Acta Scientific NUTRITIONAL HEALTH (ISSN:2582-1423)

Volume 10 Issue 1 January 2026

Research Article

Evaluation Pesticide Residues in Soil on Seasonal Agricultural Schemes in Blue Nile State - Sudan

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Received: December 01, 2025

Published: December 16, 2025

Abstract

Background: Pesticide contamination in agricultural soils poses significant environmental and health risks. This study investigated the presence and distribution of commonly used pesticides—including organochlorines, organophosphates, and herbicides—in selected areas of the Blue Nile State, Sudan.

Methods: Soil samples were collected from ten sites across five localities within seasonal agricultural schemes, targeting zones of both intensive and extensive pesticide use. The analysis focused on residues of specific insecticides (e.g., Dimethoate, Chlorpyrifos, Profenofos, DDT, Dialdrin) and herbicides (e.g., Imazalil, Butachlor).

Results: Pesticide residues were unevenly distributed across sites. Eltadamon locality showed the highest residue levels, followed by Damazine and Baw. Notably, Profenofos was detected at a significantly high concentration (24.1 mg/kg) in Sample 3, suggesting recent or excessive use. Trace levels of banned substances such as DDT and Dialdrin were detected in Samples 5 and 6, indicating historical contamination. Sample 8 exhibited multiple pesticide residues, possibly due to combined applications. Five samples (2, 4, 7, 9, 10) had no detectable residues. Group-wise classification showed that organophosphates accounted for 73% of all detected residues, while organochlorines made up 27%. Among individual pesticides, DDT and Chlorpyrifos were each present in 18% of the contaminated samples.

Conclusion: The findings highlight localized pesticide contamination in agricultural soils of Blue Nile State, with potential environmental and public health implications. The presence of banned substances and excessive organophosphate levels warrants regulatory oversight, further monitoring, and awareness programs for safer pesticide use.

Keywords: Pesticide; Food; Sudan

Introduction

Pesticides use in agriculture is the most economical approach to control various pests, though they are considered major contaminant of our environment, There are several definitions of pesticide; the Food and Agriculture Organization, (FAO) defines pesticide as any substance or mixture of substances intended for preventing, destroying or controlling any pest during the production processing, storage or marketing of food in all agricultural commodities for controlling the pests [1].

Pesticides are playing a pivotal role in meeting the food, cotton fibre and tobacco demand of escalating population and control of vector-borne diseases. However, most of the applied pesticides get dispersed in the environment and affects the health of un-protected agricultural and industrial, workers [2].

Pesticides are used extensively throughout the world, The three major routes of entry for pesticides include contamination of the skin, mouth and the nose. Although pesticides furnish some benefits for crop, they a number of risks and problems, have the potential for causing a range of short-term or long-term health problems [3]. Documented health effects include a wide variety of illnesses and diseases, from eye irritation, skin rashes and respiratory problems, neurological damage, birth defects, cancer and death [4]. The risk for and severity,verse health effects from pesticide factors Pesticides have improved the standard of human health by controlling vector-borne diseases, however, their long term and indiscriminate use has resulted in serious health effects [5]. Human beings especially infants and children are highly vulnerable to deleterious effects of pesticides due to the non-specific nature and inadequate application of pesticides. As the pesticide use has increased over the past few decades, the likelihood of exposure to these chemicals has also increased considerably [6].

Pesticides enter the human body through ingestion, inhalation or penetration via skin [7]. But the majority of people get affected via the intake of pesticide contaminated food. After crossing several barriers, they ultimately reach human tissues or storage compartments [8]. Although human bodies have mechanisms for the excretion of toxins, however, in some cases, it retains them through absorption in the circulatory system [9]. Toxic effects are produced when the concentration of pesticide in the body increases far more than its initial concentration in the environment [8].

The effects of pesticides on human health are highly variable. They may appear in days and are immediate in nature or they may take months or years to manifest and hence are called chronic or long-term effects. Acute and chronic effects of pesticide exposure on human health are very crucial [10].

Material and Methods

Study area

The study was conducted in Blue Nile State, located in southeastern Sudan, an area known for its seasonal agricultural schemes characterized by intensive farming practices, often involving the widespread use of chemical pesticides and herbicides to control pests and boost crop yields.

Collection of soil samples

A purposive sampling method was used to select 10 soil sampling sites across five localities in Blue Nile State. Locations were chosen based on known agricultural activity and expected variability in pesticide use intensity to ensure meaningful assessment of residue levels.

A total of 10 soil samples were collected from various agricultural areas across five localities in Blue Nile State, Sudan. The sampling sites included:

- Eltadamon locality – 3 samples from the Al-Arabiya Company for Agricultural Activities
- Damazine locality – 2 samples from Elgamiea Agricultural Area
- Leproseries locality – 3 samples from the Eltacamol Company for Agricultural Activities
- Gassan locality – 1 sample from the Abu Gamia Agricultural Area
- Baw locality – 1 sample from the Wad Abuk Agricultural Scheme

Each soil sample was collected at a depth suitable for detecting pesticide residues and weighed approximately 1 kilogram. The sampling sites were selected to represent areas with varying levels of pesticide use, including both intensive and extensive farming practices.

Sample storage

Water samples were stored in a cold chain system at −20°C, with temperature monitoring conducted twice daily—morning and evening—for over one year to ensure sample integrity.

Soil samples were stored at a temperature range of 2°C to 8°C under similar cold chain conditions, with twice-daily monitoring maintained throughout the storage period of more than one year.

Extraction of soil samples

Soil extracts were prepared following the method described by [11]. For each sample:

- The sample was transferred to a 500 ml separatory funnel.
- 400 ml of n-hexane and 100 ml of acetone were added.
- The funnel was tightly sealed and placed on an end-over-end shaker for 2 hours.
- After shaking, samples were allowed to stand and were then filtered using 240 mm filter paper into a round-bottom flask containing 100 g of anhydrous sodium sulfate to absorb any residual moisture.
- The filtrate was subjected to rotary evaporation under vacuum at 40°C until dryness.
- Dried extracts were reconstituted in 10 ml of n-hexane and transferred into closed vials stored at 4°C until cleanup and residue analysis.
- Prior to analysis, two drops of potassium hydroxide (KOH) were added to each vial to convert DDT to DDE, ensuring accurate detection.

Clean-up of soil samples

Clean-up was performed based on the method by [12]:

- A chromatographic column (20 x 40 mm) was packed with:
    - A bottom plug of glass wool
    - A 4-inch layer of activated silica gel
    - A top layer of anhydrous sodium sulfate
- The column was pre-rinsed with a small volume of hexane.
- Once the hexane dried, the soil extract was applied to the top of the silica layer.
- Elution was performed using 200 ml of a toluene:acetone mixture (19:1).
- The eluates were concentrated to dryness using rotary evaporation and then reconstituted in 10 ml of acetone, transferred into 10 ml volumetric flasks, and stored at 4°C for final pesticide residue analysis.

Method of analysis

Multiresidue Method for Soil Analysis was used.

Pesticide residues in soil samples were analyzed using a Multiresidue Detection Method employing Liquid Chromatography–Tandem Mass Spectrometry (LC-MS/MS) and Gas Chromatography–Tandem Mass Spectrometry (GC-MS/MS). This approach allows for the simultaneous detection and quantification of multiple pesticide classes, including organochlorines, organophosphates, and herbicides, with high sensitivity and specificity.

Result

Several commonly used insecticides, primarily from the organochlorine and organophosphorus groups, along with two herbicides, were selected for evaluation in this study. The selected pesticides reflect those frequently applied in agricultural practices across Blue Nile State. Soil samples were collected from ten different sites within the seasonal agricultural schemes of the Blue Nile region. These sites were strategically chosen to represent areas with both intensive and extensive pesticide use, providing a comprehensive overview of pesticide residue distribution in the region's agricultural soils.

The above map showed the distribution of Pesticide residue by various areas showed that Eltadamon locality has most residue followed by Damazine and Baw.

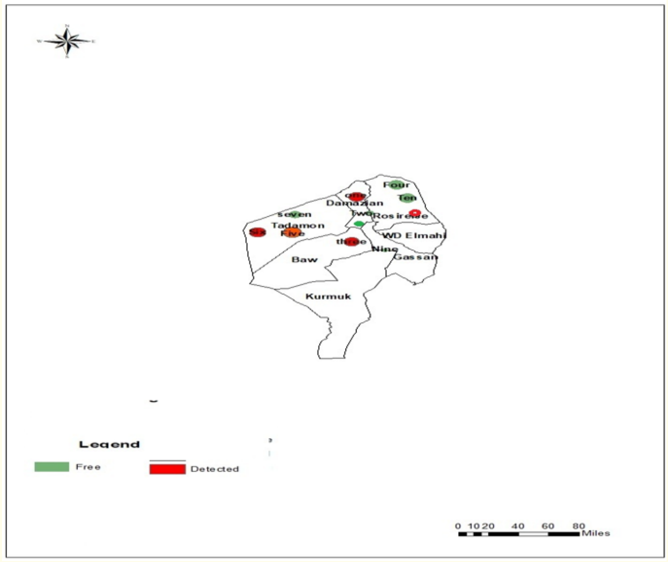

Figure 1: The map showed distribution of samples in various areas In Blue Nile State.

No of Sample	Pesticide/concentrations									
	Dimethoate	Chiopyrifos	Profenosfos	Biphenyi	DDT	Dialdarian	Malaoxon	Imazalil	Butachor	Rogar
1	0.024	0.035			0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3		0.01	24.1	0.05	0	0	0	0	0	0
4	0	0	0	0			0	0	0	0
5	0	0	0	0	0.001	0.002	0	0	0	0
6	0	0	0	0	0.002		0	0	0	0
7	0	0	0	0	0	0	0	0		
8	0	0	0	0			0.04	0.023	0.11	0.022
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0

Figure 2: The table showed the type of Pesticide and their presence.

Pesticide residue findings in soil samples

The analysis of soil samples collected from ten sites revealed variable levels of pesticide residues across locations. Notably, Sample 3 showed the highest concentration, with 24.1 mg/kg of Profenofos and 0.05 mg/kg of Biphenyl, indicating possible recent or excessive application in that area. Sample 1 contained moderate levels of Dimethoate (0.024 mg/kg) and Chlorpyrifos (0.035 mg/kg), both organophosphates. Sample 5 showed trace levels of banned organochlorines—DDT (0.001 mg/kg) and Dialdrin (0.002 mg/kg)—suggesting historical contamination. Sample 6 also had DDT present at 0.002 mg/kg. Sample 8 was the most chemically diverse, containing Malaoxon (0.04 mg/kg), Imazalil (0.023 mg/kg), Butachlor (0.11 mg/kg), and Rogar (0.022 mg/kg), indicating mixed pesticide usage. In contrast, Samples 2, 4, 7, 9, and 10 showed no detectable pesticide residues, which may be due to the absence of recent pesticide application or degradation of previously applied chemicals.

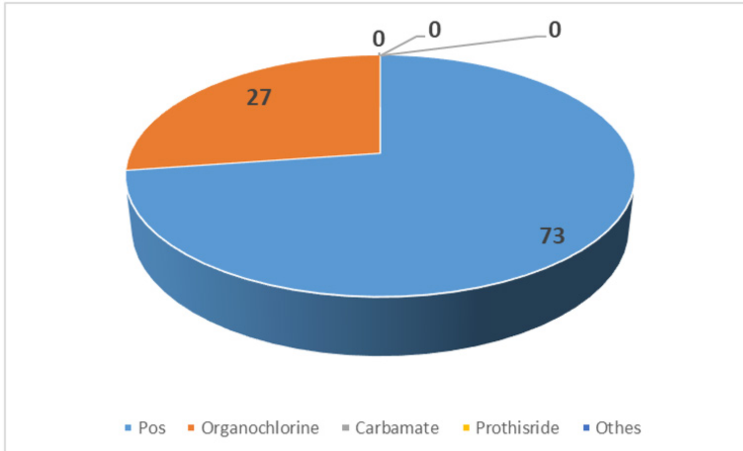

Figure 3: The table showed the type of Pesticide and their presence.

Pesticide residue classification by chemical group

Figure (3) illustrates the distribution of pesticide residues in the soil samples based on their chemical classification. Organophosphates (labeled "Pos") accounted for 73% of the detected residues, indicating their dominant use in the study area. Organochlorines represented 27%, reflecting either continued use or persistent legacy contamination. No residues from carbamates, prothiofos, or other pesticide groups were detected in the samples, as indicated by their 0% representation. This highlights the prominence of organophosphate and organochlorine compounds in the pesticide profile of agricultural soils in Blue Nile State.

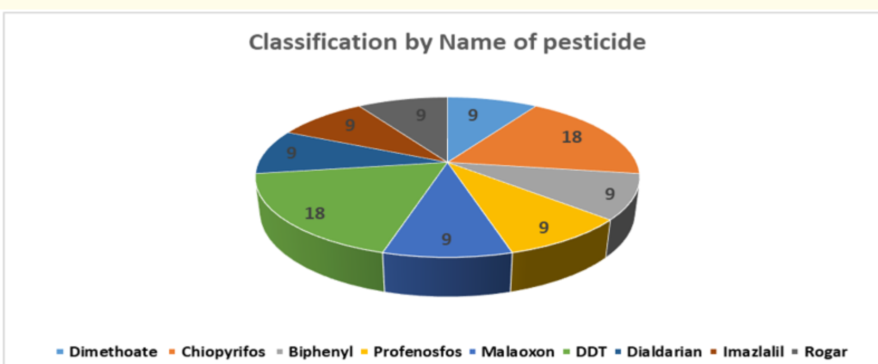

Figure 4: Classification of Pesticide residue by Name of Pesticide.

Classification by name of pesticide

Figure 4 displays the distribution of detected pesticide residues by specific chemical name across all soil samples. Profenofos and DDT were the most frequently detected pesticides, each accounting for 18% of total residues. This suggests both recent application (Profenofos) and legacy contamination (DDT). Other pesticides, including Dimethoate, Chlorpyrifos, Biphenyl, Malaoxon, Dialdrin, Imazalil, and Rogar, each made up 9% of the total. This diverse profile reflects a broad spectrum of pesticide types used in the study area, with a mix of both insecticides and herbicides present.

Discussion

The detection of pesticide residues in 50% of the soil samples collected from various locations in Sudan's Blue Nile State raises substantial concerns regarding environmental safety, agricultural sustainability, and public health. These findings reflect both current pesticide application practices and historical contamination, highlighting ongoing challenges in pesticide regulation and land management in Sudan's agricultural zones.

Numerous studies conducted in Sudan, particularly in major agricultural zones such as Gezira State, have consistently reported the presence of pesticide residues in soil, especially organochlorines and organophosphates [13]. These patterns reflect improper handling, overapplication, and inadequate training in pesticide use among farmers. The current findings from Blue Nile State reinforce these earlier conclusions and suggest that pesticide mismanagement is a systemic issue across agricultural regions in Sudan.

Despite being banned or severely restricted under international frameworks like the Stockholm Convention, DDT was detected in 18% of samples. This supports previous research showing residual DDT in Sudanese soils, particularly where it was historically used for malaria control or agricultural pest management [14]. DDT's long half-life and persistence in the environment—ranging from several years to decades—explains its continued detection in agricultural soils, suggesting either illegal use or legacy contamination.

The presence of chlorpyrifos in 18% of soil samples is also consistent with prior studies from other regions in Sudan [15]. As a commonly used organophosphate, chlorpyrifos is applied to various cash and staple crops. Its detection reflects ongoing use and possible overapplication, particularly in areas lacking adequate training and regulatory enforcement. The neurotoxic potential of chlorpyrifos, combined with its persistence in soil and risk of leaching into water sources, underscores the public health implications of its widespread use.

The 9% of samples containing other pesticide residues likely represent a mix of herbicides, fungicides, and insecticides, including Malaoxon, Imazalil, and Rogar. Similar findings were reported by [16], who detected carbamates, pyrethroids, and endosulfan in agricultural soils across Sudan. The presence of such diverse chemical residues may reflect unregulated chemical use, limited farmer awareness, and insufficient monitoring of banned or restricted substances.

Of all analysed samples. 72% contained organophosphate residues, indicating their dominance in current agricultural practices. 27% contained organochlorine residues, aligning with previous studies on the persistence of banned POPs (persistent organic pollutants) in Sudanese soil. No residues of carbamates or other pesticide classes were detected, which may be due to their lower usage or faster degradation rates. This distribution pattern mirrors previous research across Sudan, which has repeatedly highlighted the environmental persistence of organochlorines and the widespread use of organophosphates despite their known toxicity and risks to soil, water, and human health.

The Eltadamon locality recorded the highest pesticide residue levels, followed by Damazine and Baw. This spatial distribution is consistent with patterns observed in other studies and may be explained by the Intensive Agricultural Activity, Eltadamon hosts extensive crop production systems that likely require frequent pesticide applications. Cash crops, in particular, tend to attract higher pesticide inputs due to pest pressures and market demands. Poor Pesticide Management: Previous research has linked high residue levels with improper pesticide application, lack of protective equipment, inadequate storage, and limited farmer training. These factors are likely present in Eltadamon, where awareness and regulation may be insufficient.

Conclusion

In summary, the detection of pesticide residues in half of the soil samples from Blue Nile State confirms significant and widespread contamination. The findings, revealing prevalent organophosphates and persistent organochlorines like DDT, alongside chlorpyrifos and other residues, highlight systemic deficiencies in pesticide regulation, management practices, and farmer training across Sudan's agricultural regions. This contamination poses substantial risks to environmental health, agricultural sustainability, and public well-being. Urgent implementation of stricter regulations, enhanced monitoring, comprehensive farmer education on safer practices and IPM, and long-term soil health assessments are essential to mitigate these risks and foster sustainable agriculture.

Recommendations

The findings emphasize the need for:

- Enhanced monitoring and regulation of pesticide use.
- Farmer education programs on safe pesticide handling and integrated pest management (IPM).
- Soil health assessments and long-term environmental impact studies to guide sustainable agriculture.

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