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Evaluation of Organochlorine Pesticide Residues in a Farmland in Abuja, Nigeria

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ABSTRACT: This study conducted an extensive assessment of organochlorine pesticide residues in a farmland located in Abuja, Nigeria. Employing Gas Chromatography-Mass Spectrometry, the concentrations of these pesticide residues were determined in soil samples. The recovered residues include Alpha Lindane, Beta Lindane, Heptachlor, Aldrin, DDT and Endrin Aldehyde. The study unveiled notable fluctuations in pesticide concentrations across the sampling period. In May, the highest concentrations were observed for Endrin Aldehyde (45.932 mg/kg) while the lowest concentration was recorded for Aldrin (0.33 mg/kg) in January. These findings bear ecological and health implications, potentially impacting biodiversity, human health and soil physicochemical properties. Furthermore, it is noteworthy that the concentrations of pesticide residues in the study surpassed the maximum residue limits (MRLs). This research provides crucial insights into the presence and levels of organochlorine pesticide residues in Abuja's agricultural soils, emphasizing the urgent need for robust pesticide management and control measures within the region.

Keywords: Pesticide residues, organochlorine, soil analysis, environmental impact, Abuja, Nigeria

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INTRODUCTION

The rapid growth of the global population has exacerbated food shortages and security concerns, underscoring the need to enhance agricultural productivity to meet rising food demands. Consequently, a variety of agrochemicals have been developed and employed to increase crop yields, combat pests, and reduce pre-harvest and post-harvest losses of agricultural produce (Tufail et al., 2022). However, some of these agrochemicals contain persistent organic pollutants, leading to adverse effects on non-target organisms. Due to their known toxicities, the manufacture and use of these pesticides have been prohibited in many parts of the world. However, evidence suggests their continued proliferation and usage, especially in developing nations like Nigeria due to inadequate regulations, availability, and cost-effectiveness.Organochlorine pesticides are arguably the most widely used pesticide compounds due to their effectiveness (Ajima, 2019, Gbarakoro, 2017). The extensive use of these chemicals increases the likelihood of their bioavailability. Studies have reported the presence of organochlorine residues in several biotic and abiotic compartments including plant tissues and human serum and breast milk, with resultant disruptions in intracellular electron transfer systems and damages to organelles, eventually as well as carcinogenesis and cell death (Kiyani *et al.,* 2023). Due to the indiscriminate and unregulated use of these pesticides, residues are deposited in the soil. The overarching concern is that the concentration of these deposits may be above internationally acceptable limits thereby negatively influencing ecosystem dynamics and human health (Arivu *et al*., 2016). Given the limited data available on the extent of organochlorine pesticide contamination in Abuja, there is an urgent need to conduct a comprehensive study to determine the concentrations of these pesticide residues. This research therefore aims to address the critical gap in knowledge regarding the concentrations of organochlorine pesticide residues in agricultural lands in Abuja, this is essential for implementing effective mitigation and management strategies.

MATERIALS AND METHODS

Soil sampling

A total of 36 surface soil samples were collected from a farmland in Gwagwalada area council, Abuja Nigeria between January and September, 2020. Three subsamples were collected from each quadrant and homogenized to achieve one sample per quadrant at depths of 0-15 cm.The collected samples were stored in sealed paper bags and properly labelled consistent with methods described in (Bilikis *et al*., 2018). Test portions were drawn from the composites and properly labelled. The labelled samples were then transported to the laboratory for pre-treatment as well as analysis. The soil samples were air-dried, rolled manually, mixed, and sieved with a 2 mm mesh to remove stones and debris. Control samples were collected from a pristine location about a kilometer away from the study site. All samples were properly stored in well-labelled air-tight containers until analysis (USEPA, 2007).

GC-MS Determination of organochlorine residues

Soil samples were homogenized and kept at room temperature for ten (10) minutes. 5.00g of samples were transferred to Whatman no. 1 filter papers. Residues were extracted for eight hours with Soxhlet apparatus with 150 ml acetone-hexane (1:1 v/v). The extracts were then concentrated on a rotary evaporator at 45°C, 56 rpm, and 0.60 bar. The extracts were further treated with concentrated H_2SO_4 to remove lipids and other polar substances. After this step, residues were concentrated to 5ml and purified through a florist column (1.5 g, 8.0 mm inner diameter).

The solvent in the glass tube was entirely evaporated under a gentle stream of nitrogen and the precipitates dissolved in 1ml hexane. Aliquots of 0.5µl each of the processed samples were injected into a GC-MS (Agilent 7820A- 5975C inert mass spectrometer, Agilent Technologies®) by operating MSD in selective ion monitoring (SIM) and Scan mode to ensure low-level detection of the target constituents for the analyses.

The stationary phase of separation of the compounds was an HP-5 capillary column coated with 5% Phenyl Methyl Siloxane (30m length x 0.32mm diameter x 0.25µm film thickness) (Agilent Technologies). The carrier gas was Helium used at a constant flow of 1.48 mL/min at an initial nominal pressure of 1.49 psi and an average velocity of 44.22 cm/sec. (USEPA, 2007).

Determination of the soil physicochemical parameters

Soil samples were ground using a mortar and pestle and then sieved with a 2.0 mm mesh. 1kg of each soil sample was weighed into the crucible and heated in an oven at 105°C overnight. Sample measurements were taken after the crucibles were cooled in a desiccator for 1-2 hours after which the percentage moisture content (% MC) was calculated by calculating the loss in drying as a fraction of the initial mass of the sample and multiplied by 100 (Pathak *et al*., 2011).

$$Mc = \frac{M_{wet} - M_{dry}}{M_{dry}} \times \frac{100}{1}$$

The electrical conductance of the soil sample was determined by preparing a 1:2 slurry of 10g fresh soil in 20ml deionized water. Measurements were taken using a conductivity meter (Hanna HI 2550). Soil pH was determined for all soil samples using a separate 1:2 slurry of 10g soil sample in 20ml deionised water. The slurry was allowed to stand for 10 minutes then the pH readings were recorded using a Hana® digital pH meter. Each suspension was stirred vigorously using a glass rod immediately before pH determination using the methods described in Useh *et al*. (2015). The Total Organic Matter content for all studied samples were determined using methods described in (Ibitoye, 2006).

Statistical analysis

Statistical Package for Social Sciences (SPSS) software version 23.0 was used to generate the means. One-way Analysis of variance (ANOVA) was used to test for the significant differences and similarities between the physicochemical properties and the concentrations of pesticide residues. Significant means obtained were separated by least significant difference at 5% significance.

RESULTS AND DISCUSSION

Pesticides play a vital role in contemporary agriculture, significantly contributing to enhanced crop yields and increased food production. Nevertheless, their utilization entails substantial ecological and health ramifications.The residues recovered inthis study includes Alpha lindane, Beta Lindane, Heptachlor, Aldrin, Endrin Aldehyde, and DDT (Table 1 and Figure 1). A noteworthy observation from this research is the escalation in concentrations during the rainy season, with peak values occurring in May

Table 1 : Mean monthly concentration of organochlorine residues in soil (Mean±SD mg/kg).

	α lindane	β lindane	Heptachlor	Aldrin	DDT	Endrin Aldehyde
Control	0.52 ± 0.22	0.81 ± 0.33	0.72 ± 0.21	0.33 ± 0.22	0.98 ± 0.44	8.56± 3.47
JAN	1.36 ± 0.47	1.95 ± 0.46	1.88 ± 1.09	0.74 ± 0.46	1.95 ± 0.90	30.97 ± 15.29
FED	1.94 ± 0.34	2.42 ± 0.61	2.03 ± 1.03	0.68 ± 0.21	1.96 ± 1.18	43.44 ± 5.33
MAR	1.66 ± 0.22	2.28 ± 0.57	2.22 ± 0.98	0.92 ± 0.50	2.47 ± 0.83	42.11± 5.39
APR	2.02 ± 0.31	2.48 ± 0.59	2.52 ± 0.71	2.33 ± 2.50	2.82 ± 0.66	44.78 ± 5.35
MAY	2.06 ± 0.35	2.49 ± 0.58	2.72 ± 0.19	2.37 ± 2.50	3.04 ± 0.70	45.28 ± 5.01
JUNE	2.03 ± 0.38	2.64 ± 0.70	2.32 ± 0.57	2.96 ± 2.65	2.86 ± 0.61	43.63 ± 4.65
JULY	1.98 ± 0.31	2.45 ± 0.66	2.41 ± 0.21	2.24 ± 0.36	2.86 ± 0.61	44.92 ± 5.37
AUG	1.71 ± 0.36	2.43 ± 0.67	2.39 ± 0.15	2.22 ± 2.35	2.79 ± 0.57	44.65 ± 5.68
SEPT	1.69 ± 0.34	2.42 ± 0.67	2.37 ± 0.17	2.21± 2.35	2.75 ± 0.56	44.58 ± 5.72

Table 2: Soil Physicochemical parameters.

	pH	Conductivity (mS/M)	Moisture (%)	Organic matter (%)
Conrol	6.77	812.3	44.6	1.7
JAN	5.36	977.1	32.6	2.8
FEB	5.10	977.2	32.5	2.8
MAR	5.25	977.2	33.0	2.9
APR	5.62	977.5	43.5	2.7
MAY	5.64	978.2	40.7	2.9
JUN	5.65	977.9	42.6	3.2
JUL	5.64	977.3	42.6	3.1
AUG	5.66	978.1	53.7	3.2
SEP	5.63	977.6	53.9	3.2

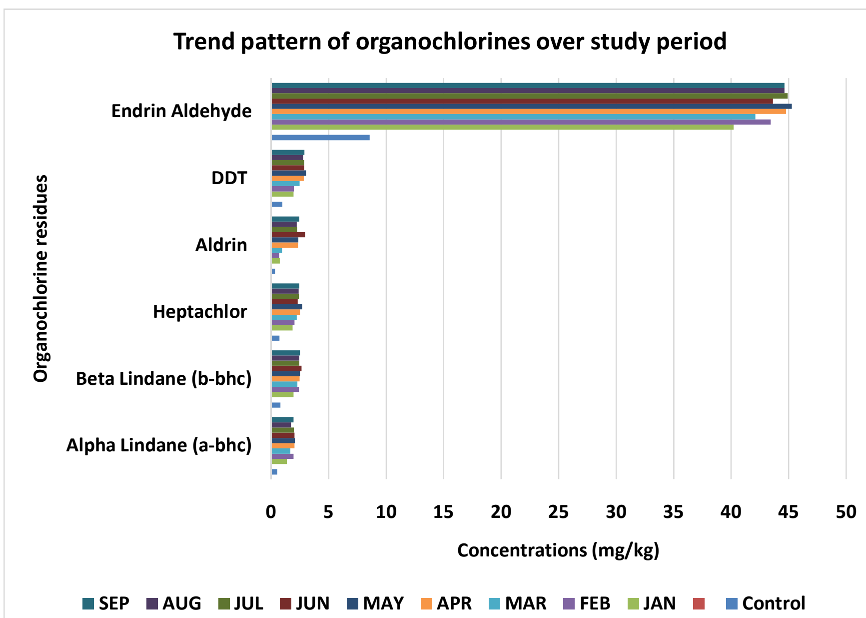

Figure1: Monthly trend pattern of organochlorine residues.

and June for most of these compounds (Table 1). This seasonal trend implies an influence associated with agricultural practices, climatic conditions, and the life cycles of the targeted pests. This pattern aligns with the findings of a previous study conducted by (Materu *et al*, 2021).

Both Alpha and Beta Lindane concentrations exhibit a consistent increase, with peak values observed at the onset of the rainy season, surpassing those of the control group. This could be attributed to heightened pesticide application during the growing season to combat various pests. The relatively low standard deviations in these values suggest a uniform trend across different sampling periods.

Heptachlor concentrations also demonstrate a similar pattern, with elevations during the rainy season. Notably, the standard deviations, particularly in March and April, are higher than in other months, signifying variability in pesticide levels during this specific period. The study reveals that DDT and Endrin Aldehyde are the most prevalent organochlorines in the soil, potentially due to their ready availability in the market and farmers' unrestricted access to them. DDT concentrations exhibit a distinctive pattern, remaining relatively stable from January to March, surging in April, and peaking in May (Table 1). Subsequently, DDT concentrations decrease throughout the study period, suggesting a seasonal variation distinct from other pesticides. It is noteworthy that the recorded DDT levels significantly exceed the maximal acceptable range of 0.05 mg/kg, as specified by (Bempah *et al*., 2012). One of the well-documented adverse effects of DDT is its detrimental impact on bird populations, especially birds of prey (Yu and Yang, 2007).Endrin Aldehyde, when leached into aquatic ecosystems proves highly toxic to fish and aquatic invertebrates. Furthermore, organochlorines have high bioaccumulation potentials and accumulates in the fatty tissues of organisms and magnifies as it moves up the food chain. Birds at the top of these food chains, such as eagles, suffer severe reproductive issues due to exposure to Endrin Aldehyde, interfering with their ability to produce viable eggs and leading to population declines in several avian species. This disruption disrupts the natural balance of ecosystems and has cascading effects on other organisms. Also, organochlorine residues have been reported in human breast milk and serum (Li *et al*, 2022)

The study also monitored various physicochemical parameters throughout the research period. The pH values exhibit slight variations, with the lowest value recorded in January (5.36) and the highest in August (5.66) (Table 2). The pH values are slightly acidic and remain relatively close to one another. Conductivity measures the soil's ability to conduct electrical current and serves as an indicator of the concentration of dissolved ions in the medium. The conductivity values consistently hover around 977-978 mS/M, indicating stable concentrations of dissolved ions in the solution. The moisture percentage signifies the water content in the soil, and it exhibits variations over the months, with the lowest moisture in January (32.6%) and the highest in September (53.9%), suggesting an increase in soil moisture with the rise in rainfall. Organic Matter (%) represents the proportion of organic materials in the sample, including plant or animal residues, humus, or other organic substances. Organic matter levels consistently increase in the subsequent months, ranging from 2.7% in April to 3.2% in several months, indicating a rise in organic matter content compared to the control condition.In summary, the data suggests very minor pH fluctuations, increased moisture content, and higher organic matter percentages, while conductivity remains stable across the months, indicating a consistent presence of dissolved ions in the solution (Table 2). The presence of pesticide residues in the soil raises concerns about bioaccumulation in organisms, leaching, and runoff into nearby water bodies, resulting in reduced biodiversity and water quality degradation.

Conclusion

The results of this study highlight the concentrations of various organochlorine pesticide residues in the soil as well as the associated significant ecological and health risks. These findings underscore the importance of sustainable pesticide management, monitoring, and regulation to mitigate these impacts and protect both the environment and human health. Further research is needed to investigate the long-term consequences of pesticide contamination in the region and to develop strategies for more environmentally and socially responsible agricultural practices.

Recommendations

1. That the proliferation of these toxic compounds be speedily checked to prevent further damage to the ecosystem and human life.
2. That other less toxic alternatives be adopted as agricultural inputs.

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