg, ND - 112µgkg and ND - 20µg/kg in that order indicating aerobic, anaerobic. Methoxychlor residues were detected in all the vegetables ranging from 4µg/kg in green pepper and green beans to 328µg/kg in cabbage.

Because the HQ was larger than 1 (>1), the study's findings suggested that lifetime use of perishable commodities including potatoes, tomatoes, and green beans from an abandoned mine in Jos South LGA, Plateau State, Nigeria, may offer certain health risks. The authors came to the conclusion that there were notable levels of OCP pesticide residues in the water, sediment, soil, and vegetable samples, and that the OCP values were typically higher than MRLs. They suggested that sales agents of these chemicals, farmers who use pesticides, and victims of food poisoning be properly monitored and have adequate health records. They also suggested that the general public, particularly end users (farmers), be made more aware of and educated about pesticide management practices. The study's weakness, according to the authors, was the inability to assess the pesticides' carcinogenic hazards because the cancer slope factors of the OCPs residues were not available.

Table 1: Characteristics of Included Studies (n=8)

S/N	Authors	Year	Study Location	Soil Type / Setting	Study Focus
1	Udoekpo et al.	2024	Southern Nigeria (Akwa Ibom)	Agricultural soils	Assessment of OCP residues and potential health risks
2	Dan-kishiya et al.	2023	Farmland, Abuja, FCT	Farmland soil	Evaluation of OCP residues
3	Adetunji et al.	2020	Iyana-Iba farm settlement, Lagos State	Vegetable farm soil	OCP residues and health risk assessment in vegetables
4	Daniel et al.	2021	Abandoned tin mine areas, Jos South LGA, Plateau State	Agricultural crops on/around mine areas	Risk assessment of OCP residues in crops
5	Micah et al.	2025	Adamawa State	Agricultural soils	Assessment of heavy metals and pesticide residues
6	Osuala et al.	2024	Selected vegetable farmlands, Lagos State	Vegetable farmlands	Occurrence and seasonal variation of OCPs
7	Aiyesanmi et al.	2012	Cocoa farms, Ondo State Central District	Cocoa farm soils	OCP residues in cocoa farm soils
8	Abiola et al.	2019	Wazo Market, Ogbomoso	Market / dumpsite soil	Assessment of pesticide residues in soil samples

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

Figure 1: PRISMA Flow Diagram OCPs in Nigerian Soils (2012–2025) IDENTIFICATION

PRISMA Stage	N	Details
Identification	259	Database search (n=247) + Other sources (n=12)
After duplicates removed	186	Records screened

SCREENING

Screening (Title & Abstract)	186	Screened
Excluded at screening	152	Not Nigeria (68), Not soil (44), Not OCPs (25), Reviews (15)

Eligibility

Eligibility (Full-text sought)	34	Full-text sought
Full-text assessed	32	2 not retrieved
Excluded at full-text	24	Out of range 2012-2025 (6), Insufficient data (8), Duplicate data (5), Methods unclear (5)

Included

Included	8	Final qualitative synthesis (n=8 studies 2012-2025)

Note: Adapted from PRISMA 2020. n = number of records. Final n=8 includes: Udoekpo (2024), Dan-kishiya (2023), Adetunji (2020), Daniel (2021), Micah (2025), Osuala (2024), Abiola (2019), Aiyesanmi (2012).

Table 2: Detected OCP Concentrations Versus Maximum Residue Limits (MRLs)

S/N	Study (Location)	Key OCPs	Detected Conc. in Soil	FAO/WHO MRL	Status vs MRL
1	Udoekpo et al. 2024 (Southern Nigeria)	13 OCPs: α-HCH, β-HCH, γ-HCH, DDD, DDE, DDT, chlordane	BDL to 18.35±13.83 µg/kg (0.018 mg/kg) for α-HCH; ∑DDT 3.95-10.74 µg/g	0.05 mg/kg (Codex) / 0.01 mg/kg (EU-HCH)	Generally < MRL, except α-HCH & β-HCH in Oron & Etinan > MRL
2	Dan-kishiya et al. 2023 (Abuja)	α-Lindane, β-Lindane, Heptachlor, Aldrin, DDT, Endrin aldehyde	0.33 ± 0.22/kg to 45.28 ± 5.01 (GC-MS)	Aldrin+Dieldrin 0.05 mg/kg	Heptachlor & Aldrin > MRL in dry season
3	Adetunji et al. 2020 (Lagos)	18 OCPs	Top Soil: BDL-3.41±0.45mg/kg; Sub soil: BDL-1.92±0.55	0.05 mg/kg (WHO/NAFDAC veg MRL)	3.41 > 0.05).
4	Daniel et al. 2021 (Jos South)	DDT, DDE, HCH, Endosulfan	ND - 733.932mg/kg	0.05 mg/kg	DDT metabolites very much > MRL
5	Micah et al. 2025 (Adamawa)	OCPs, Organophosphate pesticide residues (OPPs) + heavy metals	OCPs: ND-2.136 mg/kg; OPPs: ND-6.133mg/kg; Heavy metals: 0.563-52.684mg/kg.	0.05 mg/kg, 0.04mg/kg	Mixed - some > MRL and some <MRL

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue IX September2026

6	Osuala et al. 2024 (Lagos)	Seasonal OCPs	Far East; Wet:ND-21.37mg/kg,Dry:ND-32.70. East; Wet: ND-21.74,Dry:ND-10.26, West; Wet:ND-11.61, Dry:ND-43.03	0.05 mg/kg	Mixed; some > MRL, some < MRL
7	Aiyesanmi et al. 2012 (Ondo cocoa)	Endosulfan I, Endosulfan II,α-HCH, β-HCH, dieldrin, heptachlor-epoxide	Varied from ND-350.100mg/kg	Dieldrin 0.05 mg/kg; HCH 0.01 mg/kg	Endosulfan I, Endosulfan II, β-HCH & Dieldrin >>MRL
8	Abiola et al. 2019 (Ogbomoso)	OCPs	ND-0.5014±0.08 mg/kg	0.05 -20.00 mg/kg	At threshold, endosulfan slightly > MRL

Table 3: Human Health Risk Assessment (Non-carcinogenic and Carcinogenic Risks) for OCPs in Nigerian Soils

S/N	Study	Exposure Routes Assessed	Non-Carcinogenic Risk (HQ / HI)	Carcinogenic Risk (ILCR)	Risk Interpretation (Authors)
1	Udoekpo et al. 2024 (Southern Nigeria)	Ingestion, Dermal, Inhalation (Adult & Child)	HQ ingestion: 7.78E-13 to 1.41E-12; HQ dermal: 8.56E-14 to 1.16E-13; HQ inhalation: 9.86E-18 to 1.34E-17; (all <1)	NIL	Insignificant non-carcinogenic risk (HI<1). Very low to low carcinogenic risk per ATSDR. Child slightly higher than adult
2	Dan-kishiya et al. 2023 (Abuja)	Ingestion, Dermal	Nil Nil		Low non-carcinogenic risk. Low to moderate carcinogenic risk for Aldrin & DDT. Requires monitoring
3	Adetunji et al. 2020 (Iyana-Iba, Lagos)	Ingestion of vegetables + soil (Adult & Child)	HQ veg: Adult, BDL-0.4, Child, BDL-0.8 mg/kg (<1 for adult)	NIL	Hazard Index indicates no potential concern.
4	Daniel et al. 2021 (Jos South, tin mine)	Ingestion, Dermal (crops)	HI: Adult 0.0-5.45, Child 0.0-5.02	NIL	HI <1 for most OCPs and HI >1 for only y-BHC and d-BHC
5	Micah et al. 2025 (Adamawa)	Farming Soil	NIL	NIL	Provides data for OCPs, OPPs and heavy metal contaminations on soils.
6	Osuala et al. 2024 (Lagos, seasonal)	Ingestion, Dermal (Dry vs Wet	HQ:Adult; 9.59×10^{-6}-9.51×10^{12},Child; 7.67×10^{-6}-4.91×10^{14}	ILCR: Adult;4.54E-11 to 9.90E02;	Mixed, both adult and children showed non-carcinogenic and

		season)		Child;9.64E-11 to 9.52E02	carcinogenic health risk.
7	Aiyesanmi et al. 2012 (Ondo cocoa)	Cocoa Farm	NIL	NIL	Provided data on the contamination level of OCPs on cocoa farmland.
8	Abiola et al. 2019 (Ogbomoso market soil)	Market Soil	NIL	NIL	Very low risk. Market soil less contaminated than farm soils

HQ = Hazard Quotient (HQ <1 = no adverse effect), HI = Hazard Index = Sum HQ, ILCR = Incremental Lifetime Cancer Risk. USEPA classification: ILCR <1E-06 very low, 1E-06 to 1E-04 low, 1E-04 to 1E-03 moderate, >1E-03 high. ATSDR reference for OCPs.

CONCLUSION

The reviewed investigations carried out by different authors on oganochlorine pesticide residues in Nigerian soils including the plants grown on the contaminated soils, various depths of soils, soils in different seasons and months, revealed detection of OCPs at various concentration levels. From the results of the reviewed studies, most reported detection of OCPs concentrations were below EU/WHO MRLS thereby posing minimal health risks.

But long accumulation of these pesticide residues in the system can result to health problems. The authors therefore recommend that laws on importation and use of toxic pesticides should be strictly enforced; farmers should be properly educated on how best to apply these chemicals and their side effects; farmers should be encouraged to always make use of environmentally friendly farming practices.

Statements and Declarations

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Clinical Trial Number: Not Applicable

Consent to Publish: Not Applicable

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Ethics Declaration: Not Applicable

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