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Distribution and Risk Assessment of Aldrin, Endrin, Heptachlor, and Heptachlor Epoxide in Some Villages in Hawul River Basin

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Abstract: Aldrin, endrin, heptachlor, and heptachlor epoxide were investigated to assess their distribution in the environmental compartments of the Hawul River basin with emphasis on surface water, sediment, and fish (clarias gariepinus). GC-MS was used for the identification and quantification of the pesticide residues after extraction and clean-up of the residues using the QuEChERS method. The results indicated a high concentration of the OCPs analyzed with some locations having concentrations above the recommended MRLs values. Aldrin and endrin are the most abundant of the OCPs analyzed with 0.3mg/L and 0.04mg/L as their lowest concentration in water samples, which is above the 0.01 µg/L MRL recommended by WHO. The total OCPs burden is in the order of Garkida > Kopre > Garkida WB > Daba > Kiri > Dabna. The health risk which was computed using the Hazard Quotient and Hazard Index shows Aldrin and Endrin have HQ greater than 1 in all sampling locations in a range of 1.39 – 9.85, 1.85 – 6.44 while heptachlor and heptachlor epoxide were less than 1 in the range of 0.03 – 0.56 and 0.006 – 0.07 due to fish consumption. The HI which is the cumulative effect of the individual OCPs in fish was in the sequence Garkida (WB) > Kiri > Kopre > Garkida > Dabna > Daba.

Keywords: Pesticides, Assessment, Health risk, Cancer risk

1. Introduction

A pesticide is any substance or mixture of substances in either solid, liquid, or gaseous state of organic or inorganic origin used in agricultural, commercial, residential, and industrial applications intended for preventing, destroying, or controlling any pest. Thus, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies (FAO, 2012; Sengupta and Banerjee 2014; Li and Jennings, 2017).

The use of pesticides has increased manyfold over the past few decades. According to an estimate, about 5.2 billion pounds of pesticides are used worldwide per year (Kaur *et al*., 2019). According to The World Health Organization (WHO) estimates, at the global level, millions of severe pesticides poisoning episodes occur annually, and of these, a minimum of 300,000 people die, with 99% of cases being from low and middle-income countries (Kesavachandran *et al.,* 2009; WHO, 2018).

Pesticides have been identified as a global concern due to their indiscriminate and irresponsible use, especially persistent organic pollutants (POPs) (Abbassy *et al*., 2021). Notable among them are organochlorine pesticides (OCPs) such as Aldrin, endrin, chlordane, DDTs, heptachlor, etc. which are known to have historical use in large amounts in Africa (Untimed *et al*., 2018). Acute and chronic toxicity, persistence, bioaccumulation ability, long-range transport, broad-spectrum nature, and tendency to poison non-targets like, humans, animals, and aquatic life of OCPs are documented (Akan *et al*., 2014). Their deleterious nature necessitated the inclusion of many OCPs in the priority list of POP in the Stockholm convention (Adeleye *et al*., 2019).

In the past decade, there have been several reports indicating contamination of water bodies by pesticides on the global scale and locally. Chowdhury *et al.,* (2012), Kafilzadeh *et al.,* (2012), Singh *et al.,* (2015), Mekonen *et al.,* (2016), and Barizon *et al.,* (2019) all reported some high levels of various pesticides in Bangladesh, Iran, India, Ethiopia, and Brazil respectively. In Nigeria also, many water bodies such as rivers Asa, Challawa, and Ogbesse,

have shown some high concentrations of these contaminants (Akan *et al*., 2014, Anifowoshe *et al*., 2019, Ezemonye *et al*., 2015).

Hawul river basin is one of the largest River basins in Nigeria. It lies between Adamawa and Borno state. It is the origin of the Tum River, Hawul River, which is the major tributary of River Gongola, which is also a major tributary of River Benue. Hawul River basin is home to over a million people whose occupation is mainly farming (commercial and subsistence). It serves as the source of livelihood for the majority of the populace that live along the river basin. The rivers provide food such as fish and other aquatic animals and plants; and serve as a source of drinking water, water for irrigation and sports. This research aimed at determining the distribution and health risks associated with Aldrin, Endrin, Heptachlor, and heptachlor epoxide in water, sediment, and fish samples from some selected towns and villages along the River basin.

2. Material and methods

2.1 Materials

Plastic bottles, Spatulas, agate mortar and pestle, mesh sieve, Whitman filter paper, stainless steel dissecting kit, beakers, round bottom flask, conical flask, measuring cylinders, glass column, glass wool, separating funnels, ice box, refrigerator, soxhlet extractor, rotary evaporator, sonicator, GC-MS.

Acetone, silica gel, Octadecyl (C18), Dichloromethane (DCM), n-hexane, Anhydrous sodium sulfate (Na_2SO_4), ethyl acetate, and distilled water. All reagents used were of analytical grade

2.2 Study Area

The Study area lies between longitudes 11.00^{o}N and 10.00^{o}N and Latitudes 12.00^{o}E to 13.00^o E as shown in Fig. 1. The sample collection locations were Kopre (10° 28’2’’N, 12°50’49’’E) Dabna (10° 23’2’’N, 12°49’27’’E) in Hong L.G.A, Garkida WB (10° 24’52’’N, 12°33’58’’E) Garkida (10° 24’52’’N, 12°33’58’’E) in Gombi L.G.A, Kiri (9° 35’41’’ N, 12°00’05’’ E) and Daba (9° 40’0’’N, 12°10’59’’E) in Shelleng L.G.A. The sampling locations are steep parts of the basin, which receive their waters from the flood plains of the Hawul basin and keep them throughout the year. The important human activities around the sampling areas are

irrigation farming, fishing, washing, swimming during the day, and some pockets of illegal artisanal mining.

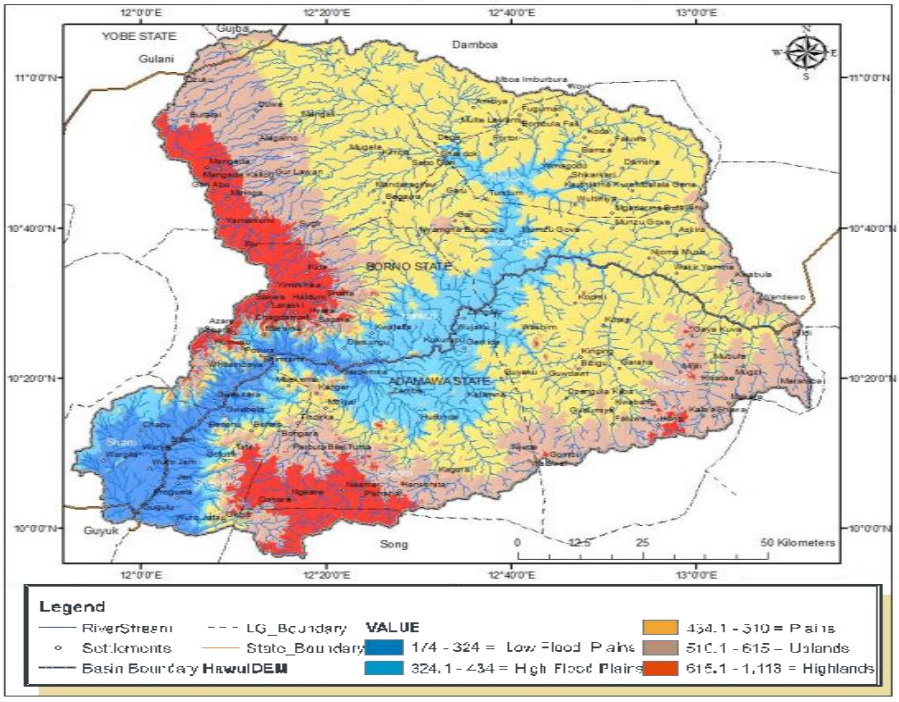

Fig. 1 Map of Hawul basin showing Hawul River and its tributaries sourced from Mayomi *et al.,* (2018).

2.3 Sample collection

The study area was divided into six sampling sites along the Adamawa part of the Hawul River Basin in which samples of water, sediments, and fish were collected. Each sample was taken in triplicate from which representative samples were drawn.

2.3.1 Water sampling

A total volume of 1 L water sample was collected as reported by Olawale *et al.*, (2016) from each site in polyethylene bottles (twice rinsed with deionized water) and acidified with 3% HNO_3 then stored in an ice box and transported to the laboratory for further analysis. Each sample was drawn in triplicate from which a representative sample was drawn.

2.3.2 Sediments sampling

A total of 50 g of sediment samples, from a depth of 2-5 cm under the riverbed were collected. The sediment samples were oven-dried in a laboratory for about 48 h at 120 °C and

then homogenized by grinding in an agate mortar and sieved. It was stored in labeled bottles until chemical analysis.

2.3.3 Fish Sampling

Live samples of African Catfish (*Clarias gariepinus*) were caught from the sampling points with the help of a local angler (Olawale *et al.,* 2016). The fish samples were briefly rinsed with distilled water to remove any adhering substances then immediately preserved on ice in an icebox, then deep frozen in the laboratory before analysis. After identification, the fish samples were dissected into separate organs (flesh, liver, and gills) using stainless steel, and then air-dried to constant weight.

2.4 Determination of OCPs concentrations

The QuEChERS method for pesticide analysis according to EPA methods was adopted as reported by Akoto *et al.,* (2016) and Modibbo *et al.,* (2019) with slight modifications in terms of sample size for all samples.

2.4.1Extraction of pesticide residues in water

A volume of 50 mL dichloromethane (DCM) was introduced into a separating funnel containing 100 mL of the water sample and agitated for 5 minutes (Raina-Fulton and Xie, 2017). The sample was allowed to settle for 30 minutes to facilitate the effective separation of the organic and aqueous phases. After separation, the organic layer was filtered into a 250 mL volumetric flask through anhydrous sodium sulfate (Na_2SO_4) that had been prewashed with DCM. The extraction was repeated twice using 50 mL of dichloromethane (DCM) (FSSAI, 2015). The extracts were then combined and dried by passing through a glass funnel packed with activated anhydrous sodium sulfate (Na_2SO_4). The extracts were concentrated to 5 mL using a rotary evaporator at a temperature of 45°C. The level of organochlorine pesticide residues in the water samples was determined using gas chromatography coupled with a mass spectrometer (GC-MS).

2.4.2 Extraction of pesticide residues in sediments

A 10.0 g dry sediment sample was placed into an extraction thimble that was previously washed with *n*-hexane and acetone and oven-dried. Pesticide residues in sediments were extracted using 150 mL of *n*-hexane/acetone mixture 4:1 v/v for 6 h by soxhlet extraction. The extract was concentrated to near dryness using a vacuum rotary evaporator at 40 °C.

Each extract was then dissolved in 10 mL of *n*-hexane and subjected to clean-up and then determination using GC-MS (FSSAI, 2015).

2.4.3 Extraction of pesticide residues in fish

Ten (10.0) g of homogenized fish sample was placed into a 100 mL conical flask and 20.0 g of activated anhydrous sodium sulfate was added and mixed (FSSAI, 2015). Then 30 mL of 2:1(v/v) hexane/acetone mixture was added and thoroughly mixed by shaking. The sample was sonicated for 20 min. The supernatant was filtered into a 250 mL round bottom flask. The extraction was repeated two more times and all the supernatants were combined and concentrated at 40 °C to near dryness using a Rotary Evaporator.

2.4.4 Sample clean-up

Approximately 2.5 g of octadecyl (C18) modified silica gel was weighed and parked into a glass column which was plugged with glass wool and 1.0 g of anhydrous sodium sulfate (FSSAI, 2015). About 10 mL of *n*-hexane was used to wet and rinse the column. The extract was then transferred into the column and eluted with 20 mL portions of hexane/acetone mixtures. The eluents were collected into a round-bottomed flask and then concentrated to dryness. The residues were then dissolved in 2 mL of ethyl acetate and placed in a GC vial for gas chromatography analysis.

3. Health risk estimation due to OCPs

The non-carcinogenic and carcinogenic health risk estimates for each of the organochlorine pesticide residues in water and fish were computed using basic standard indices: The Estimated Average Daily Intake (EDI), Average Daily Intake (mg/ kg/d), Hazard Quotients, the Hazard Index (HI) and cancer risk as reported by Akoto *et al*., (2016), Adeleye *et al*., (2019).

$$EADI = \frac{Mean\ residual\ pesticide\ concentration\ (mg/\ kg) \times food\ consumption\ rate\ (kg\ /day)}{Mean\ body\ weight\ (Kg)}$$

$$Hazard\ Quotients\ (HQ) = \frac{Estimated\ Average\ Daily\ Intake\ (EADI)}{Acceptable\ Daily\ Intake\ (mg/\ kg/d)}$$

$$Hazard\ Index\ (HI) = \frac{\sum Estimated\ Average\ Daily\ Intake\ (EADI)}{Acceptable\ Daily\ Intake\ (mg/\ kg/d)}$$

When the health risk index is > 1, the food involved is considered a risk to the consumers; when the index is < 1, the food involved is considered acceptable.

$$Cancer\ risk = EDI \times Cancer\ Slope\ Factor\left(CSF\right)$$

4. Results and discussions

4.1 Concentration of OCPs in water

Aldrin and endrin concentrations are presented in Table 1. Aldrin and endrin had the highest contribution to OCP burden in all the six sampling areas. The MRLs of 0.01 µg/L (WHO, 2011) of both Aldrin and Endrin were exceeded at all sampling areas since the minimum values recorded for Aldrin and Endrin are 0.3mg/L and 0.04mg/L. Aldrin undergoes photolysis in the environment to give dieldrin as its metabolite (Akan *et al*., 2014). The absence of its metabolite in this work may likely indicate the recent use of Aldrin despite its ban. This assertion is justified based on the findings of Akoto *et al*., (2016).

Heptachlor and Heptachlor epoxide have the least contribution to OCP burden in all the sampling areas with a maximum contribution of 0.13 mg/L in a sample from Garkida WB and a minimum of 0.01 mg/L at Kiri. The concentration of the individual OCP is in the form of Heptachlor > Heptachlor epoxide. Heptachlor epoxide being a metabolite of Heptachlor is usually expected to be higher than its parent compound due to the quick transformation of the parent compound (Erkmen *et al*., 2012). The high values of heptachlor might be an indication of continuous usage of these pesticides around the sampling areas.

Table 1 Concentrations of OCPs in water (mg/l)

	Kopre	Dabna	Garkida WB	Garkida	Daba	Kiri
Aldrin	1.62	0.3	1.42	0.84	0.68	0.63
Endrin	2.12	0.04	0.38	0.18	0.09	0.09
Heptachlor	0.05	0.02	0.13	0.01	0.02	0.01
Heptachlor epoxide	0.01	BDL	0.01	0.01	0.01	BDL

BDL = Below detection limit

The concentration of OCPs in sediments is shown in Table 2. The high concentration of aldrin in the sediments can be attributed to its property of low solubility in water and high affinity for organic matter. Aldrin and endrin readily metabolize to dieldrin and endrin ketone or aldehyde and the absence of these metabolites can be due recent application of both aldrin and endrin in the environment. These results coincide with the report by

Oyekunle *et al.,* (2021) which reported concentration of aldrin (0.070 ± 0.002 μg/L) is more than endrin (0.018 ± 0.008 μg/L) indicating a fresh application of aldrin to soils in the study areas.

In this study, Heptachlor epoxide was more abundant than its parent compound heptachlor in three of the sampling locations indicating the greater persistence of the metabolite than the parent compound. Another reason for the low concentration of heptachlor may be due to its susceptibility to bacterial degradation as some soil bacteria are known to metabolize heptachlor to chlordane epoxide. Furthermore, the environmental fate of heptachlor should also consider the fate of its major metabolites (Pokethitiyook and Poolpak, 2012).

Table 2 Concentration of OCPs in sediment (mg/Kg)

	Kopre	Dabna	Garkida WB	Garkida	Daba	Kiri
Aldrin	13.41	0.15	0.39	1.34	0.98	0.37
Endrin	0.3	0.05	0.32	0.28	0.09	0.11
Heptachlor	0.05	0.01	0.05	0.01	0.01	0.02
Heptachlor epoxide	0.01	0.02	0.06	0.02	0.01	0.02

The concentration of OCPs in fish (*clarias gariepinus*) is shown in Table 3. Aldrin and endrin were detected in 100% of the samples collected. Aldrin concentration in fish samples ranges between 0.23 mg/Kg – 1.62 mg/Kg while endrin ranges between 0.61 mg/Kg - 2.12 mg/Kg. Aldrin and endrin have the highest contribution to OCP burden in fish at three of the six sampling locations. The total OCPs burden is in the order of Garkida > Kopre > Garkida WB > Daba > Kiri > Dabna.

Both aldrin and endrin are known to be very toxic to aquatic animals and the concentration levels are all greater than the recommended MRL of 0.1 mg/Kg (WHO/FAO, 2022). The concentrations in this study are by far greater than the LC_{50} of 0.9 -53.0 μg/L recommended for freshwater fish by ANZECC and ARMCANZ (2000). Rasul *et al*., (2020) reported a high value range between 0 - 60 ppb and 332 - 812 ppb for endrin and aldrin in freshwater dried fish from different regions of Bangladesh. This also confirms the bioaccumulation and persistence of these OCPs.

Heptachlor and its degradation product heptachlor epoxide were detected in 100% of the samples collected from the sampling locations. The contribution to total OCP burden in

fish ranges between 0.02 mg/Kg – 0.93 mg/Kg and 0.01 mg/Kg – 0.12 mg/Kg for heptachlor and heptachlor epoxide respectively. Just like it was observed in water and sediment samples, heptachlor and heptachlor epoxide still maintain the least contribution to the total OCP burden in fish samples.

Heptachlor has a higher concentration than Heptachlor-epoxide in fish but all the concentrations are below the MRL of 0.2 mg/Kg (WHO/IPCS, 2006). Heptachlor may not be known as a recalcitrant molecule, but its ability to conserve its molecular integrity, and chemical, physical, and functional characteristics has proven its persistence in the environment (Navarro *et al*., 2007).

Abbassy *et al*., (2021) reported a low concentration of 0.00011mg/Kg of heptachlor epoxide in fish muscles from Edko Lake in Egypt.

Table 3 Concentration of OCPs in fish (*clarias gariepinus*) (mg/Kg)

	Kopre	Dabna	Garkida WB	Garkida	Daba	Kiri
Aldrin	0.57	0.45	1.62	0.23	0.36	1.14
Endrin	1.66	0.96	2.12	1.54	0.92	0.61
Heptachlor	0.16	0.02	0.05	0.93	0.22	0.76
Heptachlor epoxide	0.03	0.04	0.01	0.05	0.12	0.1

4.2 Health risk estimation

Health risks associated with the consumption of water and fish from all sampling locations in the study area were computed to assess the probability of adverse effects or otherwise due to the presence of OCPs analyzed. The carcinogenic and non-carcinogenic risks were estimated using hazard quotients and cancer risks by adopting the United States Environmental Protection Agency's (2004) protocol as reported by Akoto *et al.,* (2016) and Adeleye *et al.,* (2019).

4.2.1 Non-carcinogenic health risk in water

The hazard quotients due to water ingestion are presented in Table 4 and were mostly greater than 1 with only heptachlor epoxide being less than 1, indicating greater possibilities of non-carcinogenic health hazards occurring due to consumption of the waters from the sampling locations in the study area. The contribution to non-carcinogenic risk is in the

sequence aldrin > endrin > heptachlor > heptachlor epoxide. HQ for adults ranges from 110 - 594, 7.33 – 388, 0.36 – 4.76, and 0 – 0.36 for aldrin, endrin, heptachlor and heptachlor epoxide respectively, while the HQ for children with 30 Kg body weight ranges 220 – 1188, 14.66 – 777, 0.37 – 9.53 and 0 – 0.73 for aldrin, endrin, heptachlor and heptachlor epoxide respectively.

The cumulative HQ which is the Hazard index is in the sequence Kopre > Garkida (WB) > Garkida > Daba > kiri > Dabna. This simply implies people in Kopre may experience more health hazards due to water ingestion than other sampling locations.

4.2.2 Non-carcinogenic health risk in Fish (Clarias gariepinus)

The hazard quotients due to fish consumption are presented in Table 5. Aldrin and endrin have HQ greater than 1 in all sampling locations in a range of 1.39 – 9.85, and 1.85 – 6.44 while heptachlor and heptachlor epoxide were less than 1 in the range of 0.03 – 0.56 and 0.006 – 0.07. This implies that there are very low probabilities of adverse effects due to heptachlor and heptachlor epoxide present in the fish while there are high probabilities of non-carcinogenic health effects due to aldrin and endrin.

HQ due to fish consumption follows the same trend as water in terms of body weight effect since as the body weight increases the HQ decreases. The HI which is the cumulative effect of the individual OCPs in fish is in the sequence Garkida (WB) > Kiri > Kopre > Garkida > Dabna > Daba.

4.2.3 Carcinogenic health risk in water

The carcinogenic risk for Aldrin, heptachlor, and heptachlor epoxide were computed using the EPA guidelines and are presented in Table 6. Endrin was excluded because it has no cancer slope factor, therefore, it was deemed non-carcinogenic. The results showed the cumulative cancer risks due to water ingestion range between 1.90×10^{-1} - 1.02 and 3.81×10^{-1} – 2.04 for an adult and a child respectively. These ranges are far above the recommended threshold of 1 in a million set by the USEPA. Of the three OCPs studied, Aldrin has the highest value of cancer risk compared to heptachlor and heptachlor epoxide and could be related to liver and breast cancers as it was evident in the animal studies and epidemiological studies carried out as reported by ATSDR (2002) and Ibarluzea *et al.,* (2004).

4.2.4 Carcinogenic health risk in Fish (Clarias gariepinus)

Table 4 Hazard quotients of OCPs consumption in Water

	KOPRE		Dabna		Garkida WB		Garkida		Daba		kiri	
	adult	Child	adult	Child	adult	Child	adult	Child	adult	child	adult	child
Aldrin	594	1188	110	220	520.6667	1041.333	308	616	249.3333	498.6667	231	462
Endrin	388.6667	777.3333	7.333333	14.66667	69.66667	139.3333	33	66	16.5	33	16.5	33
Heptachlor	1.833333	3.666667	0.733333	1.466667	4.766667	9.533333	0.366667	0.733333	0.733333	1.466667	0.366667	0.733333
Heptachlor epoxide	0.366667	0.733333	0	0	0.366667	0.733333	0.366667	0.733333	0.366667	0.733333	0	0
HI=∑HQ	984.8667	1969.733	118.0667	236.1333	595.4667	1190.933	341.7333	683.4667	266.9333	533.8667	247.8667	495.7333

Table 5: Hazard quotients of OCPs consumption in Fish (*Clarias gariepinus*)

	KOPRE		Dabna		Garkida WB		Garkida		Daba		kiri	
	Adult	Child	adult	child	adult	child	Adult	Child	Adult	child	adult	child
Aldrin	3.4675	6.935	2.7375	5.475	9.855	19.71	1.399167	2.798333	2.19	4.38	6.935	13.87
Endrin	5.049167	10.09833	2.92	5.84	6.448333	12.89667	4.684167	9.368333	2.798333	5.596667	1.855417	3.710833
Heptachlor	0.097333	0.194667	0.012167	0.024333	0.030417	0.060833	0.56575	1.1315	0.133833	0.267667	0.462333	0.924667
Heptachlor epoxide	0.01825	0.0365	0.024333	0.048667	0.006083	0.012167	0.030417	0.060833	0.073	0.146	0.060833	0.121667
HI=∑HQ	8.63225	17.2645	5.694	11.388	16.33983	32.67967	6.6795	13.359	5.195167	10.39033	9.313583	18.62717

Table 6: Cancer Risk of OCPs consumption in Water

	KOPRE		Dabna		Garkida WB		Garkida		Daba		kiri	
	Adult	Child	adult	child	adult	Child	Adult	Child	adult	child	adult	child
Aldrin	1.01E+00	2.02E+00	1.87E-01	3.74E-01	8.85E-01	1.77E+00	5.24E-01	1.05E+00	4.24E-01	8.48E-01	3.93E-01	7.85E-01
Heptachlor	8.25E-03	1.65E-02	3.30E-03	6.60E-03	2.15E-02	4.29E-02	1.65E-03	3.30E-03	3.30E-03	6.60E-03	1.65E-03	3.30E-03
Heptachlor epoxide	1.65E-03	3.30E-03	0	0	1.65E-03	3.30E-03	1.65E-03	3.30E-03	1.65E-03	3.30E-03	0	0
∑ Cancer risk	1.02E+00	2.04E+00	1.90E-01	3.81E-01	9.08E-01	1.82E+00	5.27E-01	1.05E+00	4.29E-01	8.58E-01	3.94E-01	7.89E-01

The levels of Aldrin heptachlor and heptachlor epoxide in fish samples from the study areas were considered as having the potential to cause cancers when one is exposed since they have an established cancer slope factor. The computed cancer risk posed by these OCPs due to the ingestion of fish from the study area is presented in Table 7. The results showed the computed cumulative cancer risk due to Aldrin, heptachlor, and heptachlor epoxide for all sampling locations ranges between 4.65×10^{-3} - 1.69×10^{-2} and 9.31×10^{-3} - 3.38×10^{-2} for an adult and a child of 30kg body weight respectively. According to USEPA, cancer risk values above 1.0×10^{-6} are above the recommended threshold. Thus, the risk of developing cancers from Aldrin, heptachlor, and heptachlor epoxide as a result of consuming fish from all the sampling locations is very high. These results imply that on average there is the possibility that about 4,650 to 16,900 out of a million adults may develop cancers from the sampling locations in their lifetime. Therefore, there is a need to devise means of curbing the adverse effects of environmental pollutants on the inhabitants of the study areas.

5. Conclusion

Pesticides have been a major input in modern agricultural practice and they improved the output tremendously, but not without their negative consequences, since only less than a percentage of the applied pesticide reaches its intended target with the remaining going into the environment. Thus, monitoring its distribution and potential adverse effects on man and his environment becomes necessary. These studies identified aldrin, endrin, heptachlor, and heptachlor epoxide as pesticides of interest. All four OCPs were found in the three environment compartments studied, some at concentrations above the permissible limit set by regulatory agencies. HQ and HI are in most cases greater than 1 especially with regards to aldrin and endrin in both water and fish, indicating high probabilities of non-carcinogenic risk to residents of the study area. Carcinogenic health risk probabilities were far greater than the 1.0×10^{-6} recommended by regulatory agencies inferring a high likelihood of cancers occurring among the inhabitants of the study area. There is a need to educate the people residing in the study area on the dangers associated with indiscriminate usage of these pollutants and their implications on human health and the environment.

Declaration of Conflict of Interest

The authors declare no conflict of interest exists and this work is intended for the advancement of knowledge.

Table 7 Cancer risk of OCPs consumption in Fish (*Clarias gariepinus*)

	KOPRE		Dabna		Garkida WB		Garkida		Daba		kiri	
	adult	child	Adult	child	adult	Child	Adult	child	Adult	child	adult	child
Aldrin	5.89E-03	1.18E-02	4.65E-03	9.31E-03	1.68E-02	3.35E-02	2.38E-03	4.76E-03	3.72E-03	7.45E-03	1.18E-02	2.36E-02
Heptachlor	4.38E-04	8.76E-04	5.48E-05	1.10E-04	1.37E-04	2.74E-04	2.55E-03	5.09E-03	6.02E-04	1.20E-03	2.08E-03	4.16E-03
Heptachlor epoxide	8.21E-05	1.64E-04	1.10E-04	2.19E-04	2.74E-05	5.48E-05	1.37E-04	2.74E-04	3.29E-04	6.57E-04	2.74E-04	5.48E-04
$\sum$ Cancer risk	6.41E-03	1.28E-02	4.82E-03	9.64E-03	1.69E-02	3.38E-02	5.06E-03	1.01E-02	4.65E-03	9.31E-03	1.41E-02	2.83E-02

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