Distribution of Organochlorine Pesticide Residues in Surface Water and Sediments of Ogun River at Kara Abattoir, Ogun State, Nigeria

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ABSTRACT

In this study, the levels of organochlorine pesticide (OCPs) in Ogun River, at Kara abattoir were investigated to estimate the extent of pesticide pollution in the river. Two sets of water and sediment samples (A and B) were collected. Samples A were collected in April (during heavy downpour) and samples B in June (under dry weather condition). Most of the physico-chemical parameters in the water and sediment samples were within WHO limits, except the samples taken during heavy downpour. In the water samples, the DDT and metabolites (2.023±0.586 µg/L), endrin (0.671±0.256 µg/L) and aldrin and dieldrin (8.290±2.891 µg/L) exceeded 1 µg/L, 0.6 µg/L and 0.03 µg/L respectively in the WHO (2006) guideline, whereas lindane (0.046±0.034 µg/L) and methoxychlor (0.757±0.281 µg/L) were below 2 µg/L and 20 µg/L respectively in the guideline. OCP residual levels in samples A were much higher than in B. This could be attributed to the massive draining and heavy disturbance of the river during the heavy downpour when samples A were collected.

Keywords: Ogun River, Kara abattoir, Organochlorine pesticides, Water, Sediment

1.0. Introduction

Organochlorine pesticides are synthetic chemicals and among the priority chemicals already banned in several countries including Nigeria (Adeyemi *et al*., 2011). This ban is related to their persistency in the environment, toxicity and biomagnifications along the wider food chain (Chen *et al*., 2021). OCPs exposure have been linked to several body tissue and organ problems including cancers and lower sperm counts in human and animals (Deti *et al*., 2015, Xue *et al*., 2006, Zhou *et al*., 2008). Unfortunately, these chemicals are still in use in many developing countries for agricultural and public health purposes due to their high potency and lower cost compared to alternative pesticides. The presence of OCPs in the environment is typically due to human activities such as discharges of domestic sewage, industrial wastewater, atmospheric deposition, and run-off from agricultural fields (Yang *et al*., 2005).

The drinking water for the animals, as well as the feeds could contain high concentration of lindane according to Sharma *et al*. (2005) and Nag *et al*. (2011). Some studies have already indicated OCPs residues in Nigeria soil, sediments and water (Akinsanya *et al*., 2015, Alani *et al*., 2013, Williams, 2013; Okoya *et al*., 2021). A preliminary study on Ogun River at *Kara* abattoir by Alani *et al*. (2014), revealed high concentration of gamma hexachlorocyclohexane (HCH), lindane and other OCPs in water and sediments of the river. This river is used as the drinking water for the animals waiting to be slaughtered and so could be a contributing source of OCPs residue to the abattoir animals. The surrounding landmass to the river is among the most densely populated areas in the country (Alani *et al*., 2020). As it is generally known with surface waters, Ogun River receives uncontrolled loads of wastes from different sources (as diffuse pollution) and acts as a last resort for waste disposal to the public. The river, already loaded with pollutants from industries and other sources, also serves as a drain for mostly organic wastes particularly from *Kara* abattoir located along the river course (Ikotun *et al*., 2012).

The abattoir wastes include condemned meats, bones, horns, hairs, aborted foetuses, blood, gut contents, urine, dissolved detergents, and faeces. The location of the abattoir along the bank of the river led to an expansion of human settlements in the surrounding environment including butchers and other abattoir workers as settlers. Hence, this study aims to provide information on the levels and distribution of OCPs in the water and sediments of Ogun River at Kara abattoir; and to discuss their contamination profiles and possible sources of certain important OCPs in the river.

2.0. Methodology

2.1. Study area

This study was carried out on Ogun River at locations around *Kara* abattoir in Ogun State, near Lagos, Nigeria (Figure 1 and Plate 1). Ogun River rises in Oyo State near Shaki at coordinates 8°41′0″N 3°28′0″E and flows through Ogun State and discharges into the Ikorodu axis of the Lagos Lagoon at coordinates 6.745589°N 3.34259°E (Alani *et al*., 2014).
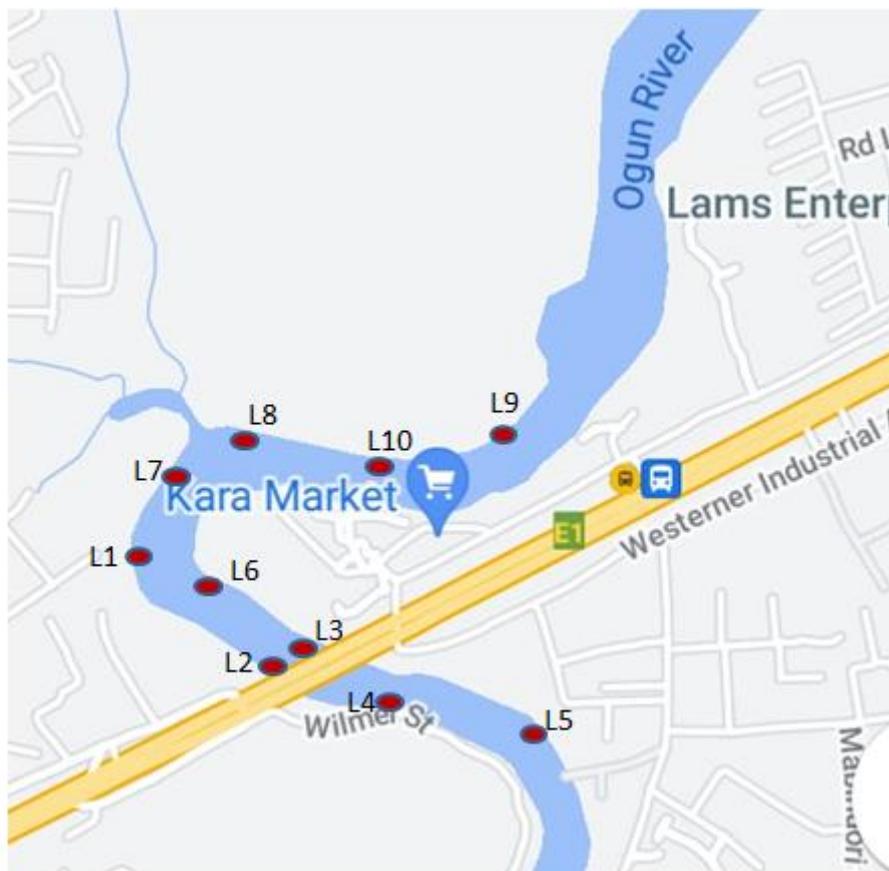

Figure 1: Map of Ogun River at Kara abattoir, showing sample locations

Plate 1: Some deposits of animal wastes at *Kara* abattoir

2.2. Sampling

Two sets of water and sediment samples tagged A and B from 10 locations were taken over a month's interval in Ogun River. The A samples which comprise 10 water and 10 sediment samples were taken in April 2016 after consecutively raining days while B samples, which also comprise 10 water and 10 sediments samples were taken in June 2016, few days without rain, under relatively dry weather.

Table 1: Location descriptions for the samples

SAMPLES	LATITUDE	LONGITUDE
L1	N 6° 38` 47.7``	E 3° 22` 42.8``
L2	N 6° 38` 43.3``	E 3° 22` 50.5``
L3	N 6° 38` 44.2``	E 3° 22` 52.0``
L4	N 6° 38` 41.7``	E 3° 22` 52.9``
L5	N 6° 38` 43.0``	E 3° 22` 58.0``
L6	N 6° 38` 47.4``	E 3° 22` 47.2``
L7	N 6° 38` 49.4``	E 3° 22` 45.4``
L8	N 6° 38` 51.5``	E 3° 22` 46.6``
L9	N 6° 38` 54.5``	E 3° 22` 51.9``
L10	N 6° 38` 53.3``	E 3° 22` 49.6``

2.3. Physico-chemical parameters of water and sediments samples

The 20 water samples were analysed for pH, turbidity, biological oxygen demand (BOD), dissolved oxygen (DO), chemical oxygen demand (COD) and suspended solids. The dissolved oxygen, biological oxygen demand and chemical oxygen demand were determined as described in APHA/AMWA/WEF (1999). The pH, turbidity and total suspended solids were direct reading instruments. The 20 sediment samples were also analysed for pH, moisture contents, and total organic carbon. The pH of each sample was measured with glass electrode pH meter using sediment: calcium chloride slurry ratio 2:1. The pH meter was previously calibrated with phosphate buffer solution at pH 4 and 7. The moisture contents of the sediments were determined gravimetrically using oven set at 105°C. Total organic carbon content was determined by Walkey-Black method (Nelson and Somners, 1996).

2.4. Sample preparation for the chemical analysis

Water samples were extracted by Liquid – Liquid extraction method while the sediment samples were extracted by Soxhlet extraction method. Both extraction procedures involved dichloromethane (DCM) / Hexane (1:1 v/v) (USEPA, 1996a; USEPA, 2000). The recovery study was done by spiking the samples with 8 μL deuterated anthracene as surrogate standard. Recovery obtained was between 71% - 104 %.

2.4.1. Florisil cleanup of sample extracts

Column chromatography was employed for the clean up of sample extracts using Florisil (magnesium silicate) as column. This method is already described in USEPA (2014) and Alani et al., (2013). Sample extracts obtained after florisil cleanup were combined and roto-evaporated to 1mL. The samples were analyzed for OCPs by gas chromatography with an electron capture detector (GC/ECD).

2.4.2. Chemical analysis with GC/ECD

USEPA Method (8081A) was employed for the analyses. The detection and determination of the residues were performed by injecting 1 µL of the 1mL purified extract into the injection port of a gas chromatograph with [63]Ni electron capture detector (GC-µECD Agilent Technology 7890A) equipped with the ChemStation software. The column consisted of a DB-5 fused silica capillary column (30m× 250um × 0.25 µm film thickness). The column temperature was programmed from 50oC at a rate of 25oC/min to 100oC, and held for 1 minute, and then at a rate of 6oC/min to 280oC, held for 5 minutes. The temperatures of the injector and detector were 250oC and 280oC, respectively. The injection was carried out on a splitless injector at 250oC and the purge activation time was 30 seconds. The carrier gas was helium while nitrogen gas was used for the makeup flow. The run time was 17 minutes. Identification of pesticide residues was accomplished using reference standards and relative retention time techniques. The stock solution of the OCPs standards was purchased from Restek Corporation, USA. It contained 1000 ppm in n-hexane and was serially diluted to obtain concentrations of 10, 20 and 40 ng/mL. All the extract samples were analysed for seventeen OCPs comprising: α –, β –, γ –, δ – HCH (Hexachlorocyclohexanes), *p,p'*-DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane), *p,p'* – DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane), *p,p'*-DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene), endrin, endrin aldehyde, endosulfan I, endosulfan II, endosulfan sulphate, endrin, endrin aldehyde, aldrin, dieldrin and methoxychlor. The concentrations of the OCP residues were calculated directly using Chemstation software. The blank analyses confirmed the absence of laboratory derived OCPs at concentration levels above the limit of detention (LOD) and limit of quantification (LOQ) of the OCPs.

2.4.3. Statistical analyses

The mean, standard deviation, and Pearson's correlation matrices were evaluated with Microsoft excel 2008 software. Pearson correlation was considered significant at $p < 0.05$ and $p < 0.01$ (two-tailed). Pearson correlation coefficient

$$ r = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}} $$

Where:
N = the number of pairs of scores
$\sum xy$ = the sum of the products of paired scores
$\sum x$ = the sum of x scores
$\sum y$ = the sum of the y scores
$\sum x^2$ = the sum of the squared x scores
$\sum y^2$ = the sum of the squared y scores

3.0. Results and Discussion

3.1. Physico-chemical parameters of water and sediment samples

The results of the physico-chemical analysis of the water and sediment (Table 2 and Figures 2, 3 & 4) showed great variations in the two sets of samples A and B. This was because of the different conditions (rainy and dry) under which the sampling took place. There was massive draining and heavy disturbance of the river during the heavy rains when samples A were collected. On the other hands the draining was lower and the disturbance of the river was less during under the dry weather when samples B were collected. The results also showed that during heavy rains most of the physico-chemical properties exceeded the WHO limits. Dissolved oxygen (DO) concentrations in unpolluted water normally range between 8 and 10 mg/L and concentrations below 5 mg/L adversely affect aquatic life (Rao, 2005). It was observed that the DO was generally low (10.05 – 11.55 mg/L); the Biochemical Oxygen Demand (BOD) ranging 54- 85 mg/L and Chemical Oxygen Demand (COD) ranging 93.52 - 180.52 mg/L were high, both exceeding the WHO limits of 50 mg/L and 80 mg/L

respectively. According to Cole et al. (1999), oxygen demand results principally from the microbial degradation of organic matter, the high BOD and COD could therefore signify high load of organic pollution, which poses a threat to the aquatic environment by reducing the dissolved oxygen concentration to levels that affect aquatic organisms, human and animals (Morrison, 2001). Higher Total solids (TS) in samples A (1200 – 2800 mg/L) than B (100 – 430 mg/L), exceeding WHO limits of 1000 mg/L confirmed the draining of solid wastes into the river during the rainy period. Total dissolved solids (TDS) in samples A (400 – 1600 mg/L) which were also higher than in samples B (30 – 90 mg/L) also exceeded the WHO limit of 1000 mg/L (WHO, 2017). Transparency values were very poor (0.040 - 0.012 meters for samples A and 0.082 – 0.093 meters for samples B), far below the WHO limit of 1.6 meters. Generally, the pollution status as shown by the physico-chemical parameters was higher in A than B. The total organic carbon and the moisture contents of the sediments (Table 2) also varied greatly because of the different rates of drainage of wastes into the river at the abattoir. The TOC contents were higher in samples A than in B due to higher waste drainage during raining period.

Table 2: Total organic carbon and moisture contents of sediments

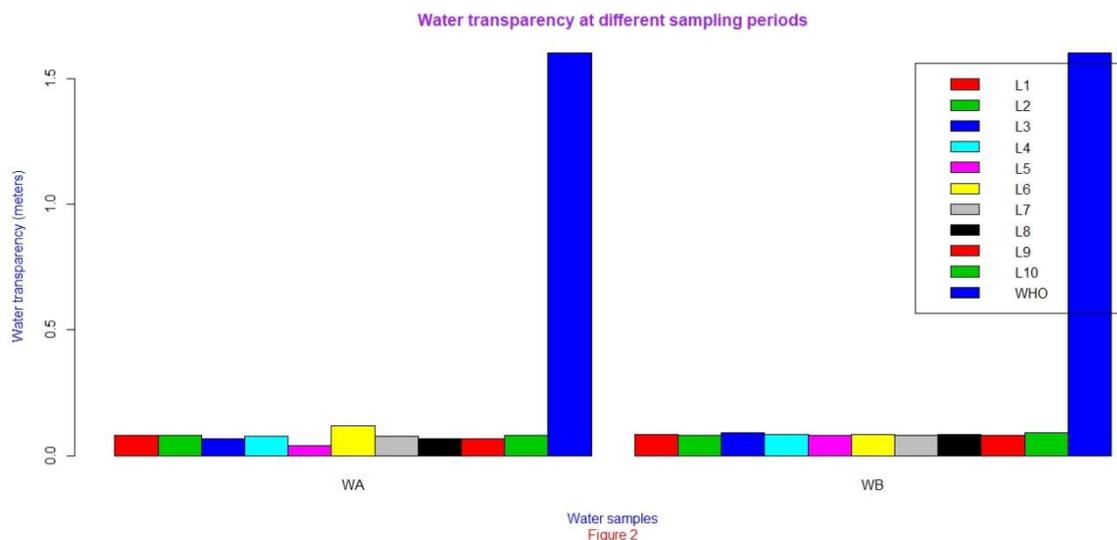| Sediments A	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9	SA10
%TOC	0.76	0.72	0.5	0.38	1.38	0.56	7.49	0.47	0.86	1.48
% Moisture	1.98	1.98	1.07	1.05	2.36	1.23	15.15	0.9	2.09	2.62
Sediments B	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	SB9	SB10
%TOC	0.47	0.21	0.13	0.17	0.09	0.09	0.13	0.26	0.04	0.04
% Moisture	3.96	3.32	2.97	2.29	2.65	1.55	3.77	3.54	2.72	2.82

Figure 2: Water transparency at different sampling periods
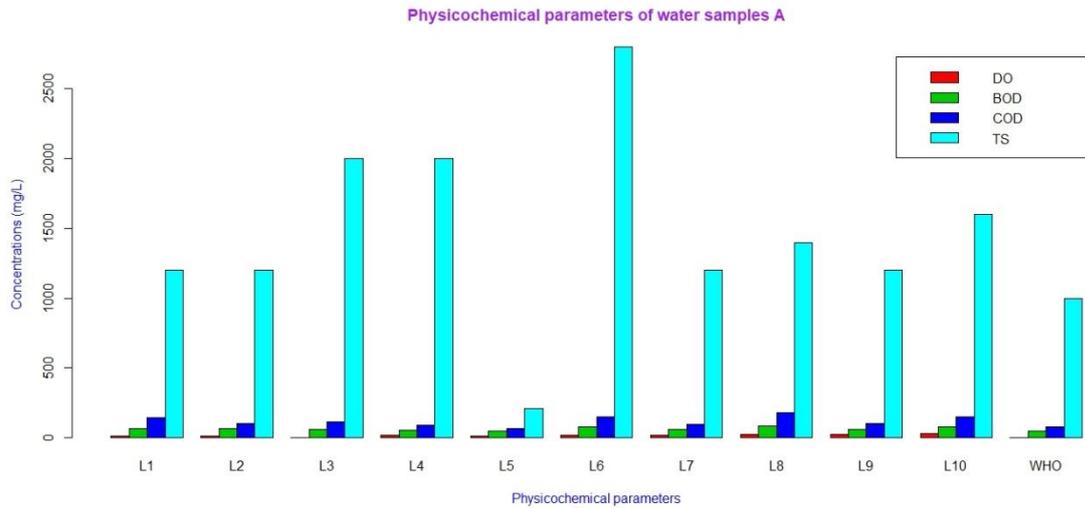
Where L1 to L10 are the sample locations
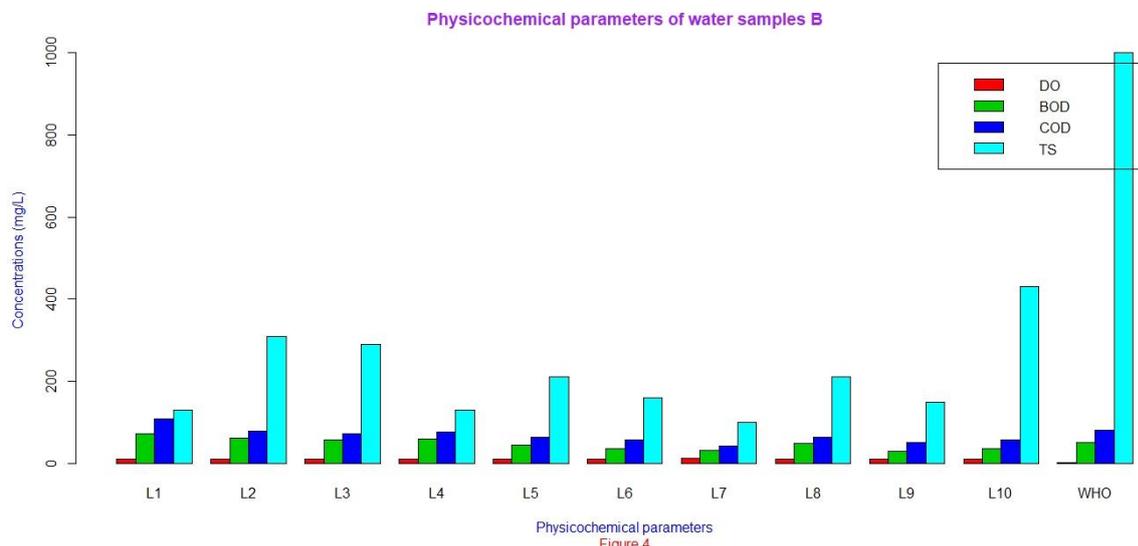
Figure 3: Physiochemical parameters of water samples A

**Figure 4:** Physiochemical parameters of water samples B

3.2. Organochlorine pesticide residues in water and sediment samples

The results for the concentrations of organochlorine pesticides in water and sediment samples are presented in Table 3 and Figure 5. OCP residual levels in samples A were much higher than in B (Table 3) possibly due to high drainage, as well as high-suspended matters resulting from water column disturbance during rains. These results showed that during the heavy rains, the water storm containing OCP residues and the related particles were represented in the water column, thus making the sediment relatively less loaded with OCP residues compare to the water column (Figure 5). This is in agreement with Ejobi et al. (1996) who showed that OCP residues are carried long distances via oceanic currents from where they are manufactured or used. On the other hand, there was less disturbance of the river during the collection of B samples, so slightly hydrophilic OCP residues in the river steadily moved via the river currents while the particulate accumulated OCP residues settled on the sediment, thus making the sediment more polluted than the water column (Figure 5). This observation has shown that OCP residues, when there was no rain, were present in the river but at very low concentrations because of their movements via the river currents, and possibly, through volatilization. Some of the OCP residues could also move from the water and sediment to partition into the lipids of the biota. According to Sarkar et al. (2008), Persistent pollutants such as OCP residues do partition themselves into water, sediment, biota and air base on the physicochemical properties of the ecosystem as well as the partition coefficients of individual OCP residues.

Table 3: OCPs in water and sediments of Ogun River at *Kara* abattoir

OCPs		Water Samples (ug/L) A	B	Sediment Samples (ng/g) A	B
α-HCH	Mean±Std			0.117±0.201	
	Range	ND	ND	(ND - 0.52762)	ND
β-HCH	Mean±Std				
	Range	ND	ND	ND	ND
γ-HCH	Mean±Std	0.046±0.034		0.010±0.033	
	Range	(0.011 - 0.104)	ND	(ND - 0.103)	ND
δ-HCH	Mean±Std	0.111±0.135	0.016±0.001	0.024±0.074	0.001±0.002
	Range	(0.027 - 0.452)	(0.001 - 0.004)	(ND - 0.234)	(ND - 0.006)
∑HCHs	Mean±Std	**0.157±0.162**	**0.002±0.001**	**0.152±0.208**	**0.001±0.002**
	Range	**(0.043-0.547)**	**(ND -0.004)**	**(ND - 0.528)**	**(ND - 0.006)**
P, P'-DDE	Mean±Std	0.202±0.137	0.005±0.001	0.122±0.221	
	Range	(0.112 - 0.559)	(ND - 0.003)	(ND - 0.694)	ND
P,P'-DDD	Mean±Std	0.949±0.376	0.012±0.001	0.145±0.458	
	Range	(0.597- 1.904)	(ND - 0.002)	(ND - 1.449)	ND
P,P'-DDT	Mean±Std	0.872±0.221		0.103±0.308	0.002±0.006
	Range	(0.537 - 1.310)	ND	(ND - 0.980)	(ND - 0.020)
∑ DDTs	Mean±Std	**2.023±0.586**	**0.002±0.002**	**0.370±0.853**	**0.002± 0.006**
	Range	**(1.238 - 3.324)**	**(ND-0.005)**	**(ND- 2.716)**	**(ND-0.003)**
Heptachlor	Mean±Std	0.005±0.0115	0.002±0.001	0.008±0.023	0.007±0.005
	Range	(ND - 0.029)	(ND - 0.002)	(ND - 0.0744)	(ND - 0.012)
Heptachlor epoxide	Mean±Std	0.146±0.068	0.010±0.001	0.064±0.124	
	Range	(0.065 - 0.268)	(ND - 0.004)	(ND - 0.304)	ND
∑ Heptachlors	Mean±Std	**0.151±0.073**	**0.001±0.002**	**0.072±0.124**	**0.007±0.005**
	Range	**(0.065 - 0.268)**	**(ND – 0.004)**	**(ND - 0.304)**	**(ND - 0.012)**
Endosulfan I	Mean±Std	0.226±0.067	0.012±0.002	0.113±0.172	0.008±0.008
	Range	(0.160 - 0.320)	(ND - 0.005)	(0.016 - 0.460)	(ND - 0.016)
Endosulfan II	Mean±Std	100.449±40.270		17.153±51.458	0.002±0.006
	Range	(40.483 - 201.502)	ND	(ND - 154.374)	(ND - 0.020)
Endosulfan sulphate	Mean±Std	24.692±7.670		4.275±13.518	0.021±0.066
	Range	(14.663 - 41.521)	ND	(ND - 42.749)	(ND - 0.210)
∑ Endosulfans	Mean±Std	**125.366±40.596**	**0.001±0.002**	**19.826±62.437**	**0.031±0.069**
	Range	**(82.165 - 231.735)**	**(ND – 0.005)**	**(0.017 – 197.524)**	**(ND-0.226)**
Endrin	Mean±Std	0.671±0.256	0.002±0.002	0.104±0.327	0.001±0.003
	Range	(0.436 - 1.329)	(ND - 0.005)	(ND - 1.035)	(ND - 1.014)
Endrin aldehyde	Mean±Std	8.779 ±3.362	0.003±0.001	1.375±4.270	0.017±0.010
	Range	(5.480 - 17.693)	(ND - 0.003)	(ND - 13.527)	(ND - 0.025)
∑ Endrins	Mean±Std	**9.449±3.610**	**0.002±0.002**	**1.480±4.597**	**0.018±0.011**
	Range	**(7.068 - 19.022)**	**(ND - 0.006)**	**(ND - 14.562)**	**(ND - 0.029)**
Aldrin	Mean±Std	0.059±0.063		0.025±0.053	0.001±0.002
	Range	(ND - 0.189)	ND	(ND - 0.061)	(ND - 0.004)
Dieldrin	Mean±Std	8.231±2.837	0.018±0.016	24.232±40.898	0.382±0.506
	Range	(5.792 - 15.862)	(ND - 0.047)	(0.020 - 120.584)	(ND - 1.239)
∑ Aldrins	**Mean±Std**	**8.290±2.891**	**0.002±0.002**	**24.257±40.907**	**0.383±0.508**
	Range	**(5.797 - 16.051)**	**(ND - 0.047)**	**(0.022 – 120.645)**	**(ND – 1.243)**
Methoxychlor	Mean±Std	0.757±0.281		0.173±0.541	
	Range	(0.111-1.099)	ND	(ND -1.713)	ND
Sum	Mean±Std	146.193±24.482	48.045±6.918	0.442±0.092	0.027±0.004

*Bold: Sum of individual OCPs
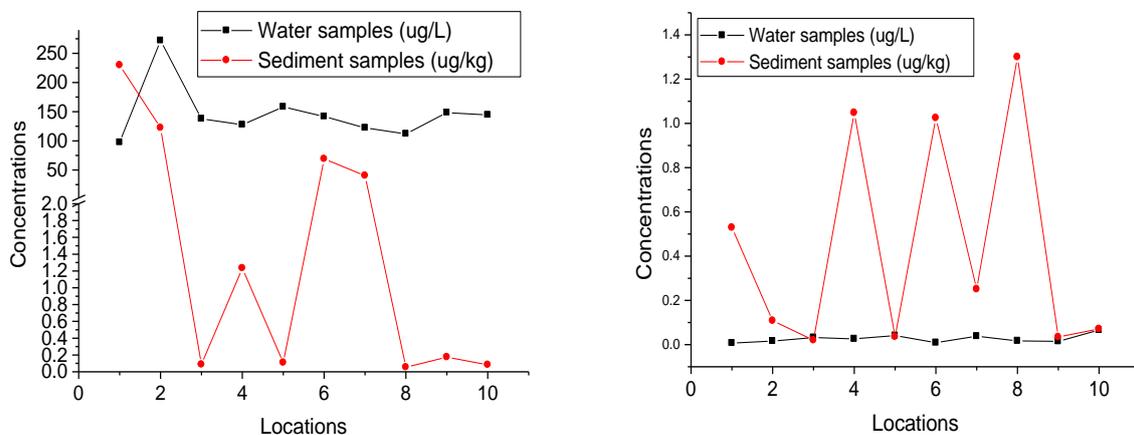
a. Samples set A   **b.** Samples set B
Figure 5: Spatial relationships of the ∑ OCPs in water and sediment locations

From Pearson correlation matrix, positive correlation was not observed between the mean OCP residues in water samples A and B (r = - 0.199, p > 0.05). This reflects the variability of OCP residue levels in samples A and B resulting from water column. However, there was a level of correlations of OCP residues in the sediment samples A and B (r = +0.777, p > 0.05). Positive correlation was observed between the mean OCPs in water A samples and the corresponding sediment samples (r = +0.589, p > 0.05). This confirms the role of the sediments as a major sink of pollutants (Doong et al., 2002, Hiller et al., 2011). According to Doong et al. (2002), persistency of OCP residues in sediment is possible due to their low solubilities in water and tendency to be adsorbed on suspended particulate matter and benthic sediments. Positive correlations were not however observed when mean concentrations of OCP residues in sediment B was correlated with mean OCPs in water A (r = -0.051, p > 0.05) and water B (r = +0.321, p > 0.05) samples. This indicated that the water was not a leading contributor of OCPs when the rain subsided, biota and larger particles not captured during the water samplings were projected as the leading sources. It is also worth noting that the concentrations of sediment B, OCP residues found were much lower than the corresponding OCPs in water B. In water samples A, endosulfan II (100.449±40.270 μg/kg) was the most abundant OCP while dieldrin (0.018±0.016 μg/kg) was the most abundant OCP in water samples B. Dieldrin was the most abundant OCP in both sediments A (24.232±40.898 μg/kg) and B (0.382±0.506 μg/kg). In the water A samples, the DDT and metabolites (2.023±0.586 μg/L), endrin (0.671±0.256 μg/L) and aldrin and dieldrin (8.290±2.891 μg/L) exceeded 1 μg/L, 0.6 μg/L and 0.03 μg/L respectively in the WHO (2006) guidelines, whereas lindane (0.046±0.034 μg/L) and methoxychlor (0.757±0.281 μg/L) were below 2 μg/L and 20 μg/L respectively in the guidelines. In the water B samples, the DDT and metabolites, endrin, and aldrin and dieldrin, lindane and methoxychlor were below the guidelines. The order of the mean OCPs were: water A, ∑Endosulfans (125.366±40.596 μg/kg) > ∑Endrins (9.449±3.610 μg/kg) > ∑Aldrins (8.290±2.891 μg/kg) > ∑DDTs (2.023±0.586 μg/kg) > Methoxychlor (0.757±0.281 μg/kg) > ∑HCHs (0.157±0.162 μg/kg) > ∑Heptachlors (0.151±0.073 μg/kg); water B, ∑Endrins (0.002±0.002 μg/kg) = ∑Aldrins (0.002±0.002 μg/kg) = ∑DDTs (0.002±0.002 μg/kg) = ∑HCHs (0.002±0.001 μg/kg) < ∑Endosulfans (0.001±0.002 μg/kg) = ∑Heptachlors (0.001±0.002 μg/kg). Sediments A, ∑Aldrins (24.257±40.907 μg/kg) >∑Endosulfans (19.826±62.437 μg/kg) > ∑Endrins (1.480±4.597 μg/kg) > μg/kg) > ∑DDTs (0.370±0.853 μg/kg) > Methoxychlor (0.173±0.541 μg/kg) > ∑HCHs (0.152±0.208 μg/kg) > ∑Heptachlors (0.072±0.124 μg/kg) and sediments B ∑Aldrins (0.383±0.508 μg/kg) > ∑Endosulfans (0.031±0.069 μg/kg) > ∑Endrins (0.018±0.011 μg/kg) > μg/kg) > ∑DDTs (0.370±0.853 μg/kg) > Methoxychlor (0.173±0.541 μg/kg) > ∑HCHs (0.152±0.208 μg/kg) > ∑Heptachlors (0.007±0.005 μg/kg).

3.3. Sources of Organochlorine Pesticides (OCPs) in water and sediment samples

The contents of the technical DDT predominantly contained the parent *p, p'*- DDT at about 80 – 85 %. It is known that the percentage of the parent *p, p'*- DDT decreases with time while the percentage of the metabolites comprising *p, p'*- DDD and *p, p'*- DDE increase (Doong et al., 2002; Sun et al., 2010). The ratio (*p, p'*- DDE + *p, p'*- DDD) / ∑DDT have therefore been used to project the sources of the OCPs in the environment. When this ratio is > 0.5, the sources are considered to be from age related use. When the ratio is < 0.5, there is an indication of fresh sources (Eqani et al., 2011, Yang et al., 2005, Zhou et al., 2008). In the sediment A samples, the ratio exceeded 0.5 in locations 1 – 4, 6 and 9 but was below the value in locations 5, 8 and 10; while in location 7, no DDT related OCP residues was found. These observations could be interpreted for a recent input of DDT in location 5, 8 and 9. In the water A samples, the ratio exceeded 0.5 in all locations except locations 4, 8 and 9. It can therefore be suggested that there was a fresh input of DDT in the locations 4, 8 and 9. In the B sediment, no DDT related OCP residues was found except in locations where only the parent *p, p'*- DDT was found indicating a fresh input. In the B water samples, no *p, p'*- DDT was found and this may indicate historical input of DDT during the sampling period. *p, p'*- DDT can be biodegraded to *p, p'*- DDE under aerobic conditions, and to *p, p'*- DDD under an anaerobic conditions. The degradation pattern of the OCPs can therefore be determined from the ratio *p, p'*- DDD / *p, p'* – DDE (Chen et al., 2011). When the ratio is > 1, the major product is *p, p'*- DDD suggesting that the routes of degradation is anaerobic. But if the ratio is < 1, the major degrading product is *p, p'*- DDE, suggesting that the degrading route is aerobic. In sediment A samples, the ratio was above 1 in location 1, but since DDD was not found in other locations, it can be assumed that the degradation pattern in the locations were aerobic. In the water A samples, the ratio in all the samples were greater than 1 indicating an anaerobic degradation route. No DDT metabolite was found in the B sediment samples. The

degradation for DDT in the B water samples can only be interpreted in locations 2, 9 and 10 because neither DDE nor DDD was found in other locations. Locations 2 and 10 indicated anaerobic routes while 9 indicated aerobic routes. The predominance of the heptachlor epoxide in the two set of water samples over the parent heptachlor (Table 4) may also indicate aged related use of the OCPs in the environment. This observation is similar for endrins, aldrins and endosulfans but fresh sources could be indicated in water B samples for endosulfan since the metabolites of endosulfan was not found in any of the water samples. In the sediment A, the heptachlor metabolite, heptachlor epoxide, was more predominant than the parent compound (Table 3) and this could be interpreted as age related usage of the OCPs. The reverse was however observed in location 2. In the sediment B samples, no heptachlor epoxide was found and heptachlor was found in 7 locations indicating a freshly usage in the 7 locations. This observation was similar to the water B sample where the metabolite was only found in 1 location. The predominance of endosulfan II over endosulfan I in the water A samples may also indicate a age related input. Endosulfan I was predominants over the two metabolites in the sediment B samples, the sulphate was only found in location 7 in higher level (0.210 µg/kg), suggesting that aside of location 7, there is a likely fresh input of endosulfan in the environment. Endrin aldehyde was predominant in the two set of sediments samples likely indicating an age related usage. Similar observation was done with Aldrins. Since methoxychlor was found only in A (water and sediment), there is a tendency of recent use of methoxychlor. The ratio α – HCH / γ- HCH is used to investigate the distribution pattern of the HCH in the environment since α – HCH and γ- HCH are expected to be transformed to β – HCH which is the more stable form (Wurl and Philip, 2005). The non-detection of the α – HCH in all the samples and the detection of γ- HCH which contain about 99% of lindane (Zhou et al., 2008), may suggest that lindane is the major source of the HCHs.

3.4. Comparison of OCPs found in water and sediment samples with other similar studies

The study on ∑HCH for water samples during the raining period (Table 3) was lower than the reports on Pearl river, China (0.213–3.116 µg/L) (Yu et al., 2008), Bahe River, China (nd–0.74 µg/L), Huaihe River, China (1.95–6.23 µg/L), Meriç Delta, Turkey (0.466 - 1.127 µg/L), Da-han river, Taiwan (nd–2.08 µg/L), Singapore (2.2–11.9 µg/L) and Agboyi Creek, Nigeria (2.5 – 17.0 2.2–11.9 µg/L); but comparable to the Nsawam, Ghana (0.04–1.07 µg/L) (Table 4). The study on ∑DDT in the same period is comparable to the Pearl river (0.228–3.284 µg/L), Bahe River, China (nd–7.51 µg/L) but lower than the reports in Huaihe River, China (4.07–17.04 µg/L), Ruzin reservoir, Slovakia (4.6–27.8 µg/L), and Agboyi Creek, Nigeria (3.0 - 14.0 µg/L); higher than the reports in Meriç Delta, Turkey (nd – 1.01 µg/L), Nsawam, Ghana (nd – 0.02 µg/L), Da-han river, and Taiwan (0.06–2.91 µg/L) (Table 4). The reports of ∑HCH on sediments studies   (nd - 0.528 µg/kg) (Table 3) were lower compared to the study on Pearl river, China (0.181–1.388 µg/kg), Huaihe River, China (1.95 - 11.05 µg/kg), Meriç Delta, Turkey (0.406 - 3.243 µg/kg), Singapore (2.2–11.9 µg/kg), Bahe River, China (nd–1.02 µg/kg), and Nsawam, Ghana (0.04–1.04 µg/kg) Table 4. The study of ∑DDT on the sediment samples (nd - 2.716 µg/kg) (Table 3) was comparable to Pearl river, China (0.057–2.244 µg/kg) and Meriç Delta, Turkey (0.524 -2.837 µg/kg) but higher than the reports on Bahe River, China (nd–0.29 µg/kg), Nsawam, Ghana (0.04–1.04 µg/kg), lower than the reports on Huaihe River, China (4.07 -23.89 µg/kg), Singapore (3.4–46.1 µg/kg), and Agboyi Creek, Nigeria (58.6 - 279.0 µg/kg) (Table 4).

Table 4: Comparison of OCPs in this study and other similar studies

Study location	Sample type	∑ HCH (µg/kg) Mean (Range)	∑ DDT (µg/kg) Mean (Range)	Reference
Pearl River, China	River	0.213–3.116	0.228–3.284	Yu et al., 2008
	Sediment	0.181–1.388	0.057–2.244	
Bahe River, China	River	0.25 (ND–0.74)	1.27 (ND –7.51)	Lu and Liu, 2016
	Sediment	0.27 (ND –1.02)	0.10 (ND –0.29)	
Huaihe River, China	River	3.98 (1.95–6.23)	9.16 (4.07–17.04)	Sun et al., 2010
	Sediment	4.53 (1.95 - 11.05)	11.07 (4.07 -23.89)	
Meriç Delta, Turkey	River	0.61 (0.466 - 1.127)	0.52 (ND – 1.01)	Erkmen and Kolankaya, 2006
	Sediment	2.303 (0.406 - 3.243)	1.704 (0.524 -2.837)	
Nsawam, Ghana	River	0.183 (0.04–1.07)	0.015 (ND – 0.02)	Kuranchie-Mensah *et al.*, 2012.
	Sediment	0.703 (0.04–1.04)	0.758 (0.04–1.04)	
Da-han river, Taiwan	River	0.39 (ND –2.08)	0.90 (0.06–2.91)	Doong et al., 2002
	Sediment	-	-	
Ruzin reservoir, Slovakia	River	-	4.6–27.8	Hiller et al., 2011
	Sediment	-	-	
Singapore	River	-	-	Wurl and Philip, 2005.
	Sediment	18.1(2.2–11.9)	6.7(3.4–46.1)	
Agboyi Creek, Nigeria	River	2.5 – 17.0	3.0 – 14.0	Williams, 2013
	Sediment	182.6 - 208.5	58.6 – 279.0	
Lagos Lagoon, Nigeria	River	-	0.005-0.169 [c]	Adeyemi et al., 2011
	Sediment	-	-	
Kara, Ogun river, Nigeria	River	0.157(0.043-0.547)	2.023(1.238 - 3.324)	This Study
	Sediment	0.152 (ND - 0.528)	0.370 (ND - 2.716)	
Kara, Ogun river, Nigeria	River	0.002 (ND -0.004)	0.002(ND -0.005)	This Study
	Sediment	0.001 (ND - 0.006)	0.002(ND -0.003)	

4.0. Conclusions

The study concludes that there are great variations in the pollution level of Ogun River water and sediment at *Kara* abattoir during different annual seasonal weather conditions (rainy and dry seasons). During heavy rains most of the physico-chemical properties exceeded the WHO limits. Total organic carbon and the moisture contents of the sediments also varied greatly because of the different rates of drainage of wastes from the abattoir into the river. The TOC contents were higher during heavy rains (samples A) than in the relatively dry period (samples B). OCP residual levels in samples A were much higher than in B possibly due to high drainage, as well as high-suspended matters resulting from water column disturbance during rains. These results showed that during the heavy rains, the water storm containing OCP residues and the related particles were more in the water column, thus making the sediment relatively less loaded with OCP residues compared to the water column. It is therefore very unsafe to feed the animals with the water from this river and especially for use in the meat product processing. The animals drinking from this river during heavy rains are more exposed to OCPs and so are the humans that feed on the meat products at this season. It would be safer to find alternative good quality drinking water for the animals at *Kara* abattoir, as well as for use in processing the meat products from this abattoir to avoid the health risks associated with OCP contamination of foods.

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