

Organochlorine Pesticides Residues in Soil of Cocoa Farms in Ondo State Central District, Nigeria

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Abstract

Ondo State being the highest producer of Cocoa in Nigeria constitutes the most probable area with the highest use of chemical pesticides to enhance cocoa production. As effective as these chemicals may be in achieving this goal, the incidence of their residues on non-targeted substances and the total environment, with the attendant adverse effects have being of serious concerns. Our objective in this paper is to assess contamination of farm soils by organochlorine pesticides applied on cocoa farms within the Central Senatorial District of Ondo State, Nigeria. Soil samples were collected from selected cocoa farms and analysed for organochlorine pesticides residues using GC-MS. Some soil physicochemical properties including pH, particle size and organic matter that may influence the dynamics of the pollutants were also determined. Organochlorine compounds detected at varied concentrations include Endosulfan I and Endosulfan II occurring most frequently with highest concentrations of 350.10 mg/kg and 3.55 mg/kg respectively. Other organochlorine compounds detected were Heptachlor, Heptachlor epoxide, Aldrin, Dieldrin, isomers of Benzene hexachloride: α -BHC, β -BHC, δ -BHC, and γ -BHC (lindane). The concentrations of the organochlorine pesticides (mg/kg) measured in the soil samples showed significant ($p < 0.05$) correlation with the total organic matter contents of the soil. 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.

Keyword: Organochlorine Pesticides (OCPs), physicochemical properties, soil, cocoa farm

1. Introduction

The invention of chemical pesticides has, no doubt, brought a great relief to agricultural production in terms of crop protection and yield, making their use almost inevitable. However, the incidence of residues from their use on non-targeted substances and the environment in general continues to generate serious concerns that the adverse effects of their use may well outweigh the overall benefits derived from them. Organochlorine compounds have a long history of widespread use as pesticides around the world. They are a class of non-polar toxic chemical compounds containing carbon, hydrogen and chlorine, and are composed of five broad groups namely: the Dichloro-diphenyl-trichloro ethane (DDT) and analogues (e.g. dicofol, methoxychlor); the Hexachlorocyclohexane or Benzene hexachloride and their isomers (e.g. lindane, the γ - isomer); the Cyclodienes (e.g. chlordane, heptachlor, aldrin, dieldrin, endrin, endosulfan, isobenzan); the Chlordecones, Kelevan, Murex; and the Toxaphenes (Pope, Skurky- Thomas & Rosen, 1994). Organochlorine Pesticides (OCPs) are ubiquitous environmental contaminants and have also been classified as a group of Persistent Organic Pollutants (POPs) due to their inability to break down in the environment; resisting degradation by chemical, physical, microbiological, and biological means (Swackhamer & Hites, 1988; National Center for Environmental Health (NCEH), 2005; Darko & Acquah, 2007). Organochlorine pesticides have half-lives ranging from months to years, and in some cases decades (Cremllyn, 1991). They are toxic to humans and other animals, and very highly toxic to most aquatic life. Organochlorines can have serious short-term and long-term impacts even at low concentrations. In addition, non-lethal effects such as immune system and reproductive damages of most organochlorines may be very significant (Lemaire, Terouanne, Mauvais, Michel & Rahmania, 2004). They build up in the fatty tissues of humans, animals and plants, and most often are attracted to fatty tissues and organs, and are accumulated significantly in animals such as fish (Swackhamer & Hites, 1988; Bentzen et al, 2008). Increase in the concentration of organochlorine molecules up the food chain, with bioaccumulation and biomagnifications

taking place in higher organisms including man had been reported (Australian Department of Environment & Heritage (DEH), 1997; Ize-Iyamu, Abia & Egwakhide, 2007). Significant exposure occurs through the consumption of contaminated agricultural products containing residues of these pesticide or their degradation products (Hall, 1999). An estimated 3 million cases of pesticide poisoning occur each year world-wide with 95% of the fatal poisoning cases occurring in the developing countries (Pope et al, 1994). Despite the ban pronounced on most of these toxic organochlorine compounds, they are still being used in most developing nations both domestically and on agricultural crops. This continued use of organochlorine pesticides has remained a matter of international concern because of their persistence and long-distance carriage through oceanic currents and atmospheric transports (Bentzen et al, 2008; Caldas, Coelho, Souza & Siba, 1999). Osibanjo (1994) identified the high potency/efficacy and lower cost of organochlorine pesticides compared with alternative pesticides as the reasons for their continued use in most developing countries, including Nigeria. The main use of the pesticides in these countries is their application as insecticides on cash crops.

Ondo State is the highest producer of Cocoa in Nigeria, with an estimated output of 45,004.5 Metric Tonnes in 2007, representing 40% of the total cocoa production in Nigeria (Aikpokpodion, 2010; Ajayi, Afolabi, Ogunbodede & Sunday, 2010). The State constitutes the most probable area with the highest agricultural use of pesticides in Nigeria, particularly in the extensive cocoa plantations found in the Central Senatorial District of the state. A survey of the local markets within this region confirmed the sales of pesticides containing organochlorines; mainly lindane, endosulfan, and heptachlor, and this not undermining the sales and use of other toxic organochlorines not openly displayed on market stalls or not bearing labels about their chemical composition. Unfortunately, the few available reports and reviews by Atuma and Okor (1985), Osibanjo and Bamgbose (1990), Osibanjo and Adeyeye (1995), Uyimandu (2002), Ize-Iyamu et al. (2007), Adeyemi, Ukpo, Anyakora and Unyimadu (2008) on the levels of organochlorine pesticides contamination of some parts of Nigeria provided no data about the Ondo State Central Senatorial District with presumably heavy use of organochlorine pesticides for cocoa production. It is therefore worthwhile to investigate the level of contamination of the various environmental phases within the region by organochlorine pesticides applied on the cocoa farms. Thus, the present study examines the level of Organochlorine Pesticides (OCPs) residues in the soil samples of some Cocoa- producing areas of Ondo State to complement the available data on pesticides residues levels in Nigerian soils

2. Materials and Methods

2.1 Study Area

The study area for the research covers three major cocoa - producing local governments within the Ondo State Central Senatorial District where pesticides are applied on cocoa farms by farmers. The Local Government Area (LGA) include Akure South, Ifedore and Idanre (Figure. 1) located between $07^{\circ} 04' - 07^{\circ} 20' N$ and $005^{\circ} 06' - 005^{\circ} 14' E$ and are within the same geographical zone. Three farms (each covering approximately 2 hectares of land) were selected in each of the local governments and topsoil samples were taken at five randomly located points from each farm.

2.2 Sampling and Sample Preparation

A standard stainless steel hand auger was used to take the topsoil samples at a depth of 20 cm because nutrients uptake by plants is usually within this horizon, which is also most prone to surface runoff into water bodies. Five randomly selected points within the farms in each of the three local government areas were sampled, given 15 soil samples per local government area and a total of 45 samples in all. All sampling points were geographically referenced with a Global Positioning System (Garmin 12 Model). The soil samples were air-dried in the laboratory for 2 weeks, picked for obvious non-soil and extraneous materials, ground in agate mortar and sieved through a 2 mm mesh. These were stored in black polythene bags prior analysis.

2.3 Physicochemical Analysis of Soil Sample

The pH of the sieved soil samples in water was determined by the method of Hendershot, Lalonde and Duquette (1993). The soil particle size was determined by hydrometer method described by Shedrick and Wang (1993), while the wet oxidation method of Walkley and Black described by Schulte (1995) was used to determine the organic carbon contents from which organic matter content was calculated.

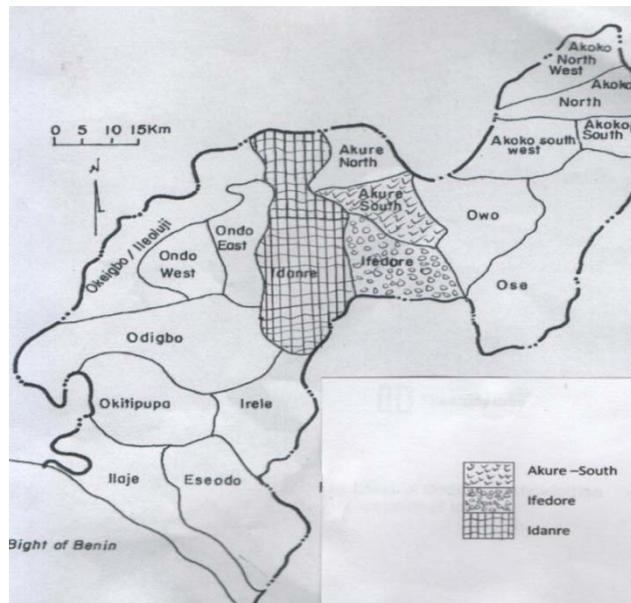


Figure 1. Ondo State map showing the study areas within the Central Senatorial District

2.4 Extraction of Organochlorine Residues from Soil Sample

All the reagents used were of analytical grade and glass wares used for the study were cleaned as prescribed by Method 1699 of USEPA (2007). Extraction of the soil samples was carried out by the method described by Ize-Iyamu et al. (2007). 10 g of each sample and 20 g of anhydrous sodium sulphate were ground into dry powder. The ground sample was extracted with 150 ml of a mixture of Acetone and n-Hexane (2:1). After extraction, the extract was transferred into a round bottomed-flask connected to a pre-weighed receiver through a Liebig condenser and concentrated to about 20 ml on a water bath maintained between 50 and 55°C. The remaining solvent in the concentrated extract was evaporated using a rotary evaporator. The almost - dry extracts were cleaned up in a micro-columns as described in ASTM (1979). 2 g of activated silica gel was packed into a chromatographic micro-column of 10 mm internal diameter. and approximately 10 cm long. The silica gel was conditioned with 10 ml n-Hexane, while the sample extracts were dissolved in 5 ml n-Hexane before they were loaded onto the separate micro-column. Elution of each of the sample was done with 50 ml of ethyl-acetate: hexane mixture (9:1). The eluents were then concentrated on a rotary evaporator at about 45°C and under a gentle stream of nitrogen gas. The almost-dry concentrates were then dissolved in 2 ml acetone and were transferred into vials for subsequent injection into the Gas Chromatograph.

2.5 Sample Analysis for Organochlorine Pesticides Residues

The internal standard technique was employed to analyse the extracted samples. The organochlorine standard containing a mixture of 14 organochlorine compounds of high purity (alpha-BHC, beta-BHC, Lindane, delta-BHC, Heptachlor, Aldrin, Heptachlor – epoxide, Endosulfan I, p,p'- DDE, Dieldrin, Endrin, Endosulfan II, p,p'- DDT, and Endosulfan sulphate) was prepared at concentrations ranging from 0.100 to 2.000 ppm, with Anthracene, PCB-153, and PF-38 added as internal standards. The modern Shimadzu GC-MS QP-2010 was employed in analysing the standards and the calibration curve for each compound was prepared automatically. Both the control and main soil samples extract from clean –up were then analysed under the same conditions as for the standards, and in the Selective Ion Mode (SIM) with m/z values ranging from 65 to 274. The efficiency of the method was validated with recoveries of studies. Fortification of reference material without pesticides residues with four organochlorine compounds at two concentration levels 0.1 mg/kg and 1.0 mg/kg was carried out in triplicate and the same method of extraction and clean-up was followed. Other quality assurance measures applied in the laboratory included rigorous contamination control procedures (washing and cleaning procedures), monitoring of blank levels of solvents and analysis of procedural blanks.

3. Results and Discussions

Tables 1 presents the physicochemical properties of the soil samples from the selected cocoa farms in the Ondo

Central Senatorial District and provide an insight into the nature of the soils being investigated. The soil particle size distribution reveals the textural class of the soils as mainly sandy – loamy (sand – silt), characteristic of most agricultural fields in region. The soil reaction (pH) varied from one location to another on the same farm as well as from farm to farm within the study area. Employing the classification of soil pH by Vitosh, John and Mengel (1995), the pH of the soil samples from Akure – South ranged from “slightly acidic” to “very slightly alkaline”; Ifedore from “strongly acidic” to “very slightly alkaline”; and Idanre from “very slightly acidic” to “very slightly alkaline”. The marked variation in the pH values is not unexpected as many dynamic soil reactions utilizing H^+ ions such as oxidation – reduction, complexation – dissociation, and sorption – desorption occur to a different extent in different parts of a soil (Sparks, 2003). The soil samples have relatively high Organic Matter content (OM) with reference to FAO classification of soil organic matter (FAO, 1990). Soil pH, organic matter and clay contents are known to influence the dynamics and behavior of both inorganic and organic pollutants in soil (Department of Petroleum Resources (DPR), 2002; Gale, Adams, Wixson, Loftin & Huang, 2004; Aiyesanmi, Tomori & Owolabi, 2008).

Table 1. Range and mean physicochemical characteristic of soil samples from the study area

Sample	Sand (%)	Clay (%)	Silt (%)	pH	0.M
AKS					
Range	59.42 – 67.48	11.06 – 13.66	20.83 – 27.60	6.20 – 7.70	3.61 – 8.07
Mean	63.30	12.08	24.61	7.19	5.33
Std	2.48	0.85	1.95	0.49	1.37
IFD					
Range	59.82 - 65.57	12.25 – 16.07	20.10 – 27.29	4.90 – 7.50	3.42 – 8.87
Mean	63.06	13.43	23.51	6.24	6.40
Std	2.13	1.18	2.33	0.73	1.57
IDR					
Range	65.26 – 68.93	6.66 – 11.89	20.47 – 26.26	6.40 – 7.20	3.51 – 8.16
Mean	66.66	10.97	22.43	6.88	5.80
Std	1.22	5.68	1.55	0.19	1.84

AKS = Akure South; IFD = Ifedore; IDR = Idanre

The observed Retention Times (RT) for each organochlorine compounds in the standard under the conditions employed are shown in Table 2. Percent recoveries of the four pesticides from fortified reference material extracts are presented in Table 3. Satisfactory results were obtained for all the pesticides at the two fortification levels. The organocchlorine pesticides were recovered in the range of 79 - 96% and 82 - 90% for 0.5 and 1.0 mg/kg, respectively. These results showed that the method has suitable range with good reproducibility.

Table 2. Retention time for various organochlorine compounds

Standard	Retention time (min)
Alpha – BHC	8.31
Beta – BHC	8.89
Lindane	8.99
Delta –BHC	9.58
Heptachlor	10.00
Aldin	10.64
Heptachlor – epoxide	11.43
Endosulfan I	12.10
P, P’ – DDE	12.44
Dieldrin	12.61
Endrin	13.04
Endosulfan II	13.31
P, P’ – DDT	13.96
Endosulfan sulphate	14.03

Table 3. Percent recovery of selected organochlorine pesticides

Pesticides	Retention Time (min)	Fortification Level (mg/kg)	Recovery (%)
β - BHC	8.89	0.1	96 \pm 1.5
		1.0	89 \pm 2.0
Heptachlor	10.00	0.1	92 \pm 0.7
		1.0	90 \pm 1.0
Endosulfan I	12.10	0.1	79 \pm 0.7
		1.0	82 \pm 1.3
Dieldrin	12.61	0.1	84 \pm 1.7
		1.0	86 \pm 1.0

The concentrations of the various organochlorine pesticides detected in the soil samples are presented in Tables 4, 5 and 6 for the respective local government areas. The specific organochlorine compounds detected in the samples and their concentrations differed markedly. The three isomers of Benzene hexachloride (BHC) or Hexa-chlorocyclohexane (HCH): α -BHC, β -BHC, and δ -BHC, were detected in few soil samples from Akure –south and Ifedore (AKS3, IFD13, IFD15), while no detectable levels of the isomers were found in the soil samples for Idanre. The measured concentrations of the three isomers of BHC (or HCH) are attributable to the use of the γ - isomer (lindane) popularly called Gammalin 20, which is the only BHC isomer with powerful insecticidal action. This is because only Akure-South and Ifedore areas with detectable levels of lindane at 0.375mg/kg (in AKS15) and 0.217mg/kg (in IFD15) respectively, gave quantifiable levels of α , β , and δ –BHC, while lindane was not detected in all the samples from Idanre area. Five organochlorine compounds belonging to the cyclodiene group were also detected in the various samples. These are heptachlor, heptachlor epoxide, aldrin, dieldrin, and endosulfan. Heptachlor was found in the soil samples from only one of the farms in Ifedore area and at very high concentrations in soil samples from Akure-South. However, the metabolic product of heptachlor, heptachlor epoxide, appeared more frequently in the samples. The levels of heptachlor epoxide found in the samples may be directly related to the application of heptachlor on the farms, since heptachlor is only converted to heptachlor epoxide in plant and insect tissues. The epoxide is more chemically potent than heptachlor itself (Cremlyn, 1991). Aldrin and dieldrin were detected more frequently in the soil samples from Ifedore and Idanre areas and dieldrin at Akure South area. The two conformational isomers of endosulfan: α - endosulfan (endosulfan I) and β - endosulfan (endosulfan II) occurred most frequently compared to the other organochlorine compounds. Much higher concentrations of endosulfan I was found in the samples than the corresponding endosulfan II.

Table 4. Concentration of organochlorine pesticide residues (mg/kg) in soils from selected cocoa farms in Akure-South LGA

Sample Code	(Lindane)										Total OCP
	α -BHC	β -BHC	δ -BHC	γ -HC	Heptachlor	Aldrin	H. poxide	Endosulfan I	Dieldrin	Endosulfan II	
AKS1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
AKS2	nd	nd	nd	nd	nd	nd	nd	78.590	0.078	0.245	78.910
AKS3	0.008	nd	0.013	nd	nd	nd	nd	0.083	nd	0.011	0.115
AKS4	nd	nd	nd	nd	nd	nd	11.874	95.050	nd	1.133	108.060
AKS5	nd	nd	nd	nd	nd	nd	28.076	63.980	nd	0.871	92.930
AKS6	nd	nd	nd	nd	nd	nd	82.536	55.843	0.064	0.065	138.510
AKS7	nd	nd	nd	nd	nd	nd	45.642	81.031	0.056	nd	126.730
AKS8	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.013	0.013
AKS9	nd	nd	nd	nd	nd	0.100	93.713	167.825	0.153	0.393	262.184
AKS10	nd	nd	nd	nd	nd	nd	nd	0.077	nd	0.026	0.103
AKS11	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.088	0.088
AKS12	nd	nd	nd	nd	nd	nd	85.796	85.796	nd	0.196	85.990
AKS13	nd	nd	nd	nd	nd	nd	94.069	94.069	nd	0.224	94.290
AKS14	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.088	0.088
AKS15	nd	nd	nd	0.375	nd	nd	109.901	109.901	nd	0.107	201.715

* None organochlorine pesticide ; nd = Below instrument detection limit

AKS- Akure-South Area Soil Sample: 1-5 = Samples from Farm 1; 6-10 = Samples from farm 2; 11-15 = Samples from Farm 3

Table 5. ncentration of organochlorine pesticide residues (mg/kg) in soils from selected cocoa farms in Ifedore LGA

Sample	(Lindane)										
	Code	α -BHC	β -BHC	δ -BHC	γ -BHC	Heptachlor	Aldrin	H. epoxide	Endosulfan I	Dieldrin	Endosulfan II
IFD1	nd	nd	nd	nd	nd	nd	nd	150.782	nd	1.817	152.600
IFD2	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.041	0.041
IFD3	nd	nd	0.013	nd	nd	nd	nd	161.613	0.439	1.225	163.280
IFD4	nd	nd	nd	nd	nd	nd	nd	155.574	0.367	1.633	157.570
IFD5	nd	nd	nd	nd	nd	0.261	nd	171.895	0.449	1.711	174.320
IFD6	nd	nd	nd	nd	nd	nd	nd	263.129	0.551	1.031	264.710
IFD7	nd	nd	nd	nd	nd	0.223	nd	129.873	0.33	2.226	132.650
IFD8	nd	nd	nd	nd	nd	0.039	nd	87.896	0.252	2.530	90.710
IFD9	nd	nd	nd	nd	nd	nd	nd	98.000	0.221	2.052	100.270
IFD10	nd	nd	nd	nd	nd	0.027	nd	261.301	0.489	1.076	262.890
IFD11	nd	nd	nd	nd	nd	0.035	nd	111.795	0.118	1.646	113.590
IFD12	nd	nd	nd	nd	nd	nd	nd	141.613	0.054	0.227	141.890
IFD13	0.295	0.617	1.075	nd	nd	nd	0.2873	350.100	0.211	0.063	352.650
IFD14	nd	nd	nd	nd	2.493	nd	nd	nd	nd	nd	2.490
IFD15	nd	nd	0.321	0.0217	0.134	0.219	0.028	nd	nd	0.159	0.880

*None organochlorine pesticide ; nd = Below instrument detection limit

IFD – Ifedore Area Soil Sample: 1-5= Samples from Farm 1; 6-10= Samples from farm 2; 11-15 = Samples from Farm3

Table 6. Concentration of organochlorine pesticide residues (mg/kg) in soils from selected cocoa farms in Idanre LGA

sample	(Lindane)										
	Code	α -BHC	β -BHC	δ -BHC	γ -BHC	Heptachlor	Aldrin	H. epoxide	Endosulfan I	dieldrin	Endosulfan II
IDR1	nd	nd	nd	nd	nd	0.141	nd	221.252	0.085	0.411	221.89
IDR2	nd	nd	nd	nd	nd	nd	nd	215.672	nd	0.344	216.020
IDR3	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.028	0.028
IDR4	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.015	0.015
IDR5	nd	nd	nd	nd	nd	nd	nd	282.337	0.123	0.180	282.640
IDR6	nd	nd	nd	nd	nd	0.068	nd	210.749	nd	0.343	211.160
IDR7	nd	nd	nd	nd	nd	nd	nd	46.937	nd	3.551	50.490
IDR8	nd	nd	nd	nd	nd	0.491	nd	202.530	nd	0.339	203.360
IDR9	nd	nd	nd	nd	nd	nd	nd	243.038	nd	0.415	243.450
IDR10	nd	nd	nd	nd	nd	0.154	nd	nd	0.013	0.026	0.190
IDR11	nd	nd	nd	nd	nd	0.171	nd	nd	0.013	0.018	0.200
IDR12	nd	nd	nd	nd	nd	0.120	nd	nd	0.022	0.016	0.160
IDR13	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.012	0.012
IDR14	nd	nd	nd	nd	nd	1.061	0.0758	nd	0.037	0.010	1.190
IDR15	nd	nd	nd	0.375	nd	0.092	nd	59.312	0.202	0.791	60.400

* None organochlorine pesticide ; nd = Below instrument detection limit

IDR – Idanre Area Soil Sample: 1-5= Samples from Farm 1; 6-10= Samples from farm 2; 11-15= Samples from Farm 3

The much higher concentrations of endosulfan I relative to those of endosulfan II in the samples may be attributed to two reasons. Firstly, the manufactured technical endosulfan normally contains about 67%

endosulfan I by mass of the total endosulfan content, while endosulfan II constitutes only 32% (World Health Organisation (WHO), 1990). It is, therefore, not unexpected that more of endosulfan I would be found in the environment wherever the pesticide is applied. Secondly, endosulfan I is thermally stable while endosulfan II is unstable and may be slowly converted to endosulfan I in the environment (Hapeman, Schmidt & Rice, 1997; Rice, Hapeman & Chernyak, 1997). However, the high concentrations of endosulfan I and II detected in the samples may be an indication of recent application of the pesticides on some of the cocoa farms, as endosulfan is easily degraded and does not accumulate in the environment unlike most other organochlorines (Cremlyn, 1991). This observation is further corroborated by the fact that endosulfan sulphate, which is the primary degradation product of endosulfan was not detected.

The occurrence and level of some of the organochlorine compounds: α -BHC, β -BHC, δ -BHC, γ -BHC (lindane), heptachlor, heptachlor epoxide, endosulfan I, endosulfan II, aldrin and dieldrin found in the soil samples from these farms are worrisome. Apart from the potential danger they may pose to the soil organisms, there is also the possibility of translocation of these residues from the soil into cocoa fruits through the root system, and into other crops like vegetables that are commonly intercropped within cocoa farms, thereby constituting serious health risks (Townsend & Specht, 1975; Quintero et al., 2008). Contamination of surrounding water bodies by pesticides residues through runoff from contaminated farm soils is also likely as widely reported (Castilho, Fenzl, Guillen & Nascimento, 2000; Konstantinou, Hela, & Albanis, 2006; Pazou et al., 2006; Sarkar et al., 2008).

Correlation analysis carried out to examine the relationship between the soil physico-chemical properties and the quantity of organochlorine pesticide (OCP) residues measured in the soil matrices is presented in Table 7. The resulting correlation coefficients between soil physico-chemical properties and the mean total organochlorine pesticides residues, revealed high significant ($p < 0.05$) correlation only between the organic matter content and the OCP measured in the soil throughout the entire study area. This suggests that pesticides residues levels in the soil are possibly more associated with organic matter content of the soil, and which could be attributed to the fact that organochlorine pesticide molecules have high tendency of binding to organic carbons in soil, similar to fats or lipids of plants and animals as reported by Swackhamer et al. (1988) and Bentzen et al. (2008). The observed correlations coefficients between other measured physico-chemical parameters of the soil and the OCP showed no significant correlation, indicating little influence of these soil characteristics on the OCP level.

Table 7. Pearson correlation of soil physico-chemical properties with total organochlorine pesticides residues concentrations

	Sand (%)	Clay (%)	Silt (%)	pH	O.M (%)
AKS TOCP	-0.3135	0.3514	0.2466	-0.364	0.9302*
IFD TOCP	-0.0175	0.2785	-0.1254	-0.4556	0.9596*
IDR TOCP	0.1680	-0.3384	0.2585	-0.3015	0.9476*

* Significant correlation at $p < 0.05$

TOCP = Mean total organochlorine pesticides

4. Conclusion

This study has provided data on the level of contamination of farm soils by organochlorine pesticides applied on cocoa farms within the Central Senatorial District of Ondo State. Varied concentrations α -BHC, β -BHC, δ -BHC, γ -BHC (lindane), heptachlor, heptachlor epoxide, endosulfan I, endosulfan II, aldrin and dieldrin were found in the different samples. In particular, the concentrations and frequency of occurrence of endosulfan I, endosulfan II, heptachlor epoxide and aldrin in the soil samples were very high and are of serious concern. Apart from the potential danger they may pose to the soil organisms, their possible translocation into edible parts of crops and emission into surrounding water bodies have elicited a great deal of interest as these are currently being investigated.

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