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Determination of Pesticide Residues in *Brycinus nurse* (*Nurse tetra*) from River Benue at Makurdi, Nigeria

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ABSTRACT

Organochlorine pesticides (OCP's) are harmful to both the health of humans and wildlife when their levels exceed safe limits. This research measured the levels of 20 different OCP's in *B. nurse* specimens collected at River Benue along Makurdi, Nigeria, during January 2025. Nine (9) samples were collected from fishermen along the river bank. This study also involved assaying pesticide residues in the River Benue using Gas Chromatography-Mass Spectrometry (GC-MS Chromatography). GC-MS was used to study liquid, gaseous or solid samples. An Agilent 6890A GC system MSD gas chromatography equipped with an auto sampler connected to an Agilent Mass Spectrophotometric Detector was used. 1 micro-litre of sample was injected in the pulsed spitless mode onto a 30m x 0.25mm ID DB 5MS coated fused silica column with a film thickness of 0.15 micrometer. The risk level of the analytes was assessed using the Life Average Daily Dose (LADD), Cancer Risk, and Hazard Quotient (HQ). Levels of organochlorine pesticides were recorded along River Benue at Makurdi, the result also indicated no statistically significant differences in most of the levels of OCP residues eluted from GCMS analyses except for Heptachlor ($F = 5.865$, $p = 0.039$) and P,P'-DDT ($F = 5.145$, $p = 0.050$). The DNMRT post hoc results revealed that the concentration of Heptachlor eluted by GCMS for OCP were similar in Wurukum and Adaka but significantly higher at Tyo Mu. Similarly, the eluted P, P'-DDT levels were also similar in Wurukum and Adaka but significantly higher in Tyo Mu but the ADD and CR were all below the minimum allowable limits for ecological and cancer risks ($< 10^{-6}$). Cancer risk assessments remained within safe limits (below 10^{-6}). Despite this, the results underscore the necessity for improved regulatory measures governing how agrochemicals are stored, used, and discarded along the River Benue at Makurdi and in other Nigerian regions.

Keywords: Pesticides, pesticide residues, pesticide residues in fish, fish, GC-MS.

1. INTRODUCTION

Aquatic ecosystems, including fisheries, ponds, lakes, rivers, streams, and oceans, represent extremely precious assets found in nature that is beneficial to the teeming global population. With relatively minimal maintenance and protection, these systems yield substantial long-term advantages. Economic benefits are significant, generating employment opportunities and income through commercial fishing, wholesale operations, and retail sales (Kumari, 2020). Beyond direct economic returns, aquatic environments provide important recreational and aesthetic value through activities such as boating, sport fishing,

swimming, and opportunities for relaxation and enjoyment of natural landscapes. However, growing awareness of the importance of fisheries and aquatic ecosystems has been paralleled by rising concerns with regards to its effects of human population expansion and anthropogenic activities on aquatic biodiversity and water quality.

Pesticides are chemical agents of either natural or synthetic origin employed to control pests, weeds, and pathogens affecting animals and plants. They are categorized into several types: insecticides, fungicides, rodenticides, herbicides, bactericides, and larvicides. Pesticides represent a significant category of toxic substances associated with human activities that substantially affect aquatic ecosystems and water quality. These chemical agents are employed in agriculture to safeguard crops from various threats, including insects, fungal infections, weeds, and other harmful organisms (Akashe, Pawade & Nikam, 2018; Kadiru, Patil & D'Souza, 2022). When used appropriately, pesticides offer considerable benefits by preventing crop losses in agricultural and forestry settings and enhancing food production efficiency. Their applications include controlling destructive forest pests such as the gypsy moth, maintaining lawns and recreational spaces, and contributing to improved food security by reducing malnutrition and hunger in human and animal populations. Additionally, pesticides have played a crucial role in managing vector-borne diseases affecting humans, including malaria, encephalitis, and bubonic plague.

According to Sebra and Mehena (2015), chemical contaminants from pesticides in water bodies pose a significant threat to aquatic life that are not targeted, with fish being the worst among them. Cypermethrin is a synthetic pyrethroid insecticide used to combat many pests, including cotton, fruit and vegetable crop moth pests. It is available in emulsifiable concentrate, and wettable powder formulations. Synthetic pyrethroids have been introduced as substitutes for more harmful pesticides, such as substitutes for more toxic pesticides, such as hydrocarbons, organophosphates and carbamates, for agricultural and domestic use during the past two decades. The study revealed that pyrethroids are extremely toxic even at very low concentrations of non-target species, such as honeybees, freshwater fish and aquatic arthropods (Houssou & Edoh, 2017).

Pesticide residues refer to specific substances present in water, food items, agricultural products, or animal feed that result from pesticide use. The definition includes the original pesticide along with its derivatives such as conversion products, metabolites, reaction products, and toxicologically relevant impurities. The World Health Organization (WHO, 2016) defines these residues as any chemical substance, or mixture thereof, found in food for humans or animals resulting from pesticide use, including toxicologically relevant derivatives such as conversion products, degradation byproducts, impurities, and metabolites. When pesticides accumulate in aquatic system, it undergoes break down depending upon the physicochemical and biological factors of the water eco-system, which affects fishes like *B. nurse*.

Brycinus nurse is classified under the kingdom *Animalia*, phylum: *Chordata*, class: *Actinopterygii*, order: *Characiformes*, family: *Alestidae*, like some other *Alestidae*, they are called Gwan-kifi in Hausa, Aru in Igbo, Eja Osan in Yoruba and Mchambe in Tiv, they are also called robber tetras due to their bold and rather carnivorous habits. In view of Abdulkarim, Yusuf and Suleiman (2017), they are not frequently kept as aquarium fishes and in their requirements resemble the South American tetras of the *Characidea*. Unlike these, *Brycinus* are not well-suited to accompany delicate fishes however they are better kept with dwarf cichlids and similar small but robust companions. The aim of this study is to conduct an audit of organochlorine pesticides used along the R. Benue at Makurdi, Nigeria., to quantify the concentration of organochlorine pesticides in *B.nurse* along the R. Benue in Makurdi., and to assess ecological and human health risks of organochlorine pesticide residues in *B.nurse* along R. Benue in Makurdi using GC-MS.

2. MATERIALS AND METHODS

2.2.1 The Study Area

The study area is Benue state in Nigeria, one of the six North Central states in the country. For administrative purposes, the state is politically divided into three agricultural zones: A, B, and C. Benue state is bordered to the northwest by Cross River state and to the southwest by Kogi state. The state's population comprises both rural and urban residents. Primary occupations include fishing, farming, civil

service, crafts, trade, and other commercial activities. Residents engage in subsistence agriculture while also producing cash crops for commercial purposes.

Major cash crops produced include soybeans, rice, groundnuts, yams, tomatoes, and oranges, among others. The state also hosts significant economic industries such as the Rice Mill, Dangote Cement Factory in Yandev, Benue Breweries in Makurdi, and a soybeans factory in Taraku. As a result of these varieties of produce in the state, the state has a natural recognition as “*Food Basket of the Nation*” (Akaahan, Olabanyi & Azua, 2015). The Benue River originates from the Adamawa Mountains in central Cameroon, flowing westward for approximately 1,400 kilometers until it joins the Niger River at a point roughly 450 kilometers above the delta, near Lokoja, Nigeria (Ashley, 2010). The upper course of the Benue River is distinguished by narrow valley formations containing waterfalls and rapids. Conversely, the lower reaches are predominantly free of such features and are characterized by extensive floodplains (spanning 1,800 km²) and anastomosing channels of various sizes that meander throughout the floodplain. The floodplain also includes seasonally inundated depressions termed fadama, which represent valuable fishery resources exploited after floodwaters subside (Sarch, Madakan & Ladu, 2001). The average annual rainfall is between 1000 and 1500mm. These seasonal differentials markedly affect the rivers physiochemistry, fauna composition and abundance. *B. nurse* was chosen because it is mostly consumed by people in Makurdi local government area of Benue state, Nigeria.

2.2.2 Reagents

The following analytical high-grade chemicals were used. All organic solvents intended for extraction were GC-MS grade. Organochlorine pesticides containing a mixture of dichloromethane/methanol, anhydrous sodium sulphate and deionized water were used.

2.2.3 Equipment

An Agilent SENCO 6890A GC system MSD, equipped with dual injector, 2 ml Amber screw cap vials, measuring cylinder, micro-syringe, refrigerator, weighing balance, extraction tubes, fractionating glass column for liquid chromatography (2mm diameter), (HP) 5 Column (length; 30mI) was used.

2.2.4 Analysis of Contaminants

An Agilent SENCO 6890A GC system with MSD was employed, equipped with dual injector, 2 mL amber screw cap vials, measuring cylinder, microsyringe, refrigerator, weighing balance, extraction tubes, fractionating glass column for liquid chromatography (2 mm diameter), and an HP5 Column (30 m length).

2.2.5 Instrument Calibration (Quality Control and Quality Assurance)

Quality control and quality assurance procedures were employed to ensure method accuracy and precision. Calibration was performed using three-point serial dilution calibration standards (3 ppm, 4 ppm, and 5 ppm) and five-point serial dilution calibration standards (0.001 to 2.50 ppm) prepared from stock solution to calibrate the GC/MS (Paramasivam & Chandrasekaran, 2014). A glyphosate mixture containing 360 g/L functioned as the source and stock concentration standard. Following this, six-point serial dilution calibration standards (1.00, 5.00, 10.00, 15.00, 20.00, 25.00 µL/mL) were prepared from sub stock solution for GC/MS calibration. Detection limits were established based on the lowest measurable residue concentration in each matrix under GC operating conditions, set at 0.0001 mg/kg. Before calibration, the Mass Spectrometer (MS) underwent autotuning to perfluorotributylamine (PFTBA) using established criteria to confirm the abundance of m/z 69, 219, 502, and other optimal instrument sensitivity parameters. Organochlorine pesticide level determination in samples was accomplished using GC/MS with the Mass Spectrometer Detector (MSD) operating in Selective Ion Monitoring (SIM) and Scan mode to ensure target constituent detection (Durović-Peješev & Dorđević, 2010). Sample analyses utilized a SENCO 6890A GC system GC/MS with dual injector and column.

2.2.6 Sampling of Fish

Nine (9) samples of *B. nurse* were obtained from fishermen at the biggest commercial fish landing sites (Adaka, Wurukum and Tyo Mu) along the bank of River Benue at Makurdi According to Akaahan, Olabanyi and Azua (2015) collection of fish should be done in the morning and under the surveillance of the supervisors to ensure proper processing and adequate packaging and conservation before sending the

samples to the laboratory. *B. nurse* was chosen because they are mostly consumed by people in the Makurdi local government area of Benue state, Nigeria.

2.2.7 Sample Clean Up

A solution standard stock (75 to 550 pg/ml) was prepared by exact weighing. It was dissolved in the acetone and will be stocked in a freezer to - 30°C without exhibition to light. The solution stock standard of work (5 µg/ml) was prepared by dilution suitable of cyclohexane and was stored inside a refrigerator (4°C) and rinsed with the hexane.

2.2.8 Preparation of the Samples

The preparation of the samples of *B.nurse* was done by BGI-Bassey and God Investment Laboratory, Port-Harcourt, Rivers state and twenty (20) organochlorine pesticides was taken into consideration because they are mostly used by farmers, pesticide retailers, agricultural extension agents and fishermen along river Benue at Makurdi and these pesticides have been selected on the basis of their frequency use.

2.2.9 Extraction by Gas Chromatography

Gas chromatography methodology involved assaying pesticide residues in the River Benue using Gas Chromatography-Mass Spectrometry (GC-MS Chromatography). The procedure of extraction of the samples by gas chromatography was done using the following. The sample (10g) was crutched/weighed into a beaker with 100 ml dichloromethane/methanol. This was mixed for about 60seconds, allowed for 10mins, then decanted into 200ml beaker. The extract was transferred into the rotary evaporator and concentrated to about 2mL. This was transferred further into a Teflon screw-cap vial well labeled. The extract was cleaned up with 3g of anhydrous sodium sulfate in a well-packed column and the extract is now ready for pesticide analysis with the gas chromatography.

2.2.10 Pesticide Analysis

The determination of pesticides was performed by gas chromatography. An Agilent SENCO 6890A GC system MSD gas chromatography equipped with an auto sampler connected to an agilent Mass Spectrophotometric Detector was used.1 micro-litre of sample was injected in the pulsed spitless mode onto a 30m x 0.25mm ID DB 5MS coated fused silica column with a film thickness of 0.15 micrometer. Helium gas was used as a carrier gas and the column head pressure was maintained at 20psi (137,895pa) to give a constant of 1ml/min pressure. Other operating conditions were preset. The column temperature was initially held at 55°C for 0.4min,increased to 200°C at a rate of 25°C/mins, then to 280°C at a rate of 8°C/mins and to a final temperature of 300°C at a rate of 25°C/mins, held for 2mins.The identification time was based on retention time. Components with lower retention time elutes first before the ones of higher retention time.

2.2.11 Risk Assessments

The risk level of the analytes was assessed using the Life Average Daily Dose (LADD), Cancer Risk, and Hazard Quotient (HQ) (Ge, Woodward, Li, & Wang, 2014; Megahed, Dahshan, Abd-El-Kader; Abd-Elall, Elbana, Nabawy & Mahmoud, 2015; Environmental Protection Agency-EPA, 1989; Lohmann, Breivik, Dachs, & Muir, 2007). Values were evaluated from Equations (1) - (4) in accordance with standard methods (ECETOC, 2016; Bozek, Adamec, Navratil, Kellner, Bumbova, Dvorak,.2009; Hamilton, Ambrus, Dieterle, Felsot, Harris, Holland, Katayama, Kurihara, Linders & Unsworth, 2003; & ECETOC, 2001).

For calculation of the risk assessment:

$$HQ = \frac{ADD}{RfD} \quad (1)$$

Where: HQ = Hazard Quotient (no unit); ADD = intake exposure level (mg/kg/day); RfD = Reference Dose (mg/kg/day).

$$ADD = \frac{C \times FI \times IR \times EF \times ED}{BW \times AT} \text{ (mg/kg/d)} \quad (2)$$

$$LADD = \frac{C \times FI \times IR \times EF \times ED}{BW \times AT} \text{ (mg/kg/d)} \quad (3)$$

ADD = Intake Exposure Level mg/kg/day; LADD = Life Average Daily Dose (mg/kg/body weight), C= Average concentration of the analyte (OCP's) during the monitoring periods (mg/L); FI = Fraction Ingested (an absolute number with 0 - 1, but previous studies estimated FI = 0.98); IR = Daily water intake based on age group; Age 0 - 6 years = 0.3 L/day, Age 7 - 17 years = 1 L/day; Adult = 1.4 L/day; EF = Exposure Frequency = 365 days/year; ED = Exposure Duration based on age group; Age 0 - 6 years = 6; Age 7 - 17 years = 11; Adult = 3; BW = Average body weight. Age 0–6 years = 30 kg; Age 7 - 17 years = 46 kg; Adult = 70 kg. AT = Averaging Times in days; AT₀₋₆ = 2190 days; AT₇₋₁₇ = 4015 days; AT_{Adult} = 10,950 days (Yahaya, Okoh, Okoh & Adeniji, 2017).

Note: For LADD, the AT = 70 years × 365 = 25,550 days (the same for all age groups).

$$\text{Cancer Risk} = \frac{C \times DI \times ED \times CSF \times CF}{BW \times AT} \quad (4)$$

C = Concentration of OCPs during the monitoring period (mg/L), DI = Daily Input L day⁻¹: 2 L day⁻¹; ED = Exposure Duration (Year): 30 years, BW = Body Weight (kg): 60 kg; AT = Average Life Span (year): 70 years × 365 = 25,550 days (for all age group); CSF = Cancer Slope Factor (mg/kg/day): 0.07 (mg/kg/day); CF = Conversion Factor: 10⁻⁶ (Yahaya, *et al.*, 2017).

HQ > 1.0 indicates that the compounds pose a potential threat to ecosystems or that harmful effect may arise (Yahaya, *et al.*, 2017); HQ < 1.0 shows a relatively low risk. A larger HQ implies a greater ecological risk. According to (Yahaya, *et al.*, 2017) ADD > 10⁻⁴ shows the maximum lifetime cancer risk while LADD > 10⁻⁶ suggests the highest risk of cancer, but LADD = 10⁻³ indicates that protective measures are required. Similarly, a cancer risk value > 10⁻⁶ suggests there is the highest cancer risk; however, values equal to 10⁻³ require protective measures (United State Environmental Protection Agency-Integrated Risk Information System-USEPA-IRIS, 2014; United State Environmental Protection Agency-USEPA, 2015).

3. RESULTS AND DISCUSSION

Results

Table 1: Audit of Pesticides Used along the R. Benue at Makurdi, Nigeria

S/N	Pesticide	Adaka n=15	Wurukum n=20	Tyo Mu n=10
1.	Force up	15(100%)	20(100%)	10 (100%)
2.	Clear weed	14(93%)	20(100%)	10(100%)
3.	Bush Klear	15(100%)	18(90%)	8(80%)
4.	Glycel	15(100%)	20(100%)	7(70%)
5.	Vinash	14(93%)	16(80%)	10(100%)
6.	Glyphotex	14(93%)	18(90%)	8(80%)
7.	Tourch			
	Down	5(33%)	20(100%)	10(100%)
8.	Round Up			
	Turbo	0(0%)	20(100%)	7(70%)
9.	Uproot	4(27%)	15(75%)	5(50%)
10.	Weedlezz	14(93%)	18(90%)	2(20%)

11	Paraforce	15(100%)	20(100%)	10(100%)
12.	Sunsate	3(20%)	16(80%)	7(70%)
13.	Relisate	0(0%)	7(35%)	2(20%)
14.	Steed	6(40%)	17(85%)	8(80%)
15.	Atalar	0(0%)	0(0%)	10(100%)
16.	Solito	0(0%)	0(0%)	9(90%)
17.	Guaforce	0(0%)	0(0%)	10(100%)
18.	2., 4 –D	14(93)	16(80%)	7(70%)
19.	Nominee Gold	15(100%)	19(95%)	10(100%)
20.	Rice Pro	15(100%)	0(0%)	10(100%)
21.	Orizo Plus	15(100%)	18(90%)	8(80%)
22.	Agil	13(87%)	17(85%)	9(90%)
23.	Stricker	14(93%)	20(100%)	5(50%)
24.	Rice view	4(27%)	19(95%)	8(80%)
25.	Narrow Down	15(100%)	20(100%)	10(100%)
26.	Fouse Lade	13(87%)	18(90%)	8(80%)
27.	Star Force	15(100%)	15(75%)	4(40%)
28.	Lara Force	0(0%)	16(80%)	6(60%)
29.	Lambate	13(87%)	19(95%)	6(60%)
30.	Karate	15(100%)	18(90%)	9(90%)
31.	Perfect Killer	13(87%)	15(75%)	6(60%)
32.	Total Control	12(80%)	18(90%)	0(0%)
33.	Hat Trick	15(100%)	19(95%)	7(70%)
34.	Best	13(87%)	16(80%)	8(80%)
36.	Sharp Shooter	14(93%)	18(90%)	10(100%)
37.	Courage	11(73%)	18(90%)	10(100%)
38.	Emmatex	14(93%)	15(75%)	4(40%)
39.	Super Core	9(60%)	14(70%)	8(80%)
40.	Imiforce	15(100%)	20(100%)	10(100%)
41.	Clean Up	10(67%)	16(80%)	8(80%)
42.	Snapper	12(80%)	15(75%)	5(50%)
43.	Mancozeb	4(27%)	9(45%)	3(30%)
44.	Captan	10(67%)	20(100%)	4(40%)
45.	Propicon	14(93%)	15(75%)	3(30%)
46.	Hexacona	15(100%)	17(85%)	5(50%)
47.	Matalaxyl	15(100%)	14(70%)	5(50)

48.	Chlorotha	5(33%)	5(25%)	3(30%)
49.	Phostozine	11(73%)	18(90%)	2(20%)
50.	Commando	1(7%)	1(5%)	2(20%)
51.	Thunder	15(100%)	0(0%)	2(20%)
52.	Rodenticide	15(100%)	0(0%)	2(20%)

Source: Fieldwork, 2025

The common pesticides used by respondents in the study area are presented in Table 1. In general, the respondents acknowledged that they used pesticides in the study area. Table 1 shows that majority (59.6%) of the respondents used pesticides very frequent in their farming activities; about 35.0% of farmers used pesticides moderately, while 5.4% of respondents did not use pesticides frequently in their crop production. In relation to the sources of pesticides, majority (95.1%) of the respondent's sourced pesticides from open market, 11.8% of farmer's sourced pesticides from farmers' cooperative, while 9.1% sourced from agricultural extension agents. With respect to the types of selective herbicides used by the respondents 81% of the farmers used 2-4-D, 33.33% used Atalar, 33.33% used Guaforce, 98.33% used Nominee Gold, 66.7% used Rice pro, 90% used Orizo plus, 87.33% used Agil, 87% used Striker, 67.33% Rice view, 100% used Narrow down, 85.66 % used Force lade while 71.66 % of the respondents used Star force.

Table 2: Occurrence of Organochlorine Pesticide in the Flesh of B. nurse along River Benue at Makurdi, Nigeria

Concentration (ng/L)	Sample (% of 3)													
	Adaka Site				Wurukum Site				Tyo Mu Site					
OCP Analyte	A1	A2	A3	Mean	B1	B2	B3	Mean	C1	C2	C3	Mean	GMean	GStdev
Alpha-BHC	0.96	ND	0.08	0.35	0.18	ND	ND	0.06	ND	0.07	0.26	0.11	0.17	0.31
Beta-BHC	ND	ND	0.90	0.30	ND	ND	ND	0.00	ND	0.14	ND	0.05	0.12	0.30
Gamma-BHC	ND	ND	ND	0.00	ND	ND	ND	0.00	ND	0.79	ND	0.26	0.09	0.26
Heptachlor	ND	0.27	ND	0.09	ND	ND	0.09	0.03	1.02	0.35	0.46	0.61	0.24	0.34
Delta-BHC	ND	ND	0.13	0.04	0.09	ND	ND	0.03	ND	0.78	0.80	0.53	0.20	0.34
Aldrin	ND	0.72	0.24	0.32	ND	0.44	0.05	0.16	ND	0.85	ND	0.28	0.26	0.34
Heptachlor Epoxide	0.75	0.43	ND	0.39	ND	ND	0.69	0.23	0.68	0.05	0.07	0.27	0.30	0.34
Gamma- Chlordane	ND	0.20	0.67	0.29	ND	ND	0.73	0.24	0.15	1.34	0.37	0.62	0.38	0.45
Alpha-Chlordane	ND	ND	0.18	0.06	ND	0.95	0.25	0.40	0.62	0.37	ND	0.33	0.30	0.34
Endosulfan I	ND	0.52	0.06	0.19	0.26	0.27	0.71	0.41	ND	0.38	ND	0.13	0.24	0.26
P,p'-DDE	0.11	ND	0.84	0.32	0.97	ND	ND	0.32	0.48	0.29	0.63	0.47	0.37	0.38
Dieldrin	ND	ND	ND	0.00	ND	0.99	ND	0.33	0.11	0.12	0.46	0.23	0.19	0.34
Endrin	ND	ND	0.17	0.06	0.58	ND	0.51	0.36	ND	ND	ND	0.00	0.14	0.24
P,P'-DDD	0.24	0.44	ND	0.23	0.27	0.66	0.24	0.39	ND	0.16	0.17	0.11	0.24	0.21
Endsulfan II	ND	ND	ND	0.00	ND	ND	ND	0.00	ND	ND	ND	0.00	ND	ND
P,P'-DDT	ND	ND	ND	0.00	ND	0.11	ND	0.04	0.97	0.86	0.10	0.64	0.23	0.39
Endrin aldehyde	ND	ND	ND	0.00	1.82	ND	0.93	0.92	0.66	0.21	0.27	0.38	0.43	0.62
Endosulfan sulfate	ND	ND	0.01	0.00	0.61	ND	0.35	0.32	ND	0.06	0.29	0.12	0.15	0.22
Methoxychlor	ND	ND	0.10	0.03	ND	ND	ND	0.00	ND	ND	ND	0.00	0.01	0.03
Endrin ketone	ND	ND	0.98	0.33	ND	ND	ND	0.00	ND	ND	ND	0.00	0.11	0.33

Key: ND-Not Detected, GMean-Grand Mean, GStdev-Grand Standard Deviation

The summary of the occurrence of OCP residues in the flesh of *B. nurse* from the three sampling sites in Table 2 and the concentrations of some residues were below the Limit of Detection (LOD) or not detected, which precluded the application of rigorous statistical analyses. The OCP residues detected in samples across the three locations were in the range of ND - 0.98 ng/L. However, Endosulfan II was not detected in any of the samples across the sampling sites.

The mean concentrations (ng/L) of the OCP residues in Adaka, such as Alpha-BHC, Beta-BHC, Heptachlor, Delta-BHC, Aldrin, Heptachlor Epoxide, Gamma-Chlordane, Alpha-Chlordane and Endosulfan I, were 0.35, 0.30, 0.09, 0.04, 0.32, 0.39, 0.29, 0.06 and 0.19. Others such as P,p'-DDE, Endrin, P,P'-DDD, Endosulfan II, Methoxychlor and Endrin ketone were 0.32, 0.06, 0.23, 0.03 and 0.33. Gamma-BHC, Dieldrin, P,P'-DDT, Endrin aldehyde and Endosulfan sulfate were not found in the samples from Adaka.

In Wurukum, the concentrations (ng/L) of Alpha-BHC, Heptachlor, Delta-BHC, Aldrin, Heptachlor Epoxide, Gamma-Chlordane, Alpha-Chlordane and Endosulfan I, were 0.06, 0.03, 0.03, 0.16, 0.23, 0.24, 0.40, and 0.41 while those of P,p'-DDE, Dieldrin, Endrin, P,P'-DDD, Endosulfan II, P,P'-DDT, Endrin aldehyde, and Endosulfan sulfate, were 0.32, 0.33, 0.36, 0.39, 0.00, 0.04, 0.92, and 0.32, respectively. Beta-BHC, Gamma-BHC, Methoxychlor and Endrin ketone were not detected in the samples from Wurukum.

The mean concentrations (ng/L) of samples from Tyo Mu were 0.11, 0.05, 0.26, 0.61, 0.53, 0.28, 0.27, 0.62, 0.33, 0.13, 0.47 and 0.23 for Alpha-BHC, Beta-BHC, Gamma-BHC, Heptachlor, Delta-BHC, Aldrin, Heptachlor Epoxide, Gamma-Chlordane, Alpha-Chlordane, Endosulfan I, P,p'-DDE and Dieldrin. The levels of P,P'-DDD, P,P'-DDT, aldehyde and Endosulfan sulfate eluted from Tyo Mu were 0.11, 0.64, 0.38 and 0.12 ng/L. Dieldrin, Methoxychlor and Endrin ketone were also not detected. The grand-mean (\pm standard deviations) of the eluted OCP residues across the three sampling sites for Alpha-BHC, Beta-BHC, Gamma-BHC, Heptachlor, Delta-BHC, Aldrin, Heptachlor Epoxide, Gamma-Chlordane, Alpha-Chlordane, Endosulfan I, P,p'-DDE, Dieldrin, Endrin, P,P'-DDD, P,P'-DDT, Endrin aldehyde, Endosulfan sulfate, Methoxychlor and Endrin ketone were 0.17(\pm 0.31), 0.12(\pm 0.30), 0.09(\pm 0.26), 0.24(\pm 0.34), 0.20(\pm 0.34), 0.26(\pm 0.34), 0.30(\pm 0.34), 0.38(\pm 0.45), 0.30(\pm 0.34), 0.24(\pm 0.26), 0.37(\pm 0.38), 0.19(\pm 0.34), 0.14(\pm 0.24), 0.24(\pm 0.21), 0.23(\pm 0.39), 0.43(\pm 0.62), 0.15(\pm 0.22), 0.01(\pm 0.03) and 0.11(\pm 0.33) respectively.

Table 3: Average Daily Dose (ADD) and Cancer Risk (CR) from Pesticide Residues in *B. nurse* along River Benue

Organochlorine Pesticides	ADD	Cancer Risk (CR)
Alpha BHC	3.91E-07	3.99E-13
Beta-BHC	2.58E-06	2.63E-12
Gamma-BHC	2.07E-07	2.11E-13
Heptachlor	5.52E-07	5.64E-13
Delta-BHC	4.60E-07	4.70E-13
Aldrin	5.98E-08	6.11E-14
Heptachlor Epoxide	6.90E-07	7.05E-13
Gamma-Chlordane	8.75E-07	8.92E-13
Alpha-Chlordane	6.90E-07	7.05E-13
Endosulfan I	5.52E-07	5.64E-13
P,p' -DDE	8.52E-07	8.69E-13
Dieldrin	4.37E-07	4.46E-13
Endrin	3.22E-07	3.29E-13
P,P'-DDD	5.52E-07	5.64E-13
P,P'-DDT	5.29E-07	5.40E-13
Endrin Aldehyde	9.90E-07	1.01E-12
Endosulfan Sulfate	3.45E-07	3.52E-13
Methoxychlor	2.30E-08	2.35E-14
Endrin Ketone	2.53E-07	3.99E-13

Table 3 is the result of the human health risks of the pesticide residues in *B. nurse* along River Benue at Makurdi, Nigeria. The computed minimum and maximum Average Daily Dose (ADD) and Cancer Risk (CR) quotients from the OCP in *B. nurse* were 2.30×10^{-9} and 2.53×10^{-14} and 2.58×10^{-7} and 9.41×10^{-12} respectively with average (\pm standard deviations) values of 1.30×10^{-8} ($\pm 1.81 \times 10^{-5}$) and 4.71×10^{-7} ($\pm 6.65 \times 10^{-4}$). The ADD and CR were all below the minimum allowable limits for ecological and cancer risks ($< 10^{-6}$).

4. CONCLUSION

The aim of this work is to determine pesticide residues in *B. nurse* from River Benue at Makurdi, Nigeria. The result of the analysis showed that there were no statistically significant differences in most the levels of OCP residues eluted from GCMS analyses except for Heptachlor ($F = 5.865$, $p = 0.039$) and P,P'-DDT ($F = 5.145$, $p = 0.050$). The DNMRT post hoc results (Table 7) revealed that the concentration of Heptachlor eluted by GCMS for OCP were similar in Wurukum and Adaka but significantly higher in Tyo Mu. Similarly, the eluted P,P'-DDT levels were also similar in Wurukum and Adaka but significantly higher in Tyo Mu too and that the ADD and CR were all below the minimum allowable limits for ecological and cancer risks ($< 10^{-6}$).

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