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Levels of organochlorine pesticide residues in fresh tomatoes from selected farming communities in Navrongo, Ghana

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Abstract

The levels of organochlorine pesticide (OCP) residues in tomatoes sourced from three agricultural communities in Navrongo (Bonia, Korania, and Nangalkenia) were analyzed using gas chromatography. A comprehensive analysis revealed the presence of nineteen (19) distinct organochlorine pesticides, with a minimum of five different residues detected in each tomato sample. The OCPs were detected within a range of 0.04 to 15.90 μg/kg. Remarkably, beta-hexachlorocylohexane (β-HCH) exhibited the highest concentration (15.90 μg/kg), while both cis-chlordane and trans-heptachlor epoxide displayed the lowest concentration (0.04 μg/kg) in Korania. In the Nangalkenia community, gamma-hexachlorocylohexane (δ-HCH) demonstrated the highest concentration (10.21 μg/kg), while trans-chlordane and o,p'-Dichlorodiphenyltrichloroethane (o, p-DDT) exhibited the lowest concentration (0.04 μg/kg). Furthermore, within the Bonia community, p, p-Dichlorodiphenyltrichloroethane (p, p-DDT) displayed the highest concentration (8.25 μg/kg), whereas o, p-DDT and trans-heptachlor epoxide exhibited the lowest concentration (0.13 μg/kg). Notably, the analysis indicated that two (2) of the organochlorine pesticides, specifically β-HCH and δ-HCH, surpassed the Maximum Residue Limits (MRLs) established by the United Kingdom/European Commission (UK/EC).

The results of the questionnaire survey unveiled a substantial proportion of illiterate farmers (54%), which potentially plays a significant role in the farmers' misuse or indiscriminate use of pesticides. Additionally, both the questionnaire responses and field visits provided insight into the specific types of pesticides employed by the farmers. These include karate, lambda, carbofuran, mancozeb, ridomil, sunpyrifos, kocide, cypermethrin, and dimethoate.

Keywords: Pesticide; Carbamate; Pyrethoid; Pollutant; Persistent

1 Introduction

Vegetables play a crucial role in promoting a nutrient-rich diet by supplying essential vitamins, minerals, antioxidants, and dietary fibers, thereby contributing to the development of a robust immune system [1]. Nevertheless, throughout the growth stages of these vegetables, they become susceptible to pests and various diseases, necessitating effective control and management measures [2]. In vegetable cultivation, farmers often resort to the utilization of pesticides, as they perceive them as the sole solution for pest and disease control [3].

Pesticides encompass a diverse range of chemical compounds developed with the intent of eradicating or discouraging pest populations [4]. They exist in various formulations, including powders that can be mixed with water for spraying, granules and dusts for dusting, liquids for spraying, seed coatings, rodenticidal pellets, and other formulations.

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Pesticides are typically categorized based on their target organisms, such as insecticides (aimed at insect control), herbicides (targeting weed control), fungicides (designed to combat fungi or molds), and other formulations for pest control purposes [5], [6]. Pesticides can be further categorized into distinct chemical families, including organochlorines, organophosphates, neonicotinoids, pyrethroids, and carbamates [7]. It is important to acknowledge that pesticides possess inherent toxicity and are frequently linked to environmental contamination and detrimental health effects in non-target organisms, including humans [8].

Organochlorines represent a group of chemical compounds characterized by the presence of hydrogen, chlorine, and carbon, and they can be broadly classified into two main groups: the Dichlorodiphenyltrichloroethane (DDT) type compounds and the chlorinated alicyclic compounds [9]. A significant number of organochlorine pesticides are categorized as persistent organic pollutants (POPs), which belong to a class of chemicals that degrade very slowly and tend to accumulate in lipid-rich tissues, such as body fat [10], [7]. Various pathways can lead to human exposure to these chemicals. Pesticides can be transported by wind and rain, resulting in the contamination of surface waters, groundwater, and soil [11]. Additionally, exposure to pesticides can occur through the consumption of fruits and vegetables that have been contaminated. Pesticides are directly applied to crops, and some residues may persist on or within the harvested fruits and vegetables, particularly in situations involving the abuse, misuse, and excessive use of pesticides [12], [13]. Extensive research has established a link between pesticide residues and various health issues, including cancer, attention-deficit hyperactivity disorder (ADHD), nervous system disorders, and compromised immune systems [14], [11]. Pesticides exhibit endocrine-disrupting properties by mimicking the body's natural hormones, thereby interfering with normal physiological functions and contributing to adverse health effects. As a result of the detrimental impacts on human health and the environment, concerns regarding pesticide residues in fruits and vegetables have escalated. To safeguard consumers from pesticide hazards, many countries have implemented legislation. In Ghana, the Pesticides Control and Management Act of 1996 (Act 528) designates the Environmental Protection Agency (EPA) as the primary authority responsible for a comprehensive pesticide regulatory program. In this capacity, the EPA holds exclusive jurisdiction and accountability for the registration of all pesticides imported, exported, manufactured, distributed, advertised, sold, or used within Ghana [15]. Furthermore, in order to safeguard global environmental well-being, conservation initiatives have emerged, leading to the establishment of the Stockholm Convention on Persistent Organic Pollutants (POPs), which became effective in May 2004 [16]. The primary objective of this convention is the elimination of twelve priority POPs, including organochlorine pesticides such as aldrin, dieldrin, DDT and its metabolites, endrin, heptachlor, chlordane, mirex, and toxaphene [17]. Despite the prohibition of organochlorine pesticides (OCPs) usage in Ghana, multiple studies have consistently reported the presence of significant pesticide residue levels in various vegetables and fruits, including cabbage, lettuce, and onions [12], as well as tomatoes, lettuce, carrots, and cucumbers [13]. Similarly, OCPs residues have been detected in watermelon, pineapple, bananas, and water [18].

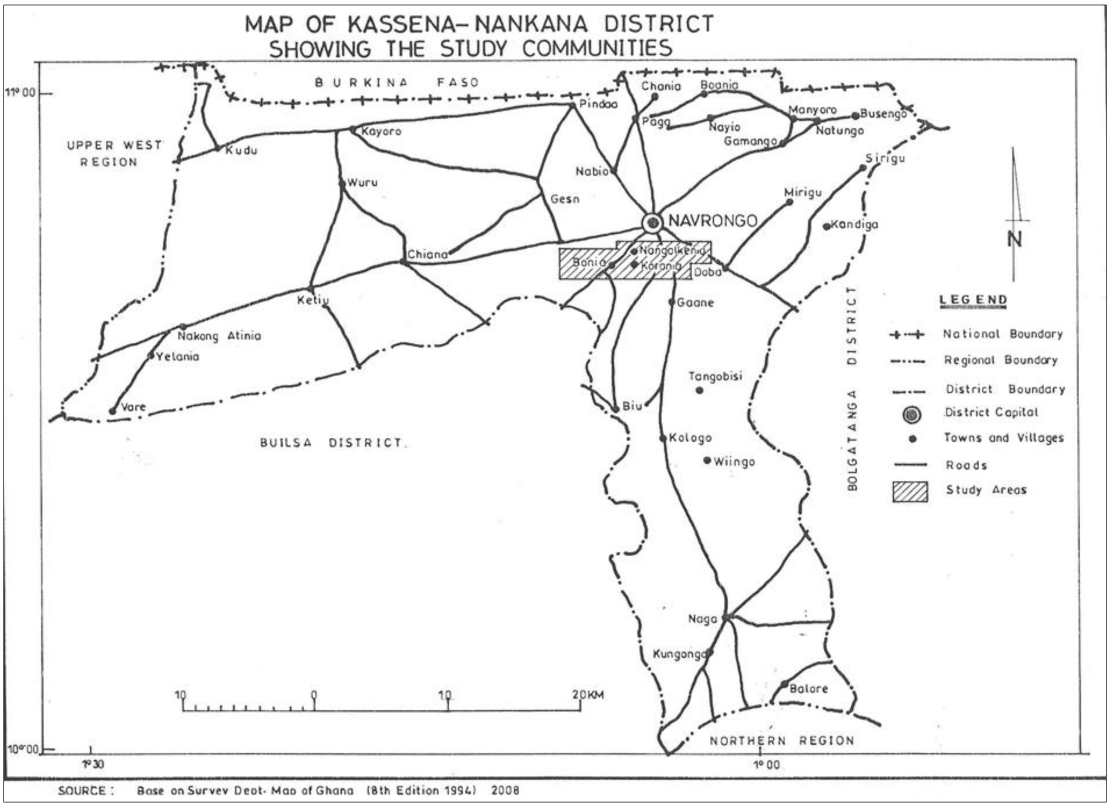
Within the past decade, Ghana has experienced a rapid surge in pesticide utilization within the agricultural sector, with approximately 80% of vegetable farmers relying on chemical pesticides for pest and disease management [12]. Organochlorine pesticides are extensively employed by Ghanaian farmers due to their efficacy and broad-spectrum activity [14]. Furthermore, the use of pesticides extends beyond the realm of agriculture and encompasses the public health sector as well. For instance, the Onchocerciasis Programme in the Volta Basin has utilized temephos to combat black flies (Simulium spp.), which serve as vectors for Onchocerciasis (African river blindness) transmission to humans, as well as for the control of domestic pests [19]. In Ghana, organochlorine pesticides such as DDT, Lindane, and endosulfan are additionally utilized for the management of ectoparasites affecting farm animals and pets [20]. The use of organochlorine pesticides raises significant concerns due to their non-biodegradable nature and persistence in the environment [21]. The presence of pesticide residues in fruits and vegetables poses an elevated risk, as these food items are often consumed raw or partially cooked, and they are typically harvested shortly after pesticide application [22].

Tomato cultivation in the Upper East region of Ghana, particularly in Navrongo has emerged as a prominent economic activity. This town has long recognized tomatoes as the most financially rewarding crop, with production perceived to be highly profitable. The cultivation of tomatoes takes place during the dry season through irrigation methods utilizing the Tono irrigation Dam, which stands as one of the largest agricultural dams in West Africa. Following production, tomatoes from Navrongo are transported to various regions across the country by traders who seize the opportunity during the tomato season. Notwithstanding the extensive use of pesticides in tomato cultivation over the years, there remains a dearth of information regarding the potential exposure to pesticides for farmers, consumers, and the environment in Navrongo. Farmers lack adequate knowledge on the appropriate usage of pesticides, and as a consequence, the misuse of these chemicals has led to the contamination of vegetables and soil with pesticides, among other issues. The uniqueness of this study compared to other studies is the use of a questionnaire survey to gather data on the educational background of selected farmers and the specific pesticides they employed on their farms prior to sample collection. The study aimed to evaluate the concentrations of organochlorines in tomato samples collected from the farms of these selected farmers situated in three distinct locations. Furthermore, the study sought to determine the educational attainment of the farmers and the types of pesticides they utilized in their agricultural practices.

2 Material and methods

2.1 Study area

Navrongo, situated in the northern part of Ghana, serves as the district capital of the Kasena/Nankana East district, which is one of the nine districts located within the Upper East Region. It shares borders with the Republic of Burkina Faso, as well as the Bolgatanga, Bongo, Builsa, Sissala, and Mamprusi West Districts. Geographically, Navrongo extends approximately 55 kilometers from north to south and 53 kilometers from east to west. Its precise geographical coordinates are 10° 53' 42" North, 1° 5' 38" West, as depicted on the Google satellite map. As of 2020, the estimated population of the town was 134,018, according to population estimates for cities in Ghana for the same year. The topography of the study area is predominantly characterized by a flat terrain, while its ecological characteristics align with the Sahel region, characterized by a hot and dry climate. The vegetation in the area primarily comprises semi-arid grassland with sporadic presence of short trees. For the purpose of this study, three communities were chosen at random within the study area. These communities are Bonia, Korania, and Nangalkenia, as depicted in Figure 1.



SOURCE : Base on Survey Dept. Map of Ghana (8th Edition 1994) 2008

Figure 1 A map of Kasena Nankana District showing the selected communities

2.2 Sample collection

Questionnaires were administered to a carefully selected group of tomato farmers hailing from the three communities of Bonia, Korania, and Nangalkenia. The questionnaires encompassed inquiries concerning the farmers' pesticide usage, educational background, and other relevant factors. Following the completion of the survey, researchers proceeded to visit the farms of 30 selected farmers across the aforementioned communities during the months of January and February in 2019. At these farms, tomato fruits were acquired directly from the farmers.

A total of 300 tomato samples were meticulously collected and promptly wrapped in pre-cleaned aluminum foil, which had been treated with acetone. Subsequently, the samples were placed within appropriately labeled zip lock bags. These labeled samples were then stored in an ice chest alongside ice to maintain their integrity during transportation to the Department of Chemistry, Ghana Atomic Energy Commission (GAEC). The transportation process took approximately

17 hours from the time of sampling. Upon arrival at the GAEC, the samples were stored in a freezer at a temperature of approximately -20 ºC until they were ready for analysis.

2.3 Extraction of OCPs from sample

The study employed a range of high-quality reagents including Dichloromethane (GFS Chemicals, Columbus), n-Hexane (Ultrafine Limited, Marlborough House, London), Acetone (GFS Chemicals, Columbus), Silica gel 60-200 mesh (Labtech Chemicals), and anhydrous sodium sulfate (Merck, Germany). These reagents were of spectra grade, ensuring their purity and reliability for the experimental procedures.

To initiate the extraction process, 20 grams of homogenized composite vegetable samples were accurately weighed and placed into a pre-extracted Whatman thimble, following the method outlined by Odhiambo et al [23]. The Soxhlet extraction method was employed, utilizing Dichloromethane (DCM) as the extraction solvent, and the process was conducted for a duration of 4 hours. Following extraction, the resulting extract underwent concentration by distilling-off the solvent (DCM) using a rotary evaporator. The concentrated extract was subsequently preserved for subsequent clean-up procedures.

2.4 Clean up of extract

To eliminate any potential interference from co-extracted substances alongside the pesticide residues, a clean-up process was implemented. A column was prepared by packing 1.5 grams of activated florisil, followed by the addition of 0.5 grams of activated charcoal and 1.0 gram of sodium sulfate (Na_2SO_4) into the column, which had been previously plugged with glass wool. Prior to the clean-up, the column was conditioned using 10 ml of ethyl acetate. The extract was carefully transferred onto the florisil column utilizing a Pasteur pipette, allowing it to pass through the column until it was fully eluted. To ensure complete extraction, the sample tube (round-bottomed flask) was rinsed with 2 ml of ethyl acetate, repeating this step twice to ensure the collection of all the extract from the tube.

After the final rinse, a volume of 9 ml of ethyl acetate was carefully applied onto the column. The solvent, containing the desired extract, was subsequently concentrated by evaporation to complete dryness using a Rota vapor R-200 rotary evaporator. Each dried residue obtained from the samples was then dissolved in 1.5 ml of isooctane and transferred into separate GC vials, ensuring their proper preservation and suitability for subsequent analysis.

2.5 Instrumental analysis

The analysis was conducted using a gas chromatograph, specifically the 2010 SHIMADZU C113245 model, which was equipped with an Electron Capture Detector (ECD). Chromatographic separation was achieved using an SGE BPX-5 capillary column with dimensions of 60 m length, 0.25 mm internal diameter, and 0.25 µm film thicknesses. Additionally, a 1 m retention gap (0.53 mm, deactivated) was incorporated into the setup. The GC conditions were as follows: The oven temperature was initially set at 90°C for 3 minutes, followed by a ramping rate of 30°C/min to reach 200°C in 15 minutes. Subsequently, the temperature was further increased to 265°C at a rate of 5°C/min for 5 minutes, then to 275°C at a rate of 3°C/min, and finally held for 15 minutes. This temperature program resulted in a total run time of 58 minutes. The injector was configured in a pulsed splitless mode with a temperature of 250°C and a pressure of 1.441 bars. The pulsed pressure was set at 4.5 bar, with a pulsed time of 1.5 minutes. The purge flow was maintained at 55.4 mL/min, and the purge time was set to 1.4 minutes. The injection volume for each sample was 1.5 mL. The detector was operated at a temperature of 300°C. Nitrogen gas (N2) was employed as the carrier gas, with a constant flow rate of 30 mL/min.

2.6 Quality assurance and control

The efficacy of the analytical method, encompassing both the extraction and clean-up procedures, was evaluated by determining the recoveries of an internal standard. For this purpose, a single blended tomato sample from each analysis batch was fortified with 50 µL of a 100 ng/mL internal standard (isodrin) and subjected to extraction under identical conditions as the analytes. To assess potential cross-contamination and interferences, a blank sample was analyzed alongside each analysis batch.

All glassware utilized in the analysis was thoroughly cleansed using a detergent and hot water, followed by rinsing with tap water and distilled water. Subsequently, the glassware was rinsed with acetone and then dried in an oven at approximately 40°C overnight.

2.7 Statistical analysis

The statistical analysis was conducted using SPSS version 20, a software package dedicated to statistical analysis. Mean concentrations were generated for the detected organochlorine compounds. To assess the potential variation in mean concentrations across different sampling locations, a one-way analysis of variance (ANOVA) was employed. The data are reported as means with a significance level set at 5%.

3 Results and discussion

A comprehensive analysis of 300 samples was conducted to determine the levels of organochlorine pesticides (OCPs). The investigation revealed the presence of 19 different OCPs in the samples, with variations observed across different locations. These findings strongly indicate that the contamination of tomato samples may originate from common sources.

3.1 Concentrations of OCPs in the tomato samples from the three communities

In Bonia location, the analysis identified a total of 14 different organochlorine pesticides (OCPs) in the samples. Among these, the OCP with the highest residual concentration was p, p-DDT at 8.25μg/kg, while the lowest residual concentrations were observed for o, p-DDT and trans-heptachlor epoxide at 0.13μg/kg. Interestingly, five OCPs, namely trans-chlordane, o, p-DDE, cis-chlordane, dieldrin, and o, p-DDD, were not detected in the samples. Furthermore, HCB was exclusively detected in the Bonia location, as depicted in figure 2.

In the Nangalkenia location, analysis revealed the presence of 13 distinct OCPs, as illustrated in figure 3. Among these, the OCP with the highest residual concentration was δ-HCH, measuring 10.2133μg/kg. Conversely, trans-chlordane and o, p-DDT exhibited the lowest residual concentrations, measuring 0.04μg/kg. Notably, the HCH isomers (δ-HCH, β-HCH, and γ-HCH) displayed relatively higher residual concentrations compared to the other detected OCPs. Furthermore, the results indicate that six OCPs were not detected by the gas chromatography (GC) method.

In the Korania location, analysis revealed the presence of 17 different OCPs. Notably, β-HCH exhibited the highest residual concentration, measuring 15.90μg/kg, while the lowest residual concentration was recorded by Cis-chlordane and trans-heptachlor epoxide, both at 0.04μg/kg (as depicted in figure 4). It is worth mentioning that α-HCH and γ-HCHs can undergo weathering, leading to their transformation into β-HCH. This phenomenon could explain the greater proportion of β-HCH observed in the sample [11]. Furthermore, the HCH isomers displayed relatively higher residual concentrations. However, only two OCPs, namely HCB and o, p-DDE, were not detected in the analyzed samples.

Overall, the findings demonstrate the presence of organochlorine pesticides (OCPs) in varying levels across all sampled locations. The HCH isomers were detected in all locations, indicating their widespread distribution. Prolonged exposure to α-HCH, β-HCH, and γ-HCH has been associated with health risks such as liver cancer, blood disorders, dizziness, headaches, and potential alterations in sex hormone levels [14]. Interestingly, the concentrations of the parent compound p, p-DDT were higher than its primary breakdown product (p, p-DDE) in all three communities. As shown in Table 1, the concentrations of p, p-DDT were 8.25μg/kg, 0.82 μg/kg, and 0.34 μg/kg in Bonia, Korania, and Nangalkenia, respectively. Conversely, the concentrations of p, p-DDE were 0.25 μg/kg, 0.34 μg/kg, and 0.24 μg/kg in Bonia, Korania and Nangalkenia respectively. These observations suggest recent usage of DDT in the examined areas. Notably, the concentrations of heptachlor exceeded those of trans-heptachlor epoxide in all three communities. For instance, Bonia exhibited a heptachlor concentration of 3.41μg/kg compared to a trans-heptachlor epoxide concentration of 0.13μg/kg. Heptachlor undergoes biological and chemical transformations in the environment, leading to the formation of heptachlor epoxide and other degradation products. Due to its slower degradation rate, heptachlor epoxide exhibits greater persistence than heptachlor [24]. Consequently, the higher concentrations of heptachlor relative to heptachlor epoxide indicate recent utilization of this pesticide. The results obtained in this study were consistent with the findings reported by Bempah et al. who examined the levels of OCPs in tomatoes and other vegetables [13]. However, the residual concentrations of OCPs observed in our study were higher than those reported by Sulaiman et al. in tomatoes [4]. Conversely, the concentrations measured in our study were lower compared to similar investigations conducted in other regions of Ghana. For instance, Essumang et al. reported OCP concentrations in tomatoes from selected markets in Accra ranging from 30 to 10760μg/kg [25]. A comparable investigation was carried out by Dada et al. in Markudi, Nigeria, aiming to determine the levels of OCPs in the shoots of salad vegetables such as lettuce, onion, and spinach. The results obtained in that study were significantly lower than the findings of the current research [6]. These findings align with the results reported in previous literature. For instance, various concentrations of HCH isomers, aldrin, endrin, and p, p-DDT were detected in vegetables (lettuce, onion, cabbage) obtained from different locations in Kumasi [12]. In contrast to the outcomes of our study, Moussaoui et al. reported that the levels of OCPs in tomatoes, pepper, and hot pepper were all below the detection limit [26].

Furthermore, the assessment of OCP residue concentrations across the sampling locations using ANOVA revealed that the majority of the OCP residues exhibited statistically significant differences in concentrations at different sampling locations ($p<0.05$). Notably, the concentration of α-HCH displayed significant differences between Bonia and Nangalkenia ($p=0.0140$). Additionally, there were significant differences in the concentrations of β-HCH between Bonia and Korania ($p=0.038$). However, a few OCP concentrations did not show significant differences. For instance, the concentration of heptachlor between Bonia and Korania exhibited no significant differences ($p=0.7250$).

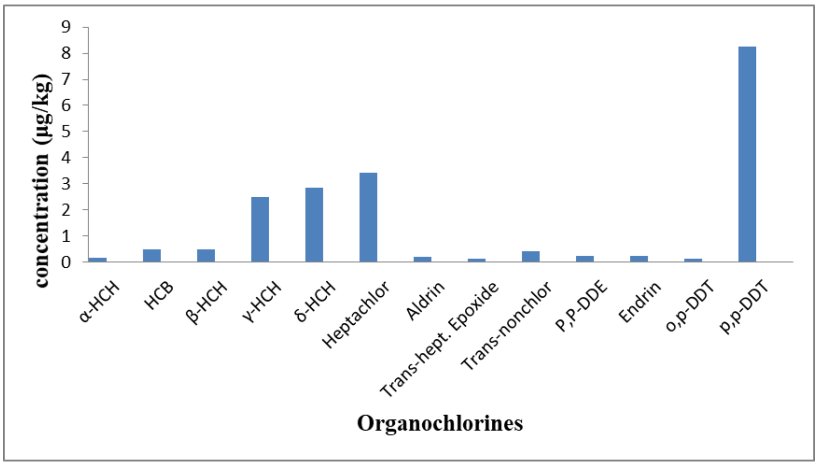


Figure 2 Average concentrations of OCPs (µg/kg) in tomatoes from Bonia location

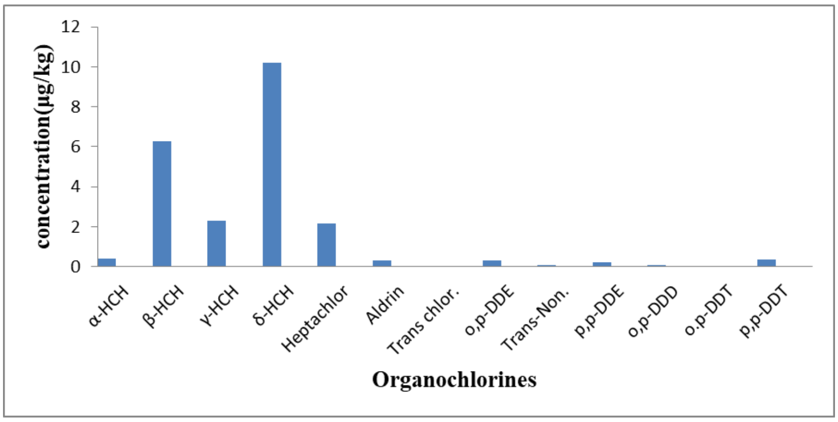


Figure 3 Average concentrations of OCPs (µg/kg) in tomatoes from Nangalkinia location

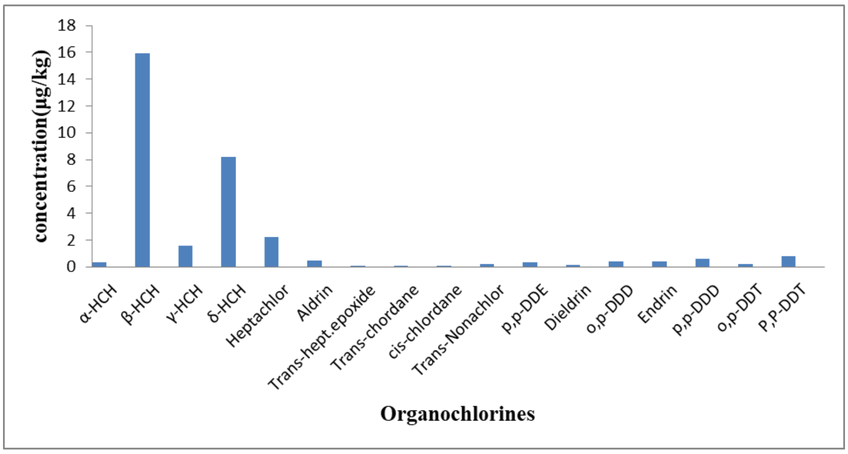


Figure 4 Average concentrations of OCPs (µg/kg) in tomatoes from Korania location

3.2 Comparison of organochlorine concentrations with the UK/EC MRLs

Based on the data presented in Table 1, it is evident that, apart from β-HCH at Korania and δ-HCH at Nangalkenia, the concentrations of the remaining 17 detected OCPs were below the UK/EC Maximum Residue Limits (MRLs). This implies that consuming tomatoes from Navrongo presents minimal risk to consumers in terms of OCP exposure. However, despite the levels being lower than the established MRLs, there is still a reason for concern. This is because individuals who regularly consume these tomatoes may experience the accumulation of these organochlorines in their bodies. Furthermore, consumers who are already exposed to other sources of these pesticides, such as drinking water and meat, will face the cumulative effects of these widely present pesticides. The findings of this study are consistent with those reported by Kolani et al, who observed low residue levels of organochlorine pesticides in vegetables (such as tomato, cabbage, and lettuce) sourced from Togo markets, with none exceeding the maximum residue limits established by the FAO [11]. In a related investigation conducted by Usman et al in Lahore, Pakistan, all sampled fruits and vegetables available in the market were found to have residue levels below the maximum residue limit (MRL) set by the World Health Organization (WHO) [27]. The findings of this investigation demonstrate a notable disparity when compared to the levels observed in vegetables obtained from three prominent markets in Ghana, wherein the concentrations of organochlorine pesticides (OCPs) exceeded the permissible Maximum Residue Limits (MRLs) for human consumption [22]. Furthermore, Al-Shamary et al. have previously reported that the OCPs levels in indigenous tomatoes were found to be below the MRLs [7]. These comparatively lower levels, as compared to the MRLs established by the United Kingdom/European Commission, strongly imply a limited occurrence of organochlorine pesticide misuse in Navrongo, in contrast to those aforementioned locations where the OCP concentrations surpassed the established MRLs.

Table 1 Comparison of average concentrations of OCPs from the three study locations against the UK/EC MRLs

Organochlorines	**Sample locations (average concentrations (µg/kg))**			**UK/EC MRLs (µg/kg)**
	Bonia	**Korania**	**Nangalkinia**	
α-HCH,	0.15	0 .32	0.41	10
HCB	0.47	ND	ND	10
β-HCH	0.50	15.90	6.29	10
γ-HCH	2.48	1.54	2.30	10
δ-HCH	2.85	8.20	10.21	10
Heptachlor	3.41	2.25	2.18	10
Aldrin	0.21	0.46	0.33	10
Trans-Heptachlor epoxide	0.13	0.04	ND	10
Trans-Chlordane	ND	0.09	0.04	10
o, p-DDE	ND	ND	0.30	50
Cis-Chlordane	ND	0.04	ND	10
Trans-Nonachlor	0.42	0.21	0.09	10
p, p-DDE	0.25	0.34	0.24	50
Dieldrin	ND	0.16	ND	10
o, p-DDD	ND	0.43	0.10	50
Endrin	0.24	0.39	ND	10
p, p-DDD	ND	0.59	ND	50
o, p-DDT	0.13	0.23	0.04	50
p, p-DDT	8.25	0.82	0.34	50

ND = Not Detected

3.3 Pesticides commonly used in Navrongo

The present study was designed to determine the type of pesticides used by the farmers. Through the implementation of a questionnaire distributed among a selected group of farmers, as well as on-site visits, it was ascertained that pesticides have indeed been utilized in the cultivation of tomatoes in Navrongo. The rationale behind their use stems from the farmers' imperative need to safeguard their vegetable crops against pests and diseases while concurrently maximizing overall production outcomes [18]. Noteworthy pesticide varieties employed include karate (lambda cyhalothrin), lambda, carbofuran (carbamate), mancozeb (carbamate), ridomil (metalaxyll), sunpyrifos (chlorpyrifos-ethyl), kocide (cupric hydroxide - a fungicide), cypermethrin (pyrethroid), dimethoate (organophosphate), methylthiophanate, and Top cop (a fungicide composed of 50% Sulphur and 8.4% tribasic copper sulphate). Interestingly, these identified pesticides bear similarities to those commonly employed in Nigeria, as previously documented by Adeleye et al [2].

3.4 Educational levels of tomato farmers

The findings of the investigation revealed a substantial proportion of tomato farmers to be illiterate, accounting for 54% of the surveyed population. Among them, 13% had completed middle school/JSS, while 7% held diplomas (as depicted in Figure 5). This highlights a concerning reality whereby the majority of farmers lack the ability to comprehend instructions and warnings presented on pesticide containers.

Interestingly, the questionnaire responses and on-site observations indicate a general tendency among illiterate farmers to disregard good agricultural practices. This phenomenon can be attributed to the prevailing circumstance in many developing countries, wherein farmers possess limited educational backgrounds and tend to underestimate the detrimental impacts of these pesticides on the environment. Consequently, this study emphasizes the pressing need for improved adherence to good agricultural practices (GAP) within the region and Ghana as a whole.

Efforts should be directed towards providing comprehensive training programs to enhance farmers' knowledge regarding pests, the ecological consequences they entail, non-chemical alternatives, and appropriate pesticide management practices. Such initiatives would contribute to empowering farmers and equipping them with the necessary tools to make informed decisions and mitigate the adverse effects associated with pesticide usage.

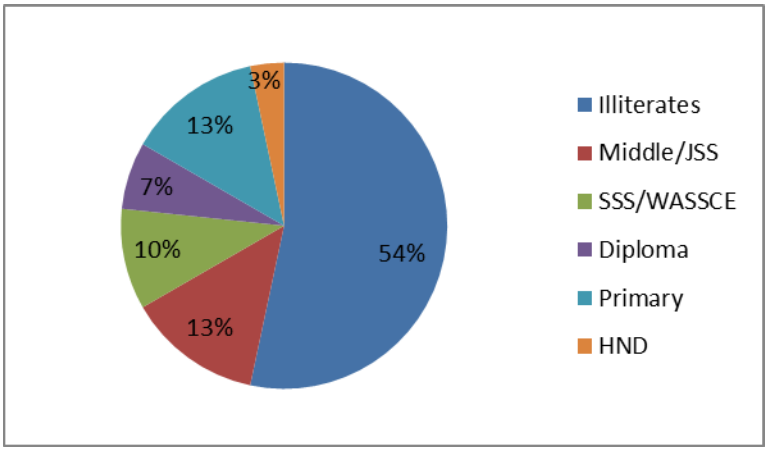


Figure 5 Educational levels of tomato farmers in Navrongo

4 Conclusion

The mean concentrations of organochlorine residues observed in the sampled tomatoes during this study were predominantly at low levels. However, it is noteworthy that out of the 19 organochlorine residues identified, two surpassed the Maximum Residue Limits (MRLs) established by the United Kingdom/European Commission. Despite the generally low concentrations of OCPs detected, the persistent consumption of these contaminated tomatoes could result in the bioaccumulation of organochlorine pesticides within human tissues, giving rise to significant health implications. Furthermore, the findings corroborate the persistence of OCPs usage by farmers, despite their ban in Ghana.

The results of the questionnaire survey revealed a notable proportion of illiterate farmers, comprising 54% of the surveyed population. This finding bears significance as it is likely to contribute significantly to the misuse or indiscriminate utilization of pesticides among these farmers. Additionally, the combined analysis of the questionnaire responses and field visits provided valuable insights into the specific types of pesticides employed by the farmers. It is therefore recommended that a similar study should be conducted on the water of the irrigation dam as well as drinking water in the communities to ascertain if these are other possible ways residents can be exposed to pesticides.

Compliance with ethical standards

Acknowledgments

This study did not receive any funding. The authors would like to express their gratitude to Ghana Atomic Energy Commission for providing access to their laboratory for analyses.

Disclosure of conflict of interest

The authors have no conflict of interest

Statement of informed consent

All participants included in this study provided an oral informed consent before their participation. Participants were assured of the confidentiality and anonymity of their data. Participation in this study was voluntary, and participants were informed of their right to withdraw at any time without providing a reason and without any negative consequences. Participants were also informed that the results of this study may be published in scientific journals or presented at conferences.

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