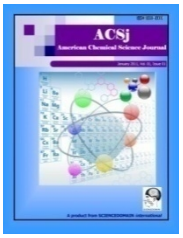

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Persistent Organochlorine Compounds in the Water and Sediment Samples from the Lake Bosomtwe in Ghana

Samuel Afful[1*], Johannes A.M. Awudza[2], Shiloh Osae[1] and Stevester K. Twumasi[2]

[1]Nuclear Chemistry and Environmental Research Centre, Ghana Atomic Energy Commission, Accra, Ghana.
[2]Chemistry Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

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. Author JAMA reviewed the scientific background. Authors SO and SKT explained the data and dissected the results involved in the preparation of the manuscript. All authors read and approved the final manuscript

Research Article

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ABSTRACT

Aims: To investigate the burden of organochlorine pesticides (OCPs) and its degradation products as well as indicator polychlorinated biphenyl (PCBs) in the water and sediments.
Study Design: This investigation involved one year monitoring of the Lake.
Place and Duration of Study: Lake Bosomtwi was the study area and analysis of samples was carried out at the Nuclear Chemistry and Environmental Research Centre of Ghana Atomic Energy Commission from January 2012 to February 2013. Samples were collected three times during dry, wet and minor wet seasons.
Methodology: Liquid-liquid extraction with hexane was used for the water samples while sediment samples were sonicated on ultrasonic bath with hexane/acetone mixture (3:1). The extracts were then cleaned up with florisil and quantified on a micro-capillary gas chromatography equipped with electron capture detector.

**Corresponding author: Email: affulsammy@yahoo.com;*

Results: Eight OCPs and four indicator PCBs were detected in water while sixteen OCPs and five indicator PCBs were also detected in the sediments. The highest OCPs concentration in water was 6.35 μg/l while that for the sediments was found to be 15.23 μg/kg. The total PCBs load (sum of all indicator PCBs) ranged from 1.09 – 7.19 μg/l and 6.43 – 19.17 μg/kg for the water and sediments respectively.
Conclusion: The study has shown that organochlorine compounds are present in the Lake Bosomtwi. The detection of organochlorine pesticides in water and sediments could be attributed either to historical use of these chemicals for agricultural purpose or environmental transport of these chemicals to the study area. The presence of indicator polychlorinated biphenyls could on the other hand be attributed to release to the environment during anthropogenic processes such as incineration, combustion and smelting. Leakages from refuse dumps containing dumped transformers and capacitors could also be a contributor to PCBs presence in the Lake.

Keywords: Persistent organochlorine; detected; lake; bosomtwi; sediment; water.

1. INTRODUCTION

Africa in the past was considered to be safe from water body pollution. However, the high anthropogenic activities in recent times have resulted in a remarkable amount of pollutants and diversity of discharges reaching aquatic environment. Common sources of water body pollution include oil spillage, wastes dumped into water bodies, and run off from agricultural and industrial sites. Oil spillage harms the water body mammals. Wastes such as plastic bags, fishing nets and other trash items which are dumped can accumulate in an area and entangle aquatic mammals. Run-off from agricultural sites may introduce pesticides residues and fertilizers into the water bodies. Pesticides contamination leads to fish kill while fertilizer pollution results in algal blooms that choke naturally occurring plants. These eventually reduce the diversity of organisms in water bodies [1].

For some time now pollutants in the environment which have generated international concern is persistent organic pollutants [2]. Persistent organochlorine pollutants are organic compounds that, to a varying degree, resist photolytic, biological and chemical degradation [3]. They are characterized by low water solubility and high lipid solubility. Exposure of persistent organochlorine compounds such as polychlorinated biphenyls (PCBs), DDTs, hexachlorohexanes (HCHs), hexachlorobenzene (HCB) has been linked to range of conditions including reproductive toxicity, immunotoxicity, hepatoxicty, neurotoxicity, necrosis and endocrine abnormalities [4]. They are semi-volatile, and this nature enables them to move long distance in the atmosphere before deposition [5]. Evidence available indicates that because they are able to undergo long range environmental transport, they may be found in areas where they have never been produced or used. The high lipid solubility and stability of organochlorine compounds have resulted in their widespread distribution in nearly all environmental compartments such as in air, water bodies, rain, soil and biota. The lipophilic nature of organochlorine has led to their bioaccumulation and biomagnifications in living organisms including fishes, humans and other animals. Although many different forms of organochlorine compounds exist, both natural and anthropogenic, those which are noted for their persistence and bioaccumulative characteristics include PCBs, many of the first generation organochlorine insecticides, toxaphenes and dioxins.

Persistent organochlorine compounds, thus DDTs, HCHs, HCB, endosulfan and PCBs had in the past been used in Ghana. While, PCBs were used as dielectric fluid in transformers and capacitors by Electricity Company of Ghana and Volta River Authority [4], DDTs, HCHs, endosulfans were applied as pesticides for agricultural purpose. Other organochlorines are used in industrial processes and in the production solvents, polyvinyl chloride and pharmaceuticals [5]. Many congeners of PCBs are formed and released to the environment during incineration, combustion, smelting and metal reclamation [5,6]. In Ghana the Environmental Protection Agency (EPA) has banned the use of persistent organochlorine pesticides and it is a requirement that dielectric fluids in transformers and capacitors is tested to ensure that PCBs concentration is not above 50 µg/g [4].

Lake Bosomtwi is one of the important water resources that the Ghana can boast of. It is the only natural Lake and situation about 30 km south east of Kumasi. The local communities dotted around the Lake use it mainly for fishing, swimming and boat transport. They also use the water from the Lake for cooking and washing. There is no doubt that the Lake has received some amount of pollution as a result of anthropogenic activities along the Lake. Previous studies on the quality of water bodies in Ghana focused mainly on physico-chemistry, nutrient burden, trace metals and pesticide residues pollution [1,7,8]. Recent studies in Ghana and neighboring countries [9,10] have revealed the presence of organochlorine pollutants in almost all compartments of environment. Indeed, Darko et al. [7] researched into organochlorine pollution of the Lake Bosomtwi. However, the investigation was limited in scope as it focused on few pollutants. The study failed to address degradation products formed in the environment by persistent organochlorines. Typical organochlorine pollutants such as indicator PCBs were not reported by Darko et al. [7]. Thus, there is no dearth knowledge on organochlorine pollution of the Lake.

This study was therefore initiated with the aim of providing adequate information on organochlorine pollution of the Lake. For the PCBs, the study focused on only indicator PCBs since they are known to persist and bioaccumulate in food chain. They are therefore are assumed to be a suitable representative for all PCBs

2. METHODOLOGY

2.1 The Study Area

Lake Bosomtwi, shown in Fig. 1 is situated within an ancient meteorite impact crater. It is approximately 8 km across [11]. The Lake has a coordinate of 6^0 30.31N 1^0 24.51W with a catchment area of 400 km^2. Lake Bosomtwi has maximum length of 8.6 km, maximum width of 8.1 km and surface area of 49 km^2. There are about 30 villages dotted around the lake, with a combined population of about 70,000 people. The Ashanti consider Bosomtwi a sacred Lake. According to traditional belief, the souls of the dead come here to bid farewell to the god Twi. Because of this, it is considered permissible to fish in the lake only with wooden planks. Lake Bosomtwi is a natural inland freshwater Lake and exhibits a radial drainage system of 106 km^2. It has diameter of about 11 km at its widest part and a maximum depth of 78 m. Lake Bosomtwi covers an area of about 52 km^2 [12]. The most important controls on the water balance of the lake are rainfall and water evaporating directly from the surface of the lake. The Lake is one of the main sources of livelihood for the communities living around and they heavily depend on the fish catch for their income and food (protein). Besides fishing, they depend on the aquatic resource for cooking, washing and irrigation water for agricultural activities. The Lake also provides the basis for other social and economic opportunities such as transportation and tourism. The Bosomtwi forest reserve, which is near the Ankaase community at Lake Bosomtwi, has an area of 140 km^2, is a legally protected area provides a typical natural environment which attracts eco-tourism.

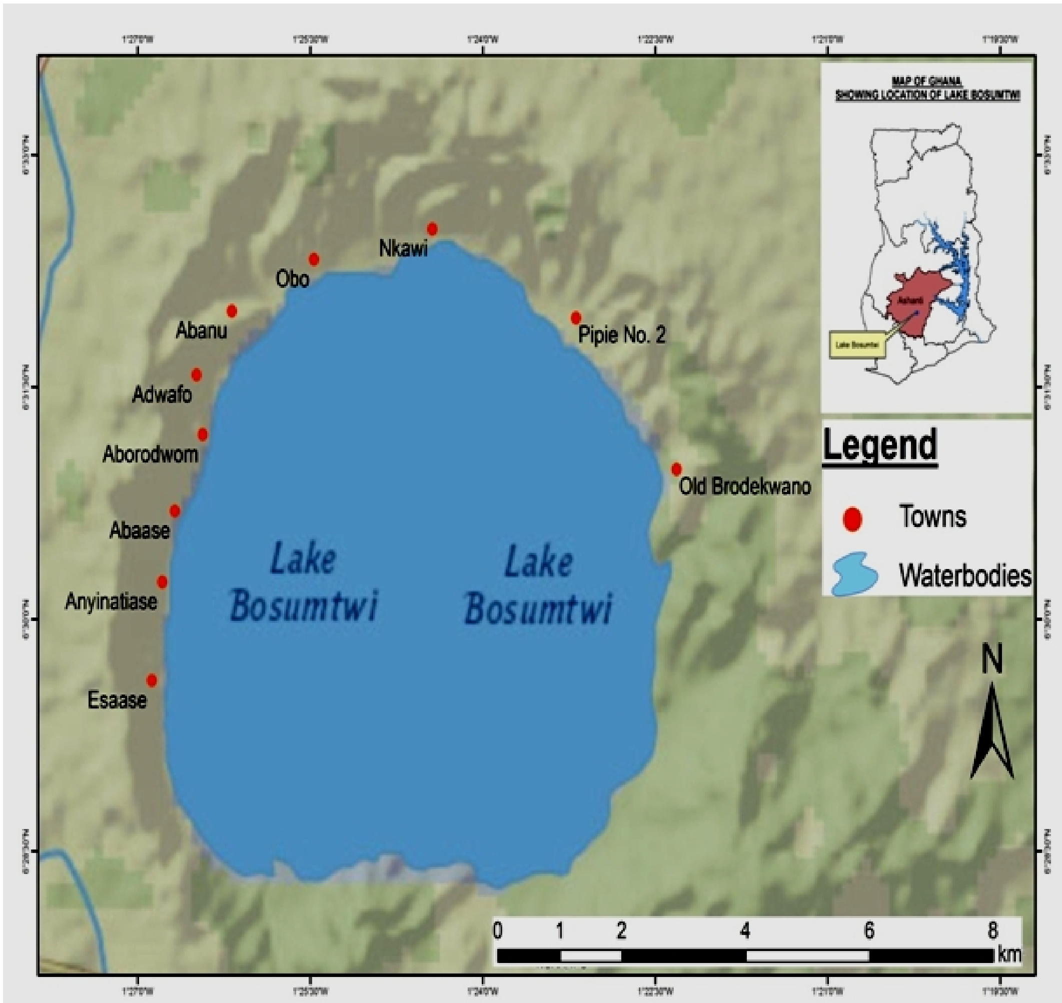

Fig. 1. Map of Lake Bosomtwi and the sampling locations

2.2 Chemicals and Reagents

Analytical grade and high purity chemicals and reagents were used for the investigation. Hexane (96+%), acetone (99 %), ethyl acetate (99.8%), anhydrous sodium sulphate were purchased from Sigma-Aldrich, Germany. Florisil adsorbent was purchased from Hopkins and William Limited, England. The organochlorine standards were from Cambridge Isotope Laboratories, incorporated and supplied by United Nation Environmental Program (UNEP) in Sweden.

2.3 Sampling and Sample Preparation

Water and sediment samples were collected from ten communities dotted around the Lake. The ten sampling points stretches from Old Brodekwano to Esaase. At each point three water and sediment samples were collected. Surface water samples were collected into 500 ml high-density polyethylene containers. Sediment samples were collected at various points in the neighborhood where the water samples were collected using Eckman grab from a depth of about 20 cm. 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 4ºC and the sediment samples were dried at room temperature. The sediments 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 kept at room temperature in a clean cupboard.

2.4 Extraction and Analysis of Samples

Liquid-liquid extraction with hexane was used for the extraction of the extractable organochlorine from the water samples while organochlorines were extracted from the sediments by sonicating on an ultrasonic bath (Branson 220, Branson Ultrasonic Cleaner, USA) for 2 hours at 40ºC with 3:1 hexane/acetone solvent system. The extracts from the sediments were passed over copper turnings to remove any extractable organosulphur compounds. Extract was concentrated on rotary evaporator and subjected to clean up. The clean up procedure was carried out according to the method of Nyarko et al. [13] with slight modifications. The extract was eluted from column first with 10 ml hexane followed by 5 ml of 2:1 hexane/diether. The eluate was concentrated to almost dryness by blowing in streams of nitrogen gas and residue re-dissolved in 1.5 ml ethyl acetate. The final extract was transferred quantitatively into 2 ml vial for GC analysis. The GC was a Varian CP-3800 equipped with electron capture detector and a volume of 1µl aliquots of sample extract was injected. The operation conditions were capillary column: VF – 5mS, 40m x 0.25mm x 0.25µm, temperature programme: 70ºC (2min) to 180ºC (1min) 25^0C/min to 300ºC at 5ºC/min, injector temperature: 270ºC, detector temperature: 300ºC, carrier gas: nitrogen at 1.0ml/min, make up: nitrogen at 29ml/min. The organochlorines were identified based on comparison of retention times to known standards and quantified by external standard method.

2.5 Quality Assurance/Control

The quality of the study was assured through analysis of standard solutions and blank samples included in each batch of analysis. Analysis of blanks did not contain traces of the pollutants. Recovery studies involving analysis of spiked samples with organochlorine standards were carried out and percentage recoveries were between 96.0–101.0%. The GC-ECD method used for the study was also validated with certified reference material.

3. RESULTS AND DISCUSSION

3.1 Mean Concentrations of Organochlorines Compounds in the Samples

The mean concentrations of the detected organochlorines are presented in Tables 1 and 2. Margins of errors are standard deviation based on triplicate determination. The Tables also show the percentage occurrence for the detected compounds. Analysis of the water samples revealed the presence of eight persistent organochlorine pesticides and four indicator PCBs.

Sixteen organochlorine pesticides and five indicator PCBs were detected in the sediments. The detected compounds were α- HCH, β-HCH, δ-HCH, γ-HCH, heptachlor, aldrin, γ-chlordane, α-endosulfan, p,p^1-DDE, dieldrin, endrin, β-endosulfan, p,p^1-DDD, p,p^1-DDT and methoxychlor, PCB 28, PCB 52, PCB 101, PCB 138 and PCB 180. The concentrations of the compounds, β-HCH, α-HCH, aldrin, δ-chlordane, α-endosulfan, PCB 28 and PCB 153 were below detection limit at some of the sampling locations. The limit of detection (LOD) is defined as the lowest practical concentration of the pollutant that can be identified and quantitatively measured in a specific matrix [14]. This was estimated as concentration which peak was three times the peak of signal to noise ratio. The trends of persistent organochlorine distribution in the samples indicate higher concentrations in sediments. In an aquatic medium, persistent organochlorine compounds being hydrophobic tend to settle more in sediments than remain in the overlying water. Sediments therefore serve as sink for persistent organochlorine compounds. The mean concentrations of organochlorine pesticides and PCBs in sediments ranged from 0.05 – 15.23 μg/kg and 0.16 – 10.50 μg/kg respectively.

Table 3 compares the results of the current study to Darko et al. [7] and other studies. It is obvious by comparison that Darko et al. [7] investigation was limited in scope and that the current study has brought new findings on organochlorine pollutants in Lake Bosomtwi. Indeed this study has revealed the presence of p, p^1 - DDE, p, p^1 – DDD, endosulfan sulfate, methoxychlor and indicator PCBs which Darko et al. [7] did not report. However, the levels of organochlorine compounds in this study are lower than values reported by Rochel et al. [9] and Kalyonu et al. [15] from Cote d'Ivoire and Turkey respectively.

The sources of organochlorine pesticides in the Lake Bosomtwi could be attributed to historical use of these chemicals by farmers while the present of indicator PCBs could possibly be linked to release to the environment during incineration, combustion, smelting and metal reclamation processes [5,6]. Leakages of PCBs from dumped decommissioned transformers and capacities in refuse dumps in the past could also be sources of PCBs congeners to the Lake. However, nowadays, when these electrical units are decommissioned, their PCB content is stored to prevent further pollution. In all PCB 52 was the most ubiquitous organochlorine compound in the water while γ-HCH, endrin and PCB 52 were the ubiquitous compounds in the sediments. The ubiquity of PCB 52 in the present study might be attributed to its persistency in the environment compared to the other indicator PCBs. Kuranchie-Mensah et al. [17] reported PCB 52 as one of the predominant organochlorine pollutant in Weija Lake of Ghana.

Table 1. Concentration of detected organochlorines (mean ±SD in µg/l) and percentage occurrence in water from Lake Bosomtwi

Compounds	Sampling points										
	Esaase	Anyinatiase	Abaase	Aborodwom	Obo	Nkawi	Pipie 2	Bodekwamo	Abonu	Adwafo	%occ
β-HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
α-HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
δ-HCH	<0.01	<0.01	<0.01	<0.01	0.15±0.01	0.40±0.10	0.15±0.01	<0.01	<0.01	<0.01	30
γ-HCH	0.15±0.01	<0.01	<0.01	0.30±0.01	<0.01	0.05±0.01	<0.01	<0.01	0.05±0.02	<0.01	40
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	<0.02	90
Aldrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0
δ-chlordane	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0
α-endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
β-endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
Dieldrin	0.05±0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	10
Endrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0
p,p-DDT	<0.01	<0.01	0.25±0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	10
p,p-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
p,p-DDD	6.35±0.11	<0.01	<0.01	0.30±0.011	3.20±0.03	4.30±0.11	0.15±0.01	1.30±0.08	2.55±0.50	<0.01	70
Endosulfan Sulfate	5.63±0.05	1.30±0.08	0.65±0.21	<0.01	0.50±0.02	0.35±0.02	0.10±0.02	0.15±0.1	<0.01	<0.01	70
Σ HCHs	0.15±0.01	<0.01	<0.01	0.30±0.01	0.15±0.01	0.45±0.11	0.15±0.01	<0.01	0.05±0.02	<0.01	60
ΣDDTs	6.35±0.11	<0.01	0.25±0.04	0.30±0.011	3.20±0.03	4.30±0.11	0.15±0.01	1.30±0.08	2.55±0.50	<0.01	80
PCB 28	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
PCB 52	4.47±0.55	1.09±0.2	3.62±0.61	4.13±0.99	1.68±0.40	0.75±0.06	1.99±0.13	4.72±0.03	4.26±0.33	1.81±0.11	100
PCB 101	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02±0.002	<0.01	<0.01	<0.01	10
PCB 153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
PCB 138	<0.01	<0.01	0.12±0.02	<0.01	<0.01	<0.01	<0.01	1.15±0.02	<0.01	<0.01	20
PCB 180	<0.01	<0.01	<0.01	3.06±0.81	<0.01	0.51±0.03	<0.01	<0.01	<0.01	<0.01	20
Σ PCBs	4.47±0.55	1.09±0.2	3.74±0.63	7.19±1.80	1.68±0.40	1.26±0.09	2.01±0.13	5.87±0.05	4.26±0.33	1.81±0.11	100

% occ = percentage occurrence

Table 2. Concentration of detected organochlorines (mean ±SD in µg/kg) and percentage occurrence in sediments from Lake Bosomtwi

Compounds	Sampling points										
	Esaase	**Anyinatiase**	**Abaase**	**Aborodwom**	**Obo**	**Nkawi**	**Pipie 2**	**Brodekwano**	**Abonu**	**Adwafo**	**% occ**
β-HCH	<0.01	0.05±0.01	0.05±0.01	<0.01	<0.01	<0.01	0.50±0.02	0.05±0.01	<0.01	<0.01	40
α-HCH	0.15±0.02	1.15±0.03	<0.01	<0.01	0.50±0.02	<0.01	0.22±0.04	<0.01	<0.01	<0.01	40
δ-HCH	<0.01	0.15±0.07	0.40±0.01	1.29±0.25	<0.01	0.40±0.05	1.50±0.72	0.40±0.02	<0.01	<0.01	60
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
Heptachlor	<0.02	0.60±0.11	<0.02	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	80
Aldrin	<0.02	<0.02	<0.02	0.25±0.08	1.20±0.07	<0.02	<0.02	<0.02	<0.02	<0.02	20
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
α-endosulfan	0.15±0.02	0.10±0.02	<0.01	<0.01	<0.01	0.25±0.02	1.00±0.05	<0.01	<0.01	<0.01	40
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
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
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
p,p-DDT	0.10±0.01	<0.01	<0.01	<0.01	1.79±0.07	0.15±0.02	0.10±0.01	<0.01	<0.01	<0.01	40
p,p-DDE	<0.01	3.60±0.27	1.50±0.08	1.25±0.06	4.95±0.14	<0.01	3.60±0.36	1.50±0.07	4.75±0.55	0.25±0.06	80
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
Endosulfan Sulfate	15.23±1.04	4.50±0.32	<0.01	<0.01	6.65±0.32	<0.01	4.50±0.46	0.15±0.05	6.65±0.55	<0.01	60
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
ΣHCHs	0.75±0.04	2.50±0.2	1.55±0.32	2.04±0.28	1.55±0.06	1.00±0.13	3.37±0.87	1.55±0.24	0.75±0.03	1.05±0.04	100
Σ DDTs	2.10±0.21	4.25±0.34	1.80±0.10	4.26±0.47	6.99±0.25	2.15±0.82	4.35±0.41	1.80±0.10	5.00±0.60	3.15±0.16	100
PCB 28	<0.01	<0.01	<0.01	0.55±0.22	<0.01	0.91±0.31	5.90±1.05	3.53±0.90	5.25±0.74	<0.01	50
PCB 52	5.79±1.23	5.51±1.34	4.87±1.53	5.45±0.15	5.43±0.96	<0.01	4.85±1.20	4.26±1.12	5.24±1.92	5.74±1.81	90
PCB 101	0.78±0.61	1.14±0.55	1.06±0.09	1.37±0.04	0.70±0.08	1.10±0.22	0.39±0.07	0.16±0.02	0.33±0.08	<0.01	90
PCB 153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
PCB 138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.95±0.10	<0.01	3.90±0.63	<0.01	20
PCB 180	<0.01	<0.01	<0.01	5.03±0.12	<0.01	2.07±0.43	7.08±1.23	7.55±1.33	<0.01	<0.01	40
Σ PCBs	6.57±1.84	6.65±1.89	5.93±1.62	12.40±0.53	6.13±1.04	4.08±0.96	19.17±3.65	15.50±3.37	14.72±3.37	5.74±1.81	100

% occ = percentage occurrence

Table 3. Comparison of the present study to Darko et al. [7] and other studies

Compounds	Present study	Darko et al. [7]	Kalyonu et al. [15]	Rochel et al. [9]
P,P^1-DDT	<0.01 – 0.25	0.012 – 4.41	-	-
p,p^1 –DDD	<0.01 – 6.35	-	-	-
P,P^1-DDE	<0.01 – 4.95	0.016 – 8.342		-
DDTs	0.15 – 5.00	-	43.7	124.10
α-HCH	<0.01 – 1.15	-	-	-
β-HCH	<0.01 – 0.50	-	-	-
γ-HCH	<0.01 – 1.15	0.015 – 1.26	-	-
δ-HCH	<0.01 – 1.29	-	-	-
HCHs	<0.15 - 2.50	-	31.70	206.00
endrin	<0.02 - 1.20	-	6.90	-
dieldrin	<0.02 - 0.90	0.030 - 0.42	2.80	15.53
aldrin	<0.02 - 0.25	0.024 - 0.35	3.30	11.30
α-endosulfan	<0.01 – 1.00	-	-	-
β-endosulfan	<0.01 – 7.25	-	-	-
endosulfans sulfate	<0.01 – 15.23	-	-	-
methoxychlor	<0.01 – 5.95	-	-	-
PCB 28	<0.01 – 5.90	-	-	-
PCB 52	0.75 – 5.79	-	-	-
PCB 101	<0.01 – 1.37	-	-	-
PCB 138	<0.01 – 3.90	-	-	-
PCB 153	<0.01	-	-	-
PCB 180	<0.01 – 7.55	-	-	-
PCBs	1.06 – 19.17	-	-	25.22

Levels in parts per billion, - not reported

3.2 Variation of DDTs in Sediment

Fig. 2 shows the distribution of DDT and its metabolites in the sediments. In Ghana DDT was used extensively in the past for agriculture activities. However, the use of DDT in Ghana has now been limited to malaria programs to fight the insect mosquito. Indeed, its use in agriculture had been banned by the Environmental Protection Agency of Ghana [16]. Detected DDTs in the sediments were p, p^1 –DDT, p,p^1-DDE , and p,p^1-DDD. p, p^1 –DDT was however, only dominant at Pipie 2. p,p^1-DDE and p,p^1-DDD were the dominant DDT in the study area. The ratios DDT / (DDE+DDD) were less than one in the sampling communities. The ratio of DDT/(DDE+DDD) can be used to assess or estimate if there is recent input of DDT in the study area [17,18]. If the ratio is less than one then there is no recent input of DDT. The low concentration of p,p^1-DDT compared to the sum of its metabolites (DDE+DDD), is an indication that there might not be fresh input of the DDT in the study area. This therefore, suggests that DDTs concentrations might mainly be due to historical use and environmental persistence.

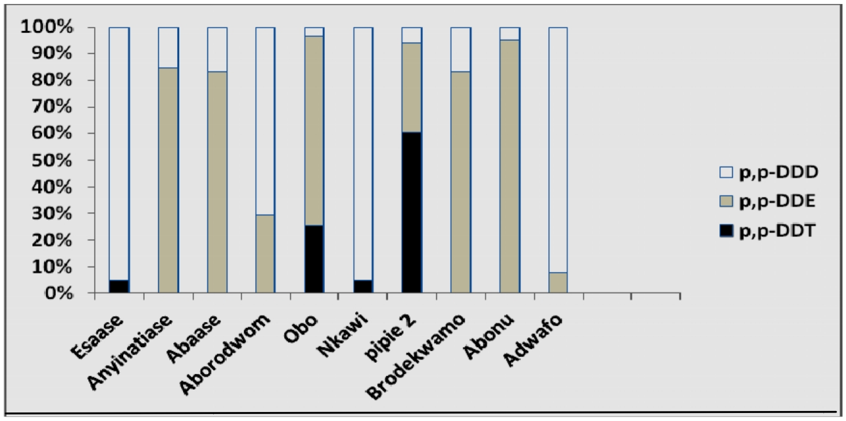

Fig. 2. Percentage composition of DDTs in the sediments at various sampling points along Lake Bosumtwi

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 isomers (mainly as α, β, γ, δ- HCH isomers) and later in the form of γ-HCH (lindane) in protection of plants and woods against insect attack. It was also used to control parasites and pests in household. Research has shown that only the γ-isomer has insecticidal properties and was sold as insecticide under the trade name lindane [19,20]. In Ghana lindane was historically used in the cocoa industry to control the insects that spread the swollen shoot disease. Fig. 3 shows the percentage distribution of the HCHs. Only the γ- isomer was detected with 100 percent occurrence. The α and β- isomeric forms were not significant at the study area. The prominence of the γ-isomer in the study area was expected as it had been used widely as agrochemical [21].

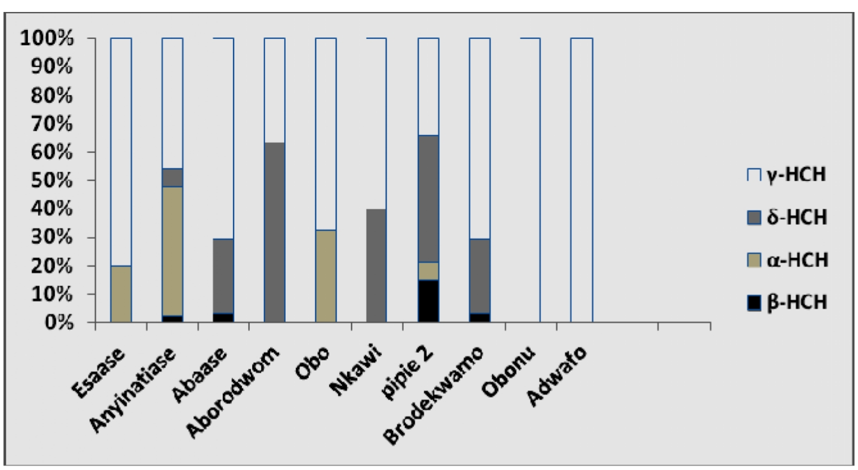

Fig. 3. Percentage composition of HCHs in the sediments at various sampling locations along Lake Bosomtwi

3.4 Variation of Endosulfan in the Sediment

Fig. 4 presents the percentage composition of two isomeric forms of endosulfan and its metabolite, endosulfan sulfate. The results show that β is the predominant isomer and accounted for more than 50 % of the total endosulfan load at most of the sampling locations. Indeed, at Abaase, Aborodwom and Adwafo, the isomer accounted for 100 % of the total endosulfan load. The α-isomeric form was less prominent and accounted for between 5 – 10 % at Nkawi and Pipie 2. This finding is interesting since technical endosulfan consists of 7: 3 mixtures for α and β stereo isomers [22]. This observation could be attributed to the stability or persistence of the β form in sediments. Endosulfan breaks down into endosulfan sulfate and endosulfan diol and both have structures similar to the parent compound. The two are therefore of toxicological concern. However, only the endosulfan sulfate was detected and accounting for more than 80 % of the total endosulfans at Esaase and Obo. The detection of endosulfan sulfate rather than endosulfan diol is an indication that metabolism of the parent occurred through oxidation and not by hydrolysis [23].

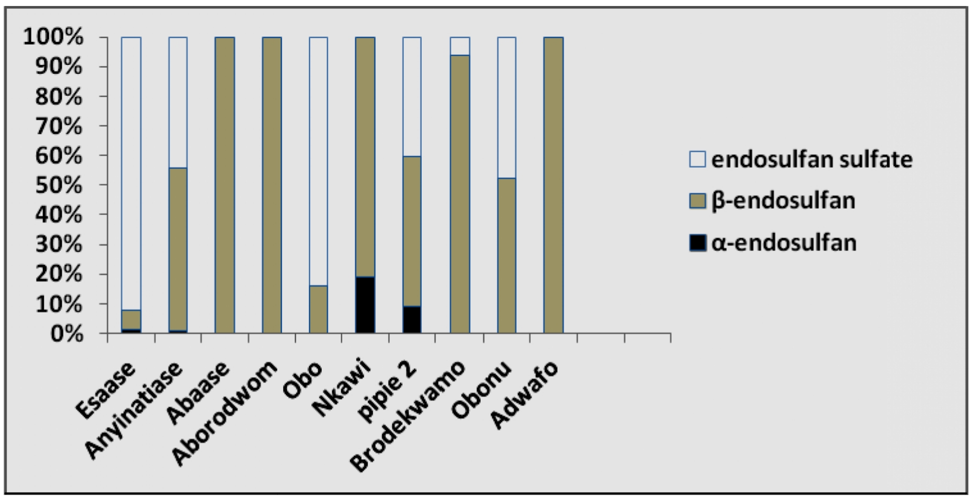

Fig. 4. Percentage composition of the endosulfans at the various sampling locations along Lake Bosomtwi

3.5 Variation of the Drin

Drin is a group name used for aldrin, dieldrin and endrin. They are among the insecticides banned by the Stockholm Convention. Aldrin and dieldrin are chemicals that were widely used in agricultural throughout the world to control insects in soil. In the public health it was used for the control of mosquitoes and tsetseflies, the vectors that cause malaria and sleeping sickness respectively. Aldrin breaks down to dieldrin in living systems but dieldrin is known to resist bacterial and chemical breakdown [24]. Endrin on the other hand, had been used primarily as an insecticide on cotton as well as rodenticide and avicide. The profile of the drins is as shown in Fig. 5. Dieldrin and endrin were the predominant Drins. Indeed, the two accounted for 100 % of the total Drin load in eight of the sampling locations. Aldrin was the least significant Drin. The predominance of dieldrin over aldrin came as no surprise since in the environment aldrin is likely to break down to dieldrin [24]. In the environment endrin breaks down to endrin ketone and endrin aldehyde through photodecomposition and microbial degradation [21]. These were however, not detected. The non detection of the degradation products suggests that photodecomposition and microbial degradation of endrin are less prominent in the study area.

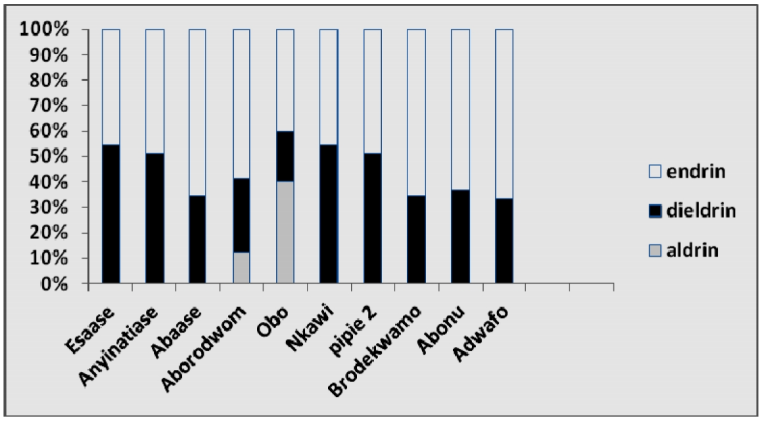

Fig. 5. Percentage compositions of the Drins at the various sampling locations along Lake Bosomtwi

3.6 Variation of the Indicator PCBs Congeners in the Sediments.

Fig. 6 presents the composition of detected indicator PCBs congeners. PCB 52 was the most ubiquitous and predominant PCB congener in the study area, accounting for more than 50 % composition at five sampling locations. At Adwafo it was the only detected indicator 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 respectively detected with percentage occurrence of 50, 100 and 91.6 %. The PCB congener 153 was not detected at any of the sampling locations while congener 138 was detected at three sampling locations. It was however, interested to note that PCB 180 was quite prominent and accounted for nearly 40% of total PCBs load at Aborodwom, Pipie 2 and Brodekwamo.

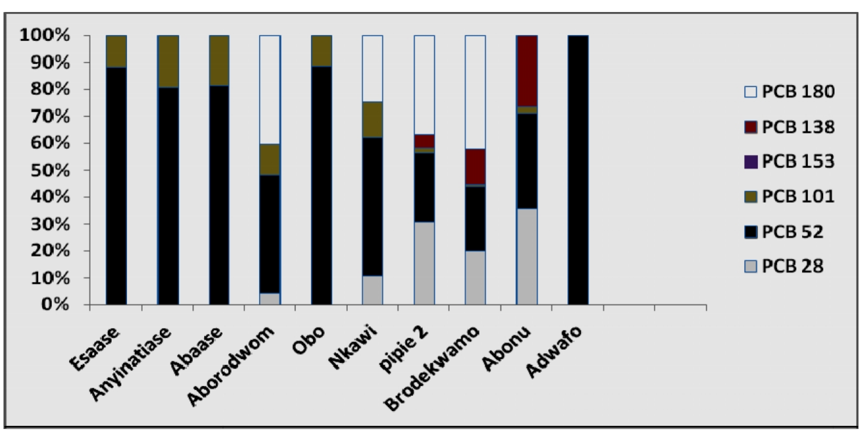

Fig. 6. Percentage composition of PCBs congeners at the various sampling locations along Lake Bosomtwi

3.7 Comparison of Organochlorine Residue Levels to International Standards

Table 4 compares mean organochlorine concentration of some organochlorines in the present study to maximum residue limit (MRL) set by some International bodies [25]. Generally, the mean levels of the organochlorines in the Bosomtwi water were far below maximum residue limits set by European Union (EU), Italian Government and Food and Agriculture Organization (FAO) (Table 4). The results, based on one year monitoring, therefore suggest that organochlorine compounds investigated in the present study may not pose health hazard in the waters from Lake Bosomtwi.

Table 4. Comparison of mean OCPs and PCBs concentrations (mg/kg) in the Lake waters to maximum residue limit (MRL) stipulated by some statutory agencies

Compounds	This work	European Union MRL	Italian MRL	FAO, 1983
∑chlordane	<0.0002	0.0500	0.0500	
∑DDT	0.0182	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	0.0330	0.2000		

4. CONCLUSION

The results of this study indicate that some organochlorine compounds are present in the Lake Bosomtwi in Ghana. The detection of organochlorine pesticides in waters and sediments of the Lake indicates either a historical use of these chemicals in the catchment of the Lake or environmental transport from other places to the study area. However, in most the water samples concentrations of the compounds were below detection limit. In general more organochlorine pollutants were detected in the sediments. Sediments may therefore serve as sink for organochlorine. The levels of organochlorine pollutants in the Lake water is far below the maximum residue limit set by European Union, Italian Government and Food and Agriculture Organization. In all PCB 52 was the most ubiquitous organochlorine in the water samples while γ-HCH, endrin and PCB 52 were the frequently detected compounds in the sediments.

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COMPETING INTERESTS

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

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