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Organochlorine pesticide residues in fish (*Alestes baremoze* and *Synodontis bastiani*) from Warri River, Nigeria: Levels and human exposure assessment

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Abstract

Organochlorine pesticides are among the group of agrochemicals with the potential for bioaccumulation in fish posing great threat to human health through fish consumption. In view of this, organochlorine pesticide residues (OCPs) were analysed in the muscle tissue of two freshwater fish species; *Alestes baremoze* and *Synodontis bastiani* from selected stations along Warri River, Nigeria, with the aim of assessing the human health risk associated with consumption. The fish were collected from landing sites located at Ovwian and Okwagbe communities along the Warri River. These communities are agrarian catchment areas with intensive pesticide use. Pesticides were analysed using Gas Chromatography (GC) equipped with electron capture detector (GC-ECD), while human risk assessment was carried out using human intake models. Results for pesticide analysis revealed that the concentrations of mean pesticide residues ranged from 0 to 0.0017 mg/kg in *A. baremoze* and 0 to 0.0014 mg/kg in *S. bastiani*. γ-HCH was the most commonly detected compound in *A. baremoze* and it accounted for 47.1% of the total pesticide residues in the fish, while α-HCH was the most dominant pesticide in *S. bastiani* accounting for 28.4% of the total pesticide residues in the fish samples. *S. bastiani* was the more contaminated of the two fish species; however, concentrations were not significantly higher (p>0.05). Results of the human health risk assessment from consumption of contaminated fish (*A. baremoze* and *S. bastiani*) raise the concern of possible carcinogenic health risk from exposure to pesticides through consumption of fish species.

Keywords: *Alestes baremoze*, Fish, Human exposure implications, Organochlorine pesticides, *Synodontis bastiani*

Introduction

Organochlorine pesticides (OCPs) are persistent organic pollutants which have caused global concern as toxic environmental contaminants (Covacia *et al.,* 2005). OCPs are ubiquitous, hydrophobic and lipophilic contaminants with the potential for bioaccumulation in aquatic organisms especially fish, through food chain transfer (Afful *et al.,* 2010). Fish can absorb these pesticides directly from water or by ingesting contaminated food (Teklit, 2016) and could pose potential human health hazards when consumed (Fianko *et al*., 2011). Varying levels of organochlorine residues have been reported in fish (Tongo *et al*., 2014; Ezemonye *et al*., 2015; Fianko *et al*., 2011) with different fish species varying greatly

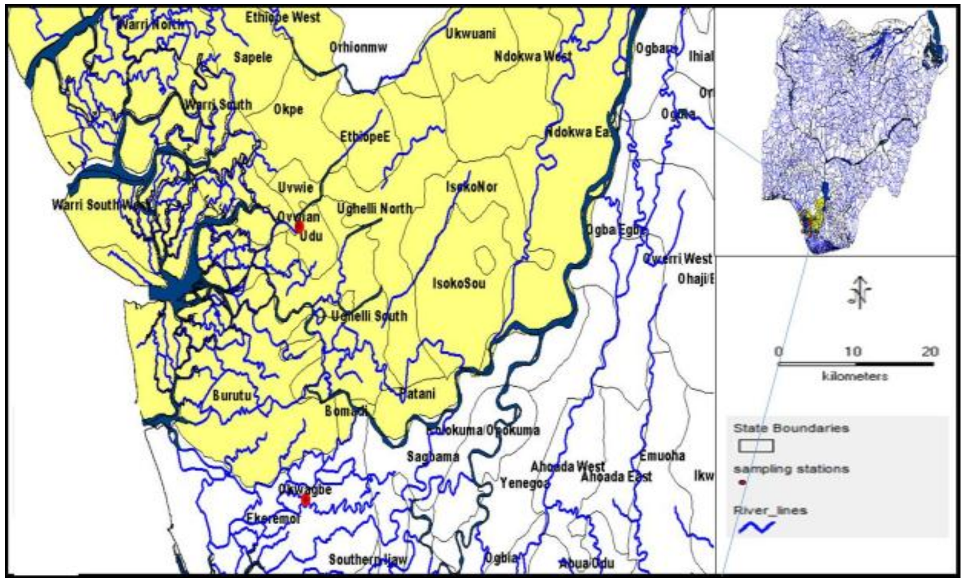

Figure I: Map of study area showing sampling stations

both in their susceptibility to OCPs and in their ability to store residues in their tissues (Johnson *et al.* 1973). Many of these OCPs and their respective metabolites have been implicated in a wide range of adverse environmental and human health effects (Edwards, 1987; Adeyemi *et al*., 2008). Fish consumption has been identified as an important route of human exposure to pesticides (USEPA, 1998). Since fishes are important sources of proteins and lipids for humans, contaminants in fish can pose health concerns to consumers. In fact, fish and seafoods have been identified as being the group with the most significant dietary contributors of pesticides into the human body (Törnkvist *et al*., 2011). The potential health implications of OCP exposures have been observed in increasing cases of cancer, chronic kidney diseases, sterility in both males and females, endocrine disorders, neurological and behavioural disorders (Abhilash & Singh, 2009).

Several studies investigating the residual levels of pesticides in environmental media have reported hazardous concentrations in water, sediments and biota samples including fish (Okoya *et al*., 2013; Williams, 2013; Tongo *et al*., 2014), however, only a few studies have assessed the associated risks to human health from exposure to pesticide through fish consumption. Recent studies indicate that exposure to pesticide contaminants in food may pose a public health risk (Teklit, 2016). MacIntosh *et al.* (1996) reported exposure of adult populations to pesticide contaminants in foods at concentrations above thresholds of concern. Ezemonye *et al.* (2015) observed that consumption of pesticide-contaminated fish species (*Clarias gariepinus and Tilapia zilli)* from rivers around agrarian areas could lead to potential health risks of population groups. This study was therefore carried out to assess the levels of ten OCPs (Alpha-Hexachlorocyclohexane (α-HCH), Beta-*Hexachlorocyclohexane (β-HCH),* Gamma- Gamma-hexachlorocyclohexane (*γ-HCH) (lindane),* Heptachlor, Aldrin, Heptachlor Epoxide, Endosulfan, Dieldrin, Endrin and Dichlorodiphenyltrichloroethane (DDT) in muscle tissues of two freshwater fish species: *Alestes baremoze* and *Synodontis bastiani* from selected stations along Warri River with the aim of assessing the human health risk associated with consumption.

Materials and Methods

Study area

Warri River is an ecological and economically important coastal river in Delta State, Nigeria. The banks of the river are characterised by intensive agricultural activities, in which farmers make use of an array of pesticidPes especially OCPs for the control of weeds, insect and animal pests. Two sampling stations along the stretch of the Warri River were selected for the study: Ovwian (05° 29.875′ N and 005° 46.901′E) and Okwagbe (05° 21.186′ N and 005° 47.799′E) (Figure I). These stations are catchments for intensive agricultural activities with extensive pesticide use. The communities around these stations are famous for the production of palm oil/palm kernel, cassava, and rubber. Most of the people in these communities are fishermen who depend on the fishes caught from the river as an important source of their daily protein needs and also as their source of income, as the fishes caught are sold in major markets in Delta State and negbouring states.

Sample collection

A total of 12 each of two freshwater fish species: *Alestes baremoze* and *Synodontis bastiani* were collected for a period of 6 months. The fishes were caught using fishing gears (cast nets, gill net). The fishes collected were wrapped in aluminum foil, labelled, placed in polyethylene bags and then stored in ice and transported to the laboratory in polythene bags for analysis. Fish samples were refrigerated at 4 °C until extraction (Ezemonye *et al*., 2008).

Analytical procedures

The muscle tissues of fish samples were analyzed for OCPs. The muscle tissues were weighed and homogenized using a blender. 10g of the homogenized samples were then mixed with 100 ml of acetone and homogenized again for 20 min. Extraction was done using a Soxhlet extractor for approximately 25 min using a solvent mix (hexane/dichloromethane mixture (1:1, v/v). The sample was sonicated for about an hour and the extracts obtained were concentrated to about 10ml using the rotatory evaporator (Steinwandter, 1992). The concentrated extracts were cleaned using the florisil solid phase extraction (SPE) method. The cleaned extracts were transferred to a florisil column and eluted with an 80 mL eluting mixture (15 % hexane). Elutes were then concentrated and made into 1 mL with hexane. Samples were then transferred into vial bottles for gas chromatographic analysis (USEPA 2007). Gas chromatographic analysis was carried out to determine the concentrations of OCP residues in the fish samples using a Hewlett-Packard (hp) 5890 Series II, equipped with Ni electron capture detector (ECD). The carrier and makeup gas was nitrogen maintained at a constant flow rate of 1.0 and 29 ml/min.

Quality assurance and validation of analytical procedures

Samples were subjected to stringent quality control procedures. Instrumental calibration was performed prior to the sample analysis using standard OCP pesticide mixture consisting of the analytes. Qualitative and quantitative analysis was achieved by comparing the retention time and peak area of the sample, respectively, with those of the calibrated OCP reference standards. The recovery assays for pesticides were carried out using samples spiked the working standard mixture of OCPs. This was followed by extraction, cleanup, and analytical procedures as previously described above. The recoveries of OCPs were determined by comparing the retention time and peak area of the sample with the OCP reference standard residues obtained from the extract after spiking. The percentage recovery was then evaluated (Steinwandter, 1992). The percentage of recoveries of the OCPs ranged from 85 to 90%. The method detection limits (MDL) and limit of quantification (LOQ) were determined from the curve obtained from the recovery studies (Su, 1998). The MDLs of OCPs were described a signal to noise ratio (S/N) of 3. The MDL was equivalent to the LOQ with the value of 0.01 µg/kg for each of the pesticides assessed.

Assessment of human health risk

The assessment of risk to human health through dietary consumption of contaminated fish was carried out using standard human health risk models (USEPA, 1996). The assessment was carried out for adults (70kg) population for both non-carcinogenic and carcinogenic health risks. The estimated daily intake, hazard quotient (HQ) and hazard index (HI) were used to assess the risk of human exposure through fish consumption. The description and values of parameters used for the various estimations are presented in Table 1.

The estimated daily intakes (EDI) (mg/kg/day) of OCPs in the fish samples were estimated using Equation 1, while non-carcinogenic and carcinogenic health risks were assessed using Equations 2 to 4.

$$\text{Estimated Daily Intake (EDI)} = \frac{Cf\ X\ IFR}{BW} \qquad \textit{Equation 1}$$

$$\text{Hazard Quotient } (HQ_{\text{non-carcinogenic}}) = \frac{EDI}{RfD} \qquad \textit{Equation 2}$$

Table 1: Parameters used for estimating exposure assessment through Fish Consumption

Parameters	Unit	Value	Reference
Mean concentration of OCPs (Cf)	mg/kg-fish	Table 2	Table 2
Reference Dose (RfD)	mg/kg/day	USEPA, 1993	USEPA (1993)
Fish ingestion rate *(IFR)*	Kg/capita/day	0.055 (Freshwater Fish)	FAO (2014)
Adult body weight (*BW*)	kg	70	Tongo *et al*. (2015)
Oral Slope Factor *(SF)*	mg/kg/day	US EPA 2005	USEPA (2005)
Safety Benchmark	-	1×10^{-6}	USEPA (2005)

Hazard Quotient ($HQ_{carcinogenic}$) $= EDI \ X \ SF$ *Equation 3*

$$HI_{non\text{-}carcinogenic\ /\ carcinogenic} = \sum_{i=1}^{n} HQi$$ *Equation 4*

Where EDI-Estimated Daily Intake, Cf = Mean concentration of OCPs in fish (mg/kg), IFR = Fish ingestion rate (Kg/capita/day), RfD = Reference Dose (mg/kg/day), SF= Oral Slope Factor (mg/kg/day).

Statistical analysis

The data were analysed for statistical significance using one-way analysis of variance (ANOVA) to compare OCPs between the fish species and across sampling stations at 0.05 level of probability.

Results

Mean concentrations of OCPs in the fish species and water are presented in Table 2. Varying concentrations of OCPs were quantified in water and in the muscle tissues of the two assessed fish species. Nine OCPs (α-HCH, γ-HCH, β-HCH, Heptachlor, Aldrin, Heptachlor epoxide, Endosulfan, Dieldrin, and Endrin) out of the ten pesticides assessed were quantified in the water and fish samples (Table 2). Mean concentrations of total OCPs in water ranged from 0.0006 to 0.0011 mg/L (Table 2). Total OCPs (mg/kg ww) in *A. baremoze* ranged from 0.0022 to 0.0048 with a mean concentration of 0.0035 mg/kg ww, while total mean concentrations in *S. bastiani* ranged from 0.0046 to 0.0049 mg/kg ww with a mean concentration of 0.0048 mg/kg ww (Figure II). The concentration of γ-HCH was higher in *A. baremoze* accounting for 47.1% of the total pesticide residues in the fish (Figure III), while α-HCH was the most dominant pesticide in *S. bastiani* accounting for 28.4% of the total pesticide residues in the fish samples (Figure III). *S. bastiani* was the more contaminated of the two fish species, the average concentration of total OCPs in *S. bastiani* was 2-folds the total OCPs in *A. baremoze;* however, concentrations were not significantly higher ($p>0.05$). In general, mean concentrations of total pesticide residues in *A. baremoze* and *S. bastiani* was 3.8 and 5.3 folds higher than the concentrations in water respectively. Spatial variation showed higher concentrations of OCPs in Ovwian station for *A. baremoze* and in Okwagbe station for *S. bastiani* (Table 2); however, concentrations were not statistically significant ($p>0.05$) between the species.

Using the mean OCP concentrations in fish from both stations and the mean OCPs from the individual stations, the average EDIs of OCPs via fish consumption and the EDI for spatial exposure were evaluated. The EDIs of the assessed OCPs via fish consumption are presented in Table 3. Total mean pesticide EDI values were 2.8E-06 mg/kg/d for *A. baremoze* and 3.7E-06 mg/kg/d for *S. bastiani* (Table 3). γ-HCH had the highest EDI value (1.3E-06 mg/kg/d) in *A. baremoze* while α-HCH had the highest EDI value (1.1E-6 mg/kg/d) in *S. bastiani* (Table 3). Values for HQ and HI for non-carcinogenic and carcinogenic risks of the pesticides in the fish samples are presented in Table 3. HQ values for non-carcinogenic risk for *A. baremoze* ranged from 0 to 0.151 with HI value of 0.027 while the HQ values for non-carcinogenic risk for *S. bastiani* ranged from 0 to 0.157 with HI value of 0.029. For carcinogenic risks, HQ values for *A. baremoze* ranged from 0 to 2.7E-06 with HI value of 1E-05 while the HQ values for *S. bastiani* ranged from 0 to 8.0E-06 with HI value of 2E-05.

To assess spatial exposure, human health risk was assessed based on the individual stations (Ovwian and Okwagbe) to determine spatial differences in risk assessment from consuming the fish species collected from these stations. In general, there was a higher exposure to OCPs by consumption of *A. baremoze* from Ovwian station and *S. bastiani* from Okwagbe station (Figure IV). However, human exposure through fish consumption was not spatially significant ($p>0.05$).

Discussion

Organochlorine pesticide residues tend to accumulate in living organisms especially aquatic organisms (Sabra & Mehana, 2015). The presence of the observed OCPs in the fish species might be attributed to bioaccumulation of pesticides either through feeding (via water and food), direct absorption through the skin, direct uptake through the gills during respiration or orally through drinking pesticides contaminated-water or feeding on pesticide contaminated-prey (Sabra & Mehana, 2015). Evidence of bioaccumulation of OCPs in the fish species was observed, as the concentrations of OCPs in the fish species were higher than the concentrations in water. However, mean pesticide concentration in water was observed to be below the maximum residual limits (MRL) of pesticides in freshwater bodies set by European Union (EU). The results showed higher values in comparison with values of total pesticide residues in fish (0.0 4- 2.34 µg/kg for *C. gariepinus* and 0.02-1.73 µg/kg for *Tilapia zilli*) reported by Ezemonye *et al.* (2015), (0.0

4- 2.34 µg/kg for *C.gariepinus* and 0.02-1.73 µg/kg for *Tilapia zilli*), Ogbeide *et al.* (2015) and 4.53 mg/kg for *C. gariepinus*), Adeyemi *et al.* (2008) in Southern Nigerian waters. The presence of higher concentrations of OCPs in the fish suggests continuous usage of pesticides notwithstanding the fact that some of the OCPs detected (aldrin, endosulfan, dieldrin, endrin, and lindane) have been banned (FEPA, 1991). The continuous use of banned pesticides still strives in most developing countries as a result of low cost and poor enforcement on usage (Olatunbosun *et al.*, 2011). More worrisome is the fact that these pesticides are considered to be probable human carcinogens (ATSDR, 2005) and have already been implicated in a broad range of adverse human and environmental effects, including reproductive failures and birth defects (Edwards, 1987), immune system dysfunction, endocrine disruptions, and cancers (Edwards, 1987; Paasivirta, 1991; World Wildlife Fund, 1999). The Warri River being a source of potable water and fish for communities around the river could likely pose a threat to both aquatic organisms and humans as a result of pesticide contamination.

The high concentrations of HCH isomers in the fish samples from the river may be attributed to the heavy use of these pesticides in agricultural sites located around the river, which clearly indicates illegal use by farmers. It could also be attributed to the persistence of the pesticides from previous application, similar results of high usage and persistence of the pesticide have been reported (Jiang *et al*., 2005; Omwenga *et al*., 2016). The relatively high concentrations of the γ-HCH isomers probably will not be unconnected with the widespread use of lindane (Gammalin 20) for crop protection and fish capture, despite the fact that lindane has been banned in Nigeria (FEPA, 1991).

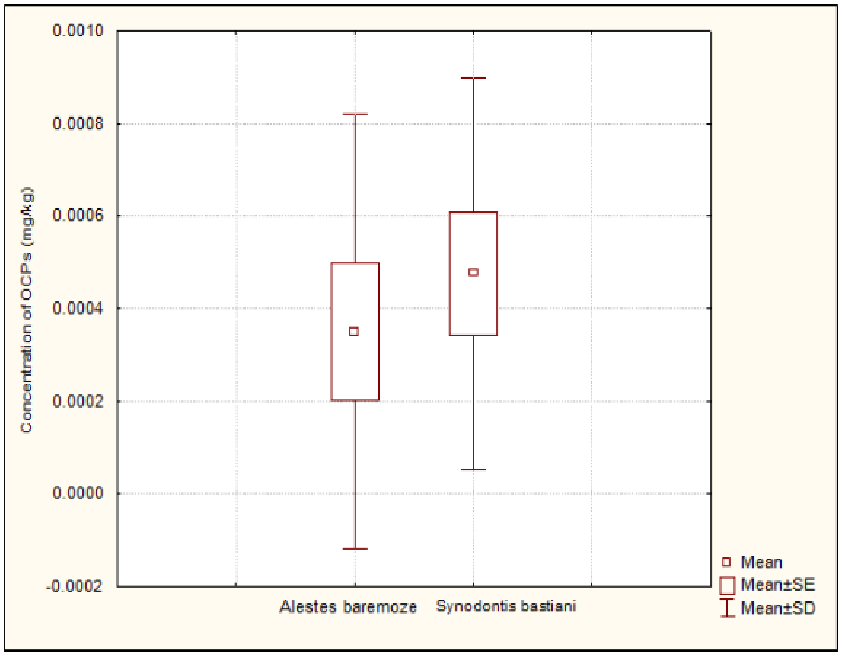

Figure II: Total mean concentrations of OCPs (mg/kg ww) in *A. baremoze* and *S. bastiani* from Warri River, Nigeria

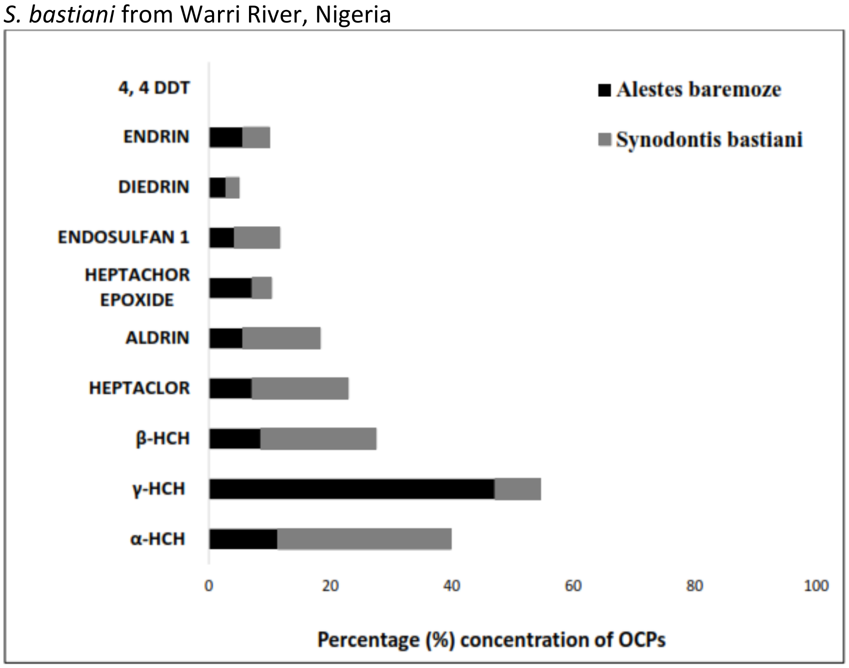

Figure III: Mean percentage (%) composition of OCPs fish species from Warri River, Nigeria

The predominance of γ-HCH among the Hexachlorocyclohexane (HCHs) could be attributed to the fact that γ-HCH is the most active and stable isomer of the HCHs (Raslan *et al*., 2018). The concentrations of HCHs in this study are comparable to the recorded concentrations in fish samples from other rivers in Nigeria (Ize-Iyamu *et al*., 2007; Ezemonye *et al*., 2015; Ogbeide *et al*., 2015) and the

Table 2: Concentrations (Mean ± SD) of organochlorine pesticides (OCPs) (mg/kg) in fish species from Warri river

OCPs	Water		*Alestes baremoze*		*Synodontis bastiani*	
	Ovwian Station	**Okwagbe Station**	**Ovwian Station**	**Okwagbe Station**	**Ovwian Station**	**Okwagbe Station**
α-HCH	0.0001 ± 0.0001	0.0003 ± 0.0004	0.0002 ± 0.0002	0.0006 ± 0.005	0.0016 ± 0.0012	0.0011 ± 0.0014
γ-HCH	0.0002 ± 0.0001	0.0002 ± 0.0002	0.0030 ± 0.0002	0.0003 ± 0.0003	0.0003 ± 0.0005	0.0004 ± 0.0005
β-HCH	0.0001 ± 0.0001	0.0001 ± 0.0001	0.0002 ± 0.0001	0.0004 ± 0.0003	0.0005 ± 0.0005	0.0013 ± 0.0013
HEPTACLOR	0.0001 ± 0.0002	0.0002 ± 0.0002	0.0004 ± 0.0004	0.0001 ± 0.0001	0.0008 ± 0.0006	0.0007 ± 0.0006
ALDRIN	0.0001 ± 0.0001	0.0001 ± 0.0002	0.0003 ± 0.0003	0.0001 ± 0.0001	0.0004 ± 0.0007	0.0008 ± 0.0006
HEPTACLOR EPOXIDE	BDL	0.0001 ± 0.0003	0.0003 ± 0.0003	0.0002 ± 0.0003	0.0003 ± 0.0004	0.0000 ± 0.0001
ENDOSULFAN	BDL	0	0.0001 ± 0.0002	0.0002 ± 0.0003	0.0004 ± 0.0005	0.0003 ± 0.0005
DIEDRIN	0 ± 0.0001	0.0001 ± 0.0001	0.0001 ± 0.0003	0.0001 ± 0.0002	0.0000 ± 0.0000	0.0002 ± 0.0004
ENDRIN	0	0	0.0000 ± 0.0000	0.0002 ± 0.0003	0.0003 ± 0.0029	0.0001 ± 0.0003
4, 4 DDT	0	0	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000

*BDL= Below Detection Limit

Table 3: Estimated daily intake (EDI) and health risk assessment of OCPs in fish species from Warri River, Nigeria

OCPs	Reference Dose (mg/kg/day)	Fish species	Human health risk estimation		
			Estimated daily intake (EDI) (mg/kg/day)	HQ(Non-carcinogenic)	HQ (Carcinogenic)
α-HCH	0.008	*Alestes baremoze*	3.14E-07	3.93E-05	1.98E-06
		Synodontis bastiani	1.06E-06	0.0001	6.68E-06
γ-HCH	0.0003	*Alestes baremoze*	1.3E-06	0.0043	1.69E-06
		Synodontis bastiani	2.75E-07	0.0009	3.58E-07
β-HCH	NA	*Alestes baremoze*	2.36E-07	NA	NA
		Synodontis bastiani	7.07E-07	NA	NA
HEPTACLOR	0.0005	*Alestes baremoze*	1.96E-07	0.0004	8.84E-07
		Synodontis bastiani	5.89E-07	0.0012	2.65E-06
ALDRIN	0.00003	*Alestes baremoze*	1.57E-07	0.0052	2.67E-06
		Synodontis bastiani	4.71E-07	0.0157	8.01E-06
HEPTACLOR EPOXIDE	0.000013	*Alestes baremoze*	1.96E-07	0.0151	1.79E-06
		Synodontis bastiani	1.18E-07	0.0091	1.07E-06
ENDOSULFAN	0.006	*Alestes baremoze*	1.18E-07	0.0000	NA
		Synodontis bastiani	2.75E-07	0.0000	NA
DIELDRIN	0.00005	*Alestes baremoze*	7.86E-08	0.0016	1.26E-06
		Synodontis bastiani	7.86E-08	0.0016	1.26E-06
ENDRIN	0.0003	*Alestes baremoze*	1.57E-07	0.0005	NA
		Synodontis bastiani	1.57E-07	0.0005	NA
4, 4 DDT	0.0005	*Alestes baremoze*	0	0	0
		Synodontis bastiani	0	0	0
		Alestes baremoze	-	HI=0.027	HI=1E-05
		Synodontis bastiani	-	HI=0.029	HI=2E-05

Reference Dose (mg/kg/day) adopted from IRIS-USEPA Integrated Risk Information System (USEPA 2005)

HCH profiles with γ-HCH being the most dominant OCPs in the fish species is comparable to previous studies (Jiang *et al*., 2004; Ize-Iyamu *et al*., 2007; Omwenga *et al*., 2016). The presence of higher concentrations of γ-HCH (lindane) in both fish species raises concern since these pesticides have been banned (Badejo & Sosan, 2005) and their presence in these fish species indicate that these pesticides are still being used. The result of the α-HCH /γ -HCH ratio was observed to be less than 3 in the fish species which further indicates that the fish species were contaminated by recently used Technical-grade HCH. Similar results of α-HCH /γ -HCH ratio less than 3 indicating fresh release into the environment have been reported (Doong *et al*., 2002; Chen *et al*., 2009; Olatunbosun *et al*., 2011). The occurrence of OCPs in the fish species from the two stations seems to be consistent with the agricultural activities of the study area, as the stations are catchments for intensive agricultural activities with extensive pesticide use. The stations are characterized by farmlands which flank the riverbanks, allowing easy passage for pesticides to enter the river through runoffs. Water bodies that drain agricultural farmlands have been reported to have high levels of pesticide residues (Ogbeide *et al.,* 2015; Teklit, 2016).

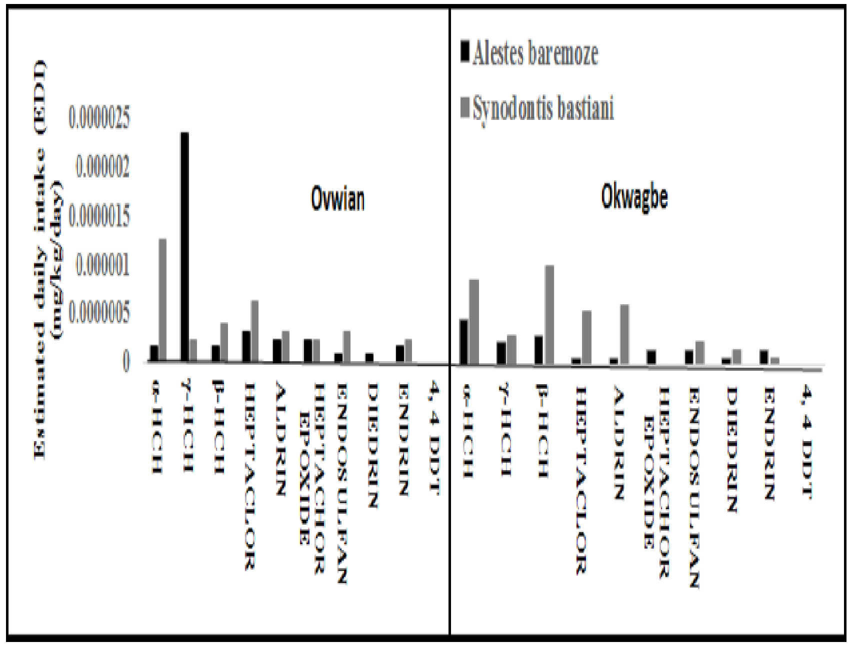

Figure IV: Spatial Human exposure to OCPs through consumption of *A. baremoze* and *S. bastiani* from Warri River, Nigeria

The levels and occurrence of OCPs residues in fish samples seem to be governed by the feeding mode, age, and mobility of the biota (Ezemonye *et al*., 2015). Subsequently, the higher concentration of OCPs residues observed in *S. bastiani* may be attributed to the feeding mode of the fish (Diomandé *et al*., 2001**)** as *S. bastiani* inhabits bottom sediments where it gets most of its food, hence exposes this fish more to the pollutants compared to *A. baremoze*. Mwevura *et al*. (2002) reported that biota in close proximity to sediments pick up residues from the sediment and this occurs by passive equilibration process through their membranes. This result corroborates findings of Ezemonye *et al*. (2015) who reported relatively higher concentrations of pesticides residues in bottom-dwelling *Clarias gariepinus* than *Tillapia zillii* from three rivers in Edo state and of Ize-iyamu *et al*. (2007) who observed higher concentrations of OCPs in the bottom-dwelling fishes. In addition, higher concentrations of OCPs in *S. bastiani* relative to *A. baremoze* may be as a result of the high lipid content of *S. bastiani* (El-Kasheif *et al*., 2012) which corroborates the findings of Kidwell *et al.* (1990) Ezemonye *et al.* (2015) who reported higher pesticide concentrations in fish with higher lipid content.

Fish consumption had been identified as a significant route of human exposure to pesticides (USEPA, 1998). The assessment of potential health risk associated with these pesticides through fish consumption is therefore important. The average EDIs for *S. bastiani* were generally higher than for *A. baremoze* for most of the OCPs assessed, indicating higher levels of human exposure to OCPs through the consumption of *S. bastiani*. Generally, the estimated EDIs were below the reference dose (Table 3) indicating low risk. Similar results of estimated EDIs lower than the reference dose for assessed pesticides through fish consumption have been reported (Liu *et al*., 2010; Ezemonye *et al*., 2015; Ogbeide *et al*., 2015). In spite of the risk assessment results showing a low risk in this study, the accumulation of OCPs in these fish species over time could result in possible health risks. Therefore, monitoring efforts to ensure the long-term safety of consumers are imperative.

Results of the estimated non-carcinogenic and carcinogenic risks from exposure to OCPs through fish consumption showed no evidence of risks as the estimated HQ and HI values were below 1. However, the estimated carcinogenic risks estimated for γ-HCH and α-HCH were considered high through consumption of *A. baremoze* and *S. bastiani* respectively, as values were higher than the USEPA benchmark value of 1×10^{-6}, which represents exposure concentrations at which lifetime cancer risk is 1 in 1 million (USEPA, 2006). Similarly, health risk assessment studies of fish from coastal areas in Southern Nigerian waters have also reported possible risk in humans especially in children, as a result of exposure to pesticides through fish consumption (Ezemonye *et al.,* 2015; Ogbeide *et al.,* 2015).

The results of the human health risk assessment based on spatial exposure through the consumption of the fish species collected from the two stations (Ovwian and Okwagbe) suggest that the residents along the Warri River from the two communities are subjected to the same levels of exposure to OCPs through the consumption of *A. baremoze* and *S. bastiani,* and are thus exposed to the same level of risk. Liu *et al.* (2010) reported no significant difference in exposure to pesticide residues between coastal and inland cities through consumption of aquatic products from Liaoning province, China, and thus explained that the residents of both inland and coastal regions were subjected to the same total exposure to OCPs by consuming fish and mollusks from the region.

In conclusion, the results of the human health risk assessment from the consumption of contaminated fish (*A. baremoze* and *S. bastiani*) raise concern of possible carcinogenic health risk from exposure to pesticides through consumption of the fish species from Warri River, Nigeria. Continuous monitoring efforts should be intensified to ensure the long-term safety of consumers of fish around this region.

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Conflicts of Interest

The authors declare no conflicts of interest.

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