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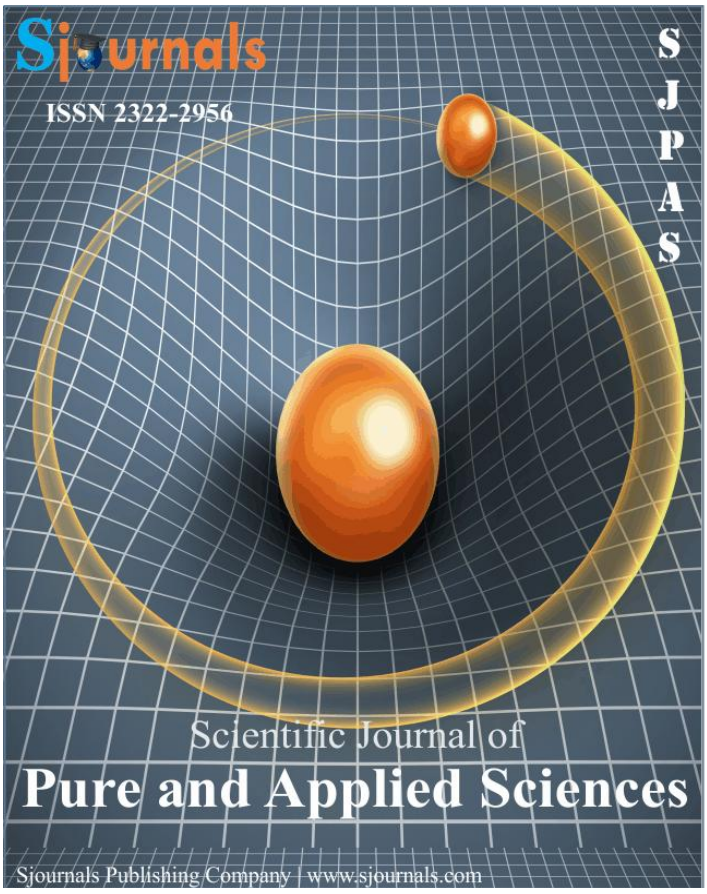

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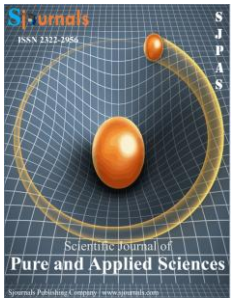

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Original article

Consideration of organochlorine pesticide levels in water, sediment and fish from Ethiope River at Sapele, Delta State, Nigeria

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ABSTRACT

Water, sediment and fish samples from the Ethiope River at Sapele in the Niger Delta region of Nigeria were collected and analyzed for organochlorine pesticide (OCPs) with the aim of ascertaining the level of concentration and distribution of the organochlorine content for the purpose of safe guarding organisms in these matrices. Samples from the three matrices: water, sediment, fish (*T. Zilli*) were collected in December (dry season) and July (rainy season). 26 OCPs was set out to be investigated, but only 21 was detected. Results from this study revealed the presence of 21 organochlorine pesticide (OCPs) of varying concentrations across the three matrices in Ethiope River. The hazard quotient (HQ) values for all studied site were all between 1 and 10 (1.66, 1.84), this was indicative of moderate hazard contamination; however, that of the bioaccumulation index (BI) for the fish were all greater than 1 (72.426 and 144.996) for rainy and dry season respectively. The distribution of organochlorine pesticides could be associated with land-use practices including agriculture and urbanization. The results suggest the need for sustained monitoring of importation, distribution, usage and disposal of OCPs.

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1. Introduction

Organochlorine pesticides (OCPs) are chlorine-containing compounds which are found in the environment as the result of human activities (Idowu et al., 2013; Ssebugere et al., 2013, 2014; Olutona et al., 2016). They are generally regarded as any substance or mixture of substances intended for: preventing, destroying, repelling or mitigating any pest. Pesticides are the only group of chemicals that are purposely applied to the environment with the aim to suppress plant and animal pests and to protect agricultural and industrial products. General survey revealed the intentions of farmers and other user of pesticides was to eliminate or destroy harmful insect to crops. The continuous use of organochlorine pesticide in farmland allows the persistent organochlorine pesticides in the environment (Idowu et al., 2013; Olutona et al., 2016).

Organochlorine pesticides enter aquatic environment from a variety of sources, including the atmosphere, industrial and municipal effluents, agriculture and urban nonpoint-source runoff. Most especially, in the Niger Delta region of Delta State, the chemicals are washed off into water bodies by rain, flood accompanied by poor drainage system and subsequently transported through soil erosion and surface runoff. Fundamental studies reveal that organochlorine pesticides typically have low solubility and are mostly associated with bottom sediments, which could be ingested by benthic organisms (Jayaraj et al., 2016; Osesua et al., 2017). These organisms are then eaten by fish and birds, which can result in higher concentrations through aquatic and terrestrial food chains. Many organochlorine pesticides are known animal carcinogens and are potential human carcinogens (Osesua et al., 2017).

Pesticides have adverse effects on the environment, especially when they are leached into the soil, thus resulting to soil and water contamination. Many organochlorine pesticides have been linked to hormone disruption and reproductive problems in aquatic invertebrates, fish, birds and mammals (Brockmeier et al., 2013; Kumar and Holt, 2014; Jayaraj et al., 2016). These effects, combined with a slow rate of breakdown, make many organochlorine pesticides a long-term environmental concern. Literature revealed that the long term applications of pesticide have adverse effects on soil microbes which possibly have a significant impact on function of whole terrestrial and aquatic ecosystem (Jayaraj et al., 2016). Nigeria has a strong and growing agricultural sector, which requires increased and wide use of pesticides (Alufohai and Oyoboh, 2013).

In Nigeria OCPs find applications for agricultural purposes and especially for the control of pest including mosquitoes (Golfinopoulos et al., 2003; Ahmed et al., 2015). This study was aimed at estimating the levels, distributions and concentrations of OCPs in water, sediment and fish samples from the Ethiope River, Sapele, a river in the Niger Delta region of Nigeria with an extensive screening of twenty six (26) OCPs in the water, sediment and fish (*T. zilli*) from these matrices.

2. Materials and methods

2.1. Study area

The study area was River Ethiope in Sapele in the Niger Delta area of Delta State, Nigeria, which is the second largest Delta in the world and the largest mangrove swamps in Africa. It spans over 20,000 square kilometers. The Niger Delta region is located at latitudes $5^{o}31^{'}$N and $5^{o}33^{'}$N and longitudes $5^{o}30^{'}$E and $5^{o}32^{'}$E. The Niger Delta covers an area of 70,000 km^2 of marshland, creeks and tributaries that drains the River Niger into the gulf of Guinea in the Atlantic Ocean. The coastal region cuts across nine (9) states in southern Nigeria. This region has an estimated population of over 30 million people, with fishing and farming as the main source of livelihood and sustenance. Economic activities include oil and gas exploration and exploitation, fishing industries, agriculture and tourism.

2.2. Sampling

Samples were collected from Ethiope River, at the Sapele axis during the dry season (December, 2012) and wet season (July, 2013). A total of 72 samples made up of 24 samples each for water, sediment and fish (*T. zilli*) were collected and analyzed. Twenty-six (26) components of organochlorine pesticides were investigated in this study. The grab sampling technique was employed for the collection of all the water samples at about 1 m below surface using a 1.0 L amber bottle. The samples were collected, the pH of the water samples was recorded immediately using a portable pH meter, and then kept at <4°C until further analysis.

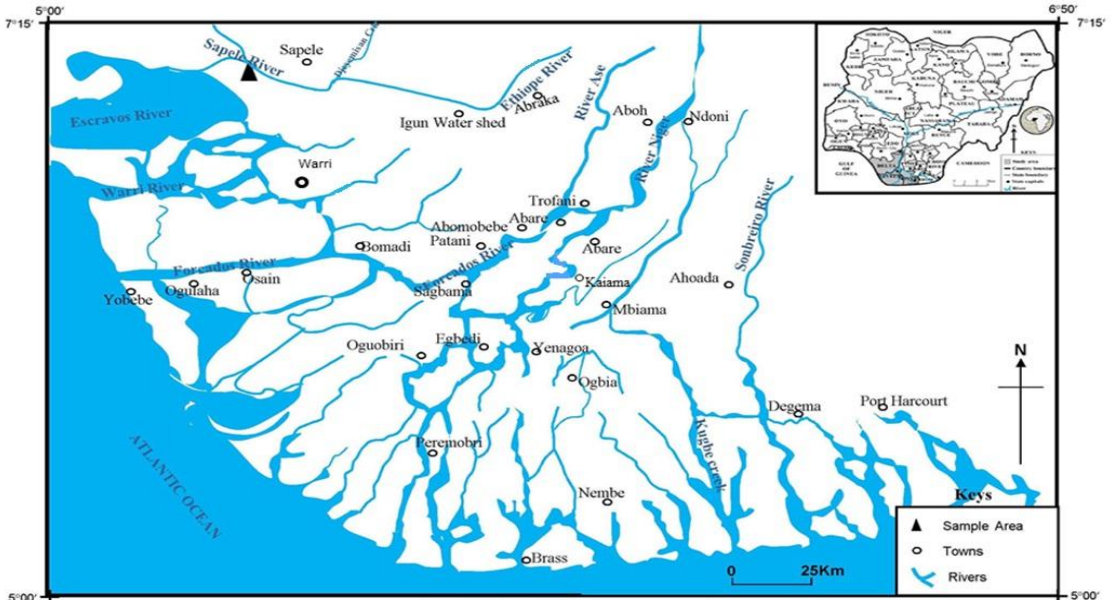

Fig. 1. Map of Southern Nigeria showing sampling location (Ethiope River) (Modified after Ministry of Lands, Survey and Urban Development, Abuja, 2008).

2.3. Sediment samples

The sediment samples were air dried, sieved through a 2 mm mesh and then 50 g of sample was accurately measured. Twenty (20) ± 0.5 g sodium sulphate were then added. The samples were spiked with PCB Nr. 209 and tetramethylxylene (TMX) (surrogates) (Ehrenstofer, Germany). Two hundred (200) mL of cyclohexane: acetone mixture (50:50) was used for the extraction. The sample was then sonicated for about 20 minutes and then transferred to a mechanical shaker for about one hour. Aliquots of the extract were then taken for analysis. Extraction efficiency, as indicated by recovery of the surrogate standards (TMX), was consistent at 98± 2%.

2.4. Water samples

One (1) L water sample was measured into a calibrated Erlenmeyer flask and 1 mL internal standard (ISTD) spike solution (2.5 µL 1-Br-Dodecane in 250 mL Cyclohexane) 50 µL PCB Nr. 209 + 50 µL TMX (surrogates) + 5 mL cyclohexane were then added. Liquid/Liquid Extraction (LLE) was carried out for one hour (Maier, 2011). The solvent extract was then transferred into a 10 mL vial and gently reduced to 1 mL using nitrogen gas (99%).

2.5. Sample clean up

Sample clean-up was carried out on the water sample extract using silica based Solid Phase Extraction (SPE) cartridges. A combined double effect Isolute1g FL 712-0100-C (Biotage, Sweden) and Resprep 500 mg carboprep 90 (Restek, USA) SPE cartridge was used as previously reported by Maier (Maier, 2011; Bylda et al., 2014). The cartridges were pre-conditioned using 10 mL of the cyclohexane: acetone (99: 1) under very low vacuum condition (0.51 psi). One (1) mL extract was introduced directly unto the cartridge and eluted with 50 mL of (cyclohexane: acetone). The collected eluent was then concentrated with the aid of a rotary evaporator (BuchiSyncore, SWISS) to ~3 mL and then reduced with nitrogen gas (Bylda et al., 2014).

2.6. Analytical determination

A five point calibration curve using internal standard was prepared to determine the concentrations of organochlorines in the different samples. Laboratory and method blanks were also carried out simultaneously to ensure good Quality Assurance and Quality Control (QA/QC) and also to eliminate any background contamination.

2.7. Data analysis and statistics

Statistical analysis was carried out using SPSS Version 21. A two-way ANOVA between groups was conducted to explore the variation in OCPs between the matrices. Concentrations were represented as mean (±) SD for

quantitative data and frequency and proportion for qualitative data representation. Pictorial representation was shown as histogram and column charts. Similarly, on the environmental significance of the apparent elevated levels of OCPs in the Niger Delta region, evaluation was made in terms of bioaccumulation index and hazard quotient.

3. Results and discussion

The results for this research are shown in Tables 1-5 with pictorial representations in figures 2-3.

Table 1
Distribution of organochlorine pesticides in water, sediment and fish samples in River Ethiope at Sapele (rainy season).

S/N	Pesticide	Water (µg/L)	Sediment (µg/kg)	Fish (µg/kg)
1	α-HCH	<0.001	<0.001	16.00 ± 1.00
2	β-HCH	<0.001	<0.001	1.00 ± 0.00
3	δ-HCH	0.015 ± 0.010	2.00 ± 0.00	14.00 ± 1.00
4	ε-HCH	<0.001	1.00 ± 0.00	2.00 ± 0.00
5	γ-HCH	0.410 ± 0.030	28.00 ± 1.00	21.00 ± 0.00
6	ΣHCH	0.425 ± 0.040	31.00 ± 1.00	54.00 ± 2.00
7	HCB	<0.001	15.00 ± 1.00	10.00 ± 0.00
8	Heptachlor	0.040 ± 0.000	<0.001	<0.001
9	γ-heptachlor	0.020 ± 0.000	<0.001	<0.001
10	t-chlordane	0.010 ± 0.000	<0.001	<0.001
11	Endrin	0.010 ± 0.000	2.00 ± 0.00	<0.001
12	Aldrin	0.510 ± 0.010	2.00 ± 0.00	<0.001
13	o,p'-DDD	0.070 ± 0.000	<0.001	52.00 ± 0.00
14	p,p'-DDD	0.494 ± 0.000	2.00 ± 0.00	<0.001
15	o,p'-DDE	<0.001	1.00 ± 0.00	2.00 ± 0.00
16	p,p'-DDE	0.010 ± 0.000	1.00 ± 0.00	40.00 ± 0.00
17	o,p'-DDT	0.140 ± 0.000	10.00 ± 0.00	3.00 ± 0.00
18	p,p'-DDT	0.540 ± 0.000	2.00 ± 0.00	3.00 ± 0.00
19	ΣDDT	1.254 ± 0.000	16.00 ± 0.00	100.00 ± 0.00
20	Endrinaldehyde	0.011 ± 0.000	1.00 ± 0.00	1.00 ± 0.00
21	Endrinketone	0.012 ± 0.000	2.00 ± 0.00	1.00 ± 0.00
Total		2.292 ± 0.050	69.00 ± 2.00	166.00 ± 3.00

Values represent mean ± SD (n= 3).

The results from Table 1 revealed that OCPs like p,p'-DDT, Aldrin, p,p'-DDD and γ-HCH were found to have the highest levels in the water sample, while γ-HCH and HCB had the highest levels of the sediment samples collected in the rainy season. The fish samples collected in the rainy season showed a high predominance levels of o,p'-DDD, pp'-DDE, γ, α, δ-HCH. Fish was found to show higher levels of the pesticides than water and sediment from the location. Of the nineteen OCPs found in the rainy season, fourteen OCPs were found in the water sample while thirteen were detected in the sediment and fish. The rainy season sample recorded mean concentrations of 2.292 ± 0.050 µg/L, 69.000 ± 2.000 µg/kg and 166.000 ± 3.000 µg/kg for water, sediment and fish.

ΣHCH and ΣDDT were determined of the sediment, water and fish samples for both sampling seasons. For the water samples ΣHCH concentrations was found to be lower than the concentration reported in the Yellow River (1.10 µg/L) by Li et al. (2015), Ebro River (3.38 µg/L) by Fernandez et al. (1999) and Illushi River (4.89 µg/L) by Ogbeide et al. (2016). Total DDT concentrations in the sediment samples from the study area ranged from below detectable limit to 5.00 µg/kg with an average of 1.83 µg/kg. Comparison of the concentrations obtained for the rainy and dry season showed that the dry season fish samples were the most contaminated. The same can also be said for the sediment sample as the ΣOCPs values recorded for the dry season was higher than the rainy seasons. The value for the water sample followed an alternate route as the rainy season values for the ΣOCPs recorded was

higher than the dry season. This was in accordance with the studies of Ukpadhi and Wokoma (2012); Williams (2013) and Yuan et al. (2013). The total OCPs in the study sites for the three matrices are shown in Fig. 2.

Table 2
Distribution of organochlorine pesticides in water, sediment and fish samples in River Ethiope at Sapele (dry season).

S/N	Pesticide	Water (µg/L)	Sediment (µg/kg)	Fish (µg/kg)
1	α-HCH	<0.001	1.00 ± 0.00	17.00 ± 0.00
2	β-HCH	<0.001	<0.001	6.00 ± 0.00
3	δ-HCH	0.020 ± 0.010	1.00 ± 0.00	30.00 ± 1.00
4	ε-HCH	<0.001	1.00 ± 0.00	5.00 ± 0.00
5	γ-HCH	0.193 ± 0.050	12.00 ± 1.00	13.00 ± 0.00
6	ΣHCH	0.213 ± 0.060	14.00 ± 1.00	71.00 ± 1.00
7	HCB	0.032 ± 0.010	2.00 ± 0.00	13.00 ± 0.00
8	Heptachlor	0.053 ± 0.010	<0.001	<0.001
9	γ-heptachlor	0.033 ± 0.010	<0.001	<0.001
10	Endrin	0.010 ± 0.000	20.00 ± 1.00	2.00 ± 0.00
11	Aldrin	0.683 ± 0.080	14.00 ± 1.00	11.00 ± 0.00
12	o,p'-DDD	0.027 ± 0.020	2.00 ± 0.00	39.00 ± 1.00
13	p,p'-DDD	<0.001	1.00 ± 0.00	<0.001
14	o,p'-DDE	<0.001	2.00 ± 0.00	28.00 ± 1.00
15	p,p'-DDE	0.033 ± 0.010	10.00 ± 0.00	17.00 ± 0.00
16	o,p'-DDT	0.120 ± 0.020	3.00 ± 0.00	2.00 ± 0.00
17	p,p'-DDT	<0.001	1.00 ± 0.00	<0.001
18	ΣDDT	0.18 ± 0.030	19.00 ± 0.00	86.00 ± 1.00
29	Endrinaldehyde	0.015 ± 0.000	1.00 ± 0.00	<0.001
20	Endrinketone	0.010 ± 0.000	2.00 ± 0.00	1.00 ± 0.00
21	Dieldrin	0.040 ± 0.020	4.00 ± 0.00	<0.001
Total		1.269 ± 0.240	76.00 ± 2.00	184.00 ± 3.00

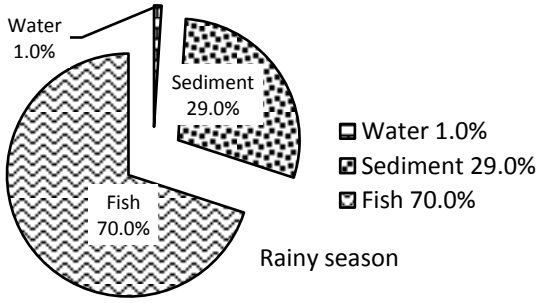

Fig. 2. Mean total percentage distribution of OCPs in the three matrices for dry season.

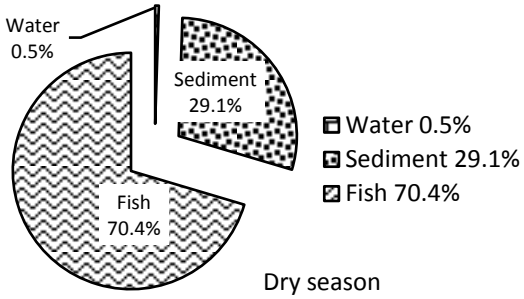

Fig. 3. Mean total percentage distribution of OCPs in the three matrices for dry season.

DDT is typically composed of 77.1% p, p'-DDT, 14.9% o, p'-DDT, 4% p, p'-DDE and some other trace impurities. In this study, o, p'-DDT was the predominant component obtained in the sediment, fish and water samples during the rainy season (Table 2). However, for the dry season, p, p'-DDT was predominant for the sediment samples only while the same trend was obtained as above for the water and fish samples. Generally, the o, p'-DDT/p, p'-DDT ratio ranged from 0.2 to 0.3 µg/kg in technical DDTs and from 1.3 to 9.3 µg/kg or higher in dicofol (Dalia et al., 2013; Qui et al., 2005). Therefore, sources of DDTs (from technical DDT or dicofol impurities or both) can be identified according to the ratio of o, p'-DDT/p, p'-DDT. In this study, the ratios of o, p'-DDT/p, p'-DDT in water, fish and sediment samples were 8.50, 0.01, and 4.00, respectively for the rainy season and 7.15, 3.00 for the respective matrix for the dry season, indicating dicofol as the major source of DDT concentration reported. DDT degrades to DDE and DDD in aerobic and anaerobic conditions, respectively. In general, a ratio of (DDE + DDD)/DDTs of more than 0.5 indicates long-term biotransformation of DDT to DDE and DDD, while a ratio of less than 0.5 may indicate recent input of DDT (Li et al., 2015). The ratios of (DDE + DDD)/DDTs in the Ethiope River was found to be 0.63, 0.29, 9.25 for water, sediment, and fish samples, respectively for rainy season and 0.53, 1.2 and 0.8 respectively for the dry season. The finding that all values except sediment samples for rainy season were higher than 0.5 indicating that the DDT compounds in Ethiope River may be mainly derived from DDT-treated aged and weathered agricultural sources as similarly reported by Li et al. (2015).

Moreover, a higher ratio of p, p-DDE/p, p-DDT can be used to indicate the long range atmospheric transport of DDT compounds because p, p-DDE is transported more efficiently than p, p-DDT. This ratio can also be used to establish if the DDT emission occurred recently or in history. The ratios of p, p-DDE/p, p-DDT varied from 1.5 to 16 in the multiple environments of the river studied, indicating that the DDTs in this area may also come from atmospheric deposition. Thus, the concentration of DDT obtained from the Ethiope River is as a result of the dicofol use from agricultural activities and also from atmospheric deposition. The relatively high detection rates of DDT indicated that a small amount of DDT input may still occur in this area despite the ban. γ-HCH was found to be the predominant isomer in the water, fish and sediment samples in both the dry season and rainy season (Tables 1 and 2).

Table 3

Correlation coefficient for various organochlorines pesticides during rainy season.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	1																		
B	1	1																	
C	0.99136	0.99136	1																
D	0.866025	0.866025	0.924127	1															
E	0.273539	0.273539	0.397342	0.717822	1														
F	0.188982	0.188982	0.316154	0.654654	0.996223	1													
G	-0.5	-0.5	-0.60928	-0.86603	-0.96977	-0.94491	1												
H	-0.5	-0.5	-0.60928	-0.86603	-0.96977	-0.94491	1	1											
I	-0.5	-0.5	-0.60928	-0.86603	-0.96977	-0.94491	1	1	1										
K	-0.50375	-0.50375	-0.38609	-0.00434	0.693104	0.75308	-0.49624	-0.49624	-0.49624	1									
L	-0.69721	-0.69721	-0.59716	-0.24537	0.49881	0.572187	-0.27222	-0.27222	-0.27222	0.970485	1								
M	0.999999	0.999999	0.991206	0.865442	0.272417	0.187837	-0.49899	-0.49899	-0.49899	-0.50476	-0.69805	1							
M	-0.69107	-0.69107	-0.59029	-0.23709	0.506187	0.579164	-0.28042	-0.28042	-0.28042	0.972508	0.999964	-0.69191	1						
N	0.866025	0.866025	0.924127	1	0.717822	0.654654	-0.86603	-0.86603	-0.86603	-0.00434	-0.24537	0.865442	-0.23709	1					
O	0.999764	0.999764	0.993973	0.876673	0.29435	0.21025	-0.51868	-0.51868	-0.51868	-0.48489	-0.68149	0.999738	-0.67522	0.876673	1				
P	-0.23559	-0.23559	-0.10608	0.281896	0.870342	0.909817	-0.72385	-0.72385	-0.72385	0.958212	0.860945	-0.23673	0.865254	0.281896	-0.21445	1			
Q	0.807354	0.807354	0.877777	0.994223	0.788405	0.73201	-0.91469	-0.91469	-0.91469	0.103019	-0.1399	0.806665	-0.13144	0.994223	0.81997	0.383251	1		
R	0.5	0.5	0.609275	0.866025	0.969766	0.944911	-1	-1	-1	0.496236	0.272218	0.498989	0.280418	0.866025	0.518678	0.723852	0.91469	1	
S	-0.00348	-0.00348	0.127713	0.496979	0.960902	0.981316	-0.86428	-0.86428	-0.86428	0.865597	0.719291	-0.00465	0.725192	0.496979	0.018219	0.972667	0.58725	0.864278	1

A=α-HCH, B=β-HCH, C=δ-HCH, D=ε-HCH, E=γ-HCH, F=Endrin, G=Heptachlor, H=γ-heptachlor, I=HCB, J=Aldrin, K=Dieldrin, L=o, p-DDD, M=p,p'-DDD, N=p,p'-DDE, O=o,p-DDE, P=o,p-DDT, Q=p,p'-DDT, R=Endrinaldehyde, S=Endrinketon.

Table 3 and 4 show the correlation analysis obtained by comparing each analyte for the three matrices. During the dry season, strong positive correlation was obtained for Endrinketone and p, p'-DDT, o, p-DDD and o, p-DDT, Heptachlor and γ-heptachlor while in rainy season α-HCH and β-HCH, Heptachlo and H=γ-heptachlor, Heptachlor and HCB, γ-heptachlor and HCB, ε-HCH and p, p'-DDE. The strong positive correlation revealed that the introductions of the organochlorines into the different matrices are from similar source.

Table 4
Correlation coefficient for various organochlorines pesticides during dry season.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	1																		
B	0.998625	1																	
C	0.99972	0.999586	1																
D	0.990536	0.981981	0.987011	1															
E	0.602229	0.559557	0.583168	0.706101	1														
F	0.996057	0.990038	0.993679	0.998807	0.670678	1													
G	-0.5447	-0.5	-0.52471	-0.65465	-0.99753	-0.61696	1												
H	-0.5447	-0.5	-0.52471	-0.65465	-0.99753	-0.61696	1	1											
I	-0.37155	-0.4197	-0.39342	-0.24061	0.517415	-0.28772	-0.57621	-0.57621	1										
J	0.35192	0.302374	0.32967	0.477062	0.959191	0.433572	-0.97667	-0.97667	0.738266	1									
K	0.999972	0.99899	0.999869	0.989481	0.596234	0.995365	-0.53841	-0.53841	-0.37849	0.344901	1								
L	-0.45392	-0.5	-0.47488	-0.32733	0.437976	-0.37308	-0.5	-0.5	0.995909	0.674299	-0.46058	1							
M	0.999932	0.997949	0.999377	0.992065	0.611467	0.997021	-0.55442	-0.55442	-0.36073	0.362776	0.999817	-0.44353	1						
N	0.840939	0.81142	0.827898	0.907252	0.938434	0.88563	-0.91187	-0.91187	0.18994	0.802457	0.836864	0.10045	0.847172	1					
O	0.225108	0.17373	0.201988	0.356708	0.9134	0.310659	-0.93972	-0.93972	0.820944	0.991226	0.217807	0.765991	0.236418	0.716543	1				
P	-0.45392	-0.5	-0.47488	-0.32733	0.437976	-0.37308	-0.5	-0.5	0.995909	0.674299	-0.46058	1	-0.44353	0.10045	0.765991	1			
Q	-0.46554	-0.51129	-0.48636	-0.33967	0.426173	-0.38519	-0.48862	-0.48862	0.994642	0.664577	-0.47216	0.999914	-0.45522	0.08742	0.757512	0.9999	1		
R	0.049517	-0.0029	0.025867	0.186132	0.827165	0.137928	-0.86457	-0.86457	0.908875	0.952308	0.042037	0.867472	0.061123	0.582107	0.984285	0.8675	0.860887	1	
S	-0.46166	-0.50752	-0.48252	-0.33554	0.430135	-0.38114	-0.49244	-0.49244	0.995085	0.667846	-0.46829	0.999962	-0.45132	0.091787	0.760367	1	0.99999	0.86311	1

A=α-HCH, B=β-HCH, C=δ-HCH, D=ε-HCH, E=γ-HCH, F=Endrin, G=Heptachlor, H=γ-heptachlor, I=HCB, J=Aldrin, K=Dieldrin, L= o,p-DDD, M= p,p′-DDD, N=p,p′-DDE, O=o,p-DDE, P=o,p-DDT, Q=p,p′-DDT, R=Endrinaldehyde, S=Endrinketone.

The hazard quotient (HQ) analysis carried out on the fish sample for both the rainy and dry season revealed that the fishes were contaminated and possess the possibility of ecological concern to the inhabitants of the sample location (Table 5). The HQ approach compares environmental concentrations of a contaminant with the measured effect or no-effect level in test organisms (Lemly, 1996).

Ratings for HQ:
HQ = <0.1 - no hazard exists
HQ = 0.1 - 1.0 - hazard is low
HQ = 1.1 - 10, hazard is moderate
HQ = > 10, hazard is high

Values of HQ obtained for the both the rainy and dry season where found to be in the range 1-10 indicating that the hazard was moderate.

Table 5
Hazard quotient for fish.

	ΣOCPs Concentration mg/kg	**HQ**
Rainy		
Toxicity	0.166	1.66
Reference level	0.1	
Dry		
Toxicity	0.184	1.84
Reference level	0.1	
Average	0.175	1.75
Reference level	0.1	

Table 6 displays the output of the bioaccumulation index (BI) of the fish samples in the sample site which showed that the fishes where not suitable for consumption as at the time of sampling with all the BI values greater than 1 (>1).

Table 6
Bioaccumulation index for fish.

	ΣOCPs Concentration		
	Fish	**Water**	**BI**
Rainy season	166	2.292	72.426
Dry season	184	1.269	144.996
Average	175	1.781	98.259

4. Conclusion

Organochlorine pesticides, which accumulate in stream bed sediments and in tissues of aquatic invertebrates and fish, continue to persist in aquatic ecosystems in the Ethiope River in the Niger Delta region of Nigeria. This study revealed clear presence of nineteen OCPs at varying concentrations across three matrices: water, sediment, fish (*T. Zilli*) in Ethiope River. The hazard quotient (HQ) values for all studied site were all between 1 and 10 (1.66, 1.84), this is indicative of moderate hazard contamination; but that of the BI for the fish were all >1 (72.426 and 144.996 for rainy and dry season respectively). These results suggest the need for sustained monitoring of importation, distribution, agricultural use and disposal of the OCPs.

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