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Human Health Risk Assessment of Organochlorines Exposure through Dietary Intake of Fishes from Lake Bosomtwi and Weija Lake in Ghana

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ABSTRACT

Human health risk assessment on intake of fish contaminated with organochlorine contaminants has been investigated in seven fish species from Lake Bosomtwi and Weija Lake in Ghana. The species studied were *Tilapia busumana, Hemiscrimis faciatus, Sarotherodon galileu* from Lake Bosomtwi and *Tilapia zilli, Tilapia nile, Tilapia galilaea* and *Clarius gariepinus* from Weija Lake. Risk assessment was carried out by estimating daily exposure as well as carcinogenic and non-carcinogenic implications on consumption of the studied fishes. Estimated daily exposures to OCs on dietary intake of fish were in the range of 0.002 µg/kg to 0.176 µg/kg and 0.001 µg/kg to 0.0892 µg/kg for children and adults respectively. Consumption of *Clarias gariepinus* indicated the highest health risk to organo chlorine exposure. Children were exposed to more OCs than adults on consumption of the same quantity of contaminated fish. Estimated daily exposures however, fell below USEPA reference doses. Cancer hazard analysis showed that more than one in a million of the consuming population could get cancer on eating *Clarias gariepinus* due to hexa chlorocyclo hexanes (HCHs) contamination. However, consumption of the investigated fish from Lake Bosomtwi presents no risk of cancer. Organochlorines were extracted from samples by sonicating on an ultrasonic bath with hexane/acetone solvent system and organochlorine contaminants were determined using capillary gas chromatograph equipped with electron capture detector.

1. Introduction

Consumption of food including eating of fishes is one of important routes of human exposure to organo chlorine (OCs) pollutants [1]. In Ghana, organo chlorine (OC) pesticides, such as DDT (dichloro diphenyl trichloroethanes), HCHs (hexachloro cyclohexanes) and endosulfan had been used widely for agriculture. Indeed, the use of OCs reached the maximum in early 1990s. Although the agricultural use of DDT, HCHs and other OCs has been banned in Ghana for some time now, relatively great concentrations of these OC residues can still be found in our environment [2, 3, 4, 5]. Concentrations of HCHs and DDTs in fish samples were reported by Afful et al [4]. Study by Kurachie-Mensah et al [6] in the Densu basin revealed varying concentrations of organo chlorine pesticides in various fish species. However, concentrations reported were below World Health Organization (WHO) recommended levels.

In Ghana Polychlorinated biphenyls (PCBs) were used as dielectric fluid in electrical transformers and capacitor by Electricity Company and Volta River Authority [7]. Although the use of PCBs has been banned by the Stockholm Convention, their presence in the environment has also been reported [8. 9]. Recent studies by Afful et al [9] revealed the presence and varying concentrations of indicator PCBs in Lake Bosomtwi while Adu-Kumi et al [8] reported the presence dioxin like PCBs in edible fishes from Lake Bosomtwi. Kuranchie-Mensah et al [5], on the other hand, reported of indicator PCBs concentrations ranging from 0.90 ng/g to 12.36 ng/g dry weights in fish species from the Volta Lake. Recent surveys in neighboring countries have reported organo chlorines presence in fish samples from Lake Taabo in Cote d'Ivoire [10] and in Queme River in Benin [11]. In China concentrations of PCBs ranging from 15.1 to 57.9 ng/g (mean: 34.5 ng/g) in fishes of Minjiang River in southern China [12], and concentrations ranging from 1.7 ng/g to 14.3 ng/g in some Chinese estuaries [13] have been reported. Thus, many OCs are still present in the environment worldwide due to their high environmental persistence.

Globally, edible fishes are eaten widely because of its high protein content. However, OCs can bioaccumulate in tissues and organs of fish because of the high lipid content. In Ghana Lake Bosomtwi and Weija Lake are noted for their roles in the fishing industry. Indeed, communities found in their catchments depend on the fish from these water systems for food and income. It must however, be stressed that organo chlorine pollutants because of its persistence and toxicity to man and wildlife have been studied in Lake Bosomtwi and Weija Lake [9, 10, 8, 3]. However, these investigations have focused on comparing measured levels to maximum residue levels to explain human health implications of these contaminants in edible fish. There is therefore, little or no data on detailed human health risk assessment on eating

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of fish contaminated with organochlorines in Ghana. Thus, human health risk assessments of OC pollutants in fish samples have not been well documented in Ghana. Organochlorines are potentially carcinogens; hence an assessment of carcinogenic and non-carcinogenic effects from eating fishes in the two water bodies will be relevant to explain the potential health risks to human population depending on it for food. Currently, Ghana has not been able to develop its own benchmarks in human risk assessments due to OC pollution, hence standards developed by United State Environmental Protection was adopted for this study.

2. Study areas

In this study, fish samples were collected from Lake Bosomtwi and Weija Lake in Ghana. Maps of the study area are shown in Figures 1 and 2.

The Weija Lake was created by damming the Densu River at Weija with the main objective of providing potable water for the residents of Western Accra in the Greater Accra Region of Ghana. It was also created for irrigation purposes and to increase the fishery potential of the river system. The vegetation in the catchment of the Lake is densely thickets interspersed with patches of grasses. The nature of the soils in the catchments have been reported to be well drained, friable, porous loam savannah ochrosols which are low in nutrients especially phosphorus and nitrogen [14]. Generally, erratic and low rainfall, averaging 840 mm a year is recorded with major rains occurring mainly from May to June and in October [14]. The hottest periods are from February to April with the highest mean monthly temperature of 32 ^{o}C occurring in March, whilst the lowest mean monthly temperature of 21.7 ^{o}C occurs in August. The main economic activities of the people in the catchment of the Lake includes fishing, animal rearing, stone quarrying and crops farming. Major crops include maize, cassava, sugarcane and vegetables. The normal surface elevation is estimated at 14.37 km with maximum of 15.24 km [15].

Lake Bosomtwi is situated within an ancient meteorite impact crater. It is approximately 8 km across and the only natural Lake in Ghana [16]. It is situated about 30 km south-east of Kumasi in the northern tip of the Adansi mountains in the forest zone of Ghana and is a popular recreational area. 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 24 villages dotted around the Lake, with a combined population of about 70,000 people [17]. The Ashantis consider Bosomtwi a sacred Lake. According to traditional belief, the souls of the dead come here to bid farewell to the Twi god. The Lake exhibits a radial drainage system of 106 km^2, a 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 [18]. The Lake has no outlet, although it has apparently overflowed in recent geologic past [19]. The water balance of the Lake is mainly control by direct rainfall and evaporation [19]. Of lesser importance is the runoff contributed by the Lake's surrounding watershed. It is reasonable to assume, when considering the hydrogeological conditions that little or no groundwater enters or leaves the basin. According to Turner et al [20], the Lake level is very sensitive to small changes in rainfall and other climatic parameters, such as annual mean temperature and evaporation [21]. 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. Besides fishing, they used the Lake water for cooking, washing and irrigation of farmlands in the catchment. The Lake also provides the basis for other social and economic opportunities such as transportation and tourism.

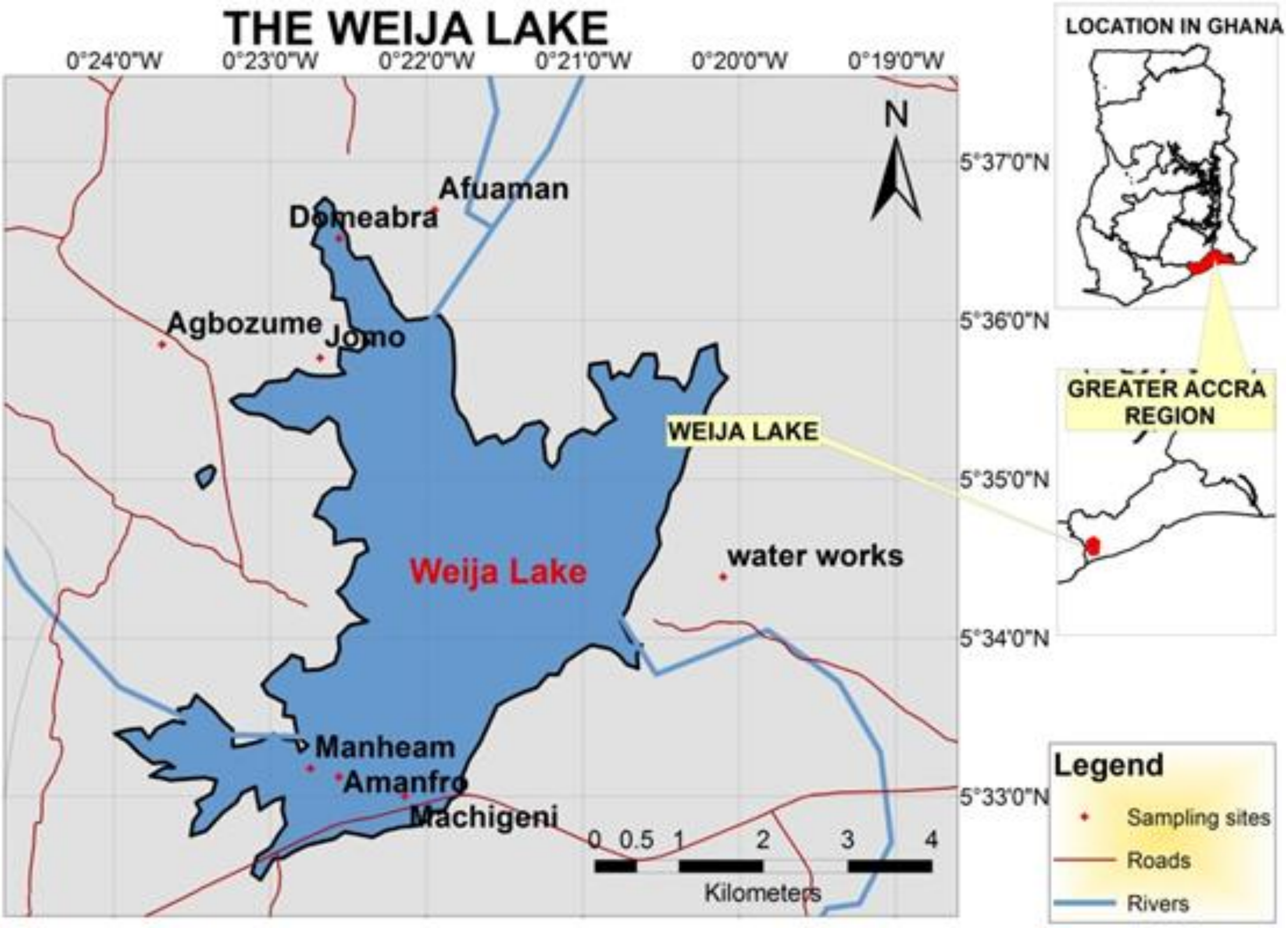


Figure 1. Map of Weija Lake Showing the Sampling Communities.

Figure 2. Map of Lake Bosomtwi Showing the Sampling Communities.

3. Materials and methods

3.1 Sampling and sample preparation

Sampling was done in 2012 from January to February and from September to October for the purpose of replicating measurement. Fish samples used for the investigation were bought from fishermen at the sampling locations. Between twelve to sixteen samples of each fish species were bought from the fishermen as composite fish samples. The intestines were removed to prevent decayed. They were wrapped in aluminium foil and packed into an ice-chest with ice block placed on them. They were transported to the laboratory for proper storage and analysis. In the laboratory they were washed with distilled water and kept frozen prior to analysis. Two samples of each species were selected for identification at the Oceanography Department of University of Ghana. Fish samples were removed from the deep freezer and rinsed several times with de-ionized water and allowed to thaw. The total length and body weight of the fishes were measured. Samples were gutted to remove scales, tail and bones with stainless steel knife. A representative sample of each fish species were selected and cut into pieces and subjected to freeze drying for 72 h. They were then homogenized with warring blender to obtain a homogenous dried fish sample.

3.2 Extraction and analysis

Organo chlorines were extracted from samples by sonicating on an ultrasonic bath (Branson 220, Branson Ultrasonic Cleaner, USA) for 3 hours at 40ºC with 3:1 hexane/acetone solvent system. Extracts were concentrated on rotary evaporator and subjected to clean up. The clean up procedure was carried out according to the method of Grimalt et al [22] 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 rotary evaporation 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 Shimadzu 2010 series equipped with electron capture detector and a volume of 1µl aliquots of sample extract was injected. The operation conditions were capillary column: SGE BPX-5 (60 m x 0.25 mm x 0.25 µm), temperature programme: 90 ^{0}C (3min) to 200 ^{0}C (15 min) at 30 ^{0}C/min to 265 ^{0}C (5 min) to 275^{0}C (15 min) at 3°C/min, injector temperature: 250^{0}C, detector temperature: 300 ^{0}C, carrier gas: nitrogen at 1.0 ml/min, make up: nitrogen at 30 ml/min. The organochlorines were identified based on comparison of retention times to known standards and quantified by external standard method.

3.3 Risk assessment of organochlorine pollution to humans

3.3.1 Estimation of daily exposure to OCs

Estimated daily intake (EDI) or exposure of OCs through consumption of the fish samples were computed by multiplying the individual organochlorine concentration in each fish species by the rate of fish consumption. In Ghana the rate of fish consumption is estimated at 68.5 g/day [23]. Mean organochlorine concentrations recorded were used in computation. Daily exposure to organochlorine through consumption of fish was computed by the following formula:

$$\text{EDI} = \text{mean OC concentration x rate of fish consumption}$$

In estimating the daily exposure, the following assumptions were adapted from the U.S Environmental Protection

Agency's guidelines [24, 25].

1) A hypothetical body weight of 30 kg for children (2 - 11 yrs) and 70 kg for adults.

2) Maximum absorption rate of 100% and a bioavailability rate of 100%.

The estimated daily intake or exposures were then compared to USEPA reference doses.

3.3.2 Cancer hazard ratio

Cancer hazard ratios (HRs) for the organochlorine pollutants in the fish investigated were also estimated by dividing the average daily intake (EDI) or exposure by the cancer benchmark concentrations. A hazard ratio greater than unity (one) indicates that the average exposure level exceeds the benchmark concentration, while HR values less than one indicate exposure level does not exceed benchmark concentration [26]. Carcinogenic HR and cancer benchmark concentration is calculated by the following formulae:

$$\text{Carcinogenic HR} = \frac{\text{estimated daily exposure}}{\text{cancer benchmark conentration}}$$

$$\text{Cancer benchmark concentration} = \frac{\text{cancer risk x body weight}}{\text{rate of fish consumption x cancer slope factor}}$$

where risk is the probability of lifetime cancer risk, which has been put to one in one million (1/1,000,000) of the population by USEPA [26]. Cancer slope factors were obtained from the USEPA Integrated Risk Information System (IRIS) for each pollutant (http://www.epa.gov/iris/). Fish consumption was expressed as daily consumption divided by body weight which was 70 kg for adults and 30 kg for children. Using the estimated cancer benchmark concentrations, carcinogenic HRs were estimated for the pollutants in the fish species.

3.4 Quality control/assurance

Blanks were run to investigate the possibility of interference or contamination. Standards were also run to check column performance and resolution. Internal standards were used for the purpose of recovery evaluation and percentage recoveries were found to be between 95.7 -101.0 %..Accuracy of the determinations, expressed as percentage relative error between the spiked level and the measured values were between - 8.0 – 4.0 % while the precision of the measurements expressed as percentage relative deviation on five independent determinations ranged from 3.4 % to 9.0 %.

3.5 Statistical analysis of data.

Means and their standard deviations were computed for the biometric data for the fish species investigated. Statistical analysis used for the organo chlorine residue concentrations in the samples, included computation of the mean values and corresponding standard deviations. Ranges were compiled from minimum and maximum values for each individual organo chlorine detected. We further subjected the organo chlorine data to one-way analysis of variance (ANOVA) to obtain 95% confidence interval for the mean values, test of significance (Fvalues), and the significance (Pvalues). All tests were regarded as statistically significant when $p < 0.05$. The calculations were performed using statistical software, SPSS version 16.0

4. Results

4.1 Biometric data of the fish samples.

The types of fish species, body length and weight of the fishes investigated are presented in Table 1. The species were *Tilapia zilli*, *Tilapia galilaea*, *Tilapia nile* and *Clarius gariepinus* from Weija Lake as well as *Tilapia bus umana*, *Hemiscromis faciatus* and *Sarotherodon galileu* from Lake Bosomtwi. In Weija Lake, the body lengths and the weights of the species ranged from 12.35 cm to 42.73 cm and 36.56 g to 231.50 g while those from Bosomtwi ranged from 10.60 cm to 16.80 cm and 18.30 g to 68.0 g. Obviously, *Clarius gariepinus* from Weija in terms of length and weight were bigger than other species, while *Sarotherodon galileu* sampled from Lake Bosomtwi was the smallest. Generally, species from Lake Bosomtwi were smaller in size.

4.2 Organo chlorines in fish samples

Results obtained for organo chlorine pollutants in fish species are presented in Table 2 and Table 3. Significant varying levels of organo chlorines were observed among the fish species. Analysis of the organo chlorine concentrations among the species revealed the following pattern: PCBs (sum of all the indicator PCBs) > HCHs (sum of α-HCH, β-HCH, γ-HCH and δ-HCH)> Drins (sum of endrin, dieldrin and aldrin) >Endosulfans (sum of α, β -endosulfan and endosulfan sulfate) ≈ DDTs (sum of p,p'-DDT and p,p'-DDE) in the Lake Bosomtwi fish compartments. In the Weija fish compartment the order of ranking was PCBs (sum of all the indicator PCBs) > HCHs (sum of α-HCH, β-HCH, γ-HCH and δ-HCH)> Drins (sum of endrin, dieldrin and aldrin) > DDTs (sum of p,p'-DDT and p,p'-DDE) >Endosulfans (sum of α, β -endosulfan and endosulfan sulfate). The mean OC concentrations ranged from <0.002 µg/kg to 7.93 µg/kg (SD = ±0.48) and <0.002 µg/kg to 12.17 µg/kg (SD = ± 0.88) in the samples from Bosomtwi and Weija respectively. Descriptive statistical analysis of organochlorine concentrations showed PCB 138 and PCB 52 as OCs with maximum concentrations in the species from Bosomtwi and Weija respectively with respective maximum concentrations of 18.43 µg/kg and 32.40 µg/kg. For the OCs detected, HCHs, heptachlor, aldrin, dieldrin, p,p' –DDE, p,p' –DDD, PCBs 28, PCB 52, PCB 101 were the ubiquitous OC in the fishes from Bosomtwi while HCHs, aldrin, dieldrin, endrin, p,p' –DDE, p,p' –DDD and PCB 28 were the ubiquitous OCs in the samples from Weija. Concentrations PCB 153 in all the samples were below detection limit (<0.02 µg/kg)

Analysis of variance (ANOVA) in most cases indicated statistically significance difference in the concentrations of the OCs detected in the fish samples (P<0.05). However, the differences in concentrations of β-HCH, aldrin in Bosomtwi species and p,p'-DDD in Weija fishes were statistically insignificant (p>0.05).The general statistical differences in mean concentrations suggest that the organochlorines might have reached the study areas through various sources. Occurrence ratio analysis showed that all the isomers of HCH, the drins, p,p'-DDE, p,p' -DDE and the lower homologous PCBs were detected with 100 % occurrence.

Table 1. Biometric Data Of Fishes.

Fish species	n	Length± SD(cm)	Range (cm)	Weight± SD(g)	Range (g)
Tilapia zilli	16	12.35±0.78	11.20 - 13.20	36.58±2.88	22.65 - 43.02
Tilapia galilaea	16	17.73±1.52	16.10 - 19.70	126.63±16.18	110.57 - 152.82
Tilapia nile	12	20.10±1.66	20.10 - 21.22	148.35±17.44	140.58 - 157.60
Clarius gariepinus	14	42.73±5.36	41.50 - 47.50	231.50±20.48	221.70 - 242.80
Tilapia busumana	16	16.80±1.22	17.50 – 15.90	68.0±5.22	64.30 – 71.40
Hemiscrimis faciatus	15	11.60±0.52	11.60±0.52	23.6±1.67	19.50 – 28.60
Sarotherodon galileu	16	10.60±0.56	9.50 – 11.50	18.3±1.34	14.80 – 22.50

n = sample size, SD = standard deviation.

Table 2. Statistical analysis of organochlorine concentrations (µg/kg) in the fish samples from Lake Bosomtwi.

				95 % confidence interval for mean				
Organochlorine	min	max	mean±SD	lower bound	upper bound	Fvalue	Pvalue	x
α – HCH	2.2	4.76	3.48±0.56	2.82	4.14	0.564	<0.05	1.00
β – HCH	3.36	5.79	4.74±0.32	4.20	5.28	0.954	>0.05	1.00
γ – HCH	6.17	8.3	7.20±0.55	6.62	7.73	0.034	>0.05	1.00
δ – HCH	0.62	6.66	2.89±0.46	1.14	4.64	26.59	<0.05	1.00
Heptachlor	6.55	8.85	7.93±0.48	7.35	8.52	2.73	<0.05	1.00
Aldrin	3.04	6.61	4.96±0.28	4.09	5.82	2.25	>0.05	1.00
Chlordane	0.66	17.18	6.27±0.31	0.49	5.37	87.72	<0.05	1.00

α-endosulfan	<0.02	6.88	3.16±0.25	1.03	5.28	164.04	<0.05	0.67
β-endosulfan	<0.02	6.63	1.92±0.07	-0.32	4.17	121	<0.05	0.33
Dieldrin	4.23	10.70	7.31±0.65	5.49	9.13	55.39	<0.05	1.00
Endosulfan sulfate	<0.02	6.06	6.08±0.51	1.27	5.12	44.96	<0.05	0.67
Endrin	<0.02	9.9	3.02±0.16	-0.48	6.51	281.31	<0.05	0.33
p,p-DDT	<0.02	1.33	0.35±0.03	-0.07	0.77	39.43	<0.05	0.33
p,p-DDE	3.35	10.99	7.55±0.45	5.40	9.69	51.06	<0.05	1.00
p,p-DDD	0.38	6.02	3.20±0.81	1.54	4.85	56.41	<0.05	1.00
Methoxychlor	<0.02	6.12	1.93±0.16	-0.29	4.16	1.04E3	<0.05	0.33
PCB 28	4.30	7.85	6.34±0.36	5.44	7.23	8.53	>0.05	1.00
PCB 52	2.35	11.28	6.06±0.47	3.23	8.91	100.87	<0.05	1.00
PCB 101	5.08	8.25	6.40±0.59	5.66	7.27	21.22	>0.05	1.00
PCB 138	<0.02	18.43	5.88±0.27	-0.90	12.67	1.86E3	<0.05	0.67
PCB 153	<0.02	<0.02	<0.02	-	-	-	-	0
PCB 180	<0.02	9.85	2.80±0.29	-0.48	6.08	90.36	<0.05	0.33

x = occurrence ratio, F = test of significance, P = significance, SD = standard deviation. 0.02 µg/kg is detection limit

Table 3. Statistical analysis of organochlorine concentrations (µg/kg) in the fish samples from Weija Lake.

				95 % confidence interval for mean				
Organochlorine	**min**	**max**	**mean±SD**	**lower bound**	**upper bound**	**Fvalue**	**Pvalue**	**x**
α – HCH	0.30	10.27	4.12±0.33	1.73	6.47	117.83	<0.05	1.00
β – HCH	2.21	16.85	9.26±0.48	6.50	12.05	28.06	<0.05	1.00
γ – HCH	7.00	20.8	12.17±0.88	9.07	15.27	53.63	<0.05	1.00
δ – HCH	5.77	12.24	8.61±0.50	7.04	10.16	13.38	>0.05	1.00
Heptachlor	<0.02	18.02	7.25±0.20	3.30	11.21	126.28	<0.05	0.75
Aldrin	0.84	8.24	5.20±0.46	3.24	7.25	148.84	<0.05	1.00
Chlordane	<0.02	5.83	2.36±0.37	0.76	3.96	232.38	<0.05	0.50
α-endosulfan	<0.02	4.66	1.58±0.04	0.36	2.80	173.93	<0.05	0.50
β-endosulfan	<0.02	3.55	0.64±0.03	-0.15	1.43	19.16	<0.05	0.25
Dieldrin	3.00	12.49	7.30±0.57	5.25	9.35	36.48	<0.05	1.00
Endosulfan sulfate	<0.02	10.53	6.03±0.44	3.60	8.47	169.16	<0.05	0.75
Endrin	3.00	6.42	4.74±0.27	4.06	5.42	4.81	>0.05	1.00
p,p-DDT	<0.02	2.44	0.79±0.08	0.13	1.43	22.03	<0.05	0.5
p,p-DDE	1.65	6.94	3.30±0.63	2.19	4.40	19.76	<0.05	1.00
p,p-DDD	2.63	12.02	6.13±0.31	4.54	7.71	3.36	>0.05	1.00
Methoxychlor	<0.02	5.62	1.21±0.09	-0.19	2.63	144.93	<0.05	0.25
PCB 28	<0.02	31.66	11.22±0.88	4.91	12.55	347.04	<0.05	0.75
PCB 52	<0.02	32.40	11.08±0.66	4.85	1240	1.01E3	<0.05	0.75
PCB 101	2.40	13.32	6.76±0.43	4.49	7.96	92.46	<0.05	1.00
PCB 138	<0.02	1.05	0.25±0.05	-0.17	2.14	303.92	<0.05	0.25
PCB 153	<0.02	<0.02	<0.02	-	-	-	-	0
PCB 180	<0.02	0.85	0.18±0.03	-0.11	1.85	121.94	<0.05	0.25

x = occurrence ratio, F = test of significance, P = significance, SD = standard deviation. 0.02 µg/kg is detection limit.

4.3 Potential sources of *organochlorines*

The sources of organochlorine pesticides in the water bodies could be attributed to historical use of these chemicals by farmers. The ratio α-HCH to γ-HCH ranged from 4 to 15 in technical HCH mixtures and from 0.2 to 1.0 in pesticide lindane [27]. In the present study, the ratios are from 0.12 to 0.53 as presented in Table 4. These results therefore, suggest lindane as the principal sources of HCH to the study areas. The ratio DDT/(DDE+DDD) is an indicatio n of how recently fresh DDT has been applied to the environment. The ratio of DDT/(DDE+DDD) is therefore used to assess or estimate if there is recent input of DDT in a study area [28]. If the ratio is greater than one (1) then there is recent or ongoing application of DDT. Analysis of the results showed that the ratios were from 0.09 to 0.19 (Table 4). These values therefore, suggest that there might not be fresh input of DDT in the study areas and that the sources of DDT could be attributed to the past use of DDT and environmental persistence of the chemical. The presence of indicator PCBs could possibly be linked to release to the environment during various anthropogenic processes such as incineration, combustion, smelting and metal reclamation [7, 29, 30]. Even though production of PCBs has been banned globally, significant quantities of these chemicals may still be available, especially in developing countries like Ghana where the importation of old goods of all sorts is still in progress. Old computers, electronics and electrical appliances among other goods are being brought into Ghana on daily basis. Electronic wastes are openly burnt and dumped at uncontrolled locations all over the country and these could contribute to PCBs presence in the environment. Leakages of PCBs from dumped decommissioned transformers and used capacitors into refuse dumps and landfill sites could also have contributed to the sources of PCBs congeners to the Lakes.

Table 4. Ratios of α -hch to γ -hch and ddt to sum of its metabolites.

Fish species	**α -HCH / γ -HCH**	**DDT/(DDE+DDD)**
Tilapia zilli	0.14	--
Tilapia nile	0.12	0.09
Tilapia galilaea	0.36	--
Clarias gariepinus	0.43	0.19
Tilapia busumana	0.47	--
Sarotherodon galileu	0.51	0.10
Hemischromis faciatus	0.53	--

-- DDT level was below detection limit.

Table 5. Estimated daily intake of organochlorines for children (µg/kg body wt) through eating of fishes from the two Lakes.

Organochlorines	Tilapia zilli[a]	Tilapia galilaea [a]	Tilapia nile[a]	Clarius gariepinus[a]	Tilapia busumana[b]	Sarotherodon galileu[b]	Hemischromis faciatus[b]	Reference dose (RfD)
δ -HCH	0.028	0.015	0.018	0.028	0.003	0.003	0.013	3.00
γ -HCH	0.022	0.030	0.017	0.054	0.017	0.016	0.017	0.30
Heptachlor	-	0.009	0.043	0.050	0.017	0.018	0.019	0.10
Aldrin	0.011	0.018	0.002	0.019	0.013	0.007	0.011	0.10
Chlordane	-	0.009	0.013	-	0.017	0.003	0.002	0.50
α-endosulfan	0.009	-	0.005	-	0.008	-	0.016	0.05
Dieldrin	0.028	0.012	0.022	0.008	0.024	0.011	0.017	0.10
Endrin	0.015	0.011	0.008	0.011	0.021	-	-	0.20
p,p-DDT	-	-	0.002	0.006	-	0.002	-	0.50
p,p`-DDE	0.006	0.006	0.004	0.016	0.019	0.025	0.011	0.50
Endosulfan sulfate	0.019	-	0.024	0.015	0.010	0.012	-	0.05
∑PCBs	0.029	0.046	0.050	0.176	0.076	0.063	0.056	0.20

[a] Fishes from Weija Lake, [b] Fishes from Lake Bosomtwi

Table 6. Estimated daily intake of organochlorines for adults (µg/kg body wt) through dietary intake of fishes from the two Lakes.

Organochlorines	Tilapia zilli[a]	Tilapia galilaea [a]	Tilapia nile[a]	Clarius gariepinus[a]	Tilapia busumana[b]	Sarotherodon galileu[b]	Hemischromis faciatus[b]	Reference dose
δ -HCH	0.0139	0.0075	0.0092	0.0139	0.0014	0.0016	0.0067	3.00
γ -HCH	0.0109	0.0151	0.0083	0.0270	0.0083	0.0080	0.0083	0.30
Heptachlor	-	0.0048	0.0217	0.0249	0.0083	0.0092	0.0097	0.10
Aldrin	0.0055	0.0092	0.0011	0.0093	0.0067	0.0035	0.0057	0.10
γ-chlordane	-	0.0047	0.0067	-	0.0082	0.0008	0.0011	0.50
α-endosulfan	0.0049	-	0.0026	-	0.0042	-	0.0078	0.05
Dieldrin	0.0143	0.0059	0.0109	0.0038	0.0122	0.0056	0.0084	0.10
Endrin	0.0073	0.0058	0.0005	0.0057	0.0105	-	-	0.20
p,p-DDT	-	-	0.0011	0.0028	-	0.0012	-	0.50
p,p`-DDE	0.0028	0.0031	0.0021	0.0079	0.0096	0.0125	0.0054	0.50
Endosulfan sulfate	0.0095	-	0.0120	0.0076	0.0051	0.0060	-	0.05
∑PCBs	0.0146	0.0205	0.0248	0.0892	0.0506	0.0318	0.0272	0.20

[a] Fishes from Weija Lake, [b] Fishes from Lake Bosomtwi

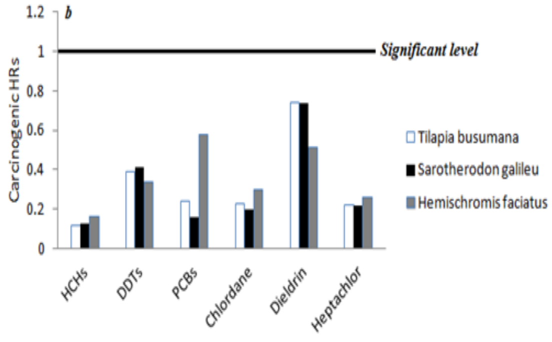
4.4 Human health risk assessment

4.4.1 Estimation of daily exposure to organochlorines through eating of the fishes.

The dietary intake of OCs through consumption of the fish samples were computed by multiplying the individual OC concentration in each fish species by the rate of fish consumption in gramme per kilogramme body weight. Fish consumption is estimated at 68.5 g/day [23]. Mean organochlorine concentrations were used in computation. The daily intake of OCs through dietary consumption of fishes from the study areas are presented in Tables 5 and 6. The estimated daily exposures were compared to USEPA reference doses. The Reference Dose (RfD) is derived from the "no observable adverse effect levels" (NOAEL) and it is reference point from which potential health effects of a chemical pollutant at other doses may be estimated. An aggregate daily exposure to organochlorine residue at or below the RfD is generally considered acceptable by the USEPA [31]. Values for estimated daily intake ranged from 0.002 µg/kg to 0.176 µg/kg and from 0.0011 µg/kg to 0.0892 µg/kg for children and adults respectively. The maximum values (0.176 µg/kg and 0.0892 µg/kg) were estimated for consumption of *Clarias gariepinus* as a result of PCBs contamination.

4.4.2 Estimation of carcinogenic hazard ratio (HR*)*

Carcinogenic hazard ratios (HRs) were computed by dividing the average daily exposure of organochlorine through consumption of fish from the study areas by the carcinogenic benchmark concentrations. A hazard ratio greater than unity (one) indicates that the average exposure level exceeds the cancer benchmark concentration and vice versa [26]. The benchmark concentrations for carcinogenic effect were estimated using USEPA cancer slope factors [32]. Cancer slope factors were obtained from USEPA's Integrated Risk Information System (IRIS), (http://www.epa.gov/iris/). Carcinogenic hazard ratios (HRs) associated with HCHs (γ-HCH + α –HCH + β- HCH + δ- HCH), DDTs (p,p-DDT + p, p –DDE + p,p –DDD), endosulfan (α-endosulfan + β-endosulfan + endosulfan sulfate), heptachlor, γ-chlordane, dieldrin, PCBs expressed as simple fractions with significant levels are presented in Figure 3a and Figure 3b for Weija and Bosomtwi fishes species respectively.



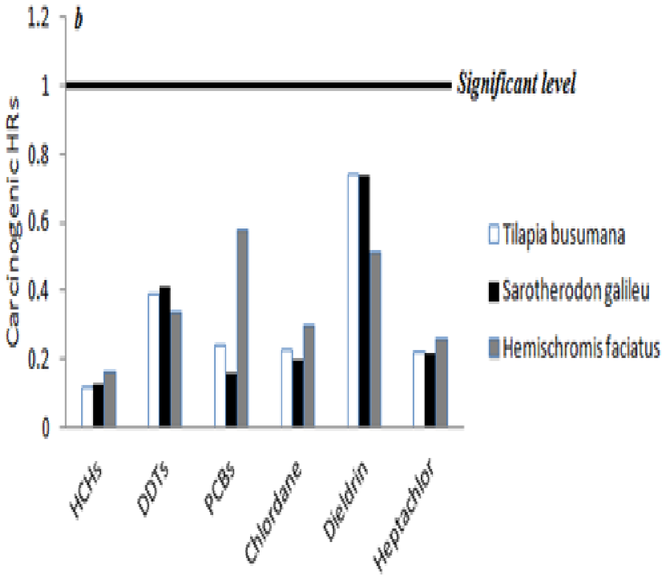


Figure 3a and 3b. cancer hazard ratios on consumption of the studied fishes.

5. Discussion

The results of the present investigation show that significant residues of OCs are still present in the fish species from Lake Bosomtwi and Weija Lake. The results collaborate with those of Kuranchie-Mensah et al [6] and Adu-Kumi et al [8] who had earlier reported varying levels of organochlorine pesticide residues in aquatic species in Weija Lake and Lake Bosomtwi respectively. In general, mean OC concentrations in the Weija fish samples were higher compared to those in Bosomtwi. The Weija Lake is in the coastal area while Lake Bosomtwi is located in forest region of Ghana. The indiscriminate dumping of refuse in coastal areas of Ghana could lead to a high incidence of domestic wastes most especially; plastics litter along the shores of the coast could easily be taken by run-off and tidal waves to the Lake. There is, therefore, fish caught from Weija Lake being contaminated by plastic wastes among others, which might have served as pesticide containers and may be a source of OC pesticides to the coastal environment.

Results of daily exposure showed that consumption of *Clarias gariepinus* among the fishes provided the highest risk of organochlorine exposure. Estimated daily exposure for both children and adults through consumption of the studied fishes however, fell below the USEPA reference doses. The implication is that consumption of the investigated fishes from Lake Bosomtwi and Weija Lake may not pose health risks to humans in terms of OC pollution.

Fig 3a and 3b show cancer hazard ratios (HRs) associated with some of organochlorines on consumption of the studied fishes. From Figure 3a, it is observed that carcinogenic HRs for exposure to DDTs, PCBs, chlordane, heptachlor and dieldrin as a result of eating of *Tilapia zilli*, *Tilapia nile* and *Tilapia galilaea* in the Weija Lake present no risk of carcinogenic effect. However, exposure to HCHs contamination as a result of eating *Clarias gariepinus* has carcinogenic HR greater than 1. The toxicological implication is that more than one in a million of the population on consumption of *Clarias gariepinus* can get cancer. The situation in Bosomtwi (Figure 3b) is quite different as all the cancer HRs values fell below the significant level. Thus, eating of the studied fishes from Lake Bosomtwi will toxicologically not result in carcinogenic effects.

It must however, be emphasized that upon ingestion of fish contaminated with OC, bioavailability of the OC may be controlled by chemical properties of the OC, the biochemical and physiological attributes of the organism. Human factors such as age, sex, social-economic status, diet and state of human health may affect human exposure to organochlorine contamination and these may present some inherent challenges in estimating the risks to human health due to OC exposure.

It must be stated that risk assessment on humans through exposure to organochlorines ought to be performed taking into account fish consumption and other kind of food and water intake. In water ecosystems it would have been relevant to assess the impact of OCs on human through drinking of water from the water bodies. However, in the present study only fish samples were used for the risk assessment since fish is the most important food item consumed from the two water bodies. Furthermore, fish intake is the relevant source of OC exposure due to bioaccumulation and biomagnifications and that exposure through drinking of water is negligible due to low solubility of OCs.

6. Conclusion

The investigation has shown that significant residues of OCs are still present in the fish species from Lake Bosomtwi and Weija Lake. In general, mean OC concentrations in the Weija fish samples were higher compared to those in Bosomtwi. *Clarias gariepinus*, a species from the Weija Lake had more OC concentration than the other species. The species is sediment bound and in such environment it is susceptible to bio-accumulating OCs as sediments serve as sink for OCs. Results of daily exposure showed that consumption of *Clarias gariepinus* provided the highest risk of organo chlorine exposure. Estimated daily exposure for both children and adults through consumption of the studied fishes fell below the USEPA reference doses. Children were found to be more vulnerable compared to adults in term of OC exposure. Organo chlorine exposure analysis showed that for the same quantity of fish consumed children are exposed to more OC than adults and this was attributed to the small body weight of children. Consumption of *Tilapia zilli*, *Tilapia nile* and *Tilapia galilaea* from the Weija Lake present no risk of carcinogenic effect. However, more than one in a million of the population on consumption of *Clarias gariepinus* can get cancer as a result of HCHs contamination. Consumption of the studied fishes from the Lake Bosomtwi presents no carcinogenic effect.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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