Adamawa State University Journal of Scientific Research
Volume 8 Issue 2, 2020; Article no. ADSUJSR 0802012
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsujsr.com

Determination of Persistent Organic Pollutants (POPs) in African Catfish (*Clarias Gariepinus*) in Fishponds along River Yedzaram Mubi, Adamawa State Nigeria

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(Received in July 2020; Accepted in September 2020)

Abstract

The use of POPs has been confirmed detrimental to health and well-being over the years leading to a ban on their use especially by developing countries such as Nigeria. Contrary to the ban, substances containing POPs have been observed to still be in use due to their low cost and effectiveness, especially for Agricultural purposes; residues from such usage run off into sediments and contaminate water and organisms such as African Catfish (Clarias gariepinus) used as food sources thereby, availing consumers to ill – effects of POPs. In this research, the concentration of POPs residues was determined in African Catfish (Clarias gariepinus), water, and sediment along River Yedzaram in Mubi Adamawa State; GC/MS was used to detect POPs residues in samples collected randomly from five different ponds, in Vimtim stream along River Yedzaram. A total of seven (7) POPs were completely undetected while eight (8) were found distributed in various concentrations in samples. Aldrin was found with the highest concentration of 0.099 µg/kg in sediment and correspondingly 0.054 µg/kg in African Catfish (Clarias gariepinus). One–way ANOVA statistical analysis was used to test the difference in concentrations of each POPs in each sample analyzed; results were considered significant at a 5% level ($p < 0.05$), and the concentrations were found to be statistically indifferent. Hence, African Catfish (Clarias gariepinus) sourced from that region is suggested to be contaminated and unsafe for consumption. It is recommended that efforts should not be relented in phasing out POPs residues, as well as surveillance on illegal use of the banned POPs until they are extinct.

Keywords: POPs; African Catfish (Clarias gariepinus); River Yedzaram; Pesticides

Introduction

Fish farming is one of the fastest-growing food production activities in the world (FAO, 1997). Although fish farming is fast becoming established in Nigeria, there is little information regarding the safety of the end product, and especially African Catfish *(Clarias gariepinus)* hence potential hazard to consumers. Several chemical contaminants enter the aquatic ecosystem through run-offs from agricultural fields, ponds, streams, and rivers that eventually drain into lakes. Previous studies in Nigeria had shown cases of Persistent Organic Pollutants – POPs pesticide residue in fish from lakes (FAO, 1997).

By their nature, POPs are organochlorine compounds with extensive longevity in the environment. They represent one of the most harmful classes of pollutants manufactured and released into the environment by humans and as such, they are of particular relevance to human health and the health of other organisms in the environment (Ibigbami *et. al.,* 2015). POPs are characterized by their persistence in the environment with a tendency to bioaccumulate in the food chain and their capacity for a long-range, trans-boundary dispersion, posing a great threat to human health and the environment globally. Pesticides (which contain mostly POPs substances) are substances or a mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage or marketing of food, agricultural commodities, wood and wood products or animal foodstuff or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies (Ogah *et. al.*, 2012). Despite the benefits accrued, pesticides have harmful effects; they can cause injury to human health as well as to the environment. Among others, environmental and health concerns include; exposure during pregnancy, transport across the placenta, gestational weight gain and newborn head circumference, cardiovascular disease and cancer, obesity, and diabetes (Wikipedia, 2017a). Other adverse health effects include acute and persistent injury to the nervous system, lung damage, and injury to the reproductive organs, dysfunction of the immune and endocrine systems, birth defects, and cancer (Olufade *et. al.*, 2014). The pesticides mainly exert their detrimental effects on non-target organisms through chronic toxicity and sub-lethal exposure. However, despite the potential environmental/health hazard, government efforts, and legal instruments in place; activities involving the use of banned POPs, continue in Nigeria (Shinggu *et. al.*, 2014). There is therefore the need for a broader assessment of banned POPs in developing countries, Nigeria in particular (Williams, 2013a, 2013b and 2013c).

The African catfish *(Clarias gariepinus)* is increasing and its culture spreading globally, thus becoming a commercially valued fish for the Nigerian fishing industry (Akeem *et al*., 2018). These mudfish are frequently and widely cultured in ponds and they also occur freely in Nigeria natural freshwater (Ezemonye *et. al.*, 2015a and 2015b). Generally, the nutrient profile of catfish shows that it is high in protein, low in fat and cholesterol, and a good source of certain vitamins and minerals (Musa *et. al.*, 2010), it is also known for its high tolerance to adverse environmental conditions, relatively rapid growth and good market value; these made African catfish *(Clarias gariepinus)* a common and affordable food source that is easily farmed directly by consumers or sold commercially for consumption, especially around river Yedzaram and its environs.

The need to investigate the safety of African catfish *(Clarias gariepinus)* sourced from the region of river Yedzaram, in Mubi Adamawa state is paramount; the region has been open to several Agricultural activities where chemical substances, which could contain hazardous POPs have been observed to be used for such activities, run-offs from such usage could contaminate the sediment, water and consequently African catfish *(Clarias gariepinus)* sourced from the region. This research, therefore, determines the concentration of POPs residues in African catfish *(Clarias gariepinus)* in the region and other soils and sediment as well.

Materials and Methods

Study Area:

The study area Mubi is located between latitudes 10° 11 '30” and 10° 22' 30” N and between longitudes 13° 13' 00" and 13° 30’ 00” 'E. The area is drained by the River Yadzaram. It is one of the major rivers that drain into the Lake Chad. It has a total length of about 330 kilometers. It takes its source from the Hudu hills south-east of Mubi town and flows northward into the Chad (Adegoke and Gadiga, 2015).

The study area covers an area of 35.1-kilometer square and falls within the Mubi (North and South) political boundary. However, it falls within the section of the middle course of River Yadzaram which covers a length of 30 km^2 from Va’atita in Mubi south to Mayo Bani in Mubi North Local government area.

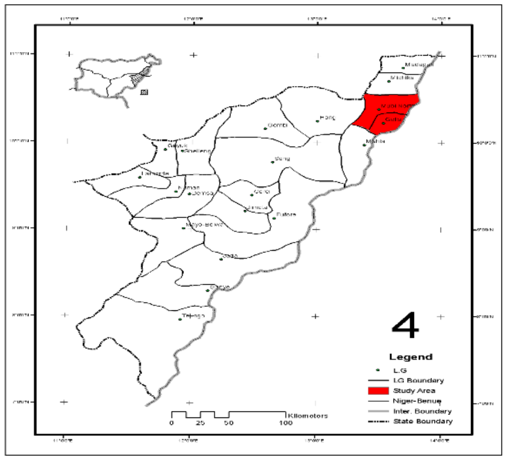

Figure 1: Study area

Sample and Sampling

African Catfish (*Clarias gariepinus*) were carefully sampled and purchased across the study area randomly, making sure that sampling cut across ponds that have boreholes as a source of water and those that use other sources of water. Fresh three sub-adult specimens of African Catfish (*Clarias gariepinus*) were purchased. The fish species were identified taxonomically using standard reference sources, measured using sensitive scale and meter rule before being put in sterile polythene bags and taken in an ice pack to the laboratory where they were stored at -4ºC before pesticide extraction and analysis.

A Uwitec fitted with Plexiglas tubes of 50 cm height was used to collect the sediment samples; five sediment samples were collected at the depths of 2-8cm each from different locations around the river Yedzaram where all the fish samples were collected and mixed thoroughly to obtain a composite sample. This was taken to the laboratory under temperature-controlled conditions to inhibit pesticide degradation. Sediment cores were weighed dried at 40°C until constant dry weight samples were obtained. A sieve of 0.5 mm mesh size was used to sieve the samples after being homogenized using Agate mortar and pestle; samples were then stored at – 4°C for further analysis. Using 2L amber glass bottles, five water samples were collected from river Yadzeram at different locations and were mixed thoroughly to obtain a composite sample for replicate analysis. The composite water samples were pre-filtered through 0.45 lm fiberglass filters (Whatman) to remove suspended material. Concentrated H_2SO_4 was added for preservation against biological activity (Lanfranchi, *et al.,* 2006). The samples were preserved by refrigeration at - 10°C until analysis was undertaken.

Materials and Reagents

The analytical persistent organic pollutants (POPs) standards which include alachlor, p, p0- DDE, lindane, aldrin, heptachlor, dieldrin, and hexachlorobenzene (HCB). These standards were purchased from Sigma (Poole, UK). Individual stock standard solutions of pesticides were prepared by dissolving 10 mg of each compound in 10 mL hexane and stored in amber bottles. A mixed standard solution was prepared from the individual stock solutions with a concentration of 100 mg/ L. A series of calibration standards were then be prepared by diluting 100 mg/ L of the mixed standard solution to produce a final concentration of 0.1, 0.2, 0.5, 1.0, 2.0 mg/ L in hexane.

Sample Extraction

The extraction and clean up technique employed in this work is as describe by Shinggu *et. al.*, (2015). The frozen composite whole-body of fish tissue samples will be homogenized using an agate mortar and pestle. Approximately 20 g of the properly chopped fish sample will further be mixed with 10 g of anhydrous sodium sulphate this will then be placed into a 50 mL centrifuge tube and mixed with 3.0 mL water. The mixture was vortexed for 1 min. A 20 mL aliquot of acetonitrile was added as an extraction solvent. The resulting mixture was stirred for 15 min and 5 g sodium chloride was added to the mixture and vortexed for another 2 min, and then centrifuged for 5 min at 4000 rpm. 10 mL of the extraction solution was collected in a 100 mL round flask, then stored in the freezer at -24 °C for 20 min to freeze lipids. The lipids were precipitated as pale yellow, condense lump on the flask surface. Cold extract at -24 °C was immediately filtered with filter paper to remove frozen lipids. The precipitated lipid on the flask surface was then re-dissolved in 10 mL of acetonitrile. The filtrate extract was then concentrated to 1 mL by rotary evaporation ready for analysis.

The dry Sediment sample was extracted as described by Darko *et al.,* (2008). About 10 g of sediment samples were weighed and transferred into an extraction thimble that had been previously washed with n-hexane and acetone and oven-dried. The sample was extracted using 100 mL of n-hexane acetone mixture 4:1 v/v for eight hours using a soxhlet extractor. The extract was evaporated to dryness using a rotary evaporator at 45°C. Each extract was dissolved in 10 mL n-hexane and subjected to a clean-up procedure.

Persistent Organic Pollutants residues were extracted using the Liquid-liquid extraction method as described by Shinggu *et al.,* (2015). About 500 mL of water sample was put into a 1 L separatory funnel at a time. This was extracted with 30 mL (3 portions) of dichloromethane DCM by vigorous shaking for 45 minutes for each of the triplicate extraction. The combined extracts were dried with anhydrous Na_2SO_4 and concentrated to about 2 mL under a pure stream of nitrogen of 99.999% purity.

Clean-up Procedure

A column of about 15 cm (length) × 1 cm (internal diameter) was packed with about 10 g activated silica gel prepared in a slurry form in n-hexane. About 10 g of anhydrous sodium sulphate was placed at the top of the column to absorb any water in the sample or the solvent. The column was pre-eluted with 20 mL of n-hexane without the exposure of the sodium sulphate layer to air. The reduced extract was placed in the column and allowed to sink below the sodium sulphate layer. Elution will be done with 2 × 10 mL portions of the extracting solvent (DCM). The eluate was then collected, dried with anhydrous sodium sulphate, and then evaporated to dryness under a stream of analytical grade nitrogen (99.999%). The dried eluate above was then reconstituted with 1 mL spectra grade n-hexane and 0.5 mL of 20 mg/kg mixture of POPs were added as an internal standard (Shinggu *et al*., 2015).

Detection Techniques (GC/MS analysis)

Gas Chromatography Agilent 7890 instrument equipped with a 5975 insertion source mass detection system (Agilent Technologies, USA) was used for this technique. The analytical capillary column is J&W Scientific, DB-1701. The column temperature was maintained at 40 °C for 1 min, and then programmed at 30 °C /min - 130 °C, then at 5 °C /min -250 °C, and finally at 10 °C /min– 300 °C, which was held for 5 min. Helium, purity >99.999%, was used as carrier gas at a flow rate of 1.2 ml min-1. The injection port temperature was 260°C and 1 μL samples were injected splitless with the purge on after 1.5 min. The MS ionization energy was 70 eV, the ion-source temperature 230 °C, and the GC–MS interface temperature 280 °C. The selected ion monitoring (SIM) was used and the dwell time of ion was set at 100ms. To improve sensitivity, the selected ions to be used in the SIM mode were divided into fourteen groups, guided by the individual pesticide retention times. All pesticides were identified by retention time and specific ions and quantified by the external standard method.

Method Validity

The recovery analysis and the validation of the extraction method were carried out at a fortification average level of 0.02, 0.05, 0.1 mg\ kg, by adding a standard solution to untreated fish samples. Samples were allowed to equilibrate for 30 min before extraction and were processed according to the procedure described above. The recovery assays were replicated five times. All samples were treated and analyzed using GC–MS–SIM mode described above.

A value of zero was assigned for results below the limit of detection. Data obtained were subjected to analysis of variance (ANOVA) to determine the differences in the concentration of each of the POPs residue in each sample analyzed. Results were considered significant at a 5% level ($p < 0.05$).

Results and Discussion

Results showing the level and distribution of POPs in African Catfish *(Clarias gariepinus)*, water, and sediment along river Yedzaram; in (μg/kg), (μg/L), and (µg/kg) respectively are summarized in Table 1. The table shows the results for each sample from five different ponds, Vimtim River; all along the River Yedzaram.

The results show a total of seven (7) POPs were below the detection limit and hence undetected, they include; Beta-BHC, Gamma – BHC, Lamda Cyhalothrin, Gamma – Chlordane, P, P' – DDE, DDD, and P, P' – DDT. This should by implication denote that, African Catfish *(Clarias gariepinus)* consumed around river Yedzaram, Mubi is most likely to not be contaminated with those POPs as also neither the sediment nor water in that region was found to contain them. Furthermore, health effects related to the seven (7) undetected POPs may likely not be observed in consumers. Whereas eight (8) POPs were found distributed in various concentrations in African Catfish *(Clarias gariepinus)*, sediment, and water in the study area, they include; Aldrin, Alpha-BHC, Endrin, Dieldrin, Endosulfan I,

Endosulfan II, Heptachlor, and Methoxychlor. Consequently, it can be inferred that the ban on the use of the detected POPs has not been adhered to in the study area and implicatively consumers of African Catfish *(Clarias gariepinus)* sourced from that region are most likely to show health risks associated with the detected POPs. This agrees with the findings by Zira, *et al*., 2018 and 2020 respectively, on the continuous use of banned persistent organic pollutants.

The results indicate that Aldrin was detected in all of the African Catfish *(Clarias gariepinus)*, sediment, and water samples from all seven (7) sampling sites, unlike the other POPs. It was found with the highest concentration of 0.099 µg/kg in sediment at POND 1; this was found considerably higher than 0.0015 µg/kg Aldrin in Fish at Biu Dam Reservoir, Borno State by Shinggu *et. al.,* (2014), much higher than 0.0002 µg/kg at Alau Dam, Borno State (Akan *et. al.,* 2013). The result ascertains the dominance of Aldrin residues in the region; and also the possibility of Aldrin health risks becoming higher in consumers of African Catfish *(Clarias gariepinus)*. Aldrin was also found with the corresponding highest concentration of 0.079 µg/L and 0.054 µg/kg in water and African Catfish *(Clarias gariepinus)* respectively at POND 1; this shows the transferability pattern of POPs residues goes from sediment to water and then to fish, as the concentration also drops respectively:

Table 1: Levels of POPs at sampling sites

	POND 1			POND 2			POND 3			POND 4			POND 5		
	µg/kg	µg/L	µg/kg	µg/kg	µg/L	µg/kg	µg/kg	µg/L	µg/kg	µg/kg	µg/L	µg/kg	µg/kg	µg/L	µg/kg
POPs		WATER	SEDIMENT	FISH	WATER	SEDIMENT	FISH	WATER	SEDIMENT	FISH	WATER	SEDIMENT	FISH	WATER	SEDIMENT
Aldrin	0.054	0.079	0.099	0.015	0.059	0.088	0.015	0.034	0.073	0.026	0.055	0.072	0.031	0.072	0.088
Alpha-BHC	0.029	0.082	0.096	0.022	0.046	0.069	0.012	0.025	0.077	0.015	0.036	0.043	0.045	0.081	0.087
Beta-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gamma - BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	0.012	ND	ND	ND	0.016	0.023	0.042
Lamda Cyhalothrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gamma - Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P' - DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P' – DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	0.064	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.022	0.046	0.067
Endosulfan I	ND	ND	0.026	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.025	0.056	0.069
Endosulfan II	ND	ND	ND	ND	0.012	0.038	ND	0.015	0.027	ND	ND	ND	0.027	0.047	0.066
Heptachlor	ND	0.029	0.035	ND	0.046	0.062	ND	0.018	0.033	ND	0.012	0.025	0.035	0.061	0.076
Methoxychlor	0.012	0.017	0.021	0.015	0.022	0.036	ND	0.012	0.029	ND	0.021	0.032	0.023	0.057	0.081

ND: Not detected (= 0); Max: 0.099; Min: 0.0

Figure 2 depicts the distribution of the various POPs residues at Pond 1, a total of nine (9) POPs were undetected, these includes; Beta-BHC, Gamma – BHC, Endrin, Lamda Cyhalothrin, Gamma – Chlordane, P, P' – DDE, DDD, P, P' – DDT and Endosulfan II; whereas five (5) POPs residues were detected at various concentrations dispersed in Fish, sediment and water at Pond 1. Aldrin had the highest concentration of 0.099 µg/kg in sediment while Methoxychlor had the least concentration of 0.012 µg/kg in Fish. Whereas Aldrin, Alpha-BHC, and Methoxychlor were found with concentrations of 0.054 µg/kg, 0.029 µg/kg, and 0.012 µg/kg respectively in Fish at POND 1, the rest were undetected. Aldrin was found to be 0.102 mg/kg in sediment and was undetected in Fish at Lake Geriyo Adamawa State Nigeria (Shinggu *et al.*, 2015); the fact that Aldrin can be transferred gradually from sediment to water and then to Fish over time suggests the danger of Fish contamination at Lake Geriyo as it has been indicative in the findings of this research.

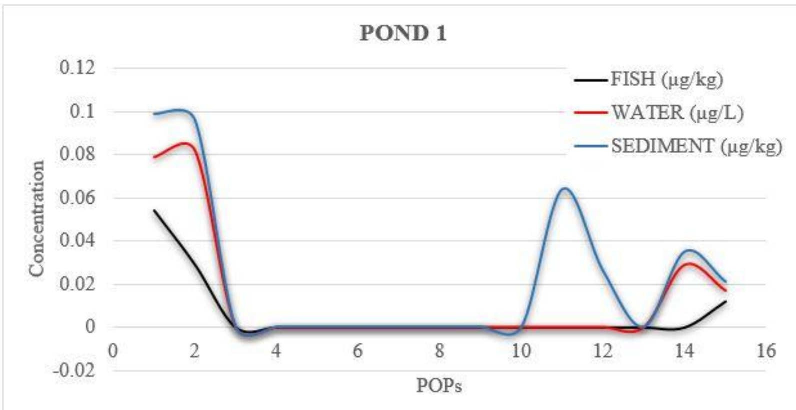

Figure 2: Show the level of POPs in POND 1

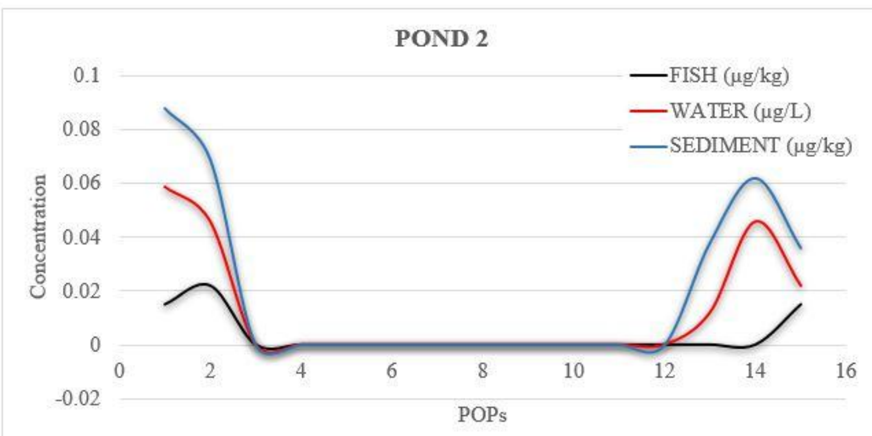

Figure 3: POPs at POND 2

In contrast with the results of POPs at Pond 1, Figure 3 indicates a total of ten POPs residues were not detected in Pond 2, these includes; Beta-BHC, Gamma – BHC, Endrin, Lamda Cyhalothrin, Gamma – Chlordane, P, P' – DDE, DDD, P, P' – DDT, Dieldrin and Endosulfan I; hence five POPs residues were detected at a various concentration in Fish, sediment and water. Aldrin had the highest concentration of 0.088 µg/kg in sediment, while a lower concentration was observed in Endosulfan II which had the least concentration of 0.012 µg/L in water in Pond 2. Aldrin, Alpha-BHC, and Methoxychlor had concentrations of 0.015 µg/kg, 0.022 µg/kg, and 0.015 µg/kg respectively in Fish. Shinggu *et al* (2015), in his studies, reported the concentration of POPs in water as follows; 0.290 mg/L alpha BHC and 0.333 mg/L Aldrin in Lake Geriyo, contrastingly all POPs residues where not detected in water at Tono reservoir (Osei *et al.*, 2016); notwithstanding the gradually transferability of these contaminants still indicates the danger of Fish contamination so long as residues have been detected in sediments and water.

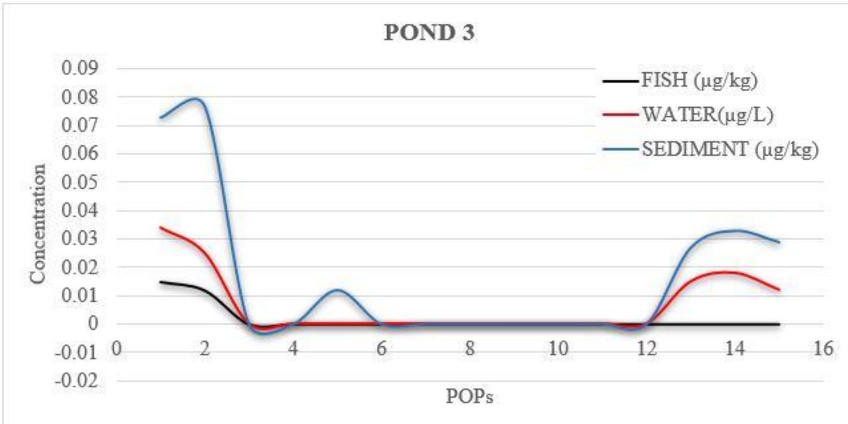

Figure 4: POPs at POND 3

A total of nine (9) POPs residues were not detected in POND 3, unlike in POND 1 and 2 higher concentration of Alpha-BHC 0.077 µg/kg in sediment was observed in pond 3, while Alpha-BHC, Endrin, and Methoxychlor were found with the least concentrations of 0.012 µg/kg in Fish, sediment and 0.012 µg/L in water respectively. A total of six POPs were found distributed at a various concentration in the Fish, water, and sediments in Pond3, similarly, only Aldrin and Alpha-BHC with concentrations of 0.015 µg/kg and 0.012 µg/kg in Fish were respectively observed.

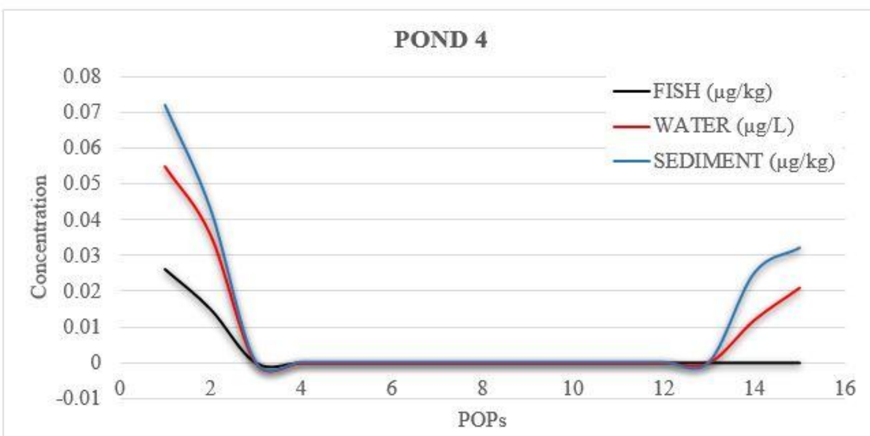

Figure 5: POPs at POND 4

Aldrin was also found with the highest concentration of 0.072 µg/kg in sediment in Pond 4 as compared to Pond 1 and 2, while Heptachlor had the least concentration of 0.012 µg/L in water, while Aldrin and Alpha-BHC had concentrations of 0.026 µg/kg and 0.015 µg/kg respectively were detected in Fish at Pond4.

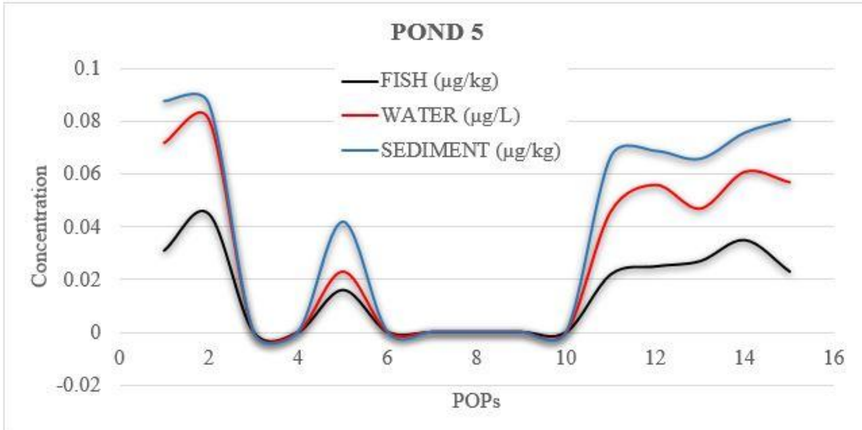

Figure 6: POPs at POND 5

The pesticide residue detected are Aldrin with a high concentration of 0.088 µg/kg in sediment while, Endrin had the least concentration of 0.016 µg/kg in Fish. Similarly Aldrin, Alpha-BHC, Endrin, Dieldrin, Endosulfan I, Endosulfan II, Heptachlor and Methoxychlor were found with concentrations of 0.031 µg/kg, 0.045 µg/kg, 0.016 µg/kg, 0.022 µg/kg, 0.025 µg/kg, 0.027 µg/kg, 0.035 µg/kg and 0.023 µg/kg respectively in Fish at Pond 5. The results at Pond 5 shows more of POPs residues detected in Fish as compared to other sampling sites, these indicate higher health risk associated with Fish consumption.

From the table of results and figures shown above, the presence of these POPs agrees with studies carried out by Lanfranchi *et al.,* (2006); where fish was found to be suitable indicators for environmental pollution monitoring as they concentrate pollutants in their tissues directly from water and also through their diets. This research has shown that some of these POPs are still been used uncontrolled along River Yedzaram. It is observable as Aldrin, Dieldrin, Endrin, etc., are used for agricultural purposes as an insecticide to control rootworms, beetles, and termites which are common pests in the study area over the years. Dieldrin especially has been used in the treatment of soil and seed and in public health to control disease vectors such as mosquitoes and tsetse flies (Akan *et. al.,* 2013).

Aldrin concentration in Fish at River Yedzaram was found higher than those reported in Allau dam reservoir by Akan *et. al.,* (2013). Due to hydrophobic properties, in aquatic ecosystems DDT and its metabolites are absorbed by aquatic organisms like fish and can be adsorbed on suspended particles, leaving little DDT dissolved in the water itself. Its breakdown products and metabolites, DDE and DDD, are also highly persistent and have similar chemical and physical properties (ATSDR, 2002).

DDT being a POP that is readily adsorbed to soils and sediments acting as both sinks and as long-term sources of exposure contributing to terrestrial organisms (WHO, 1989) was undetected similar to the studies carried out by Clark *et al*., (2013); although DDD was also undetected, it was found with a concentration of 2.25 µg/L in the studies by Clark *et al*., (2013). Because of its lipophilic properties, DDT has a high potential to bio-accumulate, especially in predatory birds. DDT, DDE, and DDD magnify through the food chain, with apex predators such as raptor birds concentrating more chemicals than other animals in the same environment (Sittig 1980).

Both Endosulfan II and Endosulfan I were detected in fish, water, and sediment samples. Endosulfans have been found highly toxic to fish and are readily absorbed in sediments; this indicates its hazardous nature in the aquatic environment (Sittig 1980). Endosulfan concentrations were found higher than those in studies carried out by Idowu *et al.,* (2002) and Shinggu *et al.,* (2014).

The statistical analysis results imply that concentrations of POPs residues in African Catfish *(Clarias gariepinus)* in all the five ponds are statistically and significantly not different at P= < 0.005. This in agreement with results by Shinggu *et al.*, (2014) suggests that African Catfish *(Clarias gariepinus)* samples consumed around River Yedzaram are more likely to contain the detected POPs residues in roughly the same concentrations thus, consumers are likely prone to having health issues related to those POPs regardless of the source so long as it is along River Yedzaram. The same may likely be applied to POPs residues in Water and Sediments along River Yedzaram. The results although is contrary to that of Joseph (1990), where some POPs were found to be significantly different in fish samples in Kenya.

Conclusion

From the findings of the research, it can also be inferred that POPs residues in African Catfish *(Clarias gariepinus)*, Water, and Sediment within each of the seven sampling sites are also roughly at the same concentration levels. Despite the ban on the use of pesticides and POPs, results from this research work indicates that some pesticide residue were still been used. This indicates that those detected are most likely been in used today in violation to the ban and hence implicatively, that water and sediment in Ponds, along river Yedzaram, has the tendency of being contaminated with POPs Despite that concentration of POPs where found at relatively low they may bioaccumulate and biomagnify in the body tissues over time which may prove to be detrimental to human health and the need to phase them out should not be overlooked.

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