Nat. Volatiles & Essent. Oils, 2021; 8(6): 6443-6463

Organochlorine Pesticide Residues In Soil Samples From The Nanumba North Municipality, Ghana

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ABSTRACT

The objective of this study was to assess the levels of pesticide residues in soil samples from the Nanumba-North Municipality in the Northern region of Ghana using gas chromatography equipped with an electron capture detector (GC-ECD). Ten (10) soil samples from the Nanumba-North Municipality in the Northern Region of Ghana were collected and analyzed.

Ten (10) pesticide residues were detected in the soil samples at varying mean concentrations. Pesticide residues detected in the soil samples of some selected farms in the Nanumba-North Municipality, were beta-endosulfan, p,p'-DDE, p,p'-DDD, p,p'-DDT, dieldrin, aldrin, beta-BHC, methoxychlor, heptachlor, and heptachlor-epoxide. The study revealed the presence of most of the selected pesticides at varying concentrations, with Beta-endosulfan recording significant concentrations in soil samples.

The mean concentrations of pesticide residues in the soil samples analyzed from the study site were generally below WHO (2017 MRLs) for agricultural soils except for beta-endosulfan, with a range of 0.030-0.041 mg/kg, which was comparable and above WHO (2017 MRLs) for agricultural soils, respectively. Pesticide residues detected showed significant differences at $p < 0.05$.

Wholistically, the presence of pesticide residues in the samples analyzed was an indication of the use of pesticides by farmers in the study area to control pests and diseases.

Keywords: Organochlorine; pesticides; GC-ECD; pests and diseases

1.0 INTRODUCTION

Organochlorine pesticides are a class of chemicals that are chlorinated hydrocarbons. Organochlorine pesticides accumulate in the tissues of animals. They stay in the environment and food web after being applied (Swackhamer and Hites, 1988). Many organochlorine pesticides have subtle toxic effects on the body's hormonal systems. (Lemaire et al., 2004). According to the Ghana Statistical Service in 2010, the Nanumba-North Municipality is principally agrarian and therefore the majority of the dwellers are mostly farmers who entirely

rely on pesticides as the final point of combating and repelling pests and diseases, which may have implications on the health of humans and animals in the area.

It is ubiquitous that, Nanumba- North and many other Municipal Assemblies stand in unhealthy uncertainty of not having sufficient to eat (WHO, 2018). As mouths increase and food resources decrease, the land is a finite quantity and the land which will augment food production is absolutely dependent on the strenuous and unpredictable natural phenomenon (2010 Population and Housing Census). Therefore, it is the application of agrochemicals such as pesticides and fertilizers by farmers, that must come to the aid of these threatened Municipalities. It is quite glaring that, forest cover in the Nanumba-North Municipality is reducing as a result of the conversion of forests and agricultural lands into commercial and industrial land uses. For example, there are conversions of arable lands and forest covers into residential and commercial land uses. These land use and cover processes have potential adverse effects on sensitive local climatic variables such as rainfall, temperature, humidity, and wind systems, and this invariably, leads to pollution of soils, water bodies, and crops through leaching, air-drift, surface run-off and erosion of agrochemicals contaminants from farmlands (Singh and Mandal, 2013; Gill and Garg, 2014).

However, according to Ntiamoah and Afrane in 2008, soil organism such as microbes, earthworms, and other natural enemies which operates as decomposers are adversely affected by pesticides when it gets to the soil after their application which intends affects soil quality. In fact, this decreases soil microbial biomass by completely combating or prompting actions such as behavior, reproduction, and metabolism of the organism which may permanently debilitate and transform the intimately interactive ecosystem (Aktar et al., 2009; Gill and Garg, 2014). These pesticides and their residues also have the potential to cause toxicity to plants and contaminate the food chain when taken up by plant roots and leaves from soils, air, and other nutrient solutions. Also, exposure to pesticides and their residues through food and drinking water has a lingering effect on our nervous system, thyroid function, low sperm count in males, birth defects, increased testicular cancer, and reproductive and immune malfunction, which are the results of endocrine disruptions, cancers, immune-toxicity, neurobehavioral and developmental disorders (Mesnage et al., 2010; Tanner et al., 2011; Cocco et al., 2013; Gill and Garg, 2014). Similarly, according to Kasozi et al., (2006) exposure to these potentially toxic chemicals is neurotoxic, carcinogenic, and causes Parkinson's disease. However, there are related cases of pesticides and their residues in the Nanumba-North Municipality. For example, in 2014 the entire household of Yenbo from Kpaturi, a village near Bimbilla town was rushed to the Bimbilla Hospital for treatment and unfortunately, Zaanzu wife died. After consuming beans (suspected to be treated with DDT) they bought from the Bimbilla Market. Similarly, in July 2018, a farmer by name of Musah Gundow accidentally spilled formulated pesticides on his body and was also rushed to the Bimbilla Hospital for treatment.

It is evident that, the consumption of food and drinking water from places where farmers solely rely on pesticides as the final point of mitigating weeds, and other pathogens on their farms could pose a serious health risk to consumers as well as reduce the nutritional values of this agricultural produce and hence the need to address this pain in the neck. This research, therefore, seeks to assess the levels of organochlorine pesticide residues in soils and their potential implications for the health of humans and animals in the Nanumba-North Municipality.

2.0 MATERIALS AND METHOD

2.1 Study area

The study was conducted in Nanumba-North municipality which is located in the Southeastern part of the Northern Region and is between the latitudes 8.5º N and 9.25º N and longitudes 0.57º E and 0.5ºE. However, it shares boundaries with five Minuncipal/Districts; Yendi Municipal to the north, Mion District to the northwest, East Gonja District to the west and south-west, Nanumba South District to the south and east, and Zabzugu Districts to the north-north-east. According to the 2010 Population and Housing Census, the population of Nanumba North Municipality is 141,584 representing 5.7 percent of the region's population of 2,479,461. 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 majority of the Municipal economically active population is involved in farming staple food crops and cash crops. In the Municipality, less than half of the population has access to safe drinking water (www.ghanadistrics.com 2011).

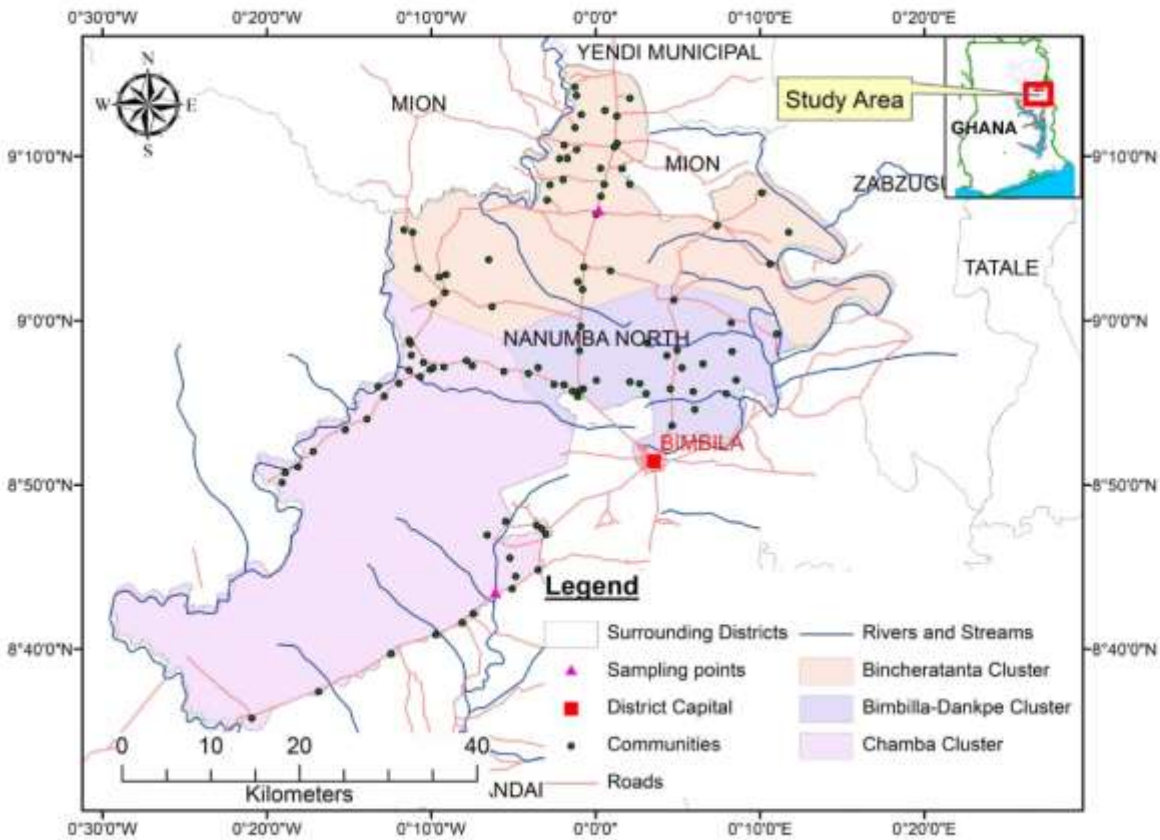

Figure 1: A map showing Nanumba North Municipality in the Northern Region of Ghana

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 quadrates of 70 × 70 m were marked meticulously in each cluster. In each quadrate, three (3) soil samples were collected randomly at depths 0–20 cm with a soil auger. Meanwhile, the rectitude of taking this depth was because nutrient uptake by plants is usually reported to be within this horizon (Aiyesanmi and Idowu, 2012). 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-labeled 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-labeled plastic polythene containers and transported to the laboratory for analysis. At the laboratory of the Council for Scientific and Industrial and 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) containing eleven (11) organochlorines pesticides were targeted. Standards were prepared by pipetting the appropriate aliquot or weight of the pesticides into 25 mL volumetric flasks, and then dissolving and diluting to the marks with ethyl acetate with the aid of a vortex mixer (Thermolyne Maxi Mix-Plus). Working solutions of standards for fortification standards in the procedural recovery process, and as calibration standards in the instrument calibration were freshly prepared through dilution of an appropriate aliquot of the stock solutions with ethyl acetate. However, distilled water was used to prepare all aqueous solutions. All solutions prepared for Gas Chromatography (GC) were filtered through a 0.45 µm nylon filter.

2.4 Extraction of soil samples

The extraction of the soil samples was carried out by the method described by Frimpong et al., (2013), with slight modification from (CSIR). 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 Rotavapor 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 Frimpong et al., (2013), with slight modifications from (CSIR). 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 sulfate 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 Rotavapor 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 an electron capture detector (ECD). All extracts were kept frozen until quantification was achieved.

3.0 Results and Discussion

3.1 Levels of organochlorine pesticide residues in soil samples

The order of decreasing magnitude of the percentage of the organochlorine pesticide residues occurring in the soil samples in the study area was as follows; beta-endosulfan (24%) > methoxychlor (22%) >beta-BHC (14%) > p,p'-DDD (11%) > heptachlor-epoxide (9%) > heptachlor (6%) > p,p'-DDE (5%) > dieldrin (4%) > p,p'-DDT (3%) > aldrin (2%) as depicted in (Table 1 and Figure 2).

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

CLUSTERS		ORGANOCHLORINE PESTICIDES (mg/kg)									
		Dieldrin	**Heptachlor-epoxide**	**Methoxychlor**	**p,p'-DDT**	**p,p'-DDD**	**p,p'-DDE**	**Aldrin**	**Heptachlor**	**Beta-BHC**	**Beta-Endosulfan**
Distance 0-20cm	BDCS1	0.002	ND	0.033	0.003	0.020	0.006	0.002	0.003	ND	0.031
	BDCS2	0.003	ND	0.034	0.004	0.021	0.007	0.002	0.005	ND	0.032
	BDCS3	0.003	ND	0.035	0.005	0.024	0.005	0.002	0.008	ND	0.035
	BCS1	0.005	0.003	0.038	0.003	0.020	0.006	0.004	0.005	0.020	0.030
	BCS2	0.012	0.004	0.020	0.003	0.020	0.008	0.003	0.006	0.036	0.030
	BCS3	0.014	0.010	0.030	0.003	0.020	0.007	0.003	0.006	0.020	0.030
	CCS1	0.004	0.031	0.031	0.002	0.002	0.008	0.002	0.016	0.005	0.034
	CCS2	0.005	0.036	0.020	0.003	0.002	0.005	0.004	0.017	0.045	0.041
	CCS3	0.006	0.024	0.034	0.004	0.003	0.011	0.004	0.013	0.040	0.033
	$\bar{x}$±SD	0.006±0.004	0.012±0.014	0.030±0.006	0.003±0.001	0.014±0.009	0.007±0.002	0.003±0.001	0.008±0.005	0.018±0.018	0.032±0.003
	X1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WHO (2017) MRLs		0.030	0.100	20.000	1.000	1.000	1.000	0.030	0.100	2.000	0.030

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.

3.2 Discussion

Beta-endosulfan($C_9H_6C_{l6}O_3S$) occupies 24% of the organochlorine pesticides in the soil samples analyzed with a mean concentration of 0.033 ± 0.004 mg/kg and ranging from a minimum concentration of 0.030 mg/kg to a maximum concentration of 0.041 mg/kg. However, the minimum concentration of beta-endosulfan($C_9H_6C_{l6}O_3S$) in the soil samples analyzed was observed at Bincherantanga cluster (BCS1, BCS2, and BCS3) while the maximum concentration was observed at the Chamba cluster (CCS2) (Table 1). There was a significant difference in the concentrations of beta-endosulfan recorded in the soil samples. Meanwhile, the mean concentrations of beta-endosulfan($C_9H_6C_{l6}O_3S$) recorded in soils sampled from BDCS1(0.031 mg/kg) BDCS2(0.032 mg/kg) BCDS2(0.035 mg/kg) CCS1 (0.034 mg/kg), CCS2 (0.035 mg/kg) and CCS2 (0.033 mg/kg), respectively, were all above the WHO MRL of 0.030 mg/kg for agricultural soils except the soil samples from BCS1 (0.030mg/kg) BCS2 (0.030 mg/kg) and BCS3 (0.030 mg/kg) which had mean concentration comparable to the WHO MRL of 0.030 mg/kg, respectively. The rate of degradation of the parent compound depends on a number of factors. Half-lives of alpha and beta isomers range from hours to months. Both isomers are stable to degradation under acidic conditions.

It is considered moderately hazardous by the WHO. The health implications of the detection of beta-endosulfan levels above and comparable to the WHO MRLs in the soil samples are quite obvious. People who come into contact with the potentially toxic chemical beta-endosulfan can suffer from mental disabilities, congenital physical disorders, and even death. According to Silva and Gammon, acute oral toxicity is a little bit greater than dermal toxicity. The adverse side effect of beta-endosulfan is an important aspect of modern agriculture. The use of beta-endosulfan is logical in terms of increasing the supply of food and other agricultural products, but it can be harmful when a substantial amount of these chemicals is left on the field as residue which tends to affect the environment such as non-target organisms and water bodies. In the Lagos lagoon, pesticide levels were found to be low compared to the level recorded in this finding. The ADI was less than the WHO's and Codex's maximum residue limit, but the concentrations of Beta-endosulfan were much high

The soil samples analyzed had a mean concentration of 0.031 ± 0.006 mg/kg. The mean methoxychlor concentrations in the soil samples analyzed ranged from a minimum of 0.02 mg/kg at BCS2 and CC2 to a maximum of 0.038 mg/kg at BS1 (Table 1). The soil samples from X1 had no methoxychlor concentration. There was a significant difference in methoxychlor among the various clusters. The mean concentrations of methoxychlor, recorded at all three clusters of soil samples from the selected farms, were found to be below the World Health Organization MRL. Methoxychlor was intended to replace DDT, but has since been banned due to its health implications activity and bioaccumulation. Astonishingly, the amount of methoxychlor in the environment changes as a result of farming activities, and it does not dissolve readily in water, so it is sometimes mixed with a petroleum-based fluid by these farmers and sprayed, or used as dust. It may take several months for this potentially toxic substance to degrade after being sprayed on the ground. Farmers in the study area use the chemical methoxychlor in crop protection. Therefore, it is a very tangible sensible form of anticipation to say that the low concentrations recorded in this study might be due to low leaching, run-off as well as drainage in the soil. The mean value of methoxychlor recorded in this study was higher than the mean value reported by Frimpong et al., (2012a). The finding of methoxychlor in this study was contrary to the findings of Frimpong et al., (2012a).

BHC has a high pesticidal activity which is crucial in fighting pests and diseases. The mean value of the soil samples was analyzed with a mean value of 0.018 ± 0.018 mg/kg. Its average concentration ranged from a minimum of 0.020 mg/kg at (BCS1 and BSC2) to a maximum of 0.045 mg/kg at (BSC2). There were significant differences in the mean values of the sample sites. In addition, the mean concentrations of beta-BHC recorded in this study were remarkable below the (WHO 2017) MRL of 2.000 mg/kg for agricultural soils with the exception of soil samples from CC1, CC2 CC3, and the control (X1) which had no detectable beta-BHC (Figure 2). Farmers from the field study said that the current use of the chemical in crop protection was confirmed by the occurrence of beta-BHC in some of the soil samples analyzed. The dramatic presence of beta-BHC in the soil samples analyzed suggests a very tangible form for anticipation of the previous or current illegal use of technical BHC pesticides in the study area since their use has been banned in crop production in Ghana. The previous use or current use of lindane in the study area was established by the measured concentrations of the BHC in the soils. The mean residue of beta-BHC recorded in this study was higher than the mean value of 0.001 mg/kg reported in soil samples from selected cocoa farms in Kade in the Eastern Region of Ghana (Agyen 2011), but far lower than the mean value of 0.617 mg/kg reported in soils from selected cocoa farms in Ondo State, Nigeria (Aiyesanmi and Idowu 2012).

p,p'-DDD residue was detected in 11 % of the organochlorine pesticide of the soil samples analyzed with a mean value of 0.015 ± 0.009 mg/kg, and ranged from a minimum mean concentration of 0.002 mg/kg at (CCS1 and CCS2) to a maximum mean concentration of 0.024 mg/kg at (BDSC3). The mean concentrations of p,p'-DDD recorded in this study were below the WHO MRL of 1.000 mg/kg for agricultural soils There were significant (p =2.68E-13) differences in mean values of p,p'-DDD among the various clusters. The mean p,p'-DDD residue observed in this study was far lower than the mean value of 0.15 mg/kg reported by Aikpokpodion et al., (2012), and the mean values of 0.01 mg/kg and 0.001 mg/kg reported by Daanu (2011) and Frimpong et al., (2012a), respectively.

5% of the soil samples were found to have p,p'-DDE in it. The concentrations ranged from a minimum mean of 0.004 mg/kg at BDCS1 and CCS2 to a maximum of 0.005 mg/kg at CC3 with a mean concentration of 0.007 ± 0.002 mg/kg. In addition, the mean concentrations of p,p'-DDE recorded in this study were vastly below the (WHO 2017) MRL of 1.000 mg/kg for agricultural soils with the exception of soil samples from the control (X1) which had no detectable p,p'-DDE. The differences in means were statistically significant (p =2.68E-13). The loss of hydrogen chloride in DDT leads to the creation of DDE, one of the metabolites of the drug. The potential toxic chemicals have the ability to build up in the fat of animals and humans and are rarely removed from the body (Aikpokpodion et al., 2012).

It is quite intriguing to note that, a survey of literature revealed that exposure to p,p'- DDE has several health implications for humans and other wildlife, and the lingering symptoms are endocrine disruptions, oxidative stress, Alzheimer's, and Parkinson's disease, also continuous exposure can lead to the horror of breast cancer as well as damage to the brain’s dopaminergic system (Aikpokpodion et al., 2012).

Long-term exposure to low doses of DDT has been shown to affect the reproductive systems, and immune systems and cause cancer, and this was later proven by Okoya et al., (2013b). However, the mean concentration of p,p’- DDE recorded in this study was far lower than the mean value of 0.04 mg/kg reported by Aikpokpodion et al., (2012). However, the mean concentration of p,p’- DDE recorded in this study was far lower than the mean value of 0.04 mg/kg reported by Aikpokpodion et al., (2012) in cocoa bean samples from three cocoa ecological zones in Nigeria, but higher than the 0.001 mg/kg reported by Frimpong et al., (2012a) in cocoa beans ready for export in Ghana. Also, the mean value of p,p’- DDE observed in this study was lower than the value of 0.02 mg/kg reported by Daanu (2011).

3% of p,p’-DDT of soil samples detected with a minimum mean concentration of 0.002 mg/kg at (CCS1) to a maximum of 0.005 mg/kg at (BDCS3). The average concentration of the soil samples analyzed was 0.003±0.001 mg/kg. In addition, the mean concentration of p,p’-DDT recorded in this study was vastly below the (WHO 2017) MRL of 1.000 mg/kg for agricultural soils with the exception of soil samples from the control (X1) which had no detectable p,p’-DDT. Furthermore, there were significant differences (p =2.68E-13) in mean values of p,p’-DDT among the sampled soil in the various clusters. The detection of DDT indicates its use by farmers to combat pests and diseases as was corroborated during the field survey. The mean concentration of p,p’-DDT reported in this study was lower than the mean values of 0.003 and 0.007 mg/kg reported in soils from Kade in Ghana (Agyen 2011) and from Ekiti State in Nigeria (Olayinka 2013), respectively. The mean value of p,p’-DDT recorded in this study was lower than the mean value of 0.03 mg/kg reported by Daanu (2011). The mean value of p,p’-DDT recorded in this study is in line with the mean value of 0.003 mg/kg reported by Frimpong et al., (2012a). The mean value of p,p’-DDT recorded in this study was lower than the mean value of 0.01 mg/kg reported by Frimpong et al., (2012b), respectively. Similarly, Aikpokpodion et al., (2012) recorded a mean p,p’-DDT value of 0.06 mg/ kg which was exceedingly higher than the mean value recorded in this study.

DDT has been banned from agricultural use and restricted due to public health concerns under the Stockholm Convention in which Ghana is a signatory (Afful et al., 2010; Agbeve et al., 2014). The current illegal use of the pesticide by farmers in the study area is an indication of the occurrence of DDT and its metabolites in soil samples from the study area. The detection of the concentration of p,p'-DDT and its metabolites p,p'- DDE and p,p'-DDD is an indication that there might be recent input of DDT in the various crops. The massive effectiveness and lower price of the products could be why the farmers continue to use them. It could be that new pesticides with the active ingredient of DDT were sold to uneducated farmers. The past use of the parent compound DDT and its long-term persistence in the environment may be to blame for the presence of the compound in the soil samples.

As alluded by Miles et al., (2009) and later attested by Hogarh et al., (2014), aldrin is readily converted to dieldrin by photolysis or bacterial activation once it is exposed to the environment or the body, and these pesticides are considered as one of the most persistent of all pesticides. Until their use was restricted, these pesticides were used a lot. The pesticides aldrin and dieldrin were found in all the soil samples analyzed from the study area. Meanwhile, aldrin was the least frequently detected residue in the soil samples analyzed, and it occupies 2% of the organochlorine pesticide of the soil samples analyzed and ranged from a minimum mean concentration of 0.002 mg/kg at (BDCS1, BDCS2, BDCS3, and CCS1) to a maximum mean concentration of 0.004 mg/kg at (BCS1, CCS2, and CCS3) with a mean value of 0.003 ± 0.001 mg/kg.

The X1 had no mean concentration of aldrin. There were significant differences in the mean values of aldrin. The mean concentrations of aldrin in this study were much lower than the WHO MRL. Similarly, its breakdown product, dieldrin, occupies 4% of the organochlorine pesticide of the soil samples analyzed with a mean value of 0.006 ± 0.004 mg/kg, which ranged from a minimum mean concentration of 0.002 mg/kg at (BDCS1) to a maximum mean concentration of 0.014 mg/kg at (BCS3). There were significant differences in the mean values of dieldrin among the samples. The mean concentrations of dieldrin were much lower than the WHO MRL.

A similar observation was made by Boakye (2012). Boakye made a similar observation. The relatively low percentage of soil samples with detectable aldrin is thought to be due to high input of dieldrin as well as high degradation of aldrin to dieldrin. The mean value of aldrin recorded in this study was lower than the mean values of 0.01 mg/kg and 0.01 mg/kg reported by (Frimpong et al., 2012a; Frimpong et al., 2012b) and the 0.11 mg/kg reported by Daanu (2011), respectively, in cocoa beans from Ghana. Similarly, the mean value of dieldrin recorded in this study was lower than the mean values of 0.01 mg/kg and 0.02 mg/kg reported by Frimpong et al., (2012a) and Frimpong et al., (2012b), respectively in cocoa beans from Ghana. The key reason could be due to the differences in the sampling methods used.

Heptachlor occurs in 6% of the organochlorine pesticide of the soil samples analyzed with a mean value of 0.009 ± 0.005 mg/kg, however, the mean concentrations of heptachlor in the soil samples analyzed ranged from a minimum of 0.003 mg/kg at (BDSC1) to maximum value of 0.017 mg/kg at (CCS2) (Table 1). The X1 soil samples recorded no heptachlor mean concentration. The mean concentrations of heptachlor were below the WHO MRL for agricultural soils. Heptachlor-epoxide occurs in 9% of the soil samples analyzed with a mean value of 0.012±0.014 mg/kg, however, the mean concentration of the residue in the soil samples ranged from 0.003 mg/kg at (BCS1) to a maximum value of 0.036 mg/kg at (CCS2) (Table 1). No heptachlor-epoxide was found in soil samples from X1.

The mean concentrations of heptachlor-epoxide were below the WHO MRL for agricultural soils. There was a significant difference in heptachlor and its metabolites among the clusters. Farmers from the field survey said that heptachlor was being used in crop protection by farmers. These pesticides are mostly applied as liquids, sprayed on the crop or the soil, or as a seed treatment by farmers on their farms or at homes in this study area, and these pesticides that reach the soil or plant material in the target area begin to disappear by degradation or dispersion. There are persistent organic pollutants that can volatilize into the air, reach into surface water or stay in the soil.

However, the higher mean concentrations of heptachlor-epoxide to its parent compound (heptachlor), could be due to the breakdown of heptachlor which can be attributed to complete favorable degradation conditions and persistence in the environment though it is among the list of banned pesticides by the Stockholm Convention for use on food (Afful et al., 2010).

The occurrence of organochlorine pesticides in the soil samples analyzed is a major concern due to human health risks such as reproductive impairment and suppression of the immune system which can have long-term consequences for human beings. The soil samples could have been contaminated if the crop was treated with pesticides before harvest. The chemicals may have been moved from the contaminated soil to the root system. Since non-water-soluble pesticides remain in the soil, the aforementioned might only hold for water-soluble pesticides. Animals and plants may be damaged by pesticides that run off to other areas.

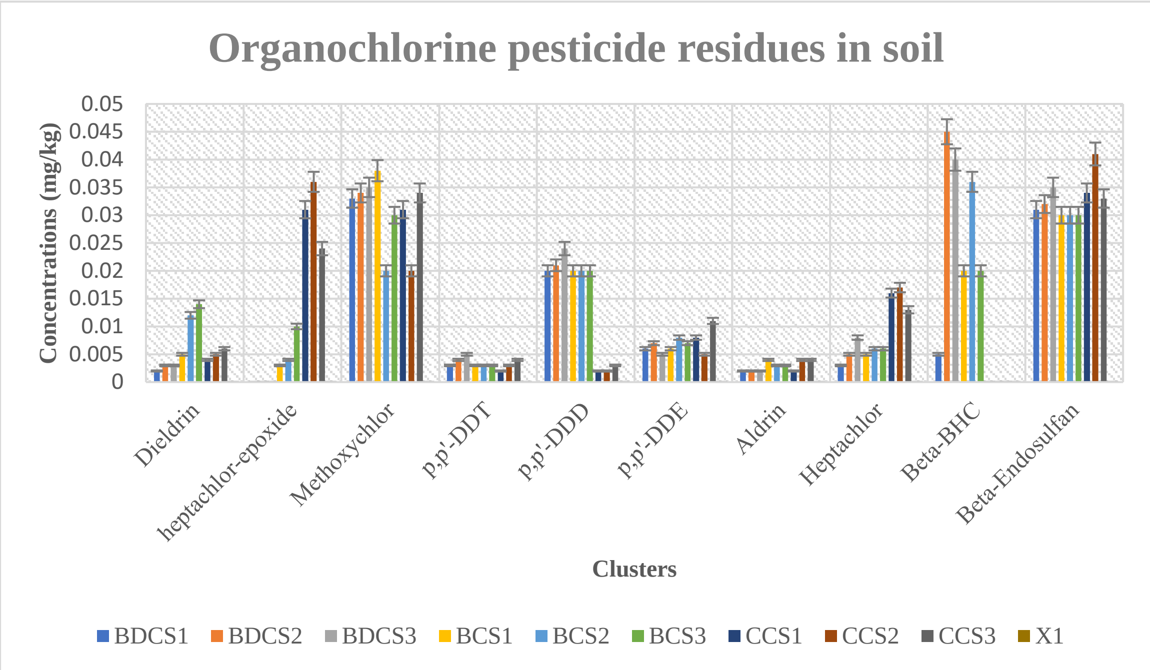

Figure 2: Organochlorine pesticide residues in soil

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

In summary, ten (10) organochlorine pesticide residues were detected in the soil samples at varying mean concentrations. Pesticide residues detected in the soil samples of some selected farms in the Nanumba-North Municipality, were beta-endosulfan, p,p'-DDE, p,p'-DDD, p,p'-DDT, dieldrin, aldrin, beta-BHC, methoxychlor, heptachlor, and heptachlor-epoxide. The study revealed the presence of most of the selected pesticides at varying concentrations, with Beta-endosulfan recording significant concentrations in soil samples.

The mean concentrations of pesticide residues in the soil samples analyzed from the study site were generally below (2017) WHO MRLs for agricultural soils except for beta-endosulfan with a range of 0.030-0.041 mg/kg, which was comparable and above (2017) WHO MRLs for agricultural soils respectively. Pesticide residues detected showed significant differences at $p < 0.05$.

Wholistically, the presence of pesticide residues in the samples analyzed was an indication of the use of pesticides by farmers in the study area to control pests and diseases.

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 MOFA such as integrated pest management.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study is that less than half of the population has access to safe drinking water is openly available in Ghana districts at https://ghanadistricts.com 2011 data.

CONFLICT OF INTEREST STATEMENT

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

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