ORGANOCHLORINE PESTICIDE RESIDUES IN FRUITS AND VEGETABLES CULTIVATED ALONG THE AFRAM RIVER AND THEIR ASSOCIATED HEALTH RISK

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Abstract
Fruits and vegetable cultivation in Ghana is known to be dependent on pesticide input for desired yields. These food crops are therefore targets for pesticide residue analyses. In this study, three crops (watermelon, onion and pepper) that are popularly grown along the Afram river were analysed for 15 organochlorine pesticides residues (OCPs) using gas chromatography with electron capture detector. The health effects of these pesticides were also evaluated. Twelve (80%) of the target pesticides were quantified with mean concentration range of 0.001 - 0.084 mg/kg in the three crops. The highest mean concentration was recorded for β-HCH in watermelon. Nine pesticides (β-HCH, γ-HCH, δ-HCH, p, p’-DDE dieldrin, endrin, heptachlor, γ-chlordane, and methoxychlor) exceeded the European Union’s (EU) maximum residue level (MRL) in the range of 0.01mg/kg - 0.05mg/kg. Also, 35%, 29% and 21% of pepper, onion and watermelon samples respectively contained residues above the EU MRL. Health risk estimates show that local children in particular are at risk to systemic toxicity of heptachlor, dieldrin and β-HCH while the entire consuming populace is pre-disposed to chronic health effects since most of the residues exceed their acceptable daily intake (ADI) toxicological benchmarks. It is therefore concluded that even though OCPs are not openly encountered in the study area, they are still in use for fruits and vegetable cultivation. Hence in areas where researches point to the use of OCPs, surveillance and monitoring efforts must increase to curb the resurgence of the use of these banned chemicals.

Introduction
Organochlorine pesticides are a group of chlorinated compounds composed primarily of carbon, hydrogen and chlorine and with insecticidal properties. They were therefore used extensively for health care purposes in the control of malaria and typhus (Aktar et al., 2009). Agriculture Statistical review on the use of different pesticides show that 40% of all pesticides used in the past belong to the organochlorine pesticide group (FAO, 2005; Gupta, 2004). The effects of organochlorine pesticides (OCPs) in humans have been extensively studied. The OCPs have been reported to cause cancer, neuro-developmental outcomes, reproductive defects, thyroid disruption and neuro-degenerative diseases, among others, in man. For instance low sperm count in males, increased testicular cancer and other reproductive as well as developmental defects have been reported (Weltman and Norback, 1983). Early exposure to dichlorodiphenyltrichloroethane (DDT) in particular has been associated with an increased breast cancer risk (Cohn et al., 2007) as well as pancreatic cancer and non-Hodgkin’s lymphoma later in life (Cantor et al., 1992; Garabrant et al., 1992). There is also evidence that exposure to OCPs disrupts normal neuro-developmental outcomes in humans, like decreased psychomotor and mental functions including memory, attention, and verbal skills in children (Jurewicz and Hanke, 2008; Korrick and Sagiv, 2008). Organochlorine pesticides such as DDT, endosulfan and lindanes produce anti-thyroid effects that lead to the development of decreased intellectual capacity, psychomotor delays, deafness as well as autism (Roberts et al., 2007; Román, 2007), while maternal concentration of others such as DDE and beta-lindane are associated with preterm birth, where the baby is likely to be small for its gestational age (Longnecker et al., 2001; Pathak et al., 2009). It is generally also known that Parkinson’s and Alzheimer’s diseases are more common in people with higher exposure to pesticides, including OCPs (Román, 2007). The accumulation of these chemicals in food chains therefore poses serious health hazards to humans (Jayashree and Vasudevan, 2007) and also affects the environment. The United Nation through the Stockholm convention banned the use of most organochlorine pesticides in 2004 and subsequently, their importation and use in Ghana was also banned (EPA-Ghana, 2007). The Volta River in Ghana was impounded in 1964 following the creation of a dam a year earlier at Akosombo for the main purpose of hydro electricity generation. With the impoundment, the volume of water in the tributaries increased, creating opportunity for lakeside farming (Kalitsi, 1999). Since the creation of the Lake some 50 years ago, there have been intensive agricultural activities along the banks of the Volta Lake and recent reconnaissance survey revealed that there is heavy re-
liance on agrochemicals. A major tributary of the Volta Lake, the Afram River, was identified with immense irrigation farming potential. Pilot projects and demonstration farms based on irrigation were undertaken along the banks of this river for the production of short-maturing fruits and vegetables such as watermelon, okra, pepper, onion, egg plants and tomatoes. The success of this pilot project resulted in instant increase and intensive cultivation of the banks of the Afram River for commercial production of fruits and vegetables; with water from the Afram River as source for irrigation (Kalitsi, 1999). In order to increase and sustain yields, farmers depend on varieties of pesticides to combat pest infestations. Communities along the Afram River are now noted for the production of these crops, which are sold at various market centres in the country. Even though the use of such organochlorine pesticides (OCPs) has been banned, they are still detected in concentrations above permissible levels in food crops in Ghana. Reported fresh input of DDT for instance in the Densu basin (Fianko et al., 2011) is an indication that indeed there is sporadic use of banned organochlorine insecticides in isolated cases in the country. There have been several investigations into pesticide content of fruits and vegetables in various markets in Ghana previously (Asiedu, 2013; Bempah et al., 2012, 2011a,b; Bempah and Donkor, 2011) as well as from various growing centres (Botwe et al., 2011; Gunu et al., 2012; Kokroko et al., 2012; Kotey et al., 2008; Ntow, 2008). So far, there is no documented report on pesticide content of crops from the Afram River bank, despite the large quantities of fruits and vegetables cultivated there. This is probably so due to the barely motorable nature of the access roads in the study area. The aim of this study was therefore to investigate the presence and levels of organochlorine pesticides in three most common crops cultivated along the Afram River banks and their associated health risk.

Materials and Methods

Sample collection and preparation

Samples of watermelon fruits (Citrus vulgaris Schrad.), red onions (Allium cepa L.) and chili pepper (Capsicum annuum L.) were bought from farmers in four communities along the lower bank of the Afram River at the harvest times. Samples were collected at four different times over two-year period to ensure diversity and consistency with codex sampling method (FAO/WHO, 2000). Each time, 1 kg each of onion and pepper samples were randomly purchased from four farms in each community. In all, 64 samples each of onion and pepper were obtained over the study period. Similarly, 5 watermelon fruits per farm were purchased. Thus 80 watermelon fruit samples in all were acquired. For each visit, all the pepper samples were pooled together to obtain one homogenous sample. Onion and watermelon samples were similarly treated. The samples were pooled together because preliminary analysis of the data showed that there were no significant differences in concentrations of pesticides in samples from the various sampling points. The Watermelon fruits were properly cleaned of soil and dirt, contained in jute sacks and moistened with water to maintain temperature as low as possible while the onion and pepper samples were transported on ice to the pesticide laboratory of the Ghana Standards Authority in Accra. Five hundred gramme (500 g) portions of pepper and onions were separately weighed, thoroughly washed in three changes of distilled water and homogenized in Waring blender. Watermelon fruits were also thoroughly washed in distilled water and each sliced into six cones (FAO/WHO, 2000). The edible part of a number of cones weighing at least 1 kg was homogenized. The homogenized samples were put into zip-locked plastic bags and kept in deep freezer pending extraction within 24 hours. Sixty subsamples in each case of the stores pepper and onion homogenized samples, and eighty of watermelon were analysed.

Sample extraction and clean-up

Samples were wet extracted following the method of Takatori et al. (2011) with necessary modifications. Briefly, frozen homogenized samples were thawed and allowed to attain ambient temperature. Ten (10) gramme portions of samples were placed in 50 ml polypropylene tubes and 10 ml acetonitrile added. The content of the tube was homogenized by vortex mixer (Thermolyne-maxi mix-plus) at high speed for one minute. Four (4) grammes of anhydrous magnesium sulphate and 1g of sodium chloride were then added and vigorously shaken for another minute. The mixture was centrifuged for 5 minutes and 4 ml supernatant organic layer transferred into a conditioned Supelclean Envi-Carb/LC-NH2 SPE cartridge (500 mg/500 mg, 6 ml size) and eluted with two portions of 5 ml acetonitrile into a pear-shaped 50 ml flask, using a 12 port visiprep vacuum manifold. The eluate was evaporated to dryness using Buchi rotary vacuum evaporator (Buchi Rotovap R.210). The concentrate was re-dissolved in 2 ml ethyl acetate and transferred into a 2ml standard opening vial for Gas chromatograph analyses.

Instrumental analysis

Organochlorine pesticides in the final pesticide extracts were analyzed by Gas Chromatograph-Varian CP-3800(Varian Association Inc. USA) equipped with combiPal autosampler and 63Ni electron capture detector (ECD). The GC conditions used for the analysis were capillary column coated with VF-5 (30 m + 10 m guard column × 0.25 mm i.d, 0.25 μm film thickness). The injector and detector temperatures were set at 270°C and 300°C respectively. The oven temperature was programmed as follows: 70°C held for 2 min, ramp at 25°C min⁻¹ to 180°C, held for 1 min, and finally ramp at 5°Cmin⁻¹ to 300°C. Nitrogen was used as carrier gas at a flow rate of 1.0 mLmin⁻¹ and detector make-up gas of 29 mLmin⁻¹. The injection volume of the GC was 1.0 μL. The total run time for a sample was 31.4 min.
Organochlorine pesticide residues in fruits and vegetables...

Koranteng et al. — 26/31

Quality assurance and control of method
For each batch of 20 samples, a procedural blank, a spiked blank and a pair of matrix spiked sample were processed. The spiked samples contained all the 15 OCPs, target analytes. All reagents used for the analysis were of high quality and were exposed to the same extraction procedures and subsequently run to check that no interfering substances were present. No analytes were detected in the blanks. Recalibration curves were run with each sample batch to ensure that correlation coefficient was kept above 0.99. Strict cleaning procedures were adhered to viz: all glassware were washed with hot water and detergents and copiously rinsed with distilled water. After drying, the glass-wares were further rinsed with acetone.

Dietary survey
The daily per capita consumptions of the cultivated crops (pepper, onion and watermelon) were determined following the method of Ntow (2008). In the estimation of the per capita consumption, face to face interviews were held with one hundred and fifty healthy adults from four farming communities along the Afram River. The information solicited was daily frequency and quantity of consumption of the three food items over 12 months. For each food item, individuals indicated the quantity and frequency of consumption within a day. In determining the quantity, they were presented with samples of the food items and asked to indicate how much of it is consumed during a meal. The quantity indicated was immediately weighed on a portable scale and recorded.

Risk assessment
The Codex Alimentarius Commission Procedural Manual (Codex Alimentarius Commission, 2006) defines exposure assessment as “the qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant”. For each type of pesticide exposure, the estimated lifetime exposure dose (mg/kg/day) is obtained by multiplying the estimated daily per capita consumption of the food crop; and dividing the product by the body weight (kg). The per capita consumption of fruits and vegetables in Ghana, according to a WHO-sponsored survey by Ruel et al. (2005) are 23.5 kg/person/year and 50.1 kg/person/year respectively. Dietary exposure was determined by the expression:

$$\text{DE} = \frac{\text{FCC} \times \text{DFC}}{\text{BW}}$$

where DE: dietary exposure (mg/(kg/day)); FCC: food chemical concentration (mg/kg) refers to the amount of a pesticide measured in food crop of interest; DFC: daily food consumption (kg/day) is the estimated daily per capita consumption of the food crop; and BW: Body weight (kg).

Hazard index (HI) is used as a measure of the risk associated with the exposure. In HI assessment, the estimated dietary exposure of a pesticide is compared with its toxicological reference value, Acceptable Daily Intake (ADI). The ADI is a level of intake of a chemical that can be ingested daily over an entire lifetime without any appreciable risk to health (WHO, 2001).

$$\text{HI} = \frac{\text{Exposure dose}}{\text{ADI}}$$

Hazard Indices based on national per capita consumption and the estimated per capita consumption in the study area were calculated for children (1–11 years) and grown-ups (12 years and above). In the health risk estimation, this study adopts the U.S. Environmental Protection Agency - USEPA (1986, 1989) assumption that: the hypothetical body weights 1–11 years old is 30 kg and 70 kg for grown-ups or adults.

Non-detects
To account for residues concentrations that were below the limit of detection, two alternative assumptions were considered. First, that actual concentrations for non-detect (ND) samples were equal to the limit of detection and second, that actual concentrations for all non-detect samples were equal to zero. If concentrations for non-detect (ND) samples were assumed to be equal to the limit of quantification, there would be overestimation of the concentrations if there were no contamination of the sampled vegetables. Therefore, the assumption that actual concentrations for all non-detect samples were equal to zero was adopted in this study.

Results and discussion
Organochlorine pesticide residues in watermelon, onion and pepper samples
Twelve organochlorine pesticide residues (OCPs), namely: \(\beta\)-HCH, \(\gamma\)-HCH, \(\delta\)-HCH, \(p\)', \(p\)', \(p\)'-DDE, \(p\)'-DDD, dieldrin, endrin, heptachlor, \(\gamma\)-chlordane, \(\beta\)-endosulfan and methoxychlor, representing 80% of the target pesticides were quantified in the crop samples analysed (watermelon, pepper and onion). The range of mean concentration of quantified pesticides was 0.001–0.084 mg/kg. The highest concentration was measured for \(\beta\)-HCH in onion (0.084 mg/kg) while the lowest (0.001 mg/kg) was recorded for \(p\)', \(p\)', \(p\)'-DDT in watermelon (Table 1). The incidence rates were lower in watermelon (Table 1). In all, nine pesticides (\(\beta\)-HCH, \(\gamma\)-HCH, \(\delta\)-HCH, \(p\)', \(p\)', \(p\)'-DDE dieldrin, endrin, heptachlor, \(\gamma\)-chlordane, and methoxychlor), representing 60% of total target pesticides exceeded the European Union maximum residue limit (EU MRL) (Table 1). Eight of them (53.3%) exceeded in onion, four (27%) in watermelon and 3 (20%) in pepper (Table 1). About 35%, 29% and 21% respectively of pepper, onion and watermelon samples analysed contained residues whose concentrations were above the EU MRL.

Similar studies were carried out elsewhere in Ghana by Botwe et al. (2011), Bempah et al. (2012, 2011b) and Asiedu (2013). Botwe et al. (2011), working in Ashanti Region measured concentrations of DDT, lindanes and methoxychlor in pepper and onion samples in a range of 0.01–7.43 µg/kg and
Table 1. Pesticides concentrations in Watermelon, pepper and Onions

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Mean ± SD (mg/kg)</th>
<th>Range</th>
<th>Incidence Rate (%)</th>
<th>EU MRL (mg/kg)</th>
<th>% of detect samples above EU MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Watermelon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.081 ± 0.031</td>
<td>0.034-0.109</td>
<td>26.7</td>
<td>0.01</td>
<td>100</td>
</tr>
<tr>
<td>γ-HCH</td>
<td>0.061 ± 0.003</td>
<td>0.057-0.063</td>
<td>20</td>
<td>0.01</td>
<td>100</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>0.011 ± 0.007</td>
<td>0.001-0.027</td>
<td>50</td>
<td>0.01</td>
<td>40</td>
</tr>
<tr>
<td>γ-Chlordane</td>
<td>0.012 ± 0.005</td>
<td>0.003-0.019</td>
<td>30</td>
<td>0.01</td>
<td>67</td>
</tr>
<tr>
<td>p,p′-DDT</td>
<td>0.001 ± 0.001</td>
<td>0.001-0.001</td>
<td>6.7</td>
<td>0.05</td>
<td>0</td>
</tr>
<tr>
<td><strong>Chili pepper</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.002 ± 0.000</td>
<td>0.001-0.002</td>
<td>45</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>γ-HCH</td>
<td>0.025 ± 0.017</td>
<td>0.008-0.054</td>
<td>90</td>
<td>0.5</td>
<td>11</td>
</tr>
<tr>
<td>δ-HCH</td>
<td>0.022 ± 0.020</td>
<td>0.001-0.053</td>
<td>100</td>
<td>0.02</td>
<td>50</td>
</tr>
<tr>
<td>γ-Chlordane</td>
<td>0.021 ± 0.002</td>
<td>0.001-0.006</td>
<td>15</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>p,p′-DDE</td>
<td>0.001 ± 0.001</td>
<td>0.001-0.004</td>
<td>80</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Endrin</td>
<td>0.005 ± 0.004</td>
<td>0.001-0.012</td>
<td>70</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Beta endosulfan</td>
<td>0.007 ± 0.003</td>
<td>0.002-0.012</td>
<td>60</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>p,p′-DDT</td>
<td>0.001 ± 0.001</td>
<td>0.001-0.003</td>
<td>100</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>p,p′-DDD</td>
<td>0.016 ± 0.011</td>
<td>0.002-0.027</td>
<td>65</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>0.053 ± 0.002</td>
<td>0.051-0.057</td>
<td>45</td>
<td>0.01</td>
<td>100</td>
</tr>
<tr>
<td><strong>Onion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.084 ± 0.020</td>
<td>0.043-0.315</td>
<td>80</td>
<td>0.01</td>
<td>100</td>
</tr>
<tr>
<td>γ-HCH</td>
<td>0.056 ± 0.027</td>
<td>0.002-0.102</td>
<td>100</td>
<td>0.01</td>
<td>90</td>
</tr>
<tr>
<td>δ-HCH</td>
<td>0.011 ± 0.005</td>
<td>0.001-0.018</td>
<td>40</td>
<td>0.01</td>
<td>12.5</td>
</tr>
<tr>
<td>γ-Chlordane</td>
<td>0.013 ± 0.004</td>
<td>0.005-0.019</td>
<td>100</td>
<td>0.01</td>
<td>25</td>
</tr>
<tr>
<td>p,p′-DDE</td>
<td>0.060 ± 0.031</td>
<td>0.001-0.086</td>
<td>35</td>
<td>0.05</td>
<td>14</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.011 ± 0.002</td>
<td>0.008-0.011</td>
<td>20</td>
<td>0.01</td>
<td>50</td>
</tr>
<tr>
<td>Endrin</td>
<td>0.013 ± 0.009</td>
<td>0.004-0.057</td>
<td>85</td>
<td>0.01</td>
<td>23</td>
</tr>
<tr>
<td>Beta endosulfan</td>
<td>0.051 ± 0.031</td>
<td>0.005-0.115</td>
<td>80</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>p,p′-DDT</td>
<td>0.022 ± 0.017</td>
<td>0.002-0.046</td>
<td>45</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>0.021 ± 0.018</td>
<td>0.001-0.062</td>
<td>60</td>
<td>0.01</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 2. Estimated daily consumption of food items in the study area and their national per capita consumption for Ghana

<table>
<thead>
<tr>
<th>Food item</th>
<th>Daily consumption in study area (g/person/day)</th>
<th>National per capita consumption (g/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion</td>
<td>173 ± 35</td>
<td>137.3</td>
</tr>
<tr>
<td>Pepper</td>
<td>14 ± 5</td>
<td>137.3</td>
</tr>
<tr>
<td>Watermelon</td>
<td>900 ± 150</td>
<td>64.4</td>
</tr>
</tbody>
</table>

0.02–46.95 µg/kg respectively. These concentrations were lower than what is reported in this study for pepper and onions from the Eastern Region. Analysis of onion samples from the Greater Accra Region by Bempah et al. (2012) recorded mean values of 0.041 mg/kg for methoxychlor; 0.023 mg/kg for p,p′-DDE and 0.035 mg/kg for p,p′-DDT which were higher than corresponding concentrations from the current study. For watermelon samples, Bempah et al. (2012) recorded higher levels of DDT (0.008 mg/kg) but lower lindane (0.004 mg/kg), methoxychlor (< LOD), dieldrin (< LOD) and endrin (< LOD) levels compared to this study. Their earlier studies in Kumasi metropolis Bempah et al. (2011a) reported γ-lindane (0.019 mg/kg in onion), methoxychlor (0.016 in pepper; 0.041 mg/kg in onion), and dieldrin (0.058 mg/kg in pepper) as exceeding their corresponding EU MRL of 0.01 mg/kg (for γ-lindane in onion), 0.01 mg/kg (for methoxychlor in pepper and onion) and 0.01 mg/kg (for dieldrin in pepper). Asiedu (2013) also investigated pesticide residues in fruits and vegetables in three regions of Ghana (Eastern, Central and Greater Accra) and recorded far higher mean concentration range of OCPs (0.01–1.27 mg/kg), as compared to 0.001–0.084 mg/kg in the present study. Asiedu (2013) quantified residues of 7 organochlorine pesticides (β-HCH, γ-HCH, heptachlor, aldrin, dieldrin, endrin and p,p′-DDE), as against 9 in the present study exceeding the EU MRL. In China, Owago et al. (2009) measured residues concentrations ranges of < 0.00001–0.00014 mg/kg and < 0.00001–0.06141 mg/kg respectively in onion and pepper for β-HCH, γ-HCH, δ-HCH, DDE, DDD and DDT in Deyang and Yantin areas which were comparably lower than findings in this study. Concentrations of β-HCH, γ-HCH, heptachlor, dieldrin, endrin, p,p′-DDE and methoxychlor from this study and others from other parts...
Table 3. Health risk estimates for systemic effects associated with pesticide residues in onion, watermelon and pepper

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>ADI mg/kg/day</th>
<th>Exposure dose- mg/kg/day (based on Per capita consumption in study area)</th>
<th>Exposure dose- mg/kg/day (based on national Per capita consumption)</th>
<th>HI&lt;sub&gt;1&lt;/sub&gt; (1)</th>
<th>HI&lt;sub&gt;2&lt;/sub&gt; (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Onion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.005</td>
<td>2.1 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>1.6 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.8 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>3.9 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.1</td>
<td>0.08</td>
</tr>
<tr>
<td>γ-HCH</td>
<td>0.005</td>
<td>1.4 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>1.1 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>2.6 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>δ-HCH</td>
<td>0.005</td>
<td>1.7 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>1.4 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>3.0 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>0.008</td>
<td>0.006</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.0001</td>
<td>2.3 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>1.8 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.23</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>4.2 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>5.300*</td>
<td>0.42</td>
</tr>
<tr>
<td>Endrin</td>
<td>0.0002</td>
<td>3.1 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>2.5 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.2 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>5.7 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.005</td>
<td>2.1 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>1.6 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.8 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>3.9 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.1</td>
<td>0.08</td>
</tr>
<tr>
<td>γ-Chlordane</td>
<td>0.001</td>
<td>2.3 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>1.8 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>4.2 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Watermelon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-HCH</td>
<td>0.005</td>
<td>1.04 × 10&lt;sup&gt;-3&lt;/sup&gt; – Adults</td>
<td>7.5 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.21</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.4 × 10&lt;sup&gt;-3&lt;/sup&gt; – Children</td>
<td>1.7 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.880*</td>
<td>0.03</td>
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<tr>
<td>γ-HCH</td>
<td>0.005</td>
<td>7.8 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>5.6 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.16</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.8 × 10&lt;sup&gt;-3&lt;/sup&gt; – Children</td>
<td>1.3 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.37</td>
<td>0.03</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>0.0001</td>
<td>1.3 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>9.3 × 10&lt;sup&gt;-6&lt;/sup&gt; – Adults</td>
<td>1.300*</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>2.2 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>3.030*</td>
<td>0.22</td>
</tr>
<tr>
<td>γ-Chlordane</td>
<td>0.001</td>
<td>1.6 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>1.14 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.16</td>
<td>0.01</td>
</tr>
<tr>
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<td>3.7 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>2.7 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>0.37</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Pepper</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>γ-HCH</td>
<td>0.005</td>
<td>5.0 × 10&lt;sup&gt;-6&lt;/sup&gt; – Adults</td>
<td>4.9 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>1.1 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.002</td>
<td>0.02</td>
</tr>
<tr>
<td>δ-HCH</td>
<td>0.005</td>
<td>4.4 × 10&lt;sup&gt;-6&lt;/sup&gt; – Adults</td>
<td>4.3 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>1.0 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.002</td>
<td>0.02</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>0.005</td>
<td>1.0 × 10&lt;sup&gt;-5&lt;/sup&gt; – Adults</td>
<td>1.0 × 10&lt;sup&gt;-4&lt;/sup&gt; – Adults</td>
<td>0.002</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 × 10&lt;sup&gt;-5&lt;/sup&gt; – Children</td>
<td>2.5 × 10&lt;sup&gt;-4&lt;/sup&gt; – Children</td>
<td>0.005</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(1): Hazard Index based on per capita consumption in the study area
(2): Hazard Index based on national per capita consumption
* : Hazard index significant enough to indicate possible health risk
of Ghana, as already indicated, consistently exceed the EU MRL in fruits and vegetables. Coincidentally, these 7 pesticides have been listed by EPA Ghana as banned for agricultural use in the country.

Although most organochlorine pesticides are banned from use in Ghana, local farmers maintain that they are very effective against persistent pests, hence their use. However, there was no indication from the field survey (both from the numerous agro-chemical shops and at farm sites), that, these chemicals were in use. Notwithstanding, some farmers confirmed that they occasionally purchase chemicals from agents who peddle them from house to house. These chemicals, they claim are very effective against persistent pests. Analysis of samples of such chemicals on two separate occasions established the presence of aldrin, lindane and endosulfan. It is obvious therefore that a cocktail of OCPs are covertly and illicitly sold to the farmers and these may account for the presence of OCPs in the analysed crop.

Analysis of the prevalence of methoxychlor on the other hand is difficult to account for, particularly because field survey did not indicate its use. One plausible reason that could be adduced is that methoxychlor may be a component of cocktail of OCPs that are illicitly peddled to the farmers.

### Health Risk Estimate

Table 2 provides estimates for the national per capita consumption of onion, pepper and watermelon and the estimated per capita consumption in the study area. Table 3 comprises acceptable daily intakes (ADIs) for pesticides, computed average daily intakes of pesticides based on national per capita consumption and estimated per capita consumption for the study area and the corresponding hazard indices for children (1–11 years) and grown-ups (12 years and above). Hazard indices of \( p, p' \)-DDT, \( p, p' \)-DDE and \( \beta \)-endosulfan were not calculated because their ADIs were not available. In principle, if the hazard index is greater than unity (1), then the pesticide in question poses potential health risk for systemic effects (Petersen et al., 2013; Reffstrup et al., 2010; Tchounwou et al., 2002). Risk analysis shows that only onion and watermelon contain pesticides that could pose health threat and these are based on the estimated per capita consumption in the study area. The residues with significant hazard indices are heptachlor (1.3 for adults; 3.03 for children), \( \beta \)-HCH (0.88) for children with respect to watermelon consumption and dieldrin (5.30) for children with respect to onion consumption. Significant hazard indices for Heptachlor, \( \beta \)-HCH and dieldrin imply health risk for systemic effects with consumption of food substances contaminated by these pesticides. It was observed that hazard indices based on per capita consumption was always higher in the study area. Indeed none of the hazard index based on national per capita consumption was found to be significant. This trend was ob-

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### Table 4. Significant hazard indices of pesticides in previous works in Ghana compared to current work

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study area</th>
<th>Food Item</th>
<th>Pesticide</th>
<th>Human category</th>
<th>Hazard index (HI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HI(^{(1)})</td>
</tr>
<tr>
<td>Bempah et al. (2011a)</td>
<td>Accra</td>
<td>Pawpaw</td>
<td>Heptachlor</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td>Bempah et al. (2011a)</td>
<td>Accra</td>
<td>Pawpaw</td>
<td>( \alpha )-endosulfan</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Accra</td>
<td>Tomato</td>
<td>heptachlor</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Accra</td>
<td>Tomato</td>
<td>Heptachlor epoxide</td>
<td>Adults</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Accra</td>
<td>Tomato</td>
<td>Heptachlor epoxide</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Accra</td>
<td>Tomato</td>
<td>Endrin aldehyde</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Accra</td>
<td>Tomato</td>
<td>Endrin ketone</td>
<td>Children</td>
<td>-</td>
</tr>
<tr>
<td>Bempah et al. (2011b)</td>
<td>Kumasi</td>
<td>Vegetables</td>
<td>Endrin</td>
<td>Not specified</td>
<td>-</td>
</tr>
<tr>
<td>Current study</td>
<td>Eastern Region</td>
<td>Onion</td>
<td>Dieldrin</td>
<td>Children</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watermelon</td>
<td>( \beta )-HCH</td>
<td>Children</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watermelon</td>
<td>Heptachlor</td>
<td>Children</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watermelon</td>
<td></td>
<td>Adults</td>
<td>1.3</td>
</tr>
</tbody>
</table>

\(^{(1)}\) : Hazard Index based on per capita consumption in the study area

\(^{(2)}\) : Hazard Index based on national per capita consumption

\(\_\) : Hazard index significant enough to indicate possible health risk
served by Ntow (2008) also and this could be accounted for by the fact that local consumption of the food items is generally higher in the producing communities.

Furthermore, the three residues (heptachlor, β-HCH and dieldrin) all indicate potential for systemic toxicity in children while only heptachlor additionally point to potential toxicity in adults. Bempah et al. (2011a,b) also estimated significant hazard indices for heptachlor, heptachlor epoxide, α-endosulfan, endrin, endrine aldehyde and endrin ketone in fruits and vegetables from markets in Accra and Kumasi metropolis of Ghana. Their significant hazard indices, together with those found in the current study are summarised in Table 4. It is evident that children are the main victims of systemic toxicity effects and are therefore more vulnerable to health risk and hazards associated with dietary exposure of pesticides. The higher risk vulnerability of children is basically due their lower body weights. It is also important to note that no pesticide had zero risk since all registered some concentration level.

Conclusion

The study shows that, twelve residues, representing 80% were quantified and nine, representing 60% of the target pesticides had concentration levels exceeding the maximum residue limits set by the European Union. Approximately 35%, 29% and 21% respectively of pepper, onion and watermelon samples analysed contain residues at levels above the EU’s MRL. Health risk analysis shows that heptachlor, dieldrin and β-HCH have potential for systemic toxicity in children particularly in the study area while adults are also at risk from health effects associated with dietary exposure to heptachlor. Even though few pesticides were associated with health risk, the residue of almost all of them in the analysed crops exceeded their ADIs hence they present chronic health challenges in the long term. The study further shows that even though the use of OCPs has been discouraged and most of them banned, they are still being used for the cultivation of food crops. There is therefore the need for greater vigilance in monitoring, particularly in areas where researches point to their use.

References


