Assessment of The Persistent Organic Compounds Residual Level in some selected Farm Soil where *Telfariaoccidentalis* Hook F. Leaves (Ugu) was Cultivated in The Federal Capital Territory, Abuja - Nigeria

Abstract

Soil samples from some selected farms where Telfariaoccidentalis Hook F. was planted within the Federal Capital Territory was during the rainy season (August 2023) soil samples were collected using a modified grid of 40m – 40m adapted from (Anibasa, 2016) with 20m apart between sampling locations at a depth of 10cm for each sampling location, these were analyzed for Persistent Organic Compounds (POCs) residue level using Gas Chromatography-Electron Capture Detector (GC-ECD). Alpha-BHC, Beta-BHC, Gamma-BHC, Heptachlor, Endrin, DDT, Endosulfan II, DDD (Dichlorodiphenyldichloroethane) and Endosulfan Sulfate were recorded. Endosulfan Sulfate was the highest concentration of 3.00±0.69mg/kg in the soil and was recorded in three Area Councils, followed by Heptachlor with concentration of 2.14±0.73mg/kg recorded in all the Area Councils, Beta- BHC with concentration of 2.12±0.48mg/kg recorded in five Area Councils and the lowest concentration of 0.67±0.22mg/kg was that of Alpha –BHC recorded from three Area Councils. Statistical analysis of the findings indicated that the data was not normally distributed and no significant difference ($p<0.05$) in the concentrations across the six Area Councils however, all the concentrations were above Maximum Residue Limits (MRLs) permissible by WHO/FAO in soil.

Keywords: Persistent, Organic Compounds, Soil,Residual, Cultivated.

Introduction

Soil is the earth's ecosystemmajor component and complex biomaterial on the planet (Young and Crawford 2004) which serves as habitat for living organisms, nutrient source, hydrological regulator of both water quality and quantity and carbon sink and mediator (Brandy and Weil 2002). The focal components of the environment such as soil, land and water are commonly contaminated by mining, weathering and agricultural practices (Usman *et al*. 2024).

Soil can be polluted through organic pesticides, industrial chemicals and antibiotics which enters the soil due to pesticide spraying, improper disposal of organic waste, irrigation of wastewater, and leakage of harmful chemicals (Tian *et al*., 2020 and Zhang *et al*., 2021), global cycling of organic contaminants is a major role of soil as it can act as a sink or source of these contaminants to other environment compartment which eventually affect food, feed and water (ECHA, 2020). Lipophilic soil organic pollutants can easily accumulate in organisms and pose great threat to human health by migrating through food chains (Li *et al*., 2016; Zhao *et al*., 2014).

In the farming season, application of pesticides and other agricultural chemicals affect the natural soil particles concentration which release contaminants as residues that poses a threat to ecological health (Mukaj*et al*., 2016). Therefore, the knowledge on permissible limits of these POPs compounds is paramount to safeguard and to mitigate the negative impacts of these components to ecosystem and human activities in general (Begum *et al*., 2021).

Persistent Organic Pollutants (POP) are organic compounds that are resistant to environmental degradation through chemical, biological and photolytic processes (Ritter *et al.,2*000). They are very persistent and as a result, bioaccumulate in the plant and bodies of consumers with potential adverse impacts on human health and the environment (Eugine and Vincent 2016). Many POPs are used as pesticides, solvents, pharmaceuticals, and industrial chemicals.

*Telfairiaoccidentalis*is one of the most important vegetables in agricultural industry, food and economy of Nigeria due to its high demand and consumption rate in various localities. Farmers of this crop testify to its economic buoyance, simple and straightforward planting method (Nwosu *et al.*, 2016). However, it is quite susceptible to a lot of diseases and pest such as *grasshoppers, aphids, beetles, bugs,* and *worms* that can easily hamper growth of the crop and destroy the farm.

In the Federal Capital Territory, *Telfairiaoccidentalis* is one of the highest consumed green vegetables hence cultivated all year round. Farmers in this area are faced with challenge of pests particularly *aphids, bugs, bettles* and *worms* which eat up or bore the leaves that affect its market value. In the bid to control these pests and improve the production, a lot of chemicals are used in the form of pesticides, herbicides and fertilizers.

This research aimed to assess the residual level of some of these commonly used persistent organic compounds (POCs) used as pesticides in the soil during *Telfariaoccidentalis* (Ugu) cultivation in the Federal Capital Territory Abuja, Nigeria.

Materials and Methods

Study area

The study was carried out in Federal Capital Territory (FCT) Abuja, Nigeria located between latitudes 8°25' and 9°26' North of equator and longitudes 6°45' and 7°39' East of the Greenwich Meridian (FCTA, 2022). The Federal Capital Territory has a total land mass of about 8000 sq. km: located geographically at the centre of the country (FCTA, 2022). Abuja's 2022 population is now estimated at **3,652,000**. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects (UNWUP). These estimates represent the Urban agglomeration of Abuja, which typically includes Abuja's population in addition to adjacent suburban areas (UNWUP, 2022).

The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a hot dry season. In between the two seasons, there is a brief interlude of harmattan occasioned by the North East Trade Wind, with the main feature of dust haze, intensified

coldness and dryness (FCTA, 2022). The rainy season begins from April and ends in October, when daytime temperatures reach 28-30°C night time lows hover around 22-23°C.

There are six Area Councils in the FCT. They are Abaji, Abuja Municipal Area Council (AMAC), Bwari, Gwagwalada, Kwali and Kuje Area Councils.

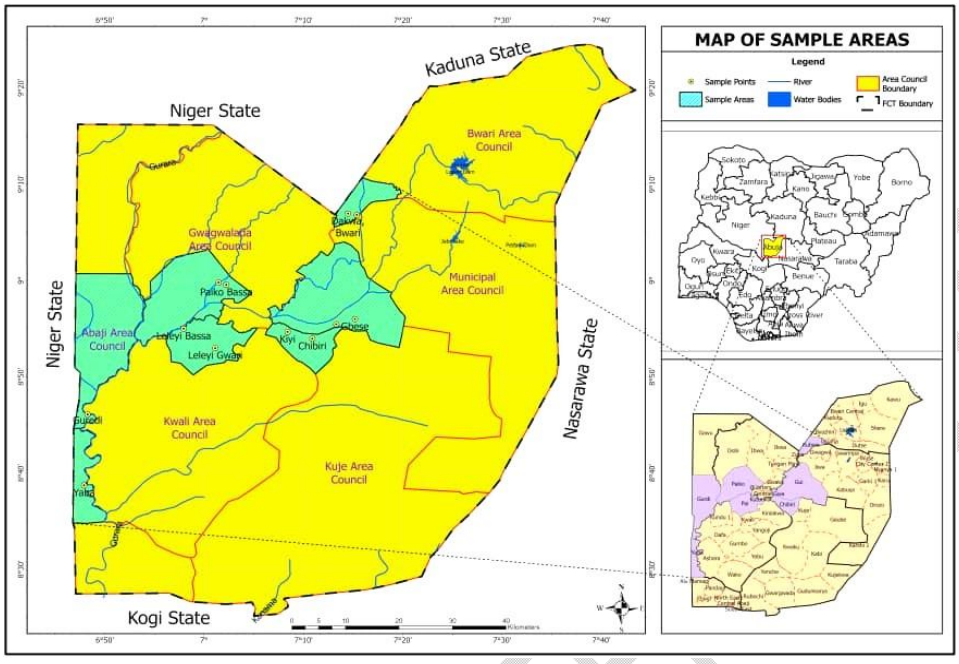

Plate 1: Map of FCT – Abuja showing the study area (Field Data) Scale: 1:50,000

Samples collectionand processing

Soil samples were collected from each of the selected farm using the specific sampling design adapted from (Anibasa, 2016). However, sample locations were original to this study. Sampling location was within the measured grid of 40m-by-40m sides with distance of 20m apart, each across the length and breadth within the sampling location.
Samples were taken at uniform depth of 10cm with the aid of a hand trowel that had been pre-cleaned with concentrated nitric acid in order to prevent heavy metal contamination prior to analysis. The soil sample were air dried at room temperature.

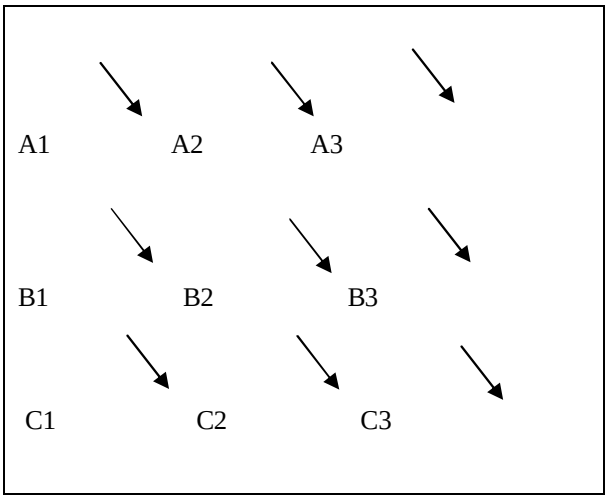

Figure 1: Modified sampling grid showing sampling locations 20m apart (Adapted from Anibasa, 2016). However, sampling locations are original to this work

Extraction of Soil Samples

The air-dry soil samples were agitated to fine grain size(>2mm) and carefully sieve. 3.0 g portion of the homogenized sample was weighed into a 50 ml polytetrafluoroethylene (PTFE) tube, and then 3.0 ml of acetonitrile containing 1% acetic acid (v/v) was added followed by 2.0 g anhydrous sodium sulphate. The sample was shaken vigorously for 3 minutes and then centrifuged at 1500 rpm for 5 minutes (Miguel *et al*. 2022).

Clean up of soil Extracts

After centrifugation, the samples were cleaned up using dispersive solid-phase extraction (dSPE). 2mL of the supernatant was transferred to a 15 ml PTFE tube to which 50 mg each of silica gel with 150 mg Na_2SO4 was added and vortexed for 30 seconds and then centrifuged for 1minute at 1500 rpm. The clear extract was then transferred to an auto sampler vial for GC-ECD analysis (Miguel *et al*. 2022).

Determination of Persistent Organic Compounds Residues

As described by (Yang et al.2019), about 1µL was injected into the GC-ECD via an Agilent auto sampler(7683B) to the GC-ECD (Agilent 7890A) System installed with a Technokrama column DB 17(30m x 250um x 0.25um) was used for the chromatographic separation. The oven was programmed as follows: initial temperature 40˚C, 1.5 minutes, to 150˚C, 15 minutes, 5˚C/minute to 200˚C, 7.5minutes. 25˚C/minute to 290˚C with a final hold time of 12 minutes and a constant column flow rate of 1 ml/minute. The detection of the organochlorine pesticides was performed using the GC-ECD. Electron capture detector. The retention time, peak area and peak height of the sample were compared with those of the standards for quantification.

Statistical Analysis

Data Minitab Version and Statistical Package for Social Sciences (SPSS) version 25 was used to analyze data. Microsoft Excel version 2019 was also used for some statistical computations, The Kolmogorov Smirnov test was used to test if data were normally distributed. Other descriptive statistical tools were also used. The Spearman rank correlation Analysis was also used to compare occurrence of the POCs across Area Councils.

Results and Discussion

The mean values of all detected Persistent Organic Compounds measured in this study ranged from 0.62 – 3.00mg/kg in Soil where *T. occidentalis*was cultivated as indicated by Area Council (Tables 1- 6). Alpha – BHC, Beta – BHC, Gamma – BHC, Heptachlor, Endrin, DDT,DDD, Endosulfan II and Endosulfan Sulfate were detected, however, some were not detected in some Area Councils. Generally, the detected POCs were 10 times higher than the FAO/WHO MRL for soil. There was no significant difference ($p<0.05$) in the concentrations of Persistent Organic Compounds across the six Area Councils.

Table 1: shows mean concentration of Persistent Organic Compounds (POCs) detected in Soil samples collected from Abaji Area Council. Endosulfan Sulfate was the highest concentration recorded with 3.00±0.69mg/kg followed by Heptachlor with 2.14±0.73mg/kg, Endosulfan II with 1.27±0.26mg/kg, DDD with 1.21±0.47mg/kg, Alpha – BHC with 1.19±0.42mg/kg, Beta – BHC with 1.19±0.42mg/kg and Endrin with lowest concentration of 1.15±0.63mg/kg. All the concentrations are 60%, 107%, 25%, 121%, 24%, 24% and 115% respectively above the maximum residue limit of 0.05mg/kg, 0.02mg/kg, 0.05mg/kg, 0.10mg/kg, 0.05mg/kg, 0.05mg/kg and 0.01mg/kg in soil, however there was no significant difference ($p<0.05$) between the POCs

Table 1: Mean Concentration of Persistent Organic Compound in Soil of Abaji Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD DDT Endosulfan Sulfate Endosulfan II	
Mean ± SEM (mg/kg)	1.19±0.42	1.19±0.42	2.14±0.73	ND	1.15±0.63	1.21±0.47 3.00±0.69 1.27±0.26	ND
FAO/WHO MRL Codex (2019)		0.05	0.02		0.05	0.10 0.05	0.05

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit
ND – Not Detected
POC – Persistent Organic Compound

Table 2: shows that Alpha – BHC, Gamma – BHC, Heptachlor, Endrin and DDT were detected in soil collected from Abuja Municipal Area Council. Gamma - BHC was the highest concentration with 1.20±0.27mg/kg followed by Endrin with 1.00±0.11mg/kg, DDT with 0.99±0.10mg/kg, Heptachlor with 0.83±0.19mg/kg and Alpha -BHC with lowest concentration of 0.67±0.22mg/kg. All the concentrations are 24%, 100%, 99%, 42% and 13% above the maximum residue limit of 0.05mg/kg, 0.01mg/kg, 0.10mg/kg 0.02mg/kg and 0.05mg/kg respectively in soil however, there was no significant difference ($p<0.05$) between the POCs.

Table 2: Mean Concentration of Persistent Organic Compound in Soil of Abuja Municipal Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD	DDT	Endosulfan Sulfate	Endosulfan II
Mean ± SEM (mg/kg)	0.67±0.22	ND	0.83±0.19	1.20±0.27	1.00±0.11	ND	0.99±0.10	ND	ND
FAO/WHO MRL Codex (2019)	0.05		0.02	0.05	0.05	0.10			

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit
ND – Not Detected
POC – Persistent Organic Compound
AMAC – Abuja Municipal Area Council

There were seven POCs recorded in the soil sample collected from Bwari Area Council as shown in Table 3 Endosulfan II has the highest mean concentration of 1.48±0.47mg/kg followed by Beta – BHC with 1.32±0.16mg/kg, Alpha – BHC with 1.01±0.31mg/kg, Endosulfan Sulfate with 0.88±0.35mg/kg, Gamma – BHC with 0.73±0.15mg/kg, DDD with 0.71±0.22mg/kg and Heptachlor 0.62±0.18mg/kg. All the concentrations are 30%, 26%, 20%, 18% 15%, 71% and 31% above the maximum residue limit of 0.05mg/kg, 0.05mg/kg, 0.05mg/kg, 0.05mg/kg, 0.05mg/kg, 0.10mg/kg and 0.02mg/kg respectively in soil however, there was no significant difference ($p<0.05$) between the POCs.

Table 3: Mean Concentration of Persistent Organic Compound in Soil of Bwari Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD	DDT	Endosulfan Sulfate	Endosulfan II
Mean ± SEM (mg/kg)	1.01±0.31	1.32±0.16	0.62±0.18	0.73±0.15	ND	0.71±0.22	ND	0.88±0.35	1.48±0.47
FAO/WHO MRL Codex (2019)	0.05	0.05	0.02	0.05	0.05	0.10	0.05	0.05	

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit

ND – Not Detected
POC – Persistent Organic Compound

Table 4: shows that Gwagwalada Area Council recorded six POCs in samples of soil collected, Beta-BHC and Alpha - BHC have the highest concentration of 0.98±0.13mg/kg and 0.98±0.87mg/kg followed by Gamma – BHC with 0.96±0.18mg/kg, Heptachlor with 0.91±0.17mg/kg, DDD with 0.85±0.17mg/kg and Endrin with lowest concentration of 0.81±0.16mg/kg all the concentrations were 20%, 20%, 19%, 46%, 85%, and 81% respectively above the MRL of 0.05mg/kg, 0.05mg/kg, 0.05mg/kg, 0.02mg/kg, 0.10mg/kg and 0.01mg/kg in the soil. There was no significant difference ($p<0.05$) between the POCs.

Table 4: Mean Concentration of Persistent Organic Compound in Soil of Gwagwalada Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD	DDT Endosulfan Sulfate Endosulfan II
Mean ± SEM (mg/kg)	0.98±0.87	0.98±0.13	0.91±0.17	0.96±0.18	0.81±0.16	0.85±0.17	ND NDND
FAO/WHO MRL Codex (2019)	0.05	0.05	0.02	0.05	0.01	0.10	

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit
ND – Not Detected
POC – Persistent Organic Compound

Kuje Area Council recorded eight POCs in soil samples collected as shown in Table 5 Beta - BHC has the highest concentration of 2.12±0.48mg/kg followed by Endosulfan Sulfate with 2.03±0.53mg/kg, Endrin with 1.73±0.40mg/kg, Endosulfan II with 1.73±0.36mg/kg, Alpha-BHC with 1.51±1.48mg/kg, DDD with 1.45±0.17mg/kg, Heptachlor with 1.31±0.43mg/kg and Gamma-BHC with lowest concentration of 0.70±0.18mg/kg. All the concentrations are 42%, 41%, 173%, 35%, 30%, 145%, 66% and 14% above the maximum residue limit of 0.05mg/kg, 0.05mg/kg, 0.01mg/kg, 0.05mg/kg, 0.05mg/kg, 0.10mg/kg, 0.02mg/kg and 0.05mg/kg of the detected POCs in soil, however, there was no significant difference ($p<0.05$) between the POCs.

Table 5: Mean Concentration of Persistent Organic Compound in Soil of Kuje Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD	DDT	Endosulfan Sulfate	Endosulfan II
Mean ± SEM (mg/kg)	1.51±1.48	2.12±0.48	1.31±0.43	0.70±0.18	1.73±0.40	1.45±0.17	ND	2.03±0.53	1.73±0.36
FAO/WHO MRL Codex (2019)	0.05	0.05	0.02	0.05	0.01	0.10	0.05		0.05

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit
ND – Not Detected
POC – Persistent Organic Compound

Table 6: shows the POCs detected in soil samples collected from Kwali Area Council. Alpha – BHC has the highest mean concentration of 2.54±3.09mg/kg followed by DDD with 0.99±0.13mg/kg, Heptachlor with 0.98±0.07mg/kg, Beta – BHC with 0.93±0.10mg/kg and Endrin with 0.91±0.13mg/kg, respectively. All the concentrations are 51%, 99%, 49%, 19% and 91% above the maximum residue limit of 0.05mg/kg, 0.10mg/kg, 0.02mg/kg, 0.05mg/kg and 0.01mg/kg in soil, however, there was no significant difference ($p<0.05$) between the POCs.

Table 6: Mean Concentration of Persistent Organic Compound in Soil of Kwali Area Council in the Rainy Season

POC	Alpha–BHC	Beta–BHC	Heptachlor	Gamma – BHC	Endrin	DDD	DDT	Endosulfan Sulfate	Endosulfan II
Mean ± SEM (mg/kg)	2.54±3.09	0.93±0.10	0.98±0.07	ND	0.91±0.13	0.99±0.13	ND	NDND	
FAO/WHO MRL Codex (2019)	0.05	0.05	0.02		0.01	0.10			

Key: SEM – Standard error on the Mean
FAO – Food and Agriculture Organization of the United Nations
WHO – World Health Organization
MRL – Maximum Residue Limit
ND – Not Detected
POC – Persistent Organic Compound

Table 7: show mean concentrations of POCs measured in soil of the six Area Councils of FCT. This ranged from 0.67 – 3.00mg/kg of all detected POCs. Alpha – BHC, Beta – BHC, Gamma – BHC, Heptachlor, Endrin DDT, DDD, Endosulfan II and Endosulfan Sulfate were detected, however, some were not detected in some Area Councils. All levels were above the WHO/FAO

MRL standard limit in soil. There was no significant difference ($p<0.05$) in the concentrations of Persistent Organic Compounds across the six Area Councils.

Table 7: Comparison of Rainy Season Persistent Organic Compound Residues in Soil with Standard Limit

Pesticide in mg/kg	Alpha–BHC	Beta–BHC	Heptachlor	Gamma–BHC	Endrin	DDD	DDT	Endosulfan Sulfate	Endosulfan II
Area Councils									
Abaji	1.19	1.19	2.14	ND	1.15	1.21	ND	3.00	1.27
AMAC	0.67	ND	0.83	1.20	1.00	ND	0.99	ND	ND
Bwari	1.01	1.32	0.62	0.73	ND	0.71	ND	0.88	1.48
Gwagwalada	0.98	0.98	0.91	0.96	0.81	0.85	ND	NDND	
Kuje	1.51	2.12	1.31	0.70	1.73	1.45	ND	2.03	1.73
Kwali	2.54	0.93	0.98	ND	0.91	0.99	ND	NDND	
FAO/WHO MRL	0.05	0.05	0.02	0.05	0.01	0.10	0.10	0.05	0.05

mg/kg (Ihedioha et al., 2020)

WHO - World Health Organization
FAO - Food and Agriculture Organization of the United Nations
MRL – Maximum Residue Limit
ND – Not Detected

The soil POCs concentration shown in Table 8, Kuje ranked first in Beta – BHC 2.12±0.48mg/kg, Endrin 1.73±0.40mg/kg, DDD 1.45±0.24mg/kg and Endosulfan II 1.73±0.36mg/kg, Abaji ranked first in Alpha – BHC 1.19±0.42mg/kg, Heptachlor 2.14±0.73mg/kg and Endosulfan Sulfate 3.00±0.69mg/kg while AMAC ranked first in Gamma – BHC 1.20±0.27mg/kg and the only Area Council that recorded DDT 0.99±0.10mg/kg in the soil. Bwari, Gwagwalada and Kwali ranked lower in the occurrence of most of the POCs in soil.
The dissimilarity in the soil and *T. occidentalis* leaves POCs concentration in terms of occurrence can be attributed to aerial application of the POCs based pesticides to this plant and the concentration in the soil may be accidental spillage or runoff.

Table 8: Occurrence of Rainy Season Pesticide Detected in Soil Across FCT by Rank

Pesticides	Area Councils	Mean±SEM(mg/kg)	Rank of occurrence
Alpha – BHC	Kwali	2.54±3.09	1st
	Kuje	1.54±1.48	2nd
	Abaji	1.19±0.42	3rd
	Bwari	1.01±0.31	4th

	Gwagwalada	0.98±0.87	5th
	AMAC	0.67±0.22	6th
Beta – BHC	Kuje	2.12±0.48	1st
	Bwari	1.32±0.16	2nd
	Abaji	1.19±0.42	3rd
	Gwagwalada	0.98±0.13	4th
	Kwali	0.93±0.10	5th
Heptachlor	Abaji	2.14±0.73	1st
	Kuje	1.31±0.43	2nd
	Kwali	0.98±0.07	3rd
	Gwagwalada	0.91±0.17	4th
	AMAC	0.83±0.19	5th
	Bwari	0.62±0.18	6th
Gamma – BHC	AMAC	1.20±0.27	1st
	Gwagwalada	0.96±0.18	2nd
	Bwari	0.73±0.15	3rd
	Kuje	0.70±0.15	4th
Endrin	Kuje	1.73±0.40	1st
	Abaji	1.15±0.63	2nd
	AMAC	1.00±0.11	3rd
	Kwali	0.91±0.13	4th
	Gwagwalada	0.81±0.16	5th
DDT	AMAC	0.99±0.10	
Endosulfan Sulfate	Abaji	3.00±0.69	1st
	Kuje	2.03±0.53	2nd
	Bwari	0.88±0.35	3rd
DDD	Kuje	1.45±0.24	1st
	Abaji	1.21±0.47	2nd
	Kwali	0.99±0.13	3rd
	Gwagwalada	0.85±0.17	4th
	Bwari	0.71±0.22	5th
Endosulfan II	Kuje	1.73±0.36	1st
	Bwari	1.48±0.47	2nd
	Abaji	1.27±0.26	3rd

Conclusion

The results of this study revealed variable Persistent Organic Compounds (POCs) residual levels in Soil where *Telfairiaoccidentalis*wascultivated in some part of FCT under investigation. Based on the results, nine POCs Alpha – BHC, Beta – BHC, Gamma – BHC, Heptachlor, Endrin, DDT DDD, Endosulfan II and Endosulfan Sulfate were recorded in the soil.

Endosulfan Sulfate was the highest concentration of 3.00±0.69mg/kg in the soil and was recorded in three Area Councils, followed by Heptachlor with concentration of 2.14±0.73mg/kg and the only POCs recorded in all the Area Councils this is an indication that Heptachlor based pesticides are used in all the Area Councils to protect this vegetable from pests or other crops and may have found its way through leaching or runoff. Beta- BHC with concentration of 2.12±0.48mg/kg recorded in five Area Councils and the lowest concentration of 0.67±0.22mg/kg was that of Alpha –BHC recorded from three Area Councils, DDT has 0.99±0.10mg/kgconcentration and was recorded in only AMAC. All the concentrations were above Maximum Residue Limits (MRLs) permissible by WHO/FAO in soil. This result is similar to that of (Akan *et al*. 2014) that determined some organochlorine pesticides residues in five freshly harvested vegetables and soil from Alau Dam and Gongulong in Borno State and (Ogbonnaya *et al*. 2017) in a study of multi-pesticide residue analysis soil and vegetable growing floodplains in Minna Niger State, (Njoku et al. 2017), (Bamigboye et al. 2017), (Dada et al. 2019) and (Adeleye et al. 2019) who investigated residue levels of pesticides in vegetables, fruits and soil in various states across Nigeria and recorded concentrations above the MRLs.

The concentration was also ranked by occurrence for vegetable by Area Councils Kuje ranked 1st in Beta-BHC, Endrin, Endosulfan II and DDD this was followed closely by Abaji which ranked 1st in Endosulfan Sulfate and Heptachlor AMAC ranked 1st in Gamma-BHC and the only Area Council that recorded DDT. The other Area Councils ranked in no particular trend this is an indication that different Area Councils have different pesticide used for the same plant. the concentrations recorded being higher than the recommended level is an indication of indiscriminate use of pesticides in these Area Councils particularly those detected for which the Area Councils ranked first.

The result obtained from this research shows that a lot of farmers around this area depend on these pesticides to protect their crops from pest however, most of these pesticides are persistent in nature and can bioaccumulate along the food chain which can results in health risk of the consumers.

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