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Organophosphorus Pesticide Residues in Soil Samples from Nanumba North Municipality, Ghana

By

Yakubu Fusheini[1*] Paul Ayekorok Abowen [1*] Kenneth B. Pelig-Ba[2], Samson A. Abagale[2], and Lateef Adebayo Oseni[3]

[1]Department of Science Education, E. P. College of Education, Bimbilla, Ghana
[2] Department of Chemistry & Biochemistry, C. K. Tedam University of Technology & Applied Sciences, Navrongo, Ghana
[3]Department of Chemistry, University for Development Studies, Tamale, Ghana

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Abstract

The objective of this study was to assess the levels of organophosphorus pesticide residues in soil samples from the Nanumba-North Municipality of the Northern region of Ghana using Gas Chromatography equipped with a Pulsed flame photometric detector (GC-PFPD). Ten (10) soil samples from the Nanumba-North Municipality of the Northern Region of Ghana were collected and analysed.

Seven (7) organophosphorus pesticide residues were detected in the soil samples at varying mean concentrations. Organophosphorus pesticide residues detected in the soil samples of some selected farms in the Nanumba-North Municipality were parathion, methamidophos, chlorpyrifos, malathion, diazinon, chlorfenvinphos, and profenofos. The study revealed the presence of most of the organophosphorus pesticide residues at varying concentrations, with methamidophos recording significant concentrations in soil samples.

The mean concentrations of pesticide residues in the soil samples analysed from the study site were generally below (2017) WHO MRLs for agricultural soils, except for methamidophos from BCS1 (0.068 µg/L) which was above the (2017) WHO permissible limit of 0.050 µg/L for agricultural soils, respectively. Organophosphorus pesticide residues detected showed significant differences at $p < 0.05$.

Holistically, the detection of organophosphorus pesticide residues in the analysed samples indicates that farmers in the study area use pesticides to control pests and diseases.

Keywords: *organophosphorus pesticides; Nanuma-North Municipality; GC-PFPD; pests and diseases*

1.0 Introduction

The increasing reliance on organophosphate pesticides in agricultural activities across Ghana, especially in areas such as the Nanumba-North Municipality, underscores the urgent need for comprehensive quantitative evaluation, given their potential to persist in the environment and pose significant risks to human health and ecological systems [1:2]. The pressure to satisfy rising food production needs has intensified the use of agrochemicals, resulting in the accumulation of appreciable levels of pesticide residues across diverse environmental compartments [3]. Organophosphate pesticides, a class of synthetic organic compounds, are extensively utilised in agriculture for pest control, crop yield enhancement, and the extension of food crop shelf-life, thereby contributing significantly to environmental pollution [4]. Their complex chemical structures, often esters of phosphoric acids, include aliphatic, phenyl, or heterocyclic derivatives that contribute to their persistence and widespread environmental contamination [5]. They possess high lipophilicity, slow environmental degradation, and a tendency to accumulate in fatty tissues and blood, frequently being linked to neurodegenerative disorders [6]. Specifically, organophosphates are known to inhibit acetylcholinesterase, a critical enzyme in the nervous system, leading to neurotoxicity in both humans and animals [4]. This inhibitory action, arising from the phosphorylation of the enzyme's active site at a serine residue, underscores the severe biological implications of organophosphate exposure [7]. Their frequent application and the indiscriminate use of these chemicals have been associated with unintended environmental and human health consequences, including potential chronic and acute health problems [8:1]. Despite their agricultural utility, these compounds are frequently transported from their intended application sites through runoff and soil penetration, subsequently contaminating surface and groundwater bodies. Globally, an estimated 200,000 deaths occur each year due to toxic pesticide exposure, highlighting the urgent need for more stringent regulatory frameworks [9]. Persistent organic pollutants accumulate in terrestrial and aquatic ecosystems, posing significant environmental risks. This accumulation adversely affects non-target organisms and leads to the degradation of biodiversity [10]. In addition, the inherent toxicity of organophosphates to aquatic organisms, coupled with their potential for bioaccumulation and biomagnification through the food web, further destabilises ecosystem health [9]. According to [10], systematic monitoring of these compounds in environmental media such as water and sediments is essential for evaluating potential ecological risks. Such assessments require comprehensive analytical approaches, often employing advanced chromatographic techniques, including gas chromatography, to accurately quantify residue concentrations and elucidate their environmental fate and transport [11]. As suggested by [12:5], in light of the widespread use and inherent toxicity of organophosphate pesticides, there is an urgent need to assess their concentrations across environmental compartments and to develop effective remediation strategies. This necessitates a deeper understanding of their environmental behaviour and the development of robust monitoring programs to safeguard ecological integrity and public health [7:12]. In addition to their acute toxic effects, the widespread occurrence of organophosphate pesticide residues in both terrestrial and aquatic ecosystems underscores the need for continuous monitoring to reduce long-term ecological impacts and the risk of bioaccumulation within food webs [5]. Furthermore, organophosphorus pesticide residue levels have been widely documented in agricultural regions worldwide [1: 8:9:10:11], providing sufficient evidence to warrant similar concerns in the Nanumba-North Municipality. However, a range of analytical approaches, notably advanced chromatographic techniques such as liquid chromatography–mass spectrometry (LC–MS), are widely employed for the sensitive detection and quantification of these compounds in diverse environmental matrices [4]. These methods are essential for characterizing the environmental burden of persistent pollutants and for supporting robust ecological and human health risk assessments. Organophosphate exposure disrupts acetylcholinesterase activity, resulting in the accumulation of acetylcholine and subsequent overstimulation of synaptic transmission, a mechanism associated with neurodegenerative disorders [13]. This mode of action underpins their classification as highly potent neurotoxic agents and clearly distinguishes organophosphates from other classes of pesticides [14]. This neurotoxicological impact necessitates stringent monitoring and regulation to mitigate the pervasive health risks associated with organophosphate exposure in agricultural regions [15:16]. The acute toxicity of these compounds is primarily attributed to their capacity to inhibit acetylcholinesterase, an enzyme vital for neural conduction in both humans and animals [17:18]. This inhibition leads to an overstimulation of cholinergic synapses due to acetylcholine accumulation, causing symptoms that range from mild to severe poisoning, depending on the exposure level [19:20]. Although organophosphates are less stable than organochlorine pesticides, their widespread application still poses significant environmental and health risks. For instance, organophosphates such as chlorpyrifos and malathion become even more potent acetylcholinesterase inhibitors after metabolic or chemical conversion of their phosphorus-sulfur bond to a phosphorus-oxygen bond [21]. Given the public health concerns surrounding pesticide use and their long-term impacts on humans and animals, this study sought to determine the levels of organophosphorus pesticide residues in soils from the Nanumba-North Municipality, with the resulting data supporting efforts to safeguard human and animal health

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carry-out in the Nanumba North Municipality, which is located in the southeastern part of Northern Region of Ghana. The area lies between latitudes 8.5º N and 9.25º N and longitudes 0.57º E and 0.5ºE. According to the 2010 Population and Housing Census, the total population of Nanumba North Municipality is 141,584. Males constitute 49.4 percent and females represent 50.6 percent in the Municipality. The Municipality has a total land area of 2260.8 sq. Km. The predominant occupation is farming. (www.ghanadistrics.com 2011).

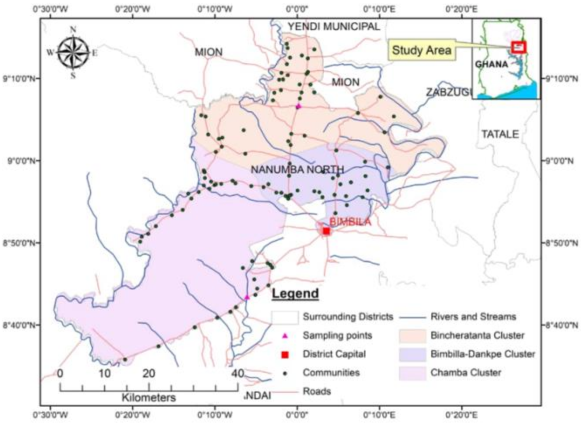

Figure 1: A map showing Nanumba North Municipality in the Northern Region of Ghana

2.2 Collection of soil samples

Each of the selected farms was simply grouped into three clusters, that is, Bimbilla-Dangbe cluster BDS, Bincheratanga cluster BS, and Chamba cluster CS also, three quadrants of 70

× 70 m were marked meticulously in each cluster. In each quadrate, three (3) soil samples were collected randomly at a depth of 0–20 cm with a soil auger. Meanwhile, the rectitude of taking this depth was because nutrient uptake by the plant is usually reported to be within this horizon [22]. Additionally, one soil sample was taken from a nearby natural forest from each cluster to act as a control (X1), where there were no farming activities. They were then placed in well-labelled clean plastic polythene bags and transported to the laboratory for analysis. These gave a total of ten soil samples for the study area. All soil samples were kept in well-labelled plastic polythene containers and transported to the laboratory for analysis. At the laboratory of the Council for Scientific and Industrial Research (CSIR) in Accra, the soil samples were oven-dried at 105 °C to constant weight and sieved using 2 mm nylon mesh. Sub-samples of the sieved soils were then taken for pesticide residue analysis.

2.3 Standard solutions

Stock solutions (100 mg/mL) of the seven organophosphorus pesticide standards were prepared by accurately weighing or pipetting appropriate amounts of each compound into separate 25 mL volumetric flasks. The contents were dissolved and made up to volume with ethyl acetate using a vortex mixer (Thermolyne Maxi Mix-Plus). Working standard solutions used for procedural recovery (fortification) experiments and for instrument calibration were freshly prepared by serial dilution of the stock solutions with ethyl acetate. Distilled water was used in the preparation of all aqueous solutions. Before gas chromatographic (GC) analysis, all prepared solutions were filtered through 0.45 µm nylon membrane filters.

2.4 Extraction of soil samples

The extraction of the soil samples was carried out by the method described by [23], with slight modification from (CSIR) in Accra, Ghana. Ten grams (10 g) of the representative soil samples were weighed and quantitatively transferred into 250 mL separating flasks. 10 mL of acetonitrile was added to each of the soil samples in the flasks and ultra-sonicated (Becon FS400b) for 5 min. An additional 10 mL of acetonitrile was added, and the flasks closed tightly. The samples were placed on a horizontal mechanical shaker (Ika-Werke HS 501 Digital) and set to shake continuously for 30 min at 300 mot/ min. The contents were then allowed to stand for 10 min to sufficiently separate the phases or layers. 10 mL of the supernatants were carefully taken by pipette and dried over 2 g anhydrous magnesium sulfate through filter paper into 50 mL round bottom flasks. The concentrates were then adjusted to about 2 mL using the rotary film evaporator (Buchi Ratovapor R-210, USA) at 35 °C, and made ready for the silica clean-up step.

2.5 Clean-up of soil extract

The silica gel clean-up process for the soil extracts was carried out by the methods described by [23], with slight modifications from (CSIR) in Accra, Ghana. Extracts clean-up was done, using polypropylene cartridge columns, packed with one-gram silica gel previously activated for 10 h in an oven at 130 °C, which has a 1 cm thick layer of anhydrous magnesium sulphate on top and conditioned with 6 mL acetonitrile. The concentrated extracts were then loaded onto the columns/ cartridges, and 50 mL pear shape flasks were placed under the columns to collect the eluates. A 10 mL acetonitrile was used to elute the columns/cartridges afterward. The total filtrates (eluents) collected were concentrated to dryness using the rotary evaporator (Buchi Ratovapor R-210) set at 40 °C. The residues were re-dissolved in 1 mL ethyl acetate by pipetting and transferred into 2 mL standard opening vials prior to quantitation by gas chromatography (GC) (Varian Association Inc. USA) equipped with Pulsed Flame Photometric Detector (PFPD). All extracts were kept frozen until quantification was achieved.

2.6 Gas chromatographic determination

Final extracts were analysed using a gas chromatography (GC)—Varian CP-3800 (Varian Association Inc. USA) equipped with pulse flame photometric detector (PFPD) and CombiPAL Autosampler at the Council for Scientific and Industrial Research, Accra,Ghana Pesticide Residues Laboratory. The GC conditions and the detector response were adjusted so as to match the relative retention times and response as spelt out by the Japanese analytical methods for agricultural chemicals [24]. The GC conditions used for the analysis were capillary column (fused silica capillary) coated with VF-1701 ms (30 m × 0.25 mm internal diameter, 0.25 µm film thickness). The injector and detector-PFPD temperatures were set at 270 and 280 °C respectively. The oven temperature was programmed as follows: 70 °C held for 2 min, ramp at 25 °C min−1 to 200 °C, held for 1 min, and finally ramp at 25 °C min−1 to 250 °C. Nitrogen was used as carrier gas at a constant flow rate of 2.0 mL/min and detector makeup gases of 17.0, 14.0 and 10.0 mL/min for air 1, hydrogen and air two respectively. The injection volume of the GC was 2.0 µL in a split less mode. The total run time for a sample was 14 min.

2.7 Quality Assurance and Quality Control

Appropriate quality assurance and quality control (QA/QC) procedures were implemented to ensure the reliability and accuracy of the analytical results. All samples were carefully handled to prevent external interference and potential contamination. Glassware was thoroughly cleaned with detergent, rinsed with distilled water, further rinsed with analytical-grade acetone, and oven-dried overnight at 150 °C. After cooling, the glassware was stored in dust-free cabinets until use. Deionized water was used throughout the study. For spectrophotometric measurements, reagent blanks were analysed to correct instrument readings. Method validation was performed through repeated analysis of samples against an internationally certified standard reference material (SRM-1570) obtained from the National Institute of Standards and Technology (NIST). Quality control for organophosphorus pesticide residue analysis was further ensured by analysing solvent blanks, procedural matrix blanks, and duplicate samples. All reagents were subjected to the same extraction and analytical procedures to check for potential interfering substances; no pesticide residues were detected in any procedural blanks. One sample from each analytical batch was analysed in duplicate, and all extracts were stored frozen before quantification. A fortification level of 0.001 mg kg^{-1} was applied to soil samples to evaluate method recovery. The efficiency of the extraction and clean-up procedures was assessed using an internal standard, with recoveries ranging from 63 % to 94 % for the organophosphorus pesticides analysed. These recovery values indicate good method reproducibility and analytical reliability.

2.8 Quantification and limit of detection of pesticides

Quantification of organophosphorus pesticide residues was performed using the external standard calibration method based on peak area measurements. Analyses were conducted within the linear response range of the detector in accordance with established procedures [25:26:23]. Peaks with retention times corresponding to those of the reference standards were identified, and their areas interpolated from the respective calibration curves to determine analyte concentrations. The limits of detection (LOD) were determined using extracts of fortified soil samples that were serially diluted by a factor of two to obtain a range of concentrations. The LOD was defined as the lowest concentration producing a signal equivalent to three times the standard deviation of the least fortified sample, thereby accounting for both analyte variability and background noise. Using this approach, the LOD for organophosphorus pesticides in soil samples was estimated at 0.001 µg L^{-1}

2.9 Data analysis

Statistical package for social sciences (SPSS) software version 16.0 was used to generate the means, standard deviation, and standard error for pesticide residues in soil. One-way analysis of variance (ANOVA) was performed to analyse significant differences in the concentrations of pesticide residues recorded from the soil samples.

3.0 Results and Discussion

The order of percentage of the pesticide residues occurring in the soil samples was as follows**:** Parathion (28%) > Methamidophos (27%) > Chlorpyrifos (25%) > Malathion (7%) > Diazinon (6%) > Chlorfenvinphos (4%) > Profenofos (3%). Results revealed a recovery range between 63–94 % for all the pesticides detected, indicating that the analytical process used was efficient and reproducible.

Diazinon constitutes 6% of the soil samples analysed at a mean concentration of 0.006 ± 0.004 µg/L and ranged from a minimum of 0.003 µg/L to a maximum of 0.007 µg/L. However, except soil samples from the (X1), which had no detectable mean concentration of diazinon. The measured concentration of diazinon from the various clusters was all lower than the WHO MRLs of 0.050 µg/L for agricultural soils, respectively. Statistically, the concentrations of diazinon recorded in the soil samples were significantly different ($p<0.05$) among the various clusters. Meanwhile, diazinon had a higher average concentration compared with Chlorfenvinphos and Profenofos of the organophosphate pesticide residues detected in the various clusters, as depicted in Table 1. Furthermore, diazinon is an organophosphate pesticide and is considered moderately hazardous (WHO II) under WHO Classification. Although the detection levels of diazinon were below the WHO MRLs of 0.050 µg/L for agricultural soils in the soil samples, its occurrences in the soil samples have several health implications. For instance, exposure to diazinon in human beings has several lingering symptoms, such as a runny nose, loss of appetite, watery eyes, drooling, coughing, urination, stomach pain, diarrhoea, and vomiting. Meanwhile, the mean values of diazinon recorded in this work were, however, lower than the values reported by [27] in soils samples 0f 0.040 µg/L at Alau dam and Gongulong Agricultural area, Boron State, Nigeria.

Mean residual concentrations of malathion were 0.008±0.004 µg/L and occupy 7% of the of the soil samples analysed, respectively. In this study, the level of malathion residues was found to range from 0.002 µg/L as the minimum to 0.026 µg/L as the maximum, and it has a higher amount compared with diazinon, chlorfenvinphos, and profenofos residues, as shown in Figure 2. The persistence of malathion in the environment is affected by sunlight and ultraviolet light exposure. Photolysis reaction occurs to reduce the toxicity of malathion. The measured concentration of malathion from the various clusters in the soil samples was generally far below the WHO MRLs of 8.000 µg/L for agricultural soils, respectively. Statistically, the concentrations of malathion recorded in the soil samples were significantly different ($p <0.05$) among the various clusters. Perhaps, malathion residue in the soil might occur due to improper handling of the current pesticide formulations during the mixing process, including spills or practices usage and poor storage. Empirically, this substance is released into the atmosphere in the form of gas and can be transported back to the surface of the soil and water through wet deposition. Also, malathion is rapidly degraded in the soil, and degradation of this pesticide usually begins within hours to about one (1) week. In fact, this potentially toxic substance can also evaporate from the soil and in addition, malathion moves very easily in the soil. However, the process of malathion leaching from the soil into the water is not possible due to the rapid degradation of this compound in the environment. Also, as typically alluded to by [28], and later attested by [29], this substance is soluble in water and can move quickly into the ground despite its low persistence (1-25 days in the ground). However, according to [30], malathion is toxic via skin contact, ingestion, and inhalation exposure. The concentration of malathion residue levels recorded in this study was far lower than the mean concentration of 18.26 µg/L reported by [31].

Methamidophos constitutes 27% of the soil samples measured with a mean concentration of 0.031±0.018 µg/L and ranged from 0.009 µg/L as the minimum to 0.068 µg/L as the maximum. However, except soil samples from the (X1), which had no detectable mean concentration of methamidophos, as shown in Table 1. The measured concentration of soil samples analysed from BDCS1 (0.043 µg/L), BDCS2 (0.010 µg/L), BDCS3 (0.035 µg/L), BCS2 (0.009 µg/L), BCS3, (0.030 µg/L), CCS1 (0.031 µg/L), CCS2 (0.019 µg/L) and CCS3 (0.033 µg/L), were all lower than the

WHO MRLs of 0.050 µg/L for agricultural soils, respectively. Except soil samples analysed from BCS1 (0.068 µg/L), which was above the WHO permissible limit of 0.050 µg/L for agricultural soils. Statistically, the concentrations of methamidophos recorded in the soil samples were significantly ($p < 0.05$) different among the various clusters. Furthermore, methamidophos is an organophosphate pesticide and is classified as highly hazardous (Class IB) by WHO classification. Although, except soil samples from BCS1 which was above its respective WHO MRLs the rest of the soil samples analyzed had detection levels of methamidophos which were remarkably below the WHO MRLs in the soil samples analyzed. The phenomenal occurrences in the soil samples have several potential health implications. For instance, methamidophos can cause cholinesterase inhibition in humans; that is, it can overstimulate the nervous system, causing nausea, dizziness, and confusion, and at very high exposure levels, it can lead to respiratory paralysis and death (U.S.EPA). Similar studies were conducted by [32], and the concentration of methamidophos in the soil of Anxi conventional plantation was the highest, and this might be closely related to the local farmers' spraying habits.

Chlorpyrifos occupies 25% of the soil samples analysed, with a mean concentration of 0.029±0.009 µg/L and ranged from a minimum of 0.020 µg/L to a maximum of 0.042 µg/L. However, except for soil samples from the (X1), which had no detectable mean concentration of chlorpyrifos. The measured mean concentration of chlorpyrifos from the various clusters was generally below the WHO MRLs of 0.050 µg/L for agricultural soils, respectively. Statistically, the concentrations of chlorpyrifos recorded in the soil samples were significantly ($p < 0.05$) different among the various clusters. However, it is very much clear that, the adsorption of pesticides to the soil increases the persistence of chlorpyrifos in the environment by reducing its availability against dissipative capability. While the adsorption effect on environmental toxicity depends on the route of exposure [33], Chlorpyrifos has low water solubility (1.4 mg/l), high soil absorption coefficient (average $K_{\text{oc}} = 8498$ ml/g), and medium vapor pressure (2.7×10^{-3} Pa at 25^{0} C) [34]. Moreso, chlorpyrifos is classified as moderately hazardous (Class II) by the WHO classification. It is quite palpable that the occurrences of chlorpyrifos levels in the soil samples have several health implications. For instance, chlorpyrifos has been linked to a runny nose, tears, and increased saliva or drooling. Other lingering symptoms are severe sweating, headache, nausea, and dizziness. Also, more serious exposures can cause vomiting, abdominal muscle cramps, muscle twitching, tremors and weakness, and loss of coordination. Perhaps, chlorpyrifos is a broad-spectrum organophosphorus pesticide under the trade name Dursban 4R and registered for use in Ghana [35]. The occurrence of chlorpyrifos in the soil samples could be as a result of its current use in crop production. The mean values of chlorpyrifos recorded in this work were, however, lower than the values reported by [27] in soil samples from Alau dam and Gongulong Agricultural area, Boron State, Nigeria. Furthermore, the mean chlorpyrifos residue levels of this finding were partly equivalent to the range (0.01-0.04 µg/L) reported by [1] in soils from cocoa-producing areas in Ghana. On the contrary, the mean chlorpyrifos residue levels recorded in this study were remarkably lower than the range of 0.52-0.97 µg/L reported by [36] in soil samples from Gashua, Bade Local Government Area, Yobe State, in Nigeria. However, this may be due to differences in the geology and extent of soil pollution by pesticides. Indeed, the occurrence of chlorpyrifos in the soil samples indicated a current use of the chemical in crop protection by farmers in the study area as was corroborated by farmers from the field survey by [37]

The measured parathion concentration ranged from a minimum of 0.030 µg/L to a maximum of 0.035 µg/L, with a mean concentration of 0.032±0.002 µg/L. However, the measured concentration of parathion from the various clusters was generally below the WHO MRLs of 0.050 µg/L for agricultural soils, respectively. Statistically, the concentrations of parathion recorded in the soil samples were significantly different ($p < 0.05$) among the various clusters. In fact, parathion is classified by the United Nations Environment Programme (UNEP) as a persistent organic pollutant and by the World Health Organisation (WHO) as extremely hazardous (Class IA)**.** Additionally, parathion is used as an insecticide on crops. However, it has several health implications. For example, parathion is extremely toxic from acute (short-term) inhalation, oral, and dermal exposures. Also, this potentially toxic substance affects human organs such as the central nervous system, blood, respiratory system, eyes, and skin. Also, with regards to chronic (long-term) inhalation and oral exposure of humans and animals to parathion, depressed red blood cell cholinesterase activity, nausea, and headache (IRIS). Even though the levels of parathion in the soil samples were below the WHO permissible limits, their occurrences in the soil samples have several impacts. [38] reported that parathion was detected in 4 of 822 soil samples collected from 49 agrichemical facilities located throughout Illinois at concentrations ranging from 69 to 5,540 µg/kg and a median value of 805 µg/kg, which was dramatically higher than this finding.

Chlorfenviphos occupies 4% of the soil samples analysed with a mean concentration of 0.005±0.001 µg/L and ranged from a minimum of 0.003 µg/L to a maximum value of 0.007 µg/L. However, except soil samples from the (X1), which had no detectable mean concentration of chlorfenviphos. The measured concentration of chlorfenviphos from the various clusters was generally below the (2017) WHO MRLs of 0.025 µg/L for agricultural soils, respectively. Statistically, the concentrations of chlorfenviphos recorded in the soil samples were significantly ($p < 0.05$) different among the various clusters. Meanwhile, chlorfenviphos was the penultimate in terms of lower mean concentration compared with all organophosphorus pesticide residues detected in the various clusters as vividly instantiated in Table 1.

Profenofos was detected in 3% of the soil samples analysed, with a mean concentration of 0.003 ± 0.001 µg/L, ranging from a minimum of 0.002 µg/L to a maximum value of 0.005 µg/L. However, except for soil samples from the (X1) and (BDSC2), which had no detectable mean concentrations of profenofos. The measured concentration of profenofos from the various clusters was generally below the WHO MRLs of 0.050 µg/L for agricultural soils, respectively. Statistically, the concentrations of profenofos recorded in the soil samples were significantly different ($p < 0.05$) among the various clusters. More so, according to the WHO classification on toxicity, profenofos is classified as a moderately hazardous (Class II) pesticide and therefore is non-carcinogenic to humans based on a lack of evidence of carcinogenicity in rats and mice. However, the occurrences of profenofos in the soil samples have several health implications, even though their mean levels were below WHO MRLs. For instance, profenofos has been linked to causing cholinesterase inhibition in humans; that is, it can overstimulate the nervous system, causing nausea, dizziness, and confusion, and at very high exposures, it can lead to death and respiratory paralysis (U.S.EPA). The mean range of profenofos residue levels of this finding was lower than the range (0.02–0.04 µg/L) reported by [1] in soils from cocoa-producing areas in Ghana.

Table 1: Organophosphorus pesticide residues in soil samples in the three clusters in Nanumba-North Municipality of Northern Region of Ghana

CLUSTERS		ORGANOPHOSPHORUS PESTICIDES (µg/L)						
		Diazinon	Malathion	Methamidophos	Chlorpyrifos	Parathion	Profenofos	Chlorfenvinphos
Distance 0-20 cm	BDCS1	0.004	0.002	0.043	0.020	0.030	0.004	0.005
	BDCS2	0.003	0.004	0.010	0.030	0.031	ND	0.006
	BDCS3	0.004	0.003	0.035	0.020	0.030	0.003	0.005
	BCS1	0.010	0.003	0.068	0.023	0.033	0.005	0.003
	BCS2	0.005	ND	0.009	0.025	0.032	0.004	0.004
	BCS3	0.014	ND	0.030	0.021	0.033	0.003	0.004
	CCS1	0.005	0.016	0.031	0.040	0.034	0.002	0.007
	CCS2	0.006	0.026	0.019	0.042	0.035	0.002	0.006
	CCS3	0.007	0.015	0.033	0.041	0.032	0.003	0.005
	$\bar{x}$±SD	0.006±0.004	0.008±0.005	0.031±0.018	0.029±0.009	0.032±0.002	0.003±0.001	0.005±0.001
	X1	ND	ND	ND	ND	ND	ND	ND
WHO MRLs		0.300	8.000	0.050	0.050	0.050	0.050	0.025

BDCS1: soil sample from Bimbilla-Dangbe cluster one; BDCS2: soil sample from Bimbilla-Dangbe cluster two; BDCS3: soil sample from Bimbilla-Dangbe cluster three; BCS1: soil sample from Bincheratanga cluster one; BCS2: soil sample from Bincheratanga cluster two; BCS3: soil sample from Bincheratanga cluster three; CCS1: soil sample from Chamba cluster one; CCS2: soil sample from Chamba cluster two; CCS3: soil sample from Chamba cluster three; Control X1; ND: Non detectable

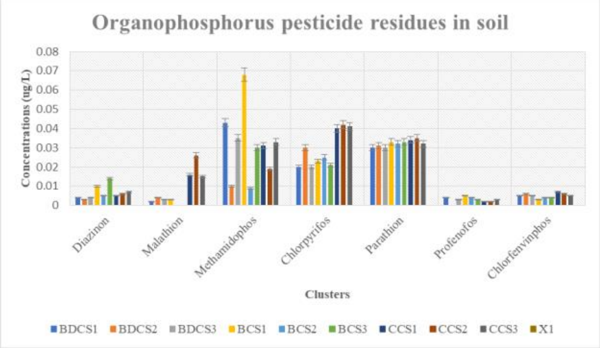

Figure 2: Organophosphorus pesticide residues in soil

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

Findings from this study revealed that the soil samples were slightly polluted with organophosphorus pesticide residues. The presence of pesticide residues in the soil samples could be a result of pesticide misuse by farmers in the study area. Farmers, therefore, use these chemicals indiscriminately, which could lead to atmospheric transport of volatilized pesticides or wind drift, direct spillage, leaching, direct overspray, and run-off due to application from fields and surroundings. Organophosphorus pesticides detected in the soil of some selected farms in the Nanumba-North Municipality were parathion, methamidophos, chlorpyrifos, malathion, diazinon, chlorfenvinphos, and profenofos.

Organophosphorus pesticides may have found their way into the soils via spray drift during the treatment of crops, wash-off from treated crops, and wrong disposal of left-over spray solution, sprayer wash water, and pesticide containers. Apart from the potential dangers, pesticides are also known to pose a threat to soil organisms, translocate into edible parts of crops, and be emitted into the environment.

4.2 Recommendations

In order to ensure sustainable crop production in the Nanumba-North Municipality, the environmental protection agency Extension officers must establish effective and protective measures, such as integrated pest management practices, organic farming, and reducing the volume of synthetic organic chemical use.

Extension officers should ensure routine monitoring of pesticide residues in the municipality for the prevention, control, and reduction of environmental pollution, so as to minimize health risks to the people.

Good agricultural practices must be encouraged by Ministry of Food and Agriculture (MOFA) such as integrated pest management.

DATA AVAILABILITY STATEMENT

Statistical package for social sciences (SPSS) software version 16.0 and One-way analysis of variance (ANOVA).

CONFLICT OF INTEREST STATEMENT

Conflict of Interest: The authors declare that they have no conflict of interest

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