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Levels of Organochlorine Pesticide Residues in Grasscutter (*Thryonomys swinderianus*) Tissues

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Abstract: The study investigated the extent of contamination of with p,p- DDT, p,p-DDE, hexachlorocyclohexane isomers, lindane (γ-HCH) and δ-HCH, dieldrin, aldrin, endrin, endrin aldehyde, endrin ketone, alpha-endosulfan, endosulfan sulfate, chlordane, heptachlor and methoxychlor in tissues of grasscutter (*Thryonomys swinderianus*), obtained from the Gomoa East district of Ghana. The organochlorine pesticide residues in the samples were soxhlet extracted using a mixture of hexane and acetone. The extracts were cleaned up using florisil and analysed using a gas chromatograph equipped with an electron detector (GC-ECD). The results indicated that all the analyzed samples were contaminated with the studied organochlorine pesticides. Aldrin and heptachlor were the principal contaminants in all the samples. The muscle had the highest pollutant load followed by the liver and then the kidney. The levels of organochlorine pesticide residues detected in all the tissues were below the accepted Maximum Residue Limits (MRL), as adopted by the WHO/FAO Codex Alimentarius Commission (2005).

Key words: Bush meat, grasscutter, Ghana, MRL, organochlorine pesticides, residues

INTRODUCTION

A wide range of organochlorine pesticides were used by farmers in Ghana because of their effectiveness, low cost and broad spectrum activity to control insect pests and diseases on crops. Lindane marketed in Ghana as Gamalin 20 was widely used on cocoa farms, vegetable farms, and for the control of stem borers in maize. Use of Lindane on cocoa was discontinued in Ghana in 2007. Endosulfan also marketed as Thiodan was widely used on cotton growing areas, vegetable farms and coffee plantations (Gerken *et al.*, 2001). Lindane, DDT, and endosulfan were also employed to control ectoparasites on farm animals and pets in Ghana (Ntow *et al*., 2006). Aldrin was extensively used on cocoa under the trade name Aldrex 40. The use of aldrin Aon cocoa was discontinued in 1985. Organochlorine pesticides were also used in the public health sector, to control black flies along the banks of the Tano and Pra Rivers (Ntow, 2005), in the Volta Basin to control black flies which transmit Onchocerciasis to human beings and for the control of domestic pests and insects. DDT was very effective against the mosquitoes that carry malaria and yellow fever, and against body lice that transmit typhus.

Based on reports of the toxicity and adverse harmful effects of organochlorine pesticides to wildlife and humans, many organochlorine pesticides were banned or restricted from use in Ghana by the Environmental Protection Agency as far back 1985. Organochlorine pesticides have been identified as one of the major classes of environmental contaminants and it is well established that human activities have resulted in its widespread distribution throughout various terrestrial and aquatic ecosystems (Herrera *et al*., 1996). This has raised toxicological concerns for both wildlife and mankind, based on historical and ongoing trends in the use of organochlorines. The necessity for continual monitoring and surveillance of these substances in natural surroundings has been recognised (Ab-dullah *et al*., 1997). The problem with organochlorine pesticides is that they tend to persist in the environment, increasing exposure to wildlife and humans (Forget, 1991).Wildlife can experience acute toxicity from organochlorines either through direct contact with the compound or through secondary exposure after ingesting contaminated food items (Henriques *et al*., 1997). Wildlife species living adjacent to farmlands may benefit from the crops grown but may be inadvertently exposed to pesticides used to reduce insect, weed, and disease pests of those crops. Evidence available indicates that hunters in their quest to generate higher incomes are now resorting to baiting game with highly potent chemical

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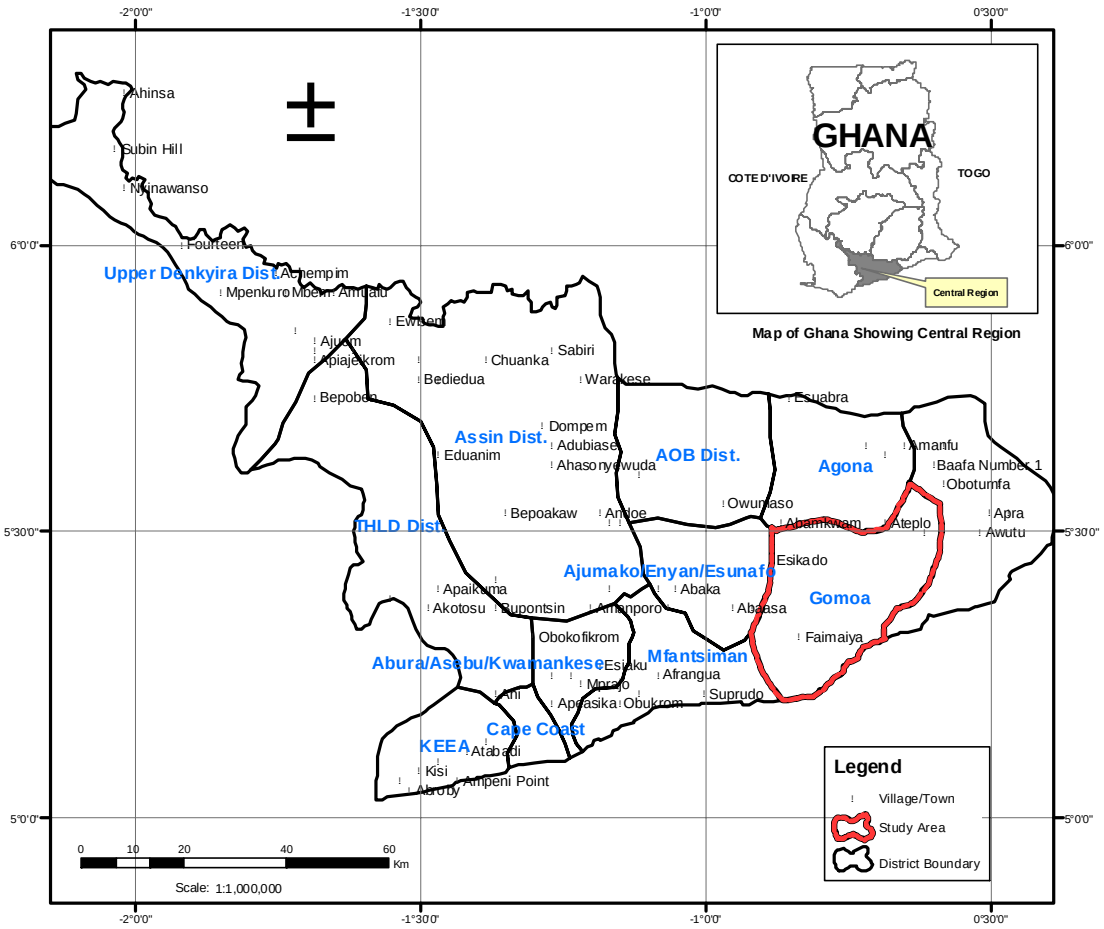

Fig. 1: Map showing the study area

pesticides probably including organochlorines. Highly potent pesticides used as baits, are smeared on the leaves of various crops including vegetables which serve as food sources for browsing animals. Bush meat killed in such manner has the tendency to retain the active ingredients in their tissues and pass them on to innocent consumers. No one is safe from this unconventional method of hunting for game. It is a risk not only to food security but to the very survival of the human race (Entsie, 2002).

Wild animals including the grasscutter (*Thryonomys swinderianus*) provide a significant proportion of protein consumed by most people in the African sub regions. In Ghana, the meat of wildlife, popularly referred to as bush meat, continues to be a popular form of animal protein and over 80% of Ghanaians, both rural and urban, would eat bush meat if available. Bush meat also constitutes an essential ingredient without which certain cultural and ceremonial events among African communities cannot be complete.

Farmed animals in Ghana have been shown to contain some residues of organochlorine pesticides at concentrations close to WHO Maximum Residue Levels (MRLs) (Darko and Acquaah, 2007), but the degree of contamination of organochlorines in bush meat is largely unknown though grasscutter meat has a very high consumption rate in Ghana, both among the rural and urban folk.

The present study was undertaken to investigate the extent of contamination with p,p- DDT, p,p-DDE, hexachlorocyclohexane isomers, lindane (γ-HCH) and δ-HCH, dieldrin, aldrin, endrin, endrin aldehyde, endrin ketone, alpha-endosulfan, endosulfan sulfate, chlordane, heptachlor and methoxychlor in tissues of grasscutter obtained in the Gomoa District of the Central Region of Ghana in order to ensure its safety for human consumption.

MATERIALS AND METHODS

Study area: The Gomoa District of the Central Region is presented in Fig. 1. The Gomoa District is one of the districts within the Central Region of Ghana. The district

has two main vegetation zones, the coastal savannah and the moist semi-deciduous forest. The former consists mainly of grassland and trees of patches of scrub, while the latter is characterized by tall trees interspersed with grass cover, shrubs and soft woody species. These vegetation zones abound with different kinds of game which are hunted and usually sold by the roadside.

Agriculture and fishing constitute the main economic activity of the people in the district. The ecology of the district encourages the cultivation of crops such as cassava, maize, sugar cane, pineapple, rice, pawpaw, vegetable, citrus, yam and plantain.

Reagents: *Acetone and hexane*- Acetone-hexane were pesticide grade from Sigma Aldrich, Germany. Solvents were used without further purification. The purity of the solvents was tested by concentrating portions 200 times and injecting 10-1 portions into the Gas chromatograph. A pure solvent produced no interfering peaks on the gas chromatogram.

Florisil: Florisil (60-100 mesh) was pesticide grade from BDH UK. Florisil was activated overnight for 12 h at 130ºC and cooled to room temperature in a desiccator before use. The florisil was kept in a sealed desiccator.

Pesticide standards: The pesticide standards were purchased from Dr Ehrenstorfer, Augsburg, Germany.

Sodium sulfate: Anhydrous analar sodium sulfate (granulated for residue analysis) was activated overnight at 200ºC , cooled and then stored in desiccators.

Sampling: Samples of freshly killed grasscutter were purchased from hunters in the Gomoa District of the Central Region of Ghana. Samples were wrapped in precleaned aluminium foil and placed in an icebox containing ice and sent to the laboratory for analysis. A total of 45 samples of grasscutter were obtained. The study was conducted at the Chemistry Department of the National Nuclear Research Institute, Ghana Atomic Energy Commission, between the months of January to July, 2009

Sample preparation: The muscle, livers and kidneys were removed from grasscutter (*Thryonomys swinderianus*) with a dissecting scalpel. The muscle, livers, and kidneys were each homogenized separately using a meat blender. Extractions were done as soon as the samples were brought to the laboratory and extracts stored in a deep freezer at -20ºC until required for analysis.

Soxhlet extraction: Ten grams of homogenized tissue was weighed into a beaker containing 30 g anhydrous sodium sulfate and mixed. The sample mixture was transferred into an extraction thimble and placed into a soxhlet extractor. The mixture was extracted for 8 h with 150 mL of acetone-hexane mixture (30: 120 mL (v/v)). The extracts were filtered and concentrated by rotary evaporation at 40ºC .

Clean-up of sample extract: Clean-up of the sample to remove residual fat and co- extractives was performed by transferring the extracts into a chromatographic column containing 1 g activated florisil (60~100 mesh) topped with 1 g layer of anhydrous sodium sulfate to absorb any moisture present in the extract. The prepared column was first conditioned with 10ml of hexane, then the extracted sample was transferred onto the column. Prior to clean-up the sample extract was reduced to 10 mL and 1 mL of the 10 mL extract subjected to clean up. The column was eluted with 10 mL of hexane at a rate of 1-2 mL/min. The collected eluant was concentrated on a rotary evaporator at a temperature of 40ºC to dryness. The residue was dissolved in 1 mL ethyl acetate and transferred quantitatively into a 2ml injection vials ready for analysis with electron capture gas chromatography.

Instrumental analysis: Organochlorine pesticide residues were determined by analysis of samples using electron capture gas chromatography. The gas chromatograph analysis was carried out using a Varian CP-3800 (Varian Associates Inc. USA) autosystem chromatograph equipped with ^{63}Ni electron capture detector (ECD). Carrier and make up gas was nitrogen at a flow rate of 1.0 and 29 mL/min respectively. The temperature of injector operating in splitless mode was held at 225ºC , oven temperature was 225ºC and Electron Capture Detector was set at 300ºC respectively. The column oven temperature was programmed as follows 60ºC for 2 min 180ºC/min up to 300ºC held for 31.80 min. The injection volume of the gas chromatograph was 1.0 . The residues detected by the GC analysis were confirmed by the analysis of the extract on 2 other columns of different polarities. The second column was coated with ZB-1 (methyl polysiloxane) connected to ECD and the second column was coated with ZB-17 (50% phenyl, methyl polysiloxane) and ECD was also used as a detector. The conditions used for these columns were the same. CTC Analytical combi PAL autosampler, split- splitless injector,PPC (programmed pneumatic control and a computer running Star Workstation data processor. For separation a 5% diphenyl 95% dimethyl siloxane capillary column (30 m 0.25 mm 0.25) ZB-5 (USA) was used. The identification of analytes was based on their retention times to the internal standard used for quantification. Multi- level calibration curves were created for quantification and good linearity ($r^2 > 0.999$) was achieved for tested intervals that included the whole concentration range found in samples. Peak area ratios

Table 1: Mean concentrations (µg /kg wet weight) of organochlorine pesticide residues in grasscutter (*Thryonomys swinderianus*) muscle

	Min.	Max.		
Organochlorine pesticide	n = 15		Mean(µg/kg wet weight)	SD
γ-HCH	0.03	0.66	0.283	0.012
δ-HCH	0.01	0.63	0.108	0.011
Heptachlor	0.01	1.48	0.695	0.031
Aldrin	0.01	4.05	1.883	0.084
Dieldrin	0.01	0.10	0.040	0.002
gamma-chlordane	0.01	0.83	0.174	0.015
alpha-endosulfan	0.01	0.41	0.162	0.008
endosulfan sulfate	0.07	0.26	0.183	0.003
p,p'-DDT	0.01	0.03	0.019	0.001
p,p'-DDE	0.01	0.04	0.014	0.005
Endrin	0.01	0.05	0.018	0.001
endrin aldehyde	0.04	0.08	0.060	0.020
endrin ketone	0.01	1.13	0.340	0.023
Methoxychlor	0.01	0.36	0.101	0.001

Nd = not detected; n = No. of samples; Limit of detection = 0.01 /g; Min = Minimum range; Max = Maximum range; SD = Standard deviation

(analyte response/internal standard response) were plotted against the concentration ratios (analyte concentration/internal standard concentration).

Recovery test: A recovery test was carried out in triplicate and fortified samples with 1.0 mL of organochlorine mix standard. The fortified samples were subjected to the same analytical procedures of extraction, cleanup and analysis. The percentage of recoveries of organochlorines tested ranged from 85 to 100%. Residue levels for each pesticide were subsequently corrected for the recovery values.

RESULTS AND DISCUSSION

Levels of organochlorine pesticide residues in Grasscutter muscle: The levels of organochlorine pesticide residues in the grasscutter muscle samples are shown in Table 1. Aldrin had the highest overall concentration of 1.883 µg /kg wet weight. The level of dieldrin in the muscle was 0.040 µg/kg. Aldrin is rapidly metabolized to dieldrin by a wide range of organisms. Consequently it is rarely found in the blood even in occupationally exposed individuals (Smith, 1991). Thus the 1.883 µg/kg of aldrin in relation to dieldrin may be the result of recent input into the organism from the environment. The use of Aldrin and dieldrin was discontinued in Ghana as far back as 1985 and their presence in the grasscutter may be due to their persistence in the environment. The 1.883 µg/kg of aldrin in the present survey is higher than that reported by Darko and Acquaah (2007) in Ghana, who detected aldrin concentrations of 1.43 and 0.73 µg/kg in beef from Kumasi and Buoho abattoirs respectively.

Heptachlor concentration in the muscles was relatively high with a mean value of 0.695 µg/kg wet weight. This level is probably due to the high persistence of heptachlor in the environment. Heptachlor adsorbs strongly to soil. It is readily absorbed following ingestion and skin contact and is transported throughout the body. Technical chlordane contains 10% heptachlor (Nollet, 2000). Thus past usage of chlordane may also have contributed to the high level of heptachlor.

The mean concentration of γ-HCH and δ-HCH (µg/kg wet weight) in the examined muscle samples are 0.283 and 0.108, respectively (Table 1). The higher level of γ-HCH may be due to the fact that it was until 2007 being used on cocoa in Ghana (Gerken *et al*., 2001). The use of γ-HCH, also known as lindane was discontinued in Ghana in 2007. A much higher concentration of 0.122 ng/g (wet weight) HCHs was found in chickens in China (Tao *et al*., 2009).

The Lindane level in the present study is much lower than those detected in meat samples by Khalid *et al*. (2007) in Egypt. In the study by Khalid *et al*., (2007) the mean levels of Lindane (ng/g wet weight) in the analysed muscle samples was 0.33 for camel carcasses; 0.72 for cattle carcasses; and 0.45 for sheep carcasses. In a study done in Belarius, a much higher level of 2000 ng/g of Lindane was detected in the meat samples (Barkatina *et al*., 1999). Lindane level of 0.09 ng/g was detected in meat and fat from Australia (Kannan *et al*., 1994) Darko and Acquaah (2007) reported 4.03 and 1.79 µg/kg Lindane in beef fat samples from Kumasi and Buoho abattoirs respectively. A level of 2.07 µg/kg lindane was detected in lean beef samples from Kumasi abattoir and 2.07 µg/kg lindane was found in lean meat from Buoho abattoir.

The mean concentrations (µg/kg wet weight) of DDT and DDE in the muscle samples are 0.019 and 0.014, respectively (Table 1). Even with the reduction in levels of DDT in the environment, since its ban in Ghana in 1985, there are still areas of concern where heavy applications of DDT during past uncontrolled uses of the pesticide have resulted in high concentration of residual DDT (Harris *et al*., 2000). The proportion of DDT/DDE has long been used as a rough indicator of the age of DDT residues in the environment. Ratios greater than one

suggest relatively recent DDT application (Biddleman *et al*., 2005). Thus the ratio of 1.357 obtained in this study may be the result of recent input into the animals. The grasscutters might have been exposed through consumption of plants that had taken up DDT from contaminated soil. Several surveys conducted in China during the past few years reported relatively high levels of DDTs and large ratio of DDT/(DDD+DDE) and claimed that dicofol which is produced from DDT could be a fresh source of input of DDT (Gao *et al*., 2005). The levels of DDT detected in the present study were far lower than those detected in muscle samples of camel, cattle and sheep in Egypt (Khalid *et al*., 2007). The mean levels (ng/g wet weight) of DDTs in the examined muscle of camel, cattle and sheep were 13.9, 17.9 and 20.3, respectively (Khalid *et al*., 2007). In a study in involving chickens in China, the mean fresh weight concentration of DDT was 0.051 ng/g in muscles (Tao *et al*., 2009). DDT levels ranging between 65.9 and 334.5 ng/g lipid were found in pork tissues in Romania (Covaci *et al*., 2004). The highest concentrations of DDT were measured in the muscle and fat (Covaci *et al*., 2004).

Much higher levels of DDT were detected in meat analyzed in Thailand (Tanabe *et al*., 1991), India (Kannan *et al*., 1992), Nigeria (Osibanjo and Adeyeye, 1997) and Belarius (Barkatina *et al*., 1999). Mean concentration of 118.45 μg/kg DDE was found in beef fat and 42.93 μg/kg in lean meat samples from the Kumasi abattoir. An average concentration of 545.22 μg/kg DDT was found in beef fat and 18.85 μg/kg in lean beef samples from the Kumasi abattoir. The DDT level in beef fat samples from Buoho was 403.82 μg/kg but lean beef samples from the same sampling site had a mean concentration of 10.82 μg/kg (Darko and Acquaah, 2007). Biochemically, p,p'-DDT is dechlorinated to p,p'-DDD which can be metabolized further to p,p'-DDE or directly excreted from the body (Kutz *et al*., 1976). The distribution and storage of DDT in humans and animals has been extensively studied (Turusov *et al*., 2002). Once absorbed they are readily distributed via the lymph and blood to all body tissues and are stored in these tissues as a function of the blood flow, lipid content of that tissue and the partition coefficient for DDT between the blood and the lipids in specific organs (Covaci *et al*., 2004).

In the present study the mean concentration of dieldrin (μg/kg wet weight) in the analyzed muscle was 0.040. The level of dieldrin may be due to the metabolism of aldrin to dieldrin.

The mean concentrations of α-endosulfan and endosulfan sulfate (μg/kg wet weight) in the analyzed muscle samples are 0.162 and 0.183. Endosulfan was until recently being used on cotton, vegetables and coffee (Gerken *et al*., 2001). Its use was discontinued in December 2008. Endosulfan sulfate is the main degradation product of endosulfan. The relatively higher level of endosulfan sulfate may be due to the degradation of α-endosulfan to endosulfan sulfate in the grasscutter muscle. Darko and Acquaah (2007) detected relatively higher concentrations of 2.28 μg/kg in fat and 0.59 μg/kg in lean beef from Buoho abattoir and 21.35 μg/kg in beef fat and 1.88 μg/kg in lean meat from Kumasi abattoir.

The mean concentrations of endrin, endrin ketone, endrin aldehyde in the muscle were in the order of 0.018, 0.340 and 0.060 μg/kg, respectively. The relatively low level of endrin may be the result of degradation of endrin to its metabolites endrin ketone and endrin aldehyde (Fan and Alexeeff, 1999).

Chlordane was detected at mean concentration of 0.174 μg/kg in the muscle. Chlordane persists for more than twenty years in some soils (Bervanan *et al*., 1981) thus chlordane level in the muscle may be the result of past usage. Higher level of chlordane of 3.1 ng/g wet weight was reported in meat in Australia (Kannan *et al*., 1994).

The mean level of methoxychlor in the examined muscle samples is 0.115 μg/kg. This may be the result of past use of DDT or past use of methoxychlor itself. Technical methoxychlor contains about 88% p,p-DDT isomer together with more than 50 structurally related contaminants, including 1,1,1,2-tetrachloro-2-(4-methoxyphenyl) ethane, o,p-dimethoxyphenyltrichloroethane, 0,0, dimethoxydiphenyltrichloroetane,1, 1-bis(4-methoxyphenyl) -2, 2- dichloroethene and o,p-dimethoxydiphenyldichloroethene which might have contributed to the actual amount of methoxychlor present.

Levels of organochlorine pesticide residues in the grasscutter liver: The levels of organochlorine pesticide residues in the liver samples are shown in Table 2. In the present study the mean levels of aldrin and dieldrin (μg/kg wet weight) in the analyzed liver were 1.32 and 0.052, respectively. Metabolism of aldrin takes place mainly in the liver where aldrin is readily transformed to dieldrin. Thus the high level of aldrin may be due to recent input into the organism from ingestion of crops planted on contaminated soil. In a study in Egypt by Khalid *et al*. (2007), the levels of aldrin (ng/g wet weight) in liver samples from camel, cattle and sheep were 0.59, 2.46 and 1.79, respectively. A higher level of dieldrin was detected in liver samples at 3.07, 6.19 and 3.91 ng/g in the camel, cattle and sheep respectively (Khalid *et al*., 2007).

The mean levels of α-endosulfan and endosulfan sulfate (μg/kg wet weight) in the liver samples were 0.094 and 0.085. The low levels of α-endosulfan and endosulfan sulfate may be due to their low persistence in the environment as endosulfan was banned in Ghana only in December 2008. The level of endosulfan sulfate may be the result of past agricultural usage of endosulfan.

The mean concentrations of γ-HCH and δ-HCH (μg/kg wet weight) in the liver were 0.233 and 0.070,

Table 2: Mean concentrations (µg /kg wet weight) of organochlorine pesticide residues in grasscutter (*Thryonomys swinderianus*) liver

	Min.	Max.		
Organochlorine pesticide	n = 15		Mean (µg/kg wet weight)	SD
γ-HCH	0.01	0.60	0.233	0.012
δ-HCH	0.02	0.15	0.070	0.002
Heptachlor	0.03	1.06	0.530	0.024
Aldrin	0.01	3.86	1.315	0.086
Dieldrin	0.02	0.07	0.050	0.001
gamma-chlordane	0.01	0.19	0.093	0.005
Alpha-endosulfan	0.01	0.16	0.094	0.003
endosulfan sulfate	0.03	0.14	0.085	0.004
p,p'-DDT	0.01	0.36	0.123	0.008
p,p'-DDE	0.02	0.06	0.043	0.001
Endrin	Nd	Nd	Nd	Nd
Endrin aldehyde	0.01	0.21	0.110	0.007
Endrin ketone	0.09	0.14	0.115	0.002
Methoxychlor	0.03	0.21	0.128	0.004

Nd = not detected; n = Number of samples; Limit of detection = 0.01 /g; Min = Minimum range; Max = Maximum range; SD = Dtandard deviation

Table 3: Mean concentrations (µg /kg wet weight) of organochlorine pesticide residues in grasscutter (*Thryonomys swinderianus*) kidney

	Min.	Max.		
Organochlorine pesticide	n = 15		Mean (µg/kg wet weight)	SD
γ-HCH	0.25	0.62	0.435	0.013
δ-HCH	0.01	0.18	0.107	0.004
AHeptachlor	0.01	0.89	0.403	0.022
Aldrin	0.01	1.99	0.917	0.050
Dieldrin	0.02	0.11	0.073	0.002
gamma-chlordane	0.01	0.03	0.020	0.001
alpha-endosulfan	0.02	0.37	0.140	0.010
endosulfan sulfate	0.01	0.05	0.033	0.010
p,p'-DDT	0.03	0.10	0.053	0.002
p,p'-DDE	0.01	0.03	0.020	0.005
Endrin	0.05	0.09	0.070	0.001
Endrin aldehyde	0.01	0.26	0.135	0.009
Endrin ketone	0.27	0.45	0.347	0.005
methoxychlor	0.10	0.39	0.183	0.005

n = Number of samples; Limit of detection = 0.01/g; Min = Minimum range; Max = Maximum range; SD = Dtandard deviation

respectively. Though Lindane was banned recently in Ghana in 2007, its level in the liver is quite low indicating its low persistence in the environment. The low level of Lindane in the liver may probably be that, most of it has been metabolized in the liver. γ-HCH is known to induce the liver mixed function oxygenase system, and thus self induced metabolism is an important factor that minimizes the accumulation of γ-HCH residues in animal tissues (Srinivasan and Rhadhakrisnamurty, 1983).

From Table 2, it can be seen that the level of δ-HCH is much lower than that of γ-HCH which is the isomer with insecticidal properties.

The mean concentrations (µg/kg wet weight) of DDT and DDE in liver samples were 0.123 and 0.043, respectively. The ratio of DDT/DDE was 2.86. The high ratio of DDT/DDE suggests a recent application of DDT in the environment. The level of DDT in the liver samples of the present study was much lower than that detected by Khalid *et al*. (2007) in Egypt who detected concentrations of 34.6, 57.2 and 49.6 ng/g in the liver samples of camel, cattle and sheep respectively.

The mean levels of endrin ketone and endrin aldehyde were 0.140 and 0.060 µg/kg (wet weight) respectively in the liver. However the parent compound endrin was below detection limit in the analyzed liver samples the absence of endrin in the liver indicates probably that endrin has been metabolized to endrin ketone and endrin aldehyde.

The present study showed that the mean levels of methoxychlor in the examined liver samples were 0.128 µg/kg. This may be the result of past usage of methoxychlor.

Levels of organochlorine pesticide residues in grasscutter kidney: The levels of organochlorine pesticide residues in grasscutter kidney samples are shown in Table 3. The mean concentration of aldrin in the kidney samples were 0.92 µg/kg wet weight. Levels of aldrin in the kidney measured in this study were significantly lower than those reported in Egypt where the mean concentrations of aldrin in kidney samples were 1.75 and 1.39 ng/g in cattle and sheep, respectively. No aldrin was reported in the kidney samples of camel in study (Khalid *et al*., 2007)

Dieldrin concentration in the analyzed kidney samples was 0.073 µg/kg wet weight. This may be due to

the past usage of dieldrin or from the degradation of aldrin to dieldrin in the environment.

The mean concentration of γ-HCH and δ-HCH (μg/kg wet weight) in the kidney samples were 0.435 and 0.107. The concentration of δ-HCH may have resulted from past usage of technical HCHs of which δ-HCH is one of the isomers.

It takes five times longer for γ-HCH to be excreted from an animal than the other isomers (Kutz *et al*., 1991). Thus more of the γ-HCH is bioaccumulated in the kidney than δ-HCH.

The mean concentration of heptachlor in the kidney samples in the present study was 0.403μg/kg wet weight. The relatively high concentration of heptachlor may be due to its high persistence in the environment. Heptachlor adsorbed to soil evaporates and hydrolyzes very slowly. A-endosulfan and endosulfan sulfate concentrations (μg/kg wet weight) in the kidney samples were 0.140 and 0.050, respectively. Though endosulfan was recently banned in December 1985, its level in the kidney was lower than expected. This may be due its low persistence in the environment. It may also be that probably most have been excreted by the kidney.

Endrin was detected at 0.090 while endrin aldehyde and endrin ketone were detected at higher concentrations of 0.450 and 0.135 (μg/kg wet weight), respectively. This may be the result of degradation of endrin to its metabolites endrin ketone and endrin aldehyde (Fan and Alexeeff, 1999). The mean concentrations (μg/kg wet weight) of DDT and DDE in the analyzed kidneys were 0.053 and 0.020, respectively.

The present study showed that the mean level of methoxychlor in the examined kidney samples was 0.100 μg/kg suggesting past application of methoxychlor.

Gamma-chlordane was detected at mean concentrations of 0.020 μg/kg in the kidney. The level of chlordane in the kidney samples may be the result of past input into the environment. Most of the gamma-chlordane in the kidney has been excreted.

CONCLUSION

Residues of p,p- DDT, p,p-DDE, hexachlorocyclohexane isomers, lindane (γ-HCH) and δ-HCH, dieldrin, aldrin, endrin, endrin aldehyde, endrin ketone, alpha-endosulfan, endosulfan sulfate, chlordane, heptachlor and methoxychlor were detected at very low levels in the examined muscle, liver and kidney samples of the grasscutter tissues obtained from the Gomoa East District of the Central Region. The highest levels of organochlorine pesticide residues were detected in the muscle samples followed by liver samples. The lowest levels of organochlorine pesticide residues were detected in the kidney samples. The pesticide residues detected in the grasscutter tissues may be the result of past usage of organochlorine pesticides in agriculture and in disease vector control. The grasscutters may have taken them into their body from ingesting plants grown on contaminated soil. From the results the levels of organochlorine pesticide residues in all the grasscutter tissue samples analyzed were below the FAO/WHO Codex Alimentarius (2005) maximum residue limits. The grasscutters from the Gomoa East District of the Central Region are therefore safe for consumption.

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