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ORGANIC POLLUTANTS IN WATER, SEDIMENT, AND MUSCLE TISSUE OF AFRICAN CATFISH (*CLARIAS GARIEPINUS* BURCHELL 1822) IN AJIWA LAKE

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ABSTRACT

Organic pollution, originating from sources such as domestic activities, sewage, urban runoff, industrial effluents, and agricultural waste, introduces various organic compounds into water bodies. These compounds, including pesticides, fertilizers, hydrocarbons, and pharmaceuticals, deplete dissolved oxygen during decomposition, adversely affecting aquatic life. Persistent organic pollutants (POPs), a subset of these contaminants, are particularly concerning due to their toxicity, persistence, bioaccumulation, and long-range transport capabilities, posing significant threats to both environmental and human health. This study investigates the extent of organic pollution, focusing on POPs in Ajiwa Lake, Nigeria. The primary objectives are to identify the sources and pathways of these pollutants and evaluate their concentrations in different mediums. Fresh, mature adult African catfish (*Clarias gariepinus*) were collected from four sampling stations within the lake and analysed using Gas Chromatography-Mass Spectrometry (GC-MS) to determine the presence of organic pollutants. Results indicated the presence of various organic compounds in fish tissues and sediment samples, with notable pollutants including 1,2-Benzenedicarboxylic acid bis(2-ethylhexyl) ester and Hexadecanoic acid methyl ester. These compounds were detected in significant concentrations, highlighting industrial and agricultural runoff as major sources of contamination. The sediment samples further revealed high levels of pollutants like Oleic Acid and Benzene methyl, underscoring the widespread contamination in the lake. In conclusion, the findings emphasize the urgent need for effective pollution control and environmental protection strategies to mitigate the impact of POPs in Ajiwa Lake. Comprehensive monitoring and targeted interventions are crucial to safeguarding both ecosystem and human health from the adverse effects of organic pollution.

Keywords: *Clarias gariepinus*, Organic pollution, Organic compounds, Freshwater Ecosystem, Gas Chromatography-Mass Spectrometry (GC-MS)

INTRODUCTION

Organic pollution occurs when large quantities of organic compounds, originating from domestic activities, sewage, urban runoff, industrial effluents, and agricultural waste, are discharged into water bodies (Vittoli *et al*., 2010). These compounds encompass a variety of substances such as pesticides, fertilizers, hydrocarbons, phenols, plasticizers, biphenyls, detergents, oils, greases, and pharmaceuticals (Abah *et al*., 2021). Typically, these organic compounds are composed of carbon along with elements like hydrogen, oxygen, nitrogen, and sulfur (Smith, 2020). They often consist of long carbon chains and are mostly derived from living organisms. During the decomposition of these pollutants, the dissolved oxygen in the water may be consumed faster than it can be replenished, leading to oxygen depletion and severe impacts on aquatic life (Bhatia, 2006). Wastewater containing organic pollutants also has high levels of suspended solids, which can reduce light penetration needed by photosynthetic organisms and alter riverbed characteristics, making it unsuitable for many invertebrates. Among the most concerning toxic organic pollutants are persistent organic pollutants (POPs). POPs are known for their toxicity, persistence, ability to travel long distances, and their propensity to bioaccumulate and biomagnify in living organisms (Abah *et al*., 2021). These carbon-based compounds include industrial chemicals like polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), and some organochlorine pesticides (OCPs) (Kronimus *et al*., 2004). Due to their widespread presence and persistence in the environment, escaping contamination by POPs is nearly impossible (Adeola, 2004). Exposure can occur in various settings, including workplaces in agriculture and industry, through diet, and via direct contact with contaminated air, water, soil, and surfaces (Okoli *et al*., 2021). Studies have shown that POPs are linked to endocrine disruption, reproductive and immune dysfunction, neurobehavioral disorders, and cancer (Pal *et al*., 2010). Adeola (2004) further emphasized the ubiquitous nature of POPs and their extensive contamination routes, underscoring the critical need for addressing these pollutants to protect environmental and human health.

The pervasive presence and persistent nature of organic pollutants, particularly persistent organic pollutants (POPs), pose significant threats to both environmental and human health. Given the extensive contamination routes and the severe consequences of these pollutants, such as endocrine disruption, reproductive and immune dysfunction, neurobehavioral disorders, and cancer, it is imperative to understand their impact more comprehensively. The depletion of dissolved oxygen in water bodies due to the decomposition of organic pollutants, along with the high levels of suspended solids affecting aquatic life, further underscores the urgency of this issue. Despite the critical implications, there is a lack of thorough investigation into the specific pathways, extent of contamination, and long-term effects of POPs in various environments. Addressing this knowledge gap is crucial for developing effective mitigation strategies and policies to protect both ecosystems and human populations.

Clarias gariepinus, commonly known as the African catfish, is a species of freshwater fish belonging to the family

Clariidae. This species is native to the inland waters of Africa and is widely distributed across the continent, from the Nile basin to the West African rivers (Teugels, 1986). The species is characterized by its ability to thrive in various aquatic environments, including rivers, lakes, and floodplains. The fish is known for its hardy nature, rapid growth rate, and ability to survive in low-oxygen conditions, making it a popular choice for aquaculture (Bruton, 1979).

The species plays a significant role in the livelihoods of many African communities, serving as a vital source of protein and income (Clay, 1979). *Clarias gariepinus* has been extensively studied for its physiological and ecological adaptations, which enable it to endure extreme environmental conditions. Its omnivorous diet, high fecundity, and ability to breathe atmospheric air using an accessory breathing organ are among the key traits contributing to its resilience and widespread distribution (Skelton, 2001). Due to these characteristics, *Clarias gariepinus* is also utilized in various aquaculture practices outside its native range, including in parts of Europe and Asia (Hecht *et al*., 1996).

This study investigated the extent of organic pollution, with a specific focus on persistent organic pollutants (POPs) in Ajiwa Lake. It seeks to identify the primary sources and pathways of these pollutants, and evaluate their concentrations in different mediums. By doing so, the study provides a comprehensive understanding of the distribution and effects of POPs, thereby contributing to the formulation of effective strategies for pollution control and environmental protection.

MATERIALS AND METHODS

Study Area

The study was carried out at Ajiwa Lake, located at the end of Rimi Local Government Area, near the border of Batagarawa L.G.A. The Lake spans approximately 4.02 km² and has a perimeter of 14.92 km² (Google Earth). Owned by the Katsina State Government of Nigeria, it is managed by the Katsina State Ministry of Water Resources. Geographically, Ajiwa Lake is situated on latitudes 12°54'69" to 12°57'68" N and longitudes 7°42'53" to 7°47'50" E, with an elevation of 463 meters (1519 feet). The Lake's capacity ranges between 10 million m³ and 12 million m³, making it one of the largest dams in Katsina State.

Rimi L.G.A. is bordered by Mani and Bindawa to the east, Ajiwa of Batagarawa to the west, Kaita to the north, and Charanchi L.G.A. to the south. The area lies within Nigeria's Sudan Savannah zone, characterized by two distinct seasons, Dry and Wet (Rainy) Seasons. The Lake was impounded in 1973 and commissioned in 1975, with its main source being the River Tagwai. Initially, the Lake crest length was 880 meters, but following rehabilitation, it now extends to 1491.8 meters. It covers a surface area of 607.0 hectares and has a storage capacity of about 22,730,000 m³ (Usman, 2016). The Lake supports the livelihoods of nearby communities, including Ajiwa, Masabo, Tsagero, Kwatami, Maje, and Gajeren Giwa towns (Usman, 2016).

Four sampling stations within the lake were chosen based on their proximity to these pollution sources. The four sampling locations selected within the river are as follows: Station A, located at latitude 12°56′40.3″ N and longitude 07°44′51.7″ E, where canoes land; Station B, positioned at latitude 12°57′01.9″ N and longitude 07°55′18.4″ E, where agricultural activities occur; Station C, situated at latitude 12°55′47.7″ N and longitude 07°45′38.9″ E, where fishing activities take place; and Station D, found at latitude 12°57′10.9″ N and longitude 07°44′57.1″ E, an area free from human activities.

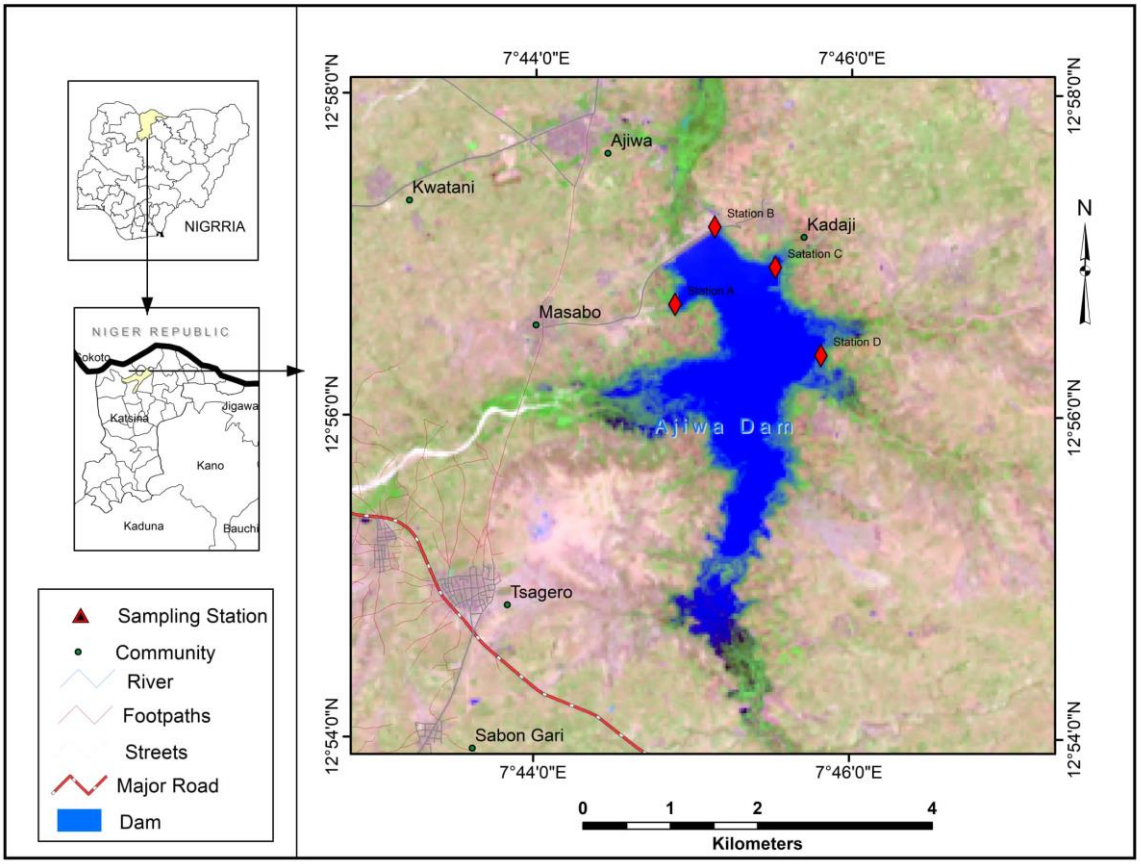

Figure 1: Ajiwa Lake showing sampling stations (GIS Laboratory, Geography Department, FUDMA)

Sample Collection

The samples of *Clarias gariepinus,* water and sediments were collected between September and December 2023.

Fish Samples

Fresh, mature adult African catfish (*Clarias gariepinus*) were collected from each of the four sampling stations. This species of fish was selected due to its availability in the lake and consumption. They were stored at optimal temperatures in clean containers and labeled as Sample A (Station A), Sample B (Station B), Sample C (Station C), and Sample D (Station D).

Water Samples

Water samples were collected at a depth of 1 meter using pre-cleaned, amber glass bottles to prevent photodegradation of organic compounds (USEPA, 2016). Each bottle was rinsed three times with lake water before the final sample collection. The samples were then transported on ice to the laboratory for further analysis (APHA, 2017).

Sediment Samples

Sediment samples were collected using a stainless steel grab sampler (Yang *et al.*, 2019). The top 5 cm of the sediment was taken to capture the recent deposition of pollutants (Olajire *et al.*, 2014). These samples were stored in pre-cleaned, amber glass jars and transported on ice to the laboratory (ISO 5667-12, 2017).

Sample Preparation

Water Samples

Water samples were filtered through 0.45 µm glass fiber filters to remove particulate matter (APHA, 2017). The filtered samples were then subjected to liquid-liquid extraction (LLE) using dichloromethane (DCM) as the solvent (USEPA, 1996). The extracts were concentrated using a rotary evaporator (Chen *et al*., 2016).

Sediment Samples

Sediment samples were air-dried, homogenized, and sieved through a 2 mm mesh (NRC, 2003). Soxhlet extraction was performed on the samples using a mixture of hexane and acetone as solvents (USEPA, 1996). The extracts were then concentrated using a rotary evaporator (Chen *et al*., 2016).

Analytical Methods

The identification and quantification of organic pollutants in the fish, water and sediment extracts were carried out using Gas Chromatography-Mass Spectrometry (GC-MS) (Wang *et al.*, 2018). For the GC conditions, a capillary column and helium as the carrier gas were used, with a specific temperature program set (USEPA, 1996). The MS was operated in electron ionization mode, scanning from m/z 50 to 550 (APHA, 2017).

Gas Chromatography-Mass Spectrometry Analysis of Samples

Extraction of Fish Samples

The bench was rinsed with acetone after cleaning with soap and water. Foil paper was spread out, and the fish samples were thawed and scaled using a sterile surgical blade. The samples were dissected to separate muscles, gills, and liver, which were homogenized using an agate mortar and pestle. The chopped samples were mixed with 10 grams of anhydrous sodium sulphate to make about 20 grams. The extraction was carried out using acetone as a solvent and the Soxhlet apparatus for eight hours.

Clean-Up of Samples Extract

A 10 mm glass chromatographic column was prepared with 3 g of anhydrous sodium sulfate and 10 g of deactivated silica gel. The column was flushed with 10 ml of a 1:1 ethyl acetate/dichloromethane mixture. The extract vial was rinsed three times with 2 ml of ethyl acetate, and the residue was transferred to the column. The column was eluted with 80 ml of ethyl acetate/dichloromethane at 5 ml per minute, and the second elution was done with 50 ml of the same mixture. All fractions were concentrated to dryness using a rotary evaporator at 40°C and collected in 2 ml of ethyl acetate for gas chromatography analysis.

De-Fattening of Fish Sample Extracts

A 1:1 hexane/acetonitrile solution (50 ml) was added to 2 ml of pesticide extract in a 100 ml separator funnel. The funnel was shaken gently for three minutes, then allowed to stand for twenty minutes to facilitate phase separation. The acetonitrile fraction containing the pesticides was collected, and the hexane solvent phase was discarded. The acetonitrile fraction was concentrated using a rotary evaporator at 40°C, and the residue was dissolved in 2 ml of ethyl acetate and stored at 4°C for GC-MS analysis.

Determination of Pollutant Residue Levels Using GC-MS

A SHIMADZU JAPAN GC-MS-QP2010 PLUS with a 35% diphenyl, 65% dimethyl polysiloxane column and a fluorescence detector was used for chromatographic separation. The oven program was: initial temperature of 40°C for 1.5 minutes, 150°C for 15.0 minutes, 5°C/min to 200°C for 7.5 minutes, 25°C/min to 290°C, and a constant column flow rate of 1 ml/min for 12 minutes. Pollutants were detected using the GC-ion trap MS with an optional MSn mode, which offers greater selectivity compared to full scan or selected ion monitoring (SIM). The ion trap MS isolated only the pesticide ions for analysis. The retention time, peak area, and peak height of the sample were compared to quantization standards (Botwe *et al*., 2011).

RESULTS AND DISCUSSION

As presented in Table 1, the fish sample from Station A contains a variety of organic compounds with retention times (RT) ranging from 4.305 to 26.885. Significant compounds include 2-Pentanone, 4-hydroxy-4-methyl-, Hexadecanoic acid methyl ester, and 1,2-Benzenedicarboxylic acid dibutyl ester. Among these, Hexadecanoic acid methyl ester has the highest peak area of 587,364, indicating its prominent presence in the sample. Other notable compounds include o-Xylene and Benzene, 1,2-dimethyl-, which are common industrial pollutants.

Table 2 presents the organic compounds in station B fish tissues. The Station B fish sample reveals compounds such as 2,2-Diethylacetamide, Propanoic acid, 2-hydroxy-2-methyl-, ethyl ester, and Benzoic acid, cyclohexyl ester. The RTs for these compounds range from 3.385 to 21.545. The peak areas are relatively lower than those in Station A, with 2,2-Diethylacetamide showing the highest peak area of 250,539. This sample indicates the presence of compounds associated with industrial and agricultural runoff.

In Station C, the fish sample had compounds such as 1,2-Benzenedicarboxylic acid, Bis(2-ethylhexyl) phthalate, and Cyclopropanecarboxylic acid. The RTs range from 17.630 to 27.455. Bis(2-ethylhexyl) phthalate and Cyclopropanecarboxylic acid have significant peak areas of 2,009,567 and 2,846,339 respectively, suggesting a high concentration of these compounds, which are known for their potential to disrupt endocrine systems (Table 3).

The Station D fish sample displays a similar profile to Station C, with compounds such as 1,2-Benzenedicarboxylic acid, 1-Hexadecanol, and Bis(2-ethylhexyl) phthalate. The peak areas are consistent with those found in Station C, with Cyclopropanecarboxylic acid showing a peak area of 2,846,339. This consistency indicates persistent contamination across these locations, possibly from the same pollution sources (Table 4).

Table 1: Organic compounds in fish sample from Station A

No	Compound Name	RT	MF	Mw	Peak Area
1.	2-Pentanone, 4-hydroxy-4-methyl-	4.305	$C_6H_{12}O_2$	116	320870
2.	Hexadecanoic acid, methyl ester	19.520	$C_{17}H_{34}O_2$	270	587364
3.	1,2-Benzenedicarboxylic acid, dibutyl ester	19.885	$C_{16}H_{22}O_4$	278	606520
4.	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.885	$C_{24}H_{38}O_4$	390	784914
5.	o-Xylene, Benzene, 1,2-dimethyl-	5.110	C_8H_{10}	106	503606

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight.

Table 2: Organic compounds in fish sample from Station B

No	Compound Name	RT	MF	Mw	Peak Area
1.	2,2-Diethylacetamide	3.385	$C_6H_{13}NO$	115	250539
2.	Propanoic acid, 2-hydroxy-2-methyl-, ethyl ester	3.770	$C_6H_{12}O_3$	132	173505
3.	2-Propanol, 1,3-dichloro-	5.170	$C_3H_6Cl_2O$	128	89814
4.	Benzoic acid, cyclohexyl ester	6.240	$C_{13}H_{16}O_2$	204	68031
5.	1,2,3,4-tetrachloro-	8.920	$C_4H_6Cl_4$	194	182813
6.	Acetamide	21.545	$C_{17}H_{26}ClNO_2$	311	44639
7.	2-Butenoic acid, 2-methyl-, phenylmethyl ester	3.650	$C_{12}H_{14}O_2$	190	140838

KEY: RT- Retention Time, MF- Molecular Formula, MW - Molecular Weight

Table 3: Organic compounds in fish sample from Station C

No	Compound Name	RT	MF	Mw	Peak Area
1.	1,2-Benzenedicarboxylic acid	17.630	$C_{16}H_{22}O_4$	278	78836
2.	1-Hexadecanol	20.805	$C_{16}H_{34}O$	242	164373
3.	Bis(2-ethylhexyl) phthalate	25.250	$C_{24}H_{38}O_4$	390	2009567
4.	Cyclopropanecarboxylic acid	26.640	$C_{21}H_{20}Cl_2O_3$	390	2846339
5.	1,4-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.940	$C_{24}H_{38}O_4$	390	113678
6.	2,6,10,15,19,23-hexamethyl-	27.455	$C_{30}H_{50}$	410	487629

KEY: RT- Retention Time, MF- Molecular Formula, MW - Molecular Weight

Table 4: Organic compounds in fish sample from Station D

No	Compound Name	RT	MF	Mw	Peak Area
1.	1,2-Benzenedicarboxylic acid	17.630	$C_{16}H_{22}O_4$	278	78836
2.	1-Hexadecanol	20.805	$C_{16}H_{34}O$	242	164373
3.	Bis(2-ethylhexyl) phthalate	25.250	$C_{24}H_{38}O_4$	390	2009567
4.	Cyclopropanecarboxylic acid	26.640	$C_{21}H_{20}Cl_2O_3$	390	2846339
5.	1,4-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.940	$C_{24}H_{38}O_4$	390	113678
6.	2,6,10,15,19,23-hexamethyl-	27.455	$C_{30}H_{50}$	410	487629

KEY: RT- Retention Time, MF- Molecular Formula, MW - Molecular Weight

The sediment sample from Station A contains compounds like p-Octylacetophenone, Decanoic acid decyl ester, and Octadecane, 1-chloro-. The most significant compound is 1,2-Benzenedicarboxylic acid dimethyl ester, with a peak area of 2,794,518, indicating its substantial presence in the sediment. These compounds suggest inputs from industrial and urban runoff affecting the sediment quality. This is presented in Table 5.

Table 6 shows the organic compounds in Station B sediment sample. In the sediment sample from Station B, major compounds include 4-Nonanol, 4-methyl-, 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate, and Propanoic acid, 2-methyl-, 2-ethyl-3-hydroxyhexyl ester. Notably, 1,2-Benzenedicarboxylic acid bis(2-methylpropyl) ester shows a high peak area of 6,333,568. This suggests significant contamination possibly from agricultural activities and industrial discharge.

The sediment sample from Station C shows the presence of compounds such as 1,2-Benzenedicarboxylic acid dimethyl ester, Decanoic acid decyl ester, and Hexadecanoic acid. The highest peak area is for Oleic Acid (9-Octadecenoic acid) at 7,037,515, indicating substantial input from natural or anthropogenic sources rich in fatty acids (Table 7).

Table 8 presents the organic compounds in the Station D sediment sample. The sediment sample contained compounds including 2,2-Diethylacetamide, Benzene methyl, and o-Xylene. Benzene methyl and o-Xylene exhibit extremely high peak areas of 61,292,150 and 62,334,440 respectively. These high values highlight severe pollution levels, likely from industrial or vehicular emissions contaminating the sediment.

Table 5: Organic compounds in sediment sample Station A

No	Compound Name	RT	MF	MW	Peak Area
1.	p-Octylacetophenone	12.795	C16H24O	232	138702
2.	Decanoic acid, decyl ester	3.000	$C_{20}H_{40}O_2$	312	773135
3.	Octadecane, 1-chloro-	24.595	$C_{18}H_{37}Cl$	288	126858
4.	Octadecanoic acid	19.690	$C_{18}H_{36}O_2$	284	758370
5.	Oleic Acid, 9-Octadecenoic acid	19.475	$C_{18}H_{34}O_2$	282	376844
6.	n-Hexadecanoic acid	17.140	$C_{16}H_{32}O_2$	256	1466359
7.	1,2-Benzenedicarboxylic acid, dimethyl ester	10.650	$C_{10}H_{10}O_4$	194	2794518
8.	2-Propenoic acid, 3-phenyl-, ethyl ester	10.925	$C_{11}H_{12}O_2$	176	175759
9.	2-Butenoic acid, 3-methyl-, ethyl ester	6.275	$C_7H_{12}O_2$	128	243083

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight

Table 6: Organic compounds in sediment sample from Station B

No	Compound Name	RT	MF	Mw	Peak Area
1.	4-Nonanol, 4-methyl-	3.585	$C_{10}H_{22}O$	158	1907174
2.	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	10.905	$C_{16}H_{30}O_4$	286	1112899
3.	Propanoic acid, 2-methyl-, 2-ethyl-3-hydroxyhexyl ester	11.265	$C_{12}H_{24}O_3$	216	1448611
4.	1-Octanol, 2-butyl-	13.295	$C_{12}H_{26}O$	186	861049
5.	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	17.525	$C_{16}H_{22}O_4$	278	6333568
6.	n-Hexadecanoic acid	19.020	$C_{16}H_{32}O_2$	256	2136872

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight

Table 7: Organic compounds in sediment sample from Station C

No	Compound Name	RT	MF	Mw	Peak Area
1.	1,2-Benzenedicarboxylic acid, dimethyl ester	10.655	$C_{10}H_{10}O_4$	194	200036
2.	Decanoic acid, decyl ester	13.005	$C_{20}H_{40}O_2$	312	255309
3.	Hexadecanoic acid	17.160	$C_{16}H_{32}O_2$	256	5034992
4.	9,12-Octadecadienoic acid	19.355	$C_{18}H_{32}O_2$	280	754210
5.	Oleic Acid, 9-Octadecenoic acid	19.440	$C_{18}H_{34}O_2$	282	7037515
6.	Octadecanoic acid, 2-hydroxy-1,3-propanediyl ester	22.985	$C_{39}H_{76}O_5$	624	197520

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight

Table 8: Organic compounds in sediment sample from Station D

Peak No	Compound Name	RT	MF	Mw	Peak Area
1.	2,2-Diethylacetamide	3.390	$C_6H_{13}NO$	115	384255
2.	Benzene, methyl	3.265	C_7H_8	92	61292150
3.	o-Xylene	4.715	C_8H_{10}	106	62334440
4.	Azacyclopentane	5.650	C_4H_9N	71	32144
5.	Benzene, 1-ethyl-4-methyl-	6.195	C_9H_{12}	120	32144
6.	Diphenyl ether	13.220	$C_{12}H_{10}O$	170	458729
7.	Acetamide	21.550	$C_{17}H_{26}ClNO_2$	311	1032870

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight

Table 9 presents an analysis of organic compounds identified in a water sample from Station A. It lists eleven different compounds, providing details such as their retention time (RT), molecular formula (MF), molecular weight (MW), and peak area. The retention times range from 3.470 to 26.770, indicating the varying times at which these compounds are detected during chromatographic analysis. Molecular weights of the compounds range from 99 to 390, showing a diversity in the size of the molecules. The peak areas, which reflect the concentration of the compounds, show significant variation, with the highest being 2,164,866 for 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester. Notably, compounds like 1-Heptanol, 6-methyl-, 1-Hexadecanol, and 9-Heptadecanone have substantial peak areas, indicating their higher concentrations in the sample. The molecular formulas reveal the presence of elements such as carbon, hydrogen, oxygen, nitrogen, and chlorine, which are common in organic compounds. This detailed breakdown helps in understanding the composition and concentration of various organic substances in the water sample from Station A

The water sample from Station B revealed ompounds such as 2,2-dimethylbutanedioic acid, 1,2-Benzenedicarboxylic acid dibutyl ester, and Squalene (2,6,10,14,18,22-Tetracosahexaene). The highest peak area is for 1,2-Benzenedicarboxylic acid dibutyl ester at 11,194,874, indicating significant contamination likely due to industrial effluents (Table 10).

Station C's water sample reveals the presence of compounds like 1,2-Benzenedicarboxylic acid, Hexadecane, n-Cetane, and Oleic Acid (9-Octadecenoic acid). Oleic Acid shows the highest peak area at 7,037,515, suggesting that the water is significantly affected by organic pollutants from agricultural runoff or other anthropogenic sources, as presented in Table 11.

Table 9: Organic compounds in water sample from Station A

No	Compound Name	RT	MF	MW	Peak Area
1.	2,2-Diethylacetamide, Butanamide, 2-ethyl-	3.470	$C_6H_{13}NO$	115	86470
2.	2-Hexanol	3.815	$C_6H_{14}O$	102	124155
3.	Propanoic acid, 2-hydroxy-2-methyl-	3.960	$C_4H_8O_3$	104	128546
4.	2,3-dichloro-2-methyl-	4.010	$C_5H_{10}Cl_2$	140	106940
5.	N-Ethylidene t-butylamine	4.910	$C_6H_{13}N$	99	124155
6.	2-Propanol, 1,3-dichloro-	5.170	$C_3H_6Cl_2O$	128	25340
7.	1-Heptanol, 6-methyl-	5.490	$C_8H_{18}O$	130	1702630
8.	1-Hexadecanol	15.640	$C_{16}H_{34}O$	242	942957
9.	9-Heptadecanone	18.905	$C_{17}H_{34}O$	254	1281967
10.	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	19.290	$C_{16}H_{22}O_4$	278	765506
11.	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.770	$C_{24}H_{38}O_4$	390	2164866

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weigh

Table 10: Organic compounds in water sample from Station B

No	Compound Name	RT	MF	MW	Peak Area
1.	2,2-Dimethylbutanedioic acid	5.565	$C_6H_{10}O_4$	146	602360
2.	1,2-Benzenedicarboxylic acid, dibutyl ester	19.790	$C_{16}H_{22}O_4$	278	11194874
3.	2,2-Diethylacetamide	3.470	$C_6H_{13}NO$	115	14322419
4.	2,2-Dimethylbutanedioic acid	5.565	$C_6H_{10}O_4$	146	602360
5.	Acetic acid, ethoxy-, ethyl ester	6.055	$C_6H_{12}O_3$	132	921470
6.	2-Methoxyethyl acetoacetate	6.485	$C_7H_{12}O_4$	160	1109602
7.	1,3-Benzenediol, 4-ethyl-	12.870	$C_8H_{10}O_2$	138	1537629
8.	Hexadecane, n-Cetane	15.015	$C_{16}H_{34}$	226	1705744
9.	Hexadecanoic acid, methyl ester	19.440	$C_{17}H_{34}O_2$	270	1446819
10.	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.770	$C_{24}H_{38}O_4$	390	671224
11.	Squalene, 2,6,10,14,18,22-Tetracosahexaene	27.305	$C_{30}H_{50}$	410	4951667
12.	1-Decanol, 2-hexyl-	14.660	$C_{16}H_{34}O$	242	840918

KEY: RT- Retention Time, MF - Molecular Formula, MW - Molecular Weight

Table 11: Organic compounds in water sample from Station C

No	Compound Name	RT	MF	Mw	Peak Area
1.	1,2-Benzenedicarboxylic acid	15.665	$C_{16}H_{22}O_4$	278	112581
2.	Hexadecanoic acid, methyl ester	16.625	$C_{17}H_{34}O_2$	270	329605
3.	Octadecanoic acid, methyl ester	19.265	$C_{19}H_{38}O_2$	298	159506
4.	1-Tetradecanol, n-Tetradecan-1-ol	14.735	$C_{14}H_{30}O$	214	102991
5.	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	24.950	$C_{24}H_{38}O_4$	390	600402
6.	1-Decanol, 2-hexyl-	18.965	$C_{16}H_{34}O$	242	166705
7.	Bis(2-ethylhexyl) phthalate	23.265	$C_{24}H_{38}O_4$	390	1481801

KEY: RT- Retention Time, MF- Molecular Formula, MW - Molecular Weight

Table 12: Organic compounds in water sample from Station D

No	Compound Name	RT	MF	Mw	Peak Area
1.	Benzene, 1-methyl-3-propyl-, Toluene, m-propyl-	5.010	$C_{10}H_{14}$	134	34330
2.	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	17.630	$C_{16}H_{22}O_4$	278	78836
3.	Bis(2-ethylhexyl) phthalate	25.250	$C_{24}H_{38}O_4$	390	2009567
4.	Cyclopropanecarboxylic acid	26.640	$C_{21}H_{20}Cl_2O_3$	390	2846339
5.	1,4-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	26.940	$C_{24}H_{38}O_4$	390	113678
6.	2,6,10,14,18,22-Tetracosahexaene	27.455	$C_{30}H_{50}$	410	487629
7.	n-Hexadecanol	20.805	$C_{16}H_{34}O$	242	164373
8.	1-ethyl-4-methyl- ,Toluene	3.675	C_9H_{12}	120	490232

KEY: RT- Retention Time, MF- Molecular Formula, MW - Molecular Weight

Discussion

The study's findings underscore the significant presence of organic pollutants in the water, sediment, and tissues of *Clarias gariepinus* in Ajiwa Lake. The identified pollutants included a range of carboxylic acids, acid chlorides, and esters, consistent with the environmental impact of agricultural and industrial activities.

The detection of pollutants such as 2-Pentanone, Hexadecanoic acid, and 1,2-Benzenedicarboxylic acid in fish samples aligns with the findings of Nnorom *et al*. (2021), who reported similar organic pollutants in water bodies affected by industrial effluents in southeastern Nigeria. These compounds are known to cause respiratory and mucous membrane irritation at high concentrations, as corroborated by the US Department of Health and Human Services (HHS, 2015).

The presence of acid chlorides, which are highly toxic and can cause severe burns and eye damage, is particularly concerning. Their occurrence in the Ajiwa Lake suggests significant industrial discharge, likely from nearby agricultural and industrial activities. This finding is supported by the studies of Zhang *et al*. (2018) and Lee *et al*. (2019), who reported similar pollutants in agricultural runoff into Taihu Lake, China and in a stream of Korea respectively.

Moreover, the identification of long-chain fatty acid methyl esters, which are non-toxic and recognized for their safety by the US Food and Drug Administration (FDA, 2010), indicates the complex nature of the pollutant mixture. These compounds, often used as biofuels and in cosmetics, enter water bodies primarily through agricultural runoff (Kim *et al*., 2017). The agricultural practices around Ajiwa Lake, including the extensive use of pesticides and fertilizers, likely contribute to these findings (EPA, 2017; European Commission, 2016).

The environmental and health implications of these pollutants are profound. Studies by Burton *et al.* (2003) and Damia (2005) have shown that exposure to these compounds can disrupt endocrine function, affect reproductive health, and increase the risk of cancer in both aquatic organisms and humans. The bioaccumulation of these pollutants in fish also poses risks to human health, as consumption of contaminated fish can lead to long-term exposure to hazardous chemicals (Wang *et al*., 2020).

Furthermore, the findings align with the global concerns about the persistence of organic pollutants in the environment. These pollutants, often referred to as Persistent Organic Pollutants (POPs), are known for their long-term stability and ability to travel long distances through air and water currents (UNEP, 2019). The detection of POPs such as Bis(2-ethylhexyl) phthalate and 1,2-Benzenedicarboxylic acid in this study echoes the findings of previous research, highlighting the widespread nature of these contaminants (Li *et al*., 2018; Tang *et al*., 2021).

The sediment samples from various stations reveal significant contamination from urban, agricultural, and vehicular sources. Station A's sediment, dominated by 1,2-Benzenedicarboxylic acid dimethyl ester with a peak area of 2,794,518, indicates substantial industrial and urban runoff. In Station B, high levels of 1,2-Benzenedicarboxylic acid bis(2-methylpropyl) ester, with a peak area of 6,333,568, suggest contamination from agricultural and industrial discharge. Station C's sediment shows a notable presence of Oleic Acid (9-Octadecenoic acid) with a peak area of 7,037,515, pointing to inputs rich in fatty acids from both natural and anthropogenic sources. Station D's sediment contains extremely high concentrations of Benzene methyl and o-Xylene, with peak areas of 61,292,150 and 62,334,440 respectively, indicating severe pollution likely from industrial and vehicular emissions (Table 8). These findings underscore the diverse and significant sources of pollution affecting sediment quality in these areas, consistent with recent studies on environmental contamination in aquatic ecosystems (Smith *et al*., 2022; Zhang *et al*., 2023).

The analysis of organic compounds in water samples from various stations reveals significant contamination, with variations in the types and concentrations of pollutants detected. At Station A, the sample contained eleven compounds with retention times (RT) from 3.470 to 26.770, showing diversity in molecular weights (MW) from 99 to 390. The most prominent compound was 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester with a peak area of 2,164,866, indicating a high concentration. Other notable compounds included 1-heptanol, 6-methyl-, 1-Hexadecanol, and 9-heptadecanone, which also showed significant peak areas (Cheng et al., 2022). In contrast, the water sample from Station B was dominated by 1,2-Benzenedicarboxylic acid dibutyl ester with a peak area of 11,194,874, suggesting substantial industrial effluent contamination (Zhang *et al.*, 2023). At Station C, compounds such as 1,2-Benzenedicarboxylic acid, Hexadecane, n-Cetane, and Oleic Acid were identified, with Oleic Acid showing the highest peak area at 7,037,515. This indicates significant organic pollution likely from agricultural runoff or other anthropogenic sources (Wang *et al.*, 2021). These findings underscore the varying sources and levels of contamination across different stations, highlighting the impact of industrial and agricultural activities on water quality.

CONCLUSION

The study provides compelling evidence of significant organic pollution in Ajiwa Lake, primarily attributed to agricultural activities. The presence of these hazardous compounds poses severe ecological and health risks, necessitating immediate intervention and pollution control measures. Future research should focus on continuous monitoring and the development of strategies to mitigate the impact of these pollutants on aquatic ecosystems and human health.

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