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Determination of Pesticide Residuals in Soil and Tomato Fruits from Two Tomato Production Areas in Northern Ghana

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Abstract

Tomato fruit (Lycopersicon esculentum Mill) is an important vegetable commodity in Ghana, as it is consumed daily in many households either heat-treated or without any form of heat treatments. Tomato production is a major source of income for many smallholder producers in Northern Ghana especially through dry season farming when the major supply of tomatoes from Southern Ghana is exhausted. Research conducted for the past decade confirmed the presence of pesticide residues in fruits and vegetables such as cabbage, onion, cucumber, lettuce, tomatoes, okra and pepper. The objective of this study was to identify and estimate pesticide residual levels in the soil and tomato fruits in comparison with the maximum allowable residual limits. The research was carried out in two production communities namely Doba where the "Burkina" variety is mostly grown in the Kassena Nankana East District of the Upper East Region and Bunglung where the "Wosowoso" variety is cultivated in the Savelugu/Nanton Municipality of Northern Region. Soil samples were collected for residue determination before transplanting of tomato seedlings. Matured and ripe tomato fruits were also collected for the determination of the presence and amount of pesticide residues. All soil and plant samples were analysed using high performance liquid chromatography to determine the presence of twenty-four organochlorines and thirteen organophosphate pesticide residues. From the analysis, pesticide residues were present in different variations which ranged from 0.002 – 0.033 and 0.003 – 0.022 (soils) and 0.330 – 1.187 and 0.002 – 0.088 (fruits) for organochlorines and organophosphates respectively for both communities. Levels of pesticide residues were generally above the acceptable maximum residue limits as farmer practices produced fruits with more pesticide residues since the land areas could have been predisposed with residues from previous seasons for other food crops, which could be translocated into the tomato plant and through into the fruits. The presence of pesticide residues could also be attributed to the influence of run-off and drift from other cultivated lands. For effective determination of pesticides residues in the tomato plants, it is essential to use uncontaminated soil and water to facilitate the efficient estimation of pesticide residues in tomatoes and plants in general.

Keywords: *Tomato, pesticide residues, soil, contamination, maximum residue limits*

INTRODUCTION

Tomato fruit (*Lycopersicon esculentum* Mill) is an important vegetable in Ghana, as it is consumed daily in many households either heat-treated or without any form of heat treatments (Horna et al., 2006). Pesticide residues are the remains from pesticides on or in food after their application on food crops. The maximum allowable levels often termed maximum residue limits (MRL) of these residues in foods are often stipulated by regulatory bodies in many countries. Residues of pesticides in plants especially vegetables may be unavoidable even when sprayed in accordance with good agricultural practices and could also be due to the composition of the pesticide. A high proportion of pesticide poisonings and deaths occur in developing countries due to inadequate protective clothing and washing facilities, insufficient enforcement of applicable laws, poor labelling of pesticides, illiteracy and insufficient knowledge of pesticide concentration for vegetable production. Most of these pesticide residues are often classified as organochlorines or organophosphates. The organophosphates are considered less persistent, and do not often bioaccumulate and are less hazardous to the farmer, consumer and environment than the organochlorines which are often persistent.

Research conducted for the past decade confirmed the presence of pesticide residues in fruits and vegetables such as cabbage, onion, cucumber, lettuce, tomatoes, okra and pepper (Hussain et al., 2002; El-Nahhal, 2004; Hanson et al., 2007). The presence of pesticide residues is a concern for consumers because pesticides are known to have potentially harmful effects on consumers' health and also to other non-targeted organisms than pests and diseases. The major concerns are their toxic effects such as interfering with the reproductive systems and foetal development as well as their capacity to cause cancer and asthma (Gilden *et al.*, 2010). It is also a fact that pesticide residues in plants could be ineluctable with the use of best practices, which are adept and effective (Uysal-Pala and Bilisli, 2006). Pesticide residues in food could be decreased through food processing techniques such as effective washing, peeling and heat treatments such as cooking (Dikshit *et al*., 2003). The objective of this study was to identify and estimate pesticide residual levels in the soil and tomato fruits in comparison with the maximum allowable residual limits.

MATERIALS AND METHODS

Study area and data collection

The study was carried out in Doba found in the Kassena Nankana East District of the Upper East Region and Bunglung in the Savelugu/Nanton Municipality of Northern Region (Fig. 1).

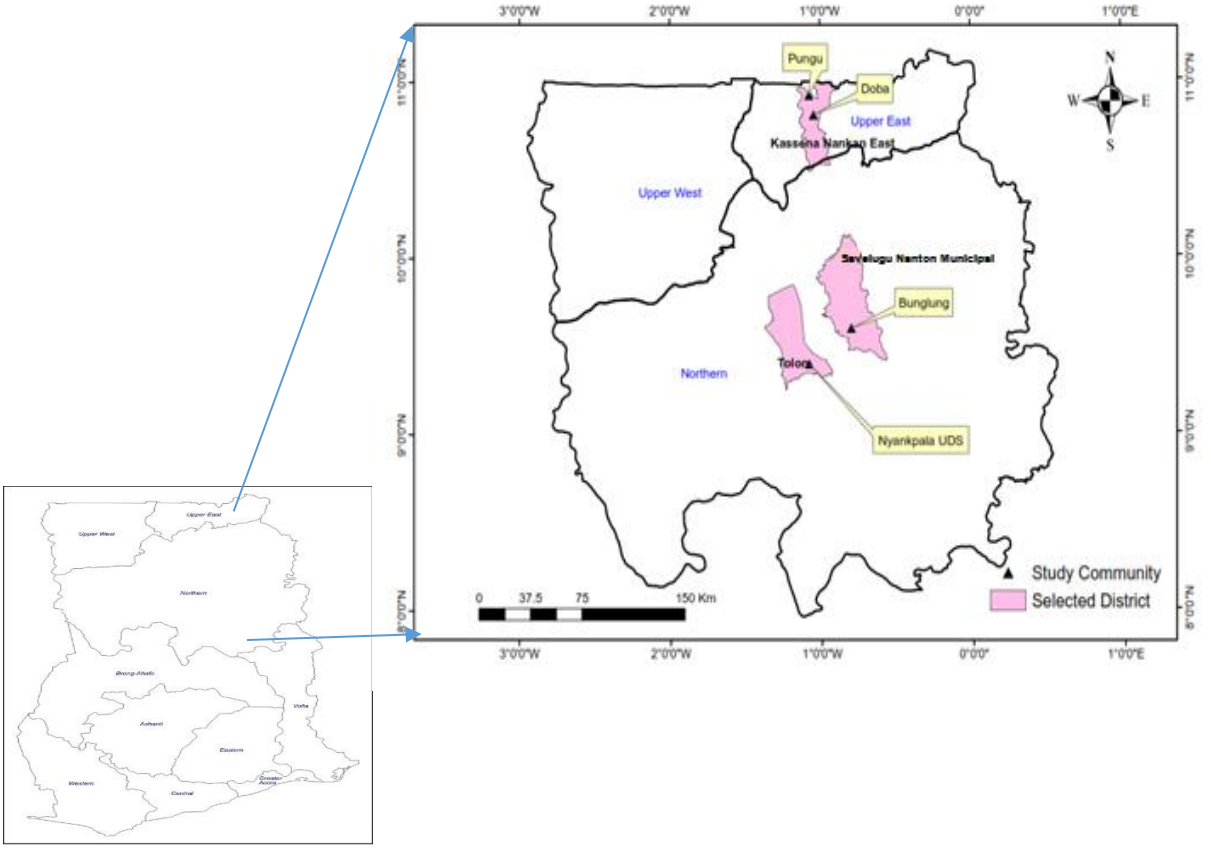

Figure 1: Map of Northern Ghana showing study areas

These two communities produce vegetables, mostly tomatoes which are supplied to the major cities such as Bolgatanga and Navrongo in the Upper East Region and, Savelugu and Tamale in the Northern Region when the tomatoes from the Southern part of Ghana are mostly sold out or not available. Tomato variety Popvriend supplied by Agriseed also known locally as "Burkina" was grown in Doba, and the local variety "Wosowoso" was grown in Bunglung. The tomato seedlings were transplanted at 26 inches apart during the dry season between December and February.

Soil samples from farmers' fields were collected with an auger of 6 inches' depth before tomato seedlings were transplanted. Ripe tomato fruit samples were collected at harvest for analysis. All collected samples were wrapped in aluminium foil and placed in plastic zip-lock bags and cooled in an icebox during transportation for laboratory analysis. All samples were analysed for A-endosulfan, Aldrin, Allethrin, alpha-HCH, B-endosulfan, beta-HCH, Bifenthrin, Chlorfenvinphos, Chlorpyrifos, Cyfluthrin, Cypermethrin, delta-HCH, Diazinon, Dimethoate, Endosulfan sulfate, Ethoprophos, Fenitrothion, Fenpropathrin, Fenvalerate, Fonofos, gamma-HCH, Heptachlor, Lambda-cyahothrin, Malathion, Methamidophos, Methoxychlor, Mirex, Parathion, Phorate, Pirimiphos-methyl, p'p'-DDD, p'p'-DDE, p'p'-DDT, Trans_Nonachlor, hexachlorobenzene (HCB), endrin and Chlordane.

Sample and data analysis
All samples were extracted and cleaned-up following the training manual standards of the United Nations Environment Programme (UNEP 2010) through extractions and clean-ups, and finally analysed using gas chromatography.

Extraction procedure for pesticides in soil
Ten grams of the soil sample was weighed into a flask and 20 ml of the mixture (ethyl acetate: hexane 3:1) was measured and added to the flask. Sonication was done for 20 minutes and repeated for 30 minutes. The first and the repeated ones were filtered and concentrated using the rotary evaporator and extracts transferred into labelled vials.

Procedure for clean-up of soil extract
Ten-millimetre chromatographic column corked with glass wool was filled with 8 g silica gel and 0.5 g anhydrous sodium sulphate was used to form a horizon for filtering the samples.

Extraction for pesticide residue in tomato
Before the extraction process, anhydrous sodium sulphate, sodium bicarbonate and silica gel were baked to remove moisture. Previously refrigerated samples were blended and homogenized for the analysis. A spatula was used to transfer 20 g of the blended filtrate into each labelled flask. 30 g of anhydrous sodium sulphate (Na_2SO_4) and 10 g of sodium bicarbonate was added to each flask of the filtrate to absorb remaining water and neutralize any acid respectively that might be present in the filtrate. After thoroughly mixing the content in each flask, 40 ml of acetonitrile was added to remove any unwanted materials that intervene with the extraction process and the flask covered with aluminium foil. Each flask was then mechanically shaken in a sonicator between 450-600 rpm for 30 minutes and the extract drained through a filter of charcoal to eliminate any colour present. The filtered extract was concentrated at 60^{o}C to remove the acetonitrile using a rotary evaporator and extracts transferred into labelled vials.

Procedure for clean-up of tomato extract
Ten-millimetre chromatographic column corked with glass wool was filled with 4 g silica gel, a half gram of anhydrous sodium sulphate and 1 g charcoal to form a horizon for filtering the samples. Twenty millilitres of hexane was added to each column to remove any unwanted material that might be present to intervene with the clean-up process. Ten millilitres of hexane and acetonitrile were added to the samples as conditioning solvent for fraction one and two respectively and was applied as drops into the columns to prevent agitation of the horizon.

Determination of extract using gas chromatography
Determination of residues was by the gas chromatographic (GC) method where the GC sample was injected using a 25 µl glass Hamilton syringe. One-two microliters of the sample were shot into the chromatography column. A small amount of the liquid sample was slowly drawn by raising the plunger and then pressed to expel the liquid. This served to “rinse” the syringe with the sample, ensuring that what was measured in the GC run was the composition of the mixture. The rinse procedure was repeated twice. The plunger was slowly drawn up until the syringe was completely occupied with the liquid (Gilvydis et al., 1999; Araoud et al., 2007). The sample was injected into the injector port. Two things were done sequentially and quickly. The needle of the syringe was

pushed through the injector pot and immediately the plunger was pressed to inject the sample. Then immediately the start button on the recorder was pressed. The residual levels were estimated as:

$$\text{Residue level} = \frac{\text{concentration in final extract} \times \text{final volume of extract}}{\text{weight of sample}}$$

All determined residue levels were transformed into means and the standard deviations calculated.

RESULTS AND DISCUSSION

Pesticide residual levels of soil samples

Fourteen out of the twenty-four organochlorine residues tested were detected (Table 1) at varying levels for both communities. There were different and varied detected pesticide residues in sample soils. Some of the detected pesticide residues were in soils where farmers had not applied any form of pesticides as inputs on the fields before the experiment. This implies that all agricultural land in the study areas could be contaminated with one or more of pesticide residues as a result of previous chemical applications, wind drifts during pesticide applications and rainwater run-off from fields of high lands to low lands.

Table 1: Mean organochlorine pesticide residues in soil samples.

Organochlorine pesticide	Bunglung(mg/kg)	Doba(mg/kg)
Aldrin	0.010±0.00	0.010±0.00
Bifenthrin	0.002±0.00	0.000
Dichlorodiphenyldichloroethane (DDD)	0.010±0.00	0.010±0.00
Dichlorodiphenyldichloroethylene (DDE)	0.010±0.00	0.010±0.00
Dichlorodiphenyltrichloroethane (DDT)	0.033±0.03	0.005±0.01
Endosulfan_ sulfate	0.010±0.00	0.010±0.00
Fenpropathrin	0.000	0.010±0.01
Fenvalerate	0.007±0.01	0.005±0.01
Heptachlor	0.010±0.00	0.010±0.00
Lambda_ cyahothrin	0.007±0.01	0.000
Methoxychlor	0.007±0.01	0.000
Beta_HCH	0.005±0.01	0.005±0.01
Delta_HCH	0.008±0.00	0.010±0.00
Gamma_HCH	0.010±0.00	0.010±0.00

± = Standard deviation

Out of the thirteen (13) organophosphate residues tested, seven (7) residues were detected (Table 2). Appreciable amounts of organophosphate residue concentrations were detected for all samples at varying levels for all soil samples. This also indicates that organophosphates though termed less

persistent were persistent in soil samples as most residues detected were not from previous chemical applications by farmers who were understudied. This could be an indication that all soils used for the production were predisposed to pesticide residues before cultivation.

Table 2: Mean organophosphate pesticide residues in soil samples.

Organophosphate pesticide	**Bunglung (mg/kg)**	**Doba (mg/kg)**
Chlorpyrifos	0.017±0.01	0.010±0.00
Dimethoate	0.003±0.01	0.005±0.01
Ethoprophos	0.003±0.01	0.010±0.00
Fenitrothion	0.007±0.01	0.000
Methamidophos	0.022±0.01	0.015±0.01
Phorate	0.003±0.01	0.005±0.01
Pirimiphos_methyl	0.008±0.01	0.000

± = Standard deviation

In general, soil samples from Bunglung and Doba contained almost all residues and this could be linked to run-off from the catchment area, leaching, wind-aided dissipations and the use of the same pieces of land used for the cultivation of other crops such as maize and legumes during the rainy season. The use of pesticide also has adverse environmental implications as researchers have documented the contamination due to pesticides on non-target sites such as surface and groundwater bodies which makes water unsafe for consumption by humans, wildlife and plant use mostly during dry season farming. Even though these aquatic environments are usually non-target destinations of applied pesticides, they are contaminated by pesticides through runoff from farmlands depending on the topography of the land, leaching, inappropriate disposal of empty pesticide containers and sachets as well as the washing of equipment used in spraying (Tariq *et al*., 2007). The use of pesticide is also known to suppress the population of soil microbes which can negatively affect soil fertility.

It is, however, important that farmers maintain the same land for both cropping seasons for the same crop despite the disadvantages of mono-cropping or keep records on the historical knowledge of pesticides applied during crop rotation. Since pesticide residues in the soil are inevitable due to persistence of chemicals and the factors above, soil improvement strategies such as the incorporation of biochar produced at 85 ^{o}C into the soil could reduce the plant uptake of pesticides from contaminated soils. According to Yu *et al*. (2009), the incorporation of biochar into the soil can eliminate about 86 - 88% of pesticide residues from the soil.

Pesticide residual limits of tomato fruit samples

Pesticide residuals in fruits for both communities (Table 3 and 4) indicate the presence of residues and the mean organochlorines were generally above the acceptable maximum residue limit (MRL) (WHO/FAO-MRL, 2015). There were varying levels of pesticide residues ranging from 0.01-1.5 mg/kg for both locations. This sustains the study by Amoah *et al*. (2006) that mean lettuce samples had residues (Lindane (0.3 mg/kg), Endosulfan (0.4 mg/kg), Lambda-Cyhalothrin (0.5 mg/kg), Chlopyrifos (1.6 mg/kg) and DDT (0.4 mg/kg)) from the three major markets (Tamale, Kumasi and

Accra) in Ghana exceeded the MRLs (0.01, 0.05, 1.0, 0.05 and 0.05 for Lindane, Endosulfan, Lambda-Cyhalothrin, Chlopyrifos and DDT respectively) for consumption. The presence of the metabolites of Dichlorodiphenyltrichloroethane (DDT) Dichlorodiphenyldichloroethylene (DDE) and Dichlorodiphenyldichloroethane (DDD) even though since 1985 DDT has been banned (EPA, 2008) for agricultural use could be an indication of photochemical degradation of DDT in the environment (Wandiga, 1995).

Table 3: Mean organochlorine pesticide residue detected in fruits

Organochlorine pesticide	**Bunglung (mg/kg)**	**Doba (mg/kg)**	**MRL**
Aldrin	1.053±0.16	1.187±0.03	0.01
Heptachlor	0.393±0.68	0.760±0.66	0.01
Trans_Nonachlor	0.00	0.917±0.79	0.01
Alpha_HCH	0.970±0.17	0.983±0.21	0.01
Delta_HCH	0.893±0.13	1.110±0.14	0.01
Gamma HCH	0.00	0.047±0.08	0.01
Pp_ Dichlorodiphenyldichloroethylene (DDE)	0.383±0.66	0.330±0.57	0.05
Pp_ Dichlorodiphenyldichloroethane (DDD)	0.00	0.683±1.18	0.05

± = Standard deviation MRL = Maximum residual limit

Organophosphate pesticide residues detected included Malathion, Phorate, Pirimiphos-methyl, Chlorpyrifos and Parathion at varying levels for both communities (Table 4) and with more than fifty percent been less or equal to the set MRL.

Table 4: Mean organophosphate pesticide residues detected in fruits

Organophosphate pesticide	**Bunglung (mg/kg)**	**Doba (mg/kg)**	**MRL(mg/kg)**
Chlorpyrifos	0.088±0.01	0.112±0.03	0.5
Malathion	0.003±0.01	0.020±0.02	0.02
Parathion	0.00	0.003±0.01	0.05
Phorate	0.002±0.00	0.00	0.01
Pirimiphos_methyl	0.010±0.02	0.008±0.01	0.01

± = Standard deviation, MRL = Maximum residual limit

The presence of these pesticide residues emphasised the fact that some pesticide residues could still be detected in fruits until adept and effective agricultural practices are used (Uysal-Pala and Bilisli, 2006), notwithstanding the fact that some farmers can be careless with the application time and the pre-harvest interval for pesticides application. This is because some farmers apply pesticides at the appearance of pests without consideration for the plant stage/phase of growth. The results also confirm the accumulation of pesticide residues into the plant (fruits). The consumption of fruits and vegetables with the presence of minute doses of man-made pesticides could suppress the immune response and cause hypersensitivity to consumers (Fianko *et al*., 2011).

CONCLUSION

There were varying pesticide residues determined in the soil and ripe fruit samples. Farmer practices produced fruits with more pesticide residues as farmers cultivated tomatoes on land areas predisposed with residues from previous seasons for other staple crops (maize, millet), and any applied pesticide residue could be translocated into the tomato fruits.

For effective determination of pesticides residues in the tomato plants, it is recommended to use uncontaminated soil or laboratory set up to facilitate the efficient estimation of pesticide residues in tomatoes and plants in general.

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