Research paper

Persistent organochlorine compounds in the water and sediments from the Bosuntwi Lake in Ghana.

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Authors' contributions

This work is part of the corresponding author's Ph.D project which is being supervised by the other three authors. Author SA did the sampling, laboratory works and prepared the manuscript.JAM reviewed the scientific background. SO and STK explained the data and dissected the results involved in the preparation of the manuscript. All authors read and approved the final manuscript

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ABSTRACT

The burden of persistent organochlorine compounds, organochlorine pesticides (OCPs) and indicator polychlorinated bipheyls (PCBs) in the Bosumtwi Lake in Ghana have been investigated in the lake water and sediments. Samples were collected from ten sampling locations along the lake. Representative samples were extracted with suitable solvent for the organochlorine compounds. Liquid-liquid extraction with hexane was used for the extraction of the extractable organochlorine compounds from water samples while the sediment samples were sonicated in an ultrasonic bath using US Branson 220,Ultrasonic Cleaner for 2 hours with hexane/acetone mixture (3:1).The extracts were then cleaned up with florisil and quantified using gas chromatography. The method was evaluated by recovery studies involving samples spiked with organochlorine standards and percentage recoveries were between 96.0 – 101.0 %. In all eight organochlorines pesticides and four indicator PCBs were detected in lake waters while sixteen OCPs and five indicator PCBs were detected in the sediments. The mean concentrations of OCPs in water and sediments ranged from 0.05- 6.35 ng/ml and 0.05 – 15.23 ng/g respectively. The total PCBs load (sum of all indicator PCBs) also ranged from 1.09 – 7.19 ng/ml and 6.43 – 20.91ng/g for the water and sediments respectively. In general, the concentrations of the organochlorine compounds were higher in the sediments than the water samples. In all PCB 52 was the most ubiquitous organochlorine compound in the lake water with 100 percent frequency of occurrence.

Keywords: persistent organochlorine, detected, bosumtwi lake, sediment, water

1. INTRODUCTION

Africa for sometime ago was considered to be safe from water body pollution. However, the high population growth and its accompanied urbanization, increases industrial activities and exploitation of natural resources have caused a remarkable increase in the amount and diversity of discharges that reach our aquatic environment. Water body pollution may result from a variety of sources. Common sources of water body pollution include oil spillage, wastes dumped into water bodies, run off from agricultural and industrial sites. Oil spillage harms river mammals. Wastes including plastic bags, fishing line and other trash items dumped can accumulate in areas and can cause mammals to be entangled and die. Run-off from agricultural sites may introduce pesticides residues or fertilizers into the water sources. Pesticides contamination can lead to fish kill, while fertilizer pollution can lead to algal blooms that choke out naturally occurring plants, thus reducing the diversity of organisms in the water body [1].

In Ghana, the Bosumtwi Lake is among the important water resources that the nation can boast of. The Bosumtwi Lake is the only natural lake in Ghana, and situation about 30 km south east of Kumasi. The local community dotted around the lake use it mainly for fishing, cooking, washing, boat transport and swimming. Apart from these the local inhabitants residing around the Lake engaged in farming activities mainly in cocoa cultivation, food and crop farming in the catchment of the Lake. There is no doubt that the lake has received some level of pollution as a result of these anthropogenic activities along and outside the lake. Indeed, studies which had been done on the water quality in Ghana had focused mainly on physico-chemistry, nutrient burden, trace metals and pesticide residues contamination [2, 1, 3].

For sometime now pollutants in the environment which have generated international concern is persistent organic pollutants [4] in which organochlorine compounds are the dominant pollutants among others. Persistent organochlorine pollutants are organic compounds that, to a varying degree, resist photolytic, biological and chemical degradation [5]. They are chlorinated compounds with carbon-chlorine bond(s), and are characterized by low water solubility and high lipid solubility. Exposure of

84 persistent organochlorine compounds such as polychlorinated biphenyls (PCBs), DDTs,
85 hexachlorohexanes (HCHs), hexachlorobenzene (HCB) has been linked to range of conditions including
86 reproductive toxicity, immunotoxicity, hepatoxicty, neurotoxicity, necrosis and endocrine abnormalities
87 [6]. They are semi-volatile, and this enables them to move long distance in the atmosphere before
88 deposition [5]. Evidence available indicates that because they are able to undergo long range
89 environmental transport, they may be found in areas where they have never been produced or used. The
90 high lipid solubility and stability of organochlorine compounds has resulted in their widespread
91 distribution in nearly all environmental compartments such as in air, water bodies, rain, soil etc. Although
92 many different forms of organochlorine compounds may exist, both natural and anthropogenic, those
93 which are noted for their persistence and bioaccumulative characteristics include PCBs, many of the first
94 generation organochlorine insecticides, toxaphene and dioxins.

95 Persistent organochlorine compounds such DDTs, HCHs, HCB, endosulfan and PCBs had been
96 used in Ghana. PCBs had been used as dielectric fluid in transformers and capacitors by Electricity
97 Company of Ghana and Volta River Authority and DDTs, HCHs, HCBs, endosulfan had also been used
98 as insecticides in Ghana. Other organochlorines are used in industrial processes and in the production of a
99 range of goods such as solvents, polyvinyl chloride and pharmaceuticals (Ritter et al., 2008). Many
100 congeners of PCBs are formed and released to the environment during various anthropogenic processes
101 such as incineration, combustion, smelting and metal reclamation [7, 8]

102 There is currently an international effort under the Stockholm convention aimed at total
103 elimination of persistent organochlorine compounds by 2025[6]. Ghana being a signatory to the
104 convention therefore has to develop a strategy of identifying and eliminating persistent organochlorine
105 compounds from our environment. In Ghana's effort to total elimination of these pollutants for our
106 environment the Environmental Protection Agency (EPA) has banned the use of these chemicals in
107 Ghana. There is therefore the need to assess the burden of persistent organochlorine pollutants in our
108 environment to help established a better picture of how our environment has been affected by these

organic pollutants. Water bodies such as the Bosumtwi Lake is important natural resource of Ghana and therefore assessment of its persistent organochlorine burden should be of prime importance in realizing the goals of Stockholm convention.

2. METHODOLOGY

2.1 Chemicals and reagents

All chemicals and reagents used for the investigation were of high purity and they were analytical grade. Hexane (96+%), acetone (99 %), ethyl acetate (99.8%), anhydrous sulphate were purchased from Sigma-Aldrich, Germany. Florisil adsorbent was purchased from Hopkins and William Limited, England. The organochlorine standards were from United Nation environmental Programme (UNEP).

2.2 Sampling and sample preparation

Water and sediment samples were collected from twelve communities dotted around the lake. The ten sampling points stretches from Pipie 2 to Essase. At each point three water and sediment samples were collected. Surface water samples were collected into 500 ml high-density polyethylene containers. High-density polyethylene containers were used because they suffer less from evaporation and adsorption exchange phenomenon [9]. Sediment samples were collected at various points in the neighborhood of the place where the water samples were collected using Eckman grab from a depth of about 20 cm. The samples were then wrapped in aluminium foil and bagged in polyethylene bags. All samples were stored in an ice-chest and transported to the laboratory. In the laboratory the water samples were kept in fridge at a temperature of about 4^0C and the sediment samples were dried at room temperature. They were then milled with pestle and mortar and sieved with 500 μm mesh size sieve to remove stones and other debris. The sieved samples were then wrapped in aluminium foil and kept at room temperature in a clean cupboard.

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134 **2.3 Extraction of organochlorine compounds (OCs) from samples**

135 Liquid-liquid extraction with hexane was used for the extraction of the extractable organochlorine from
136 the water samples. Twenty ml portion of the water sample was shaken with 20 ml of hexane as extraction
137 solvent in 100 ml separating funnel. The hexane extract (organic layer) was separated from the aqueous
138 layer. Extraction was repeated two times and the organic layers were put together and dried over
139 anhydrous sodium sulphate. The extract was then passed over copper turnings to remove any extractable
140 organosulphur compounds. Extract was then concentrated on rotary evaporator to about 5 ml and then
141 subjected to clean up. For the sediments, 2 gramme of the samples were accurately weighed and
142 sonicated in an ultrasonic bath (Branson 220, Branson Ultrasonic Cleaner, USA) for 2 hours at
143 40 ºC with 50 ml of 3:1 hexane/acetone mixture. Filtration was performed with whatman no.42 and
144 the filtrate was dried over anhydrous sodium sulphate. The filtrate was passed over copper turnings to
145 remove any extractable organosulphur compound. Extract was concentrated on rotary evaporator to about
146 5 ml and subjected to clean up.

147

148 **2.4 Clean up of extracts**

149 The clean up procedure was carried out according to the method of Nyarko et al [10]. Florisil solid phase
150 extraction columns were prepared by packing 6 ml extraction column with 2 g of activated florisil
151 adsorbent with 1 g anhydrous Na_2SO_4 on top of the florisil. The column was preconditioned with 10 ml
152 of 9:1 hexane/acetone. The extract was then transferred into the preconditioned column. The extract was
153 allowed to pass through the column slowly under gravity. The column was then eluted first with 10 ml
154 hexane followed by with 5 ml of 1: 2 hexane/diether mixtures. The eluate was concentrated to almost
155 dryness by blowing in stream of nitrogen gas and residue redissolved in 1.5 ml ethyl acetate. This was
156 finally transferred quantitatively into 2 ml vial for GC analysis.

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160 **2.5 Gas chromatography (GC) analysis**

161 A Varian CP-3800 Gas Chromatograph equipped electron capture detector was used for analysis. A
162 volume of 1µl aliquots of sample extract was injected. The operation conditions were capillary column:
163 VF – 5mS, 40m x 0.25mm x 0.25µm, temperature programme: 70^0C (2min) to 180^0C (1min) 25^0C/min to
164 300^0C at 5^0C/min, injector temperature: 270^0C, detector temperature: 300^0C, carrier gas: nitrogen at
165 1.0ml/min, make up: nitrogen at 29ml/min. The organochlorines were identified based on comparison of
166 relative retention times to those of known standards and quantified by external standard method using
167 peak area.

168

169 **3. RESULTS AND DISCUSSION**

170 **3.1 Concentration of organochlorines compounds in the samples**

171 Tables 1 and 2 respectively, show the concentrations of detected persistent organochlorine
172 compounds in the water and sediments. Margins of errors associated with the concentrations are standard
173 deviation based on replicate determination of each compound. The Tables also show the percentage
174 occurrence for each compound in the study area. Analysis of the water samples revealed the presence of
175 eight persistent organochlorine pesticides and four indicator PCBs. In the case of the sediments, fifteen
176 persistent organochlorine pesticides and five indicator PCBs were detected. The detectable compounds in
177 both water and sediment samples were β-HCH, δ-HCH, γ-HCH, heptachlor, aldrin, γ-chlordane, α-
178 endosulfan, p,p'-DDE, dieldrin, endrin, β-endosulfan, p,p'-DDD, P,P'-DDT and methoxychlor, PCB 28,
179 PCB 52, PCB 101, PCB 138, PCB 153 and PCB 180. The concentrations of the compounds, β-HCH, α-
180 HCH, aldin, δ-chlordane, α-endosulfan, o,p-DDE, o,p-DDD, PCB 28 and PCB 153 were below detection
181 limit at some of the sampling points in the water. The limit of detection (LOD) is defined as the lowest
182 practical concentration of the contaminant that can be identified and quantitatively measured in a specific
183 matrix [11]. This was estimated as concentration which peak is three times the peak of signal to noise

ratio. The trends of persistent organochlorine compounds distribution in the samples indicate higher organochlorine concentration in sediments than in the water samples. In an aquatic medium, persistent organochlorine compounds being hydrophobic tend to settle more in sediments than remain in the overlying water. Thus sediment therefore serves as sink for persistent organochlorine compounds. The mean concentrations of organochlorine pesticides and PCBs in sediments ranged from 0.05 – 15.23 ng/g and 0.16 – 10.50 ng/g respectively. Darko et al (2008) similarly reported higher concentrations of organochlorine pesticides in sediments than in water samples from Lake Bosumtwi. In all PCB 52 was the most ubiquitous organochlorine compound in the water samples with hundred percent frequency of occurrence while γ-HCH, endrin and PCB 52 were the most ubiquitous compounds in the sediments, also with hundred percent occurrences.

Figures 1 and 2 show the total organochlorine load in the samples at the various sampling points along the Bosumtwi Lake.The highest persistent organochlorine pesticide load of 26.82ng/g was recorded in sediment, which was collected from Abonu (Figure 1), while the total PCBs load (sum of all indicator PCBs) of 20.91ng/g was also recorded in sediments from Pipie 2. The high total organochlorine pesticide load recorded at Abonu came as no surprise since Abonu apart from being fishing activities has large plantation of cocoa as well as vegetable farming. The area might have witnessed the use of these chemicals for pest control. Figures 1 and 2 also indicate higher organochlorine load in sediments than in lake water. The method used for the study was evaluated by recovery studies involving samples spiked with organochlorine standards and percentage recoveries were between 96.0 – 101.0 %.

Table 1: Concentration of detected organochlorines (mean ±SD in ng/ml) and percentage occurrence in water from Lake Bosumtwi

Compounds	sampling points										
	Esaase	Anyinatiase	Abaase	Aborodwom	Obo	Nkawi	Pipie 2	Bodekwamo	Abonu	Adwafo	%occ
β-HCH	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
α-HCH	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
δ-HCH	<LOD	<LOD	<LOD	<LOD	0.15±0.01	0.40±0.10	0.15±0.01	<LOD	<LOD	<LOD	30.00
γ-HCH	0.15±0.01	<LOD	<LOD	0.30±0.011	<LOD	0.05±0.01	<LOD	<LOD	0.05±0.02	<LOD	40.00
heptachlor	0.85±0.03	0.30±0.02	0.05±0.02	0.25±0.02	0.20±0.01	0.45±0.12	0.15±0.02	0.55±0.10	0.50±0.10	<LOD	90.00
aldrin	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
δ-chlordane	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
α-endosulfan	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
β-endosulfan	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
dieldrin	0.05±0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10.00
endrin	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
p,p-DDT	<LOD	<LOD	0.25±0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10.00
o,p-DDT	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
p,p-DDE	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
p,p-DDD	6.35±0.11	<LOD	<LOD	0.30±0.011	3.20±0.03	4.30±0.11	0.15±0.01	1.30±0.08	2.55±0.50	>LOD	70.00
o.p-DDE	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
o,p-DDD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
endosulfan sulfate	5.63±0.05	1.30±0.08	0.65±0.21	<LOD	0.50±0.02	0.35±0.02	0.10±0.02	0.15±0.1	<LOD	<LOD	70.00
methoxychlor	<LOD	<LOD	<LOD	0.10±0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10.00
∑PCBs	1.92±0.15	1.26±0.09	1.09±0.20	1.68±0.40	1.81±0.11	3.74±0.63	7.19±0.98	4.26±0.33	4.47±0.55	5.87±0.50	100.00

<LOD = less than detection limit, ∑PCB = sum of all indicator polychlorinated biphenyls, %occ = percentage occurrence

Table 2: Concentration of detected organochlorines (mean±SD in ng/g) and percentage occurrence in sediments from Lake Bosumtwi

Compounds	Sampling points										
	Esaase	Anyinatiase	Abaase	Aborodwom	Obo	Nkawi	Pipie 2	Brodekwamo	Abonu	Adwafo	% occ
β-HCH	<LOD	0.05±0.01	0.05±0.01	<LOD	<LOD	<LOD	0.50±0.02	0.05±0.01	<LOD	<LOD	40.00
α-HCH	0.15±0.02	1.15±0.03	<LOD	<LOD	0.50±0.02	<LOD	0.22±0.04	<LOD	<LOD	<LOD	40.00
δ-HCH	<LOD	0.15±0.07	0.40±0.01	1.29±0.25	<LOD	0.40±0.05	1.50±0.72	0.40±0.02	<LOD	<LOD	60.00
γ-HCH	0.60±0.02	1.15±0.09	1.10±0.3	0.75±0.03	1.05±0.04	0.60±0.08	1.15±0.09	1.10±0.21	0.75±0.03	1.05±0.04	100.00
heptachlor	<LOD	0.60±0.11	<LOD	2.40±0.13	2.40±0.06	0.45±0.08	0.60±0.02	0.55±0.03	0.12±0.01	2.40±0.08	83.34
aldrin	<LOD	<LOD	<LOD	0.25±0.08	1.20±0.07	<LOD	<LOD	<LOD	<LOD	<LOD	20.00
δ-chlordane	0.25±0.01	0.05±0.03	0.05±0.01	0.25±0.03	0.05±0.01	0.25±0.03	0.50±0.02	0.05±0.01	0.25±0.01	0.05±0.02	100.00
α-endosulfan	0.15±0.02	0.10±0.02	<LOD	<LOD	<LOD	0.25±0.02	1.00±0.05	<LOD	<LOD	<LOD	40.00
β-endosulfan	1.05±0.04	5.60±0.12	2.05±0.22	1.25±0.05	1.25±0.03	1.05±0.09	5.60±0.77	2.20±0.08	7.25±0.88	1.25±0.06	100.00
dieldrin	0.90±0.20	0.95±0.04	0.50±0.09	0.60±0.01	0.60±0.01	0.90±0.07	0.95±0.06	0.50±0.03	0.70±0.02	0.60±0.03	100.00
endrin	0.75±0.11	0.90±0.07	0.95±0.16	1.20±0.09	1.20±0.07	0.75±0.04	0.90±0.07	0.95±0.08	1.20±0.02	1.20±0.09	100.00
p,p-DDT	0.10±0.01	<LOD	<LOD	<LOD	1.79±0.07	0.15±0.02	0.10±0.01	<LOD	<LOD	<LOD	40.00
o,p-DDT	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
p,p-DDE	<LOD	3.60±0.27	1.50±0.08	1.25±0.06	4.95±0.14	<LOD	3.60±0.36	1.50±0.07	4.75±0.55	0.25±0.06	80.00
p,p-DDD	2.00±0.21	0.65±0.07	0.30±0.02	3.01±0.41	0.25±0.05	2.00±0.80	0.65±0.04	0.30±0.03	0.25±0.05	2.90±0.10	100.00
o.p-DDE	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
o,p-DDD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
endosulfan sulfate	15.23±1.04	4.50±0.32	<LOD	<LOD	6.65±0.32	<LOD	4.50±0.46	0.15±0.05	6.65±0.55	<LOD	60.00
methoxychlor	0.65±0.05	2.05±0.55	5.95±0.11	0.48±0.03	4.90±0.22	0.65±0.07	2.05±0.09	5.96±1.01	4.90±0.91	4.25±0.11	100.00
∑PCBs	6.57±0.36	6.85±0.47	6.85±0.96	12.40±0.94	6.43±0.60	8.37±0.57	20.91±1.07	17.80±1.24	14.72±1.02	5.74±0.80	50.00

<LOD = less than detection limit, ∑PCB = sum of all indicator polychlorinated biphenyls

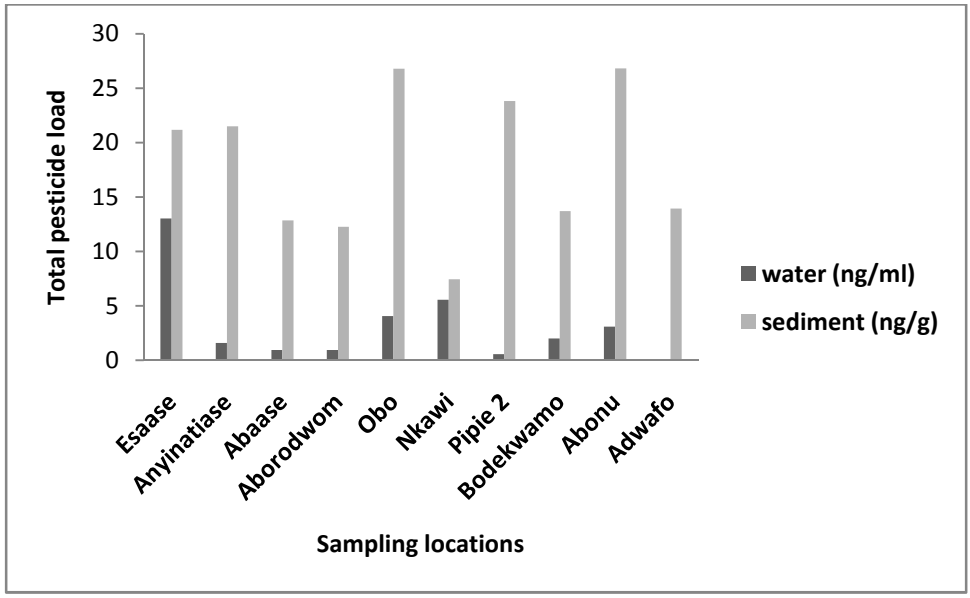

Figure 1: Total organochlorine pesticide load at the various sampling points along the Bosumtwi Lake

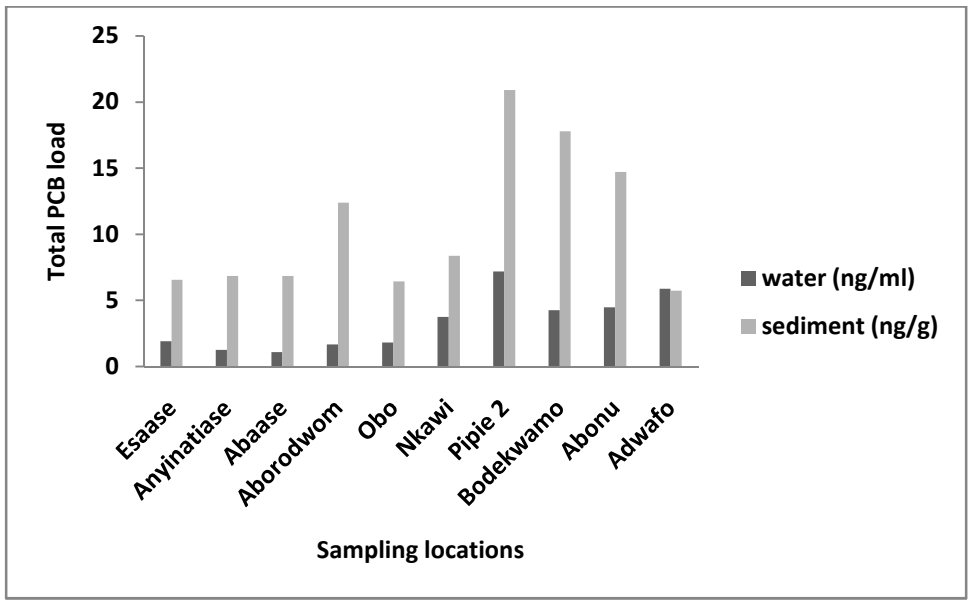

Figure 2: Total PCB load (sum of all detected indicator PCBs) at the various sampling points along the Bosumtwi Lake.

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261 3.2 Variation of DDTs in sediment

262 Figure 3 shows the distribution of DDT and its metabolites in the sediments. In Ghana DDT had
263 been used extensively in the past for agriculture activities. However, the use of DDT in Ghana has now
264 been limited only to malaria programs to fight the insect mosquito. Indeed its usage in agriculture had
265 been banned by the Environmental Protection Agency (EPA) of Ghana [12]. Detected DDTs in the
266 sediments were p, p^1 –DDT, p,p^1-DDE and p,p^1-DDD . Indeed o,p^1- DDT and its metabolites were not
267 detected. p, p^1 –DDT was only dominant at Pipie 2. In most of the sample locations it was not detected.
268 p,p^1-DDE on the other hand, was the predominant DDT in the sediments from Anyinatiase, Abaase, Obo
269 and Brodekwamo while p,p^1-DDD was the predominant DDT at Esaase, Aborodwom, Nkawi, Adwafo.
270 Only p,p^1-DDD was detected with 100 percent occurrence. The ratio DDT / (DDE+DDD) is less than one
271 in the sampling communities except at Pipie 2. The ratio of DDT/(DDE+DDD) can be used to assess or
272 estimate the extent of DDT decomposition or identify the recent input of DDT in the environment [13,
273 14]. If the ratio is less than one then there is no recent input of DDT in the study area. The low
274 concentration of p,p^1-DDT compared to the sum of its metabolites (DDE+DDD). is an indication that
275 there might not be fresh input of the parent DDT in most of the sampling communities. This therefore,
276 suggests that DDT concentrations in the study area might mainly be due to historical used or current
277 levels of DDT may primarily originate from previous contamination and environmental persistence of the
278 compound.

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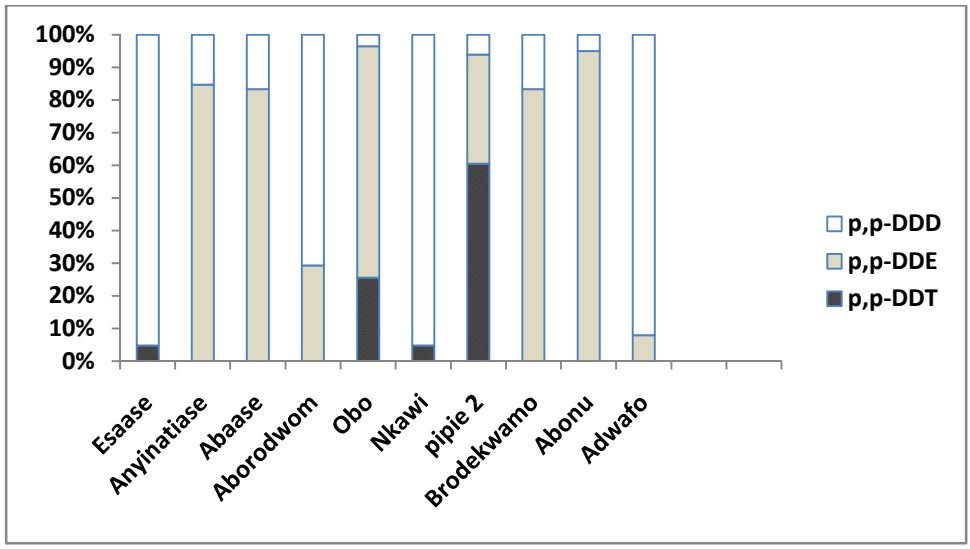

Figure 3: Percentage composition of DDTs in the sediments at various sampling points along the Bosumtwi Lake

3.3 Variation of hexachlorocyclohexane (HCHs) in sediments

1,2,3,4,5,6-hexachlorocyclohexane was used since the beginning of the 20th century, first as technical mixture of the isomers (mainly as α, β, γ, δ- HCH isomers) and later in the form of γ-HCH (lindane) in many fields of plant, wood, material, and storage protection, control of parasites and pests in human household and veterinary hygiene. Research has shown that only the γ-isomer (the gamma isomer) has insecticidal properties and was sold as insecticide under the trade name lindane [15, 16]. In Ghana lindane was used widely in the cocoa industry to control the insects that spread the swollen shoot disease. It was also used by vegetable growers. Because of its persistency, its usage in Ghana has been discontinued. Figure 4 shows the percentage distribution of HCHs in the sediments. It was only the γ-isomer that was detected with 100 percent occurrence. This was followed by δ-isomer with 66.66 percent occurrence while α and β- isomeric forms had 33.33 percentage occurrence along the sampling communities. The prominence of the γ-isomer in the study area came as no surprise since the γ-HCH had previously been used in Ghana as a pesticide with trade name grammalin-20 [17]. Thus, in most of the sampling points more than 50 % of the HCH measured was in the γ- isomeric form. The β-HCH was the least significant isomeric form in the study area.

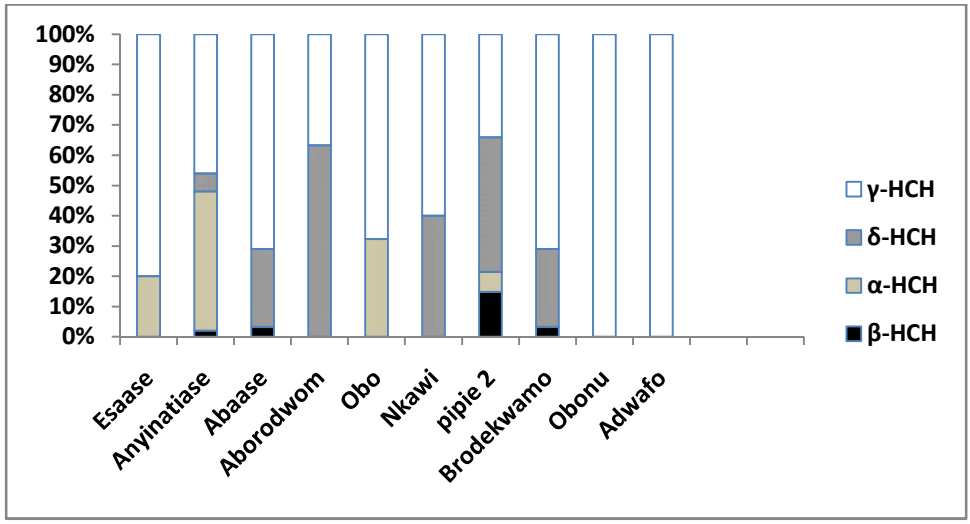

Figure 4: Percentage composition of HCHs in the sediments at various sampling point along the Bosumtwi Lake.

3.4 Variation of endosulfan in the sediment

Figure 5 presents the percentage composition of two isomeric forms (α and β) of endosulfan and the metabolites, endosulfan sulfate in the sediments. The results show that β is the predominant isomeric form in the sediment and accounted for more than 50 % of the total endosulfan load at most of the sampling points. Indeed, at Abaase, Aborodwom and Adwafo, the isomer accounted for 100 % of the total endosulfan load. The α-isomeric form was less significant in the samples and accounted for between 5 – 10 % of the total endosulfan load at Nkawi and Pipie 2. Indeed it was not detected in most of the sampling points. This finding seems interesting since technical endosulfan consists of 7: 3 mixtures of two stereo isomers, α and β [18]. This observation may be due to the stability or persistency of the β form in sediments. Endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which have structures similar to the parent compound and are therefore of toxicological concern. However, only the endosulfan sulfate was detected and accounting for more than 80 % of the total endosulfan load at Esaase and Obo. The metabolite was also prominent at Anyinatiase,

Pipie 2 and Obonu. The detection of endosulfan sulfate rather than endosulfan diol is an indication that metabolism of the parent occurred via oxidation rather than hydrolysis [19].

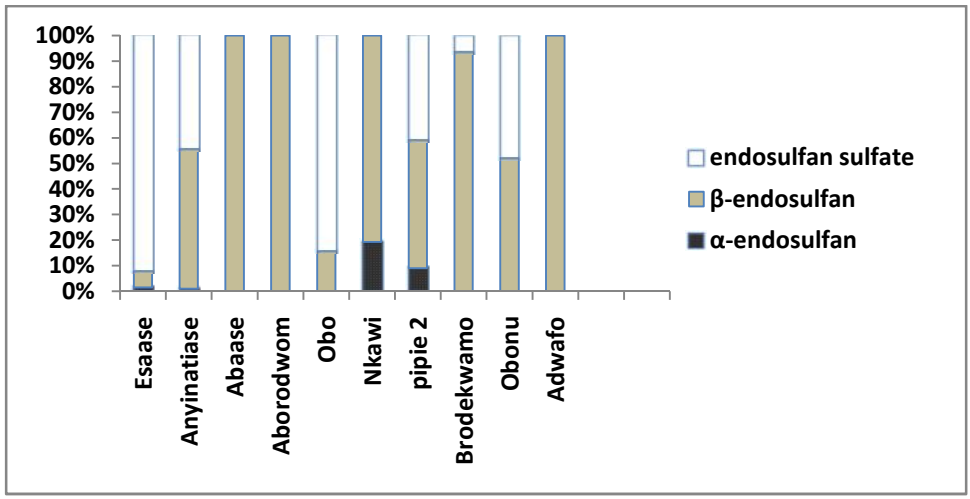

Figure 5: Percentage composition of the endosulfans at the various sampling points along the Bosuntwi Lake.

3.5 Variation of the Drin

Drin is a group name used for aldrin, dieldrin and endrin. They are among the banned insecticides by the Stockholm Convention. Aldrin and dieldrin are chemicals that were widely applied in agricultural throughout the world to control insects in soil and in public health for the control of mosquitoes and tsetseflies, the vectors that cause malaria and sleeping sickness respectively [15, 16]. Aldrin breaks down to dieldrin in living systems but dieldrin is known to resist bacterial and chemical breakdown processes in the environment [20]. Endrin had been used primarily as an insecticide on cotton as well as rodenticide and avicide [18]. Figure 6 shows the profile of the drins in the sediments. From the Figure 6 dieldrin and endrin were the predominant drin in the samples and in most of the sampling locations, the two accounting for 100 % of the total drin load. The compounds also accounted for more than 50 % of the total Drin load at Aborodwom and Obo. Aldrin was the least significant Drin in the sediment. Indeed it was detected at only Aborodwom and Obo. The predominance of dieldrin over aldrin is not surprise at all

since in the environment aldrin is likely break down to dieldrin which is noted to resist environmental degradation [20]. In the environment endrin ketone and endrin aldehyde are the degradation products of endrin through photodecomposition and microbial degradation [21]. The fact that endrin ketone and endrin aldehyde were not detected suggests less photodecomposition and microbial degradation of endrin in the study area.

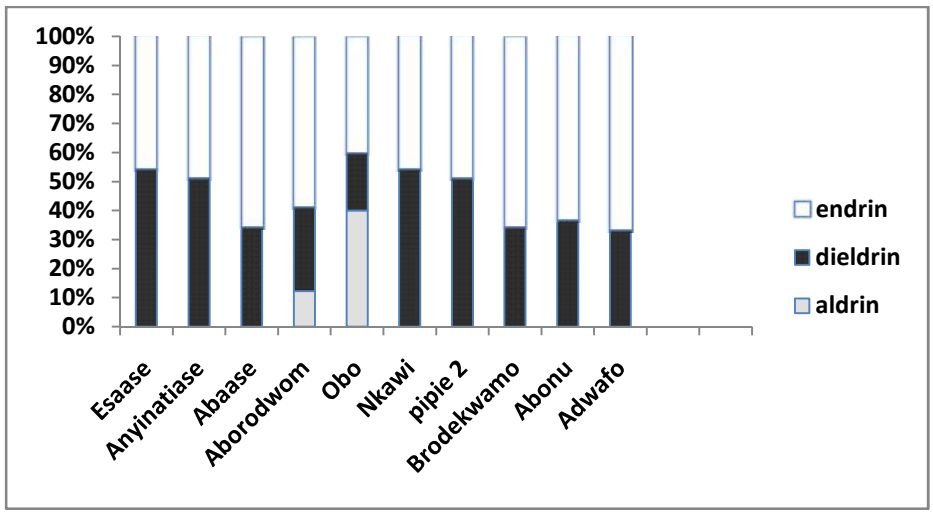

Figure 6: Percentage compositions of the Drins at the various sampling points along the Bosumtwi Lake

3.6 Variation of the PCBs congeners in the sediments

Figure 7 presents the composition of the PCBs congeners detected at the various sampling points. PCB 52 was the most ubiquitous and predominant PCB congener in the study area, accounting for more than 50 % composition at five of the sampling communities. At Adwafo it was the only detected PCB congener. In general, the less chlorinated homologues (# 28, 52 and 101) were more prominent than the most chlorinated homologues (# 138, 153 and 180). Indeed PCB # 28, 52 and 101 were detected with percentage occurrence of 50, 100 and 91.6 % respectively. The PCB congener 153 was not detected at all at any of the sampling points while that of congener 138 were detected at three sampling locations. It was

however, of interest to note that PCB 180 was quite prominent at some of the sampling locations and accounting for about 40 % of total PCBs load at Aborodwom, Pipie 2 and Brodekwamo.

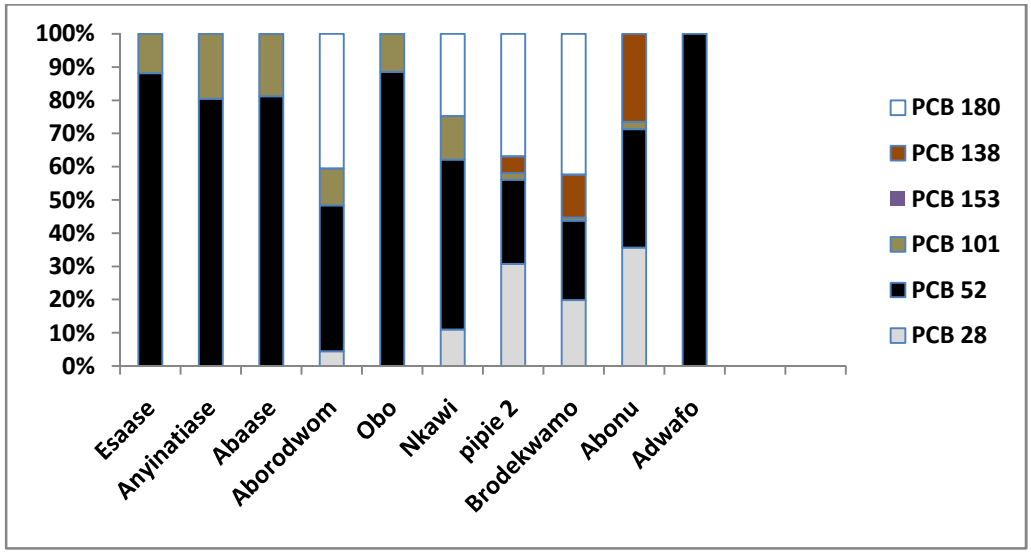

Figure 7: Percentage composition of PCBs congeners at the various sampling points along the Bosumtwi Lake.

3.7 Comparison of organochlorine residue levels to International standards

Table 3 compares mean organochlorine concentration of some of the detected organochlorines compounds in the present study and maximum residue limit (MRL) set by some International bodies [22]. Generally, the mean levels of the organochlorines in the Bosumtwi water were far below maximum residue limits set by European Union (EU), Italian Government and Food and Agriculture Organization (FAO) (Table 3). The results are therefore a suggestive that organochlorine compounds investigated in the present study may not pose health hazard in the waters from Lake Bosumtwi.

Table 3: Comparison of mean OCPs and PCBs concentrations (mg/kg) in the lake waters to maximum residue limit (MRL) stipulated by various statutory agencies.

Compounds	This work	European MRL	Italian MRL	FAO, 1983
∑chlordane	<0.0002	0.0500	0.0500	
∑DDT	0.0190	1.0000	1.0000	0.3000
dieldrin	0.0005	0.2000	0.2000	0.3000
α-HCH	<0.0002	0.2000	0.2000	
β-HCH	< 0.0002	0.1000	0.1000	0.3000
γ-HCH	0.0060	1.0000	1.0000	0.3000
endrin	<0.0002	0.0500	0.0500	0.3000
∑PCB	0.0380	0.2000		

4. CONCLUSIONS

The results of this study indicate that some organochlorine compounds are present in the Bosumtwi Lake in Ghana. The detection of organochlorine compounds in waters and sediments of the Lake indicates either wide use of these chemicals in the catchment of the lake or environmental transport of these chemicals from other places to the study area. However, in most of the sampling locations, particularly in the water samples concentrations of the compounds were below detection limit. In general there were more organochlorine compounds detected in the sediments than the water samples. Sediments may therefore serve as sink for organochlorine compounds. The levels of organochlorine pesticides and PCBs in the Lake water is far below the maximum residue limit of European Union, Italian Government and Food and Agriculture Organization. In all PCB 52 was the most ubiquitous organochlorine compound in the lake water with 100 percent frequency of occurrence while γ-HCH, endrin and PCB 52 were the most ubiquitous compounds in the sediments, also with 100 percent occurrence.

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COMPETING INTERESTS

We the authors want to declare that there is no competing interest regarding publication of the manuscripts.

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