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Assessment of Water Quality and Oxidative Stress Response in Fish Sampled from Selected Rivers in Ogbomoso, South-West Nigeria

LAMIDI W. B. OLANIYAN[1], OWOLABI O. QUDRAT[2], YAHAYA ABDULRAZAK[3], GBADAMOSI R. TAOFIK[4], ADEOSUN O. ANTHONIA[5]

[1, 2, 5]*Biochemistry Department, Faculty of Pure and Applied Sciences Ladoke Akintola University of Technology, Ogbomoso.*

[3]*Department of Pure and Industrial Chemistry, Prince Abubakar Audu University, Ayigba, Kogi State.*

[4]*Department of Biochemical Science, Federal Polytechnic Ede, Nigeria.*

Abstract- ***Surface and underground water face the challenge of pollution arising from indiscriminate dumping of wastes and agrochemical leachates. Two rivers, Ikose and Owode located at the countryside of Ogbomoso town South-West of Nigeria were selected for quality assessment in comparison with water sourced from a commercial fish farm. Physicochemical parameters including pH, temperature, turbidity, biochemical oxygen demand, chemical oxygen demand and electrical conductivity were determined from the water samples. Water quality indices (WQI) of the water samples were calculated from the summation of the physicochemical characteristics of the rivers using a published model. Water analyses were carried out using liquid-liquid extraction and GC-MS technique. The lengths and weights of the fish samples were determined and thereafter homogenized for biochemical analyses. Hepatosomatic Index (HSI) as well as Fulton's Condition Factor (K) was calculated from the fish length, body weight and liver weight. Statistical analysis was carried out; and the means were considered significantly different when $p<0.05$. The physicochemical characteristics of the three water sources were found to be significantly different from one another. Results of water analysis identified harmful chemical pollutants from all the samples. WQI of all the water samples were higher than the permitted level for purity. The values of HSI and K of the fish samples from the rivers were lower than those from the commercial farm. Biochemical tests of oxidative stress and exposure markers were positive in all the fish sample homogenates though less in the commercial fish. It is concluded that the water and fish from the rivers were not suitable for human consumption.***

Keywords: Water Quality; Pollution; Fish; Oxidative Stress

I. INTRODUCTION

In Nigeria, water pollution is a serious environmental and public health concern, driven by such factors as agricultural runoff, inadequate domestic and industrial waste management as well as oil spills. Surface and underground water sources are mostly contaminated by landfill, agrochemical leachates, and pathogens from sewage discharges invariably at levels exceeding safe limits (Vosa et al., 2025; Ighalo and Adeniyi, 2020). Globally, over four billion people have been reported to lack access to safe drinking water (Hope, 2024) and over 60 million or 33% have been affected in Nigeria as at 2020 (Ighalo and Adeniyi, 2020; Iwuala et al., 2020) relying on polluted water. The polluted water can cause water-borne diseases such as cholera and can also impair development, reproductive function and upset ecosystem (Adoamnei et al., 2018).

Surface water quality assessment refers to the evaluation of physical, chemical, and biological variables that can have significant impacts on the overall quality of the water (US EPA, 2009). Water quality deterioration associated with increased level of pollution has been receiving attention by scientists and government intervention towards improving water supply and sanitation (Carvalho et al., 2011; Abbasi and Abbasi, 2012; Ortega et al., 2016).

The urban and agricultural catchments of a river impact the biodiversity of the riverine habitats and the flow of ecosystem services (Busch et al., 2016). The quality of water bodies is threatened by anthropological activities such as livestock farming, mining, production and disposal of wastes as well as agrochemicals application (Lobato et al., 2015; Lyu et al., 2021). In Nigeria, rivers are essential for domestic use, agriculture, and fishing, but poor management leads to health hazards and reduced productivity (Adeyolanu and Okelola, 2024).

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Water quality impacts on aquatic ecosystems and ecosystem services and biodiversity. The water quality index (WQI), trophic status indices (TSIs), and heavy metal indices (HMIs) are popular tools for evaluating surface water quality (Uddin et al., 2021; Yan et al., 2022). The use of WQI in assessing water quality simplifies the complicated set of water quality variables into a single value (Sun et al., 2016). The present work was aimed at providing information on the physicochemical characteristics of the river in order to appreciate the impacts of unregulated waste discharges on the quality of the river as well as to investigate its suitability for various uses such as drinking, irrigation, and ecosystem health. Key water quality parameters such as the pH, temperature, turbidity, nutrients and dissolved oxygen affect the health of the aquatic ecosystem. Elevated levels of suspended solids and turbidity can adversely affect fish and other organisms by reducing light penetration, clogging gills, and altering food webs. Ogbomoso in the South-Western Nigeria is an agrarian society. Cassava processing spreads across the length and breadth of the town which impacts surface and underground water resources in the area (Adewoye et al., 2013).

II. MATERIALS AND METHODS

Study Area

Rivers Owode and Ikose are located in Ogbomosoland, which are relied upon for domestic uses, irrigation and for commercial fish production. Owode River is located in Ogbomoso North Local Government Area of Oyo State, Nigeria. It is located at approximately 8.11435° N and 4.25737° E. Ikose River is located in Oriire Local government in Ogbomoso Town, Oyo State, Nigeria, with coordinates at approximately 8.19441º N, 4.20031º E. The commercial private fish farm was located within the city using treated water from the private borehole.

Sampling methods

Water and fish sampling was carried out at the two rivers and at the private fish farm in the mornings, weekly for 4 weeks between July and August, 2024 (Table 1). Physicochemical parameters were analyzed on-site using handheld battery-operated multi-parameter instrument. Six physicochemical parameters were considered for calculation of water quality index (WQI) (Kesharwani et al., 2004; Padmanabha and Belagalli, 2005; Chauhan and Singh, 2010). WQI was calculated from the equation ∑qiwi (Chauhan and Singh, 2010), where qi (water quality rating) = 100 x (Va-Vi) / (Vs-Vi), when Va = actual value present in the water sample Vi = ideal value (0 for all parameters except pH and dissolved oxygen (DO) which are 7.0 and 14.6 mg/L respectively). wi = weight of each parameter (Chauhan and Singh, 2010). If quality rating qi = 0 means complete absence of pollutants, While 0 < qi < 100 implies that, the pollutants are within the prescribed standard. When qi >100 implies that the pollutants are above the standards (Mohanty, 2005; Chauhan and Singh, 2010).

The fish samples species were confirmed as African Catfish (*Clarias gariepinus)* at the Department of Pure and Applied Biology of Ladoke Akintola University of Technology, Ogbomoso Nigeria. Total length of the fish was measured from the tip of the snout to the end of the caudal fin. Body weight was determined on a sensitive balance. Hepatosomatic index (HSI) was calculated by using the equation HSI = LW / BWT × 100 where LW= weight of liver in grams and BWT= fish body weight in grams (Sadekarpawar and Parikh, 2013). Fulton's Condition Factor (K) was calculated from the equation

$$\text{Fulton's Condition Factor (K)} = \frac{W \times 100}{L^3}$$

Where W= Weight of fish, L = Total length of fish (Prakash, 2022).

The fish were dissected to extract the selected organs and frozen pending biochemical analyses. They were then homogenized in ice-cold 0.25 M sucrose solution buffered with 40 mM Tris.HCl at pH 7.4 .

Table 1. Sampling Points approximate Coordinates (GPS) upstream to downstream of the two Rivers

Sampling points	Owode	Ikose
1	8.115590° N, 4.253622° E,	8.176988º N, 4.201943º E
2	8.115781° N, 4.256176° E	8.194417º N, 4.200312º E
3	8.113699° N, 4.257785° E	8.184985º N, 4.196927º E
4	8.116376° N, 4.253579° E	8.169013º N, 4.194867º E

Chemical Profiling of the sampled waters.

The water samples from the sites were collected in pre-cleaned containers; the samples were stored at 4℃. They were filtered before extraction. 1 litre water sample was transferred into a separatory funnel, followed by the addition of 640 ml. of dichloromethane (DCM). The funnel was shaken vigorously for 10 minutes with intermittent venting to release built-up pressure. After settling, the organic layer containing the extracted hydrocarbons was observed at the bottom and carefully drained into a clean container. This liquid-liquid extraction procedure was repeated three times using fresh portions of DCM to maximize hydrocarbon recovery. The combined organic extracts were passed through a column packed with anhydrous sodium sulphate to remove residual moisture. The dried extract was collected in a clean flask and concentrated to about 1 mL using a rotary evaporator. The final concentrated samples were subjected to Gas Chromatography-Mass Spectrometry (GC-MS) analysis for compound identification.

Instrumental analysis

Analysis of the concentrated samples was performed using a gas chromatograph 7890A with a quadrupole mass spectrometer. The chromatograph with auto sampler utilized helium as the carrier gas. Electron impact ionization was at 70eV in split less injection mode. GC transfer line to MS was 280 °C while the interface temperature was at 270 °C and the source temperature was 230 °C. Chromatographic separation was carried out using a 30m length, 0.32 mm internal diameter , fused silica column HP- 5MS with 0.25 µm film thickness. Temperature program was held at 80°C for 1 min to 248°C at 15°C/min held for 1 min then up to 280°C at 3°C/min, total run time was 23.9 min. The identities of the compound were confirmed by the comparison with the standard considering full mass spectra and retention times, and also with the help of the NIST98 standard mass spectra library (Olaniyan and Okoh, 2020).

Biochemical Assays

The activity of superoxide dismutase (SOD) was determined by the method of Misra and Fridovich (1972). The absorbance at 480 nm was monitored every 30 seconds for 150 seconds. The specific was expressed as enzyme activity per mg of protein. Protein concentration was determined by Folin Phenol method (Lowry et al., 1951). Extent of lipid peroxidation was determined by using spectrophotometric determination of malondialdehyde (MDA) concentration (Quinlan et al., 1988). To 1 ml. of the sample was added 0.5 ml 2.5% v/v HCl followed by 0.5 ml of thiobarbituric acid solution (1% w/v in 50 mM sodium hydroxide). The reaction mixture was heated at 80°C for 30 min, cooled with running water and the chromogen was extracted with 2 ml. of butanol. The absorbance of the upper layer was read at 532 nm. The extinction coefficient was taken as 1.56×10^5 $M^{-1}cm^{-1}$. Acetylcholinesterase activity was determined using the colorimetric method by Ellman *et al*. (1961). Non-protein sulps takehydryl concentration was measured using Ellman's reagent, following the modified protocol by Sedlak and Lindsay (1968). The tissues were homogenized in ice-cold 0.02 M disodium EDTA. The absorbance of the resulting solution was read at 412 nm within 5 mins of DTNB addition against a blank without the homogenates. Molar extinction coefficient of 2-nitro-5-thiobenzoic acid (TNB) was taken as 14,150 $M^{-1}cm^{-1}$ (Riddles, et al., 1983). ATPase activity was determined in a reaction medium consisted of 75 mM KCl, 1 mM EDTA pH 7.2, 50 mM Tris-acetate buffer pH 7.2, 50 mM sucrose, 2 mM ATP (di-Na salt pH 7.2) in a final volume of 1.5 ml. After incubation for 15 minutes at 25^0 C., the reaction was stopped with 0.1 ml. 0.7 M perchloric acid ($HClO_4$) (Raicu et al., 1970). Inorganic phosphorus was subsequently determined by the method of Fiske and Subbarow (1925). ATPase activity was expressed as inorganic phosphate (Pi) concentration.

Statistical Analysis

Data were expressed as Mean ± standard deviation. The difference between means was analyzed with ANOVA calculated using GraphPad Prism software version 9. Post hoc analysis was done by Tukey test. When the difference between means was statistically significant, $p < 0.05$.

III. RESULTS

Water samples from the three sites showed significant differences in their physicochemical characteristics (Table 2). The Owode River water was most alkaline than other sources. The result also showed that its water was very turbid when compared with the other water samples. The chemical profiles of the sampled water are as presented in Tables 4 to 6 with their corresponding GC-MS chromatograms showing their chemical pollutants. Phthalates in

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addition to other injurious chemicals were recorded in the water samples from the two rivers. They were not detected in the water samples from the commercial fish farm. The values of WQI of all the samples were higher than the permitted values (Table 3). However, fish from the private fish pond recorded the highest HSI and K values.

Table 2. Physicochemical Characteristics of the Water samples and Environmental Biomarkers in the Fish Samples.

Sampling sites/ Parameters	Private fish Farm	Owode River	Ikose River	P value
pH	8.15 ± 0.24	6.18 ± 0.05	6.47 ± 1.5	0.03
Electrical Conductivity (µS/cm)	93.2 ± 8.7	279 ± 11.2	129.5 ±1.04	0.008
Turbidity (NTU)	58.52 ± 2.45	138.1 ± 4.95	78.1 ± 0.75	0.01
Temperature (^{0}C)	26.4 ± 0.25	34.0 ± 0.2	32.7 ± 0.5	0.04
Biochemical oxygen demand (mg/l)	129.5 ± 7.78	162.00 ± 25.1	172.5 ± 3.54	0.04
Chemical oxygen demand (mg/l)	152.50 ± 10.61	179.00 ± 20.8	142.00 ± 18.38	0.027
Fish Weight (g)	640 ± 12.25	37.28 ± 5.45	127.50 ± 11.5	0.001
Length (cm)	21 ± 0.51	12.80 ± 1.31	18.50 ± 3.5	0.001
Condition factor (K) %	6.9 ± 0.1	1.8 ± 0.7	2.0 ± 0.9	
Hepatosomatic index (HSI) %	25 ± 6.1	4.7 ± 1.6	7.7 ± 2.3	

Table 3. Water Quality Index of the Sampled River Water

Weeks	Sampling sites			Interpretation	References
	Owode River	Ikose River	Commercial Private fish Farm Water		
1	638.69	550.57	222.55	Somewhat polluted	Sinha et al., 2004
2	712.36	561.40	446.62	"Severely polluted"	Sinha et al., 2004
3	781.28	572.19	471.33	"Severely polluted"	Sinha et al., 2004

Table 4. Identified constituents of extracted water sample from the commercial fish farm

S/N	Identified compound	Retention Time	Area (%)	Molecular Formular	Molecular Weight
1	1,2,3-Propanetriol, 1-acetate	4.890	3.72	$C_5H_{10}O_4$	134.13
2	Glycerol 1,2-diacetate	6.652	3.15	$C_7H_{12}O_5$	176.17
3	Pentadecanoic acid, 14-methyl-, methyl ester	13.456	1.07	$C_{17}H_{34}O_2$	270.50
4	n-Hexadecanoic acid	13.827	4.74	$C_{16}H_{32}O_2$	256.42
5	1-Nonadecene	14.548	2.26	$C_{19}H_{38}$	266.50
6	Octadecanoic acid, 2,3-dihydroxypropyl ester	14.646	4.60	$C_{21}H_{42}O_4$	358.60
7	9,12-Octadecadienoic acid (Z,Z)-	15.127	3.61	$C_{18}H_{32}O_2$	280.40
8	Linoelaidic acid	15.218	2.64	$C_{18}H_{32}O_2$	280.40
9	Octadecanoic acid	15.378	1.27	$C_{18}H_{36}O_2$	284.50
10	Henicos-1-ene	16.528	1.10	$C_{21}H_{42}$	294.60
11	Decanedioic acid, diisooctyl ester	17.335	22.19	$C_{26}H_{50}O_4$	426.70
12	Decanal	17.450	25.84	$C_{10}H_{20}O$	156.26
13	Decanedioic acid, bis(2-ethylhexyl) ester	17.478	20.96	$C_{34}H_{66}O_4$	538.90
14	2-Propen-1-one, 1-(2,4-dihydroxyphenyl)-3-(4-hydroxyphenyl)-	18.491	2.85	$C_{15}H_{12}O_4$	256.25

Table 5. Identified constituents of extracted water sample from Owode

S/N	Identified compound	Retention Time	Area (%)	Molecular Formular	Molecular Weight
1	9-Octadecene, (E)-	8.317	0.44	$C_{18}H_{36}$	252.5
2	2,4-Di-tert-butylphenol	9.622	1.33	$C_{14}H_{22}O$	206.32
3	Dodecanoic acid	10.194	0.33	$C_{12}H_{24}O_2$	200.32
4	2-Tetradecene, (E)-	10.457	9.15	$C_{14}H_{28}$	196.37
5	Hexadecane	10.509	1.00	$C_{16}H_{34}$	226.44
6	1-Octadecene	12.077	0.50	$C_{18}H_{36}$	252.50
7	E-15-Heptadecenal	12.277	0.31	$C_{17}H_{32}O$	252.40
8	1-Nonadecene	12.363	14.67	$C_{19}H_{38}$	266.50
9	Hexadecane	12.397	1.21	$C_{16}H_{34}$	226.44
10	Phthalic acid, isobutyl octadecyl ester	12.935	0.50	$C_{30}H_{50}O_4$	474.70
11	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	13.358	1.03	$C_{17}H_{24}O_3$	276.40
12	Hexadecanoic acid, methyl ester	13.461	0.64	$C_{17}H_{34}O_2$	270.50
13	n-Hexadecanoic acid	13.845	2.33	$C_{16}H_{32}O_2$	256.42
14	1-Nonadecene	14.074	14.14	$C_{19}H_{38}$	266.50
15	Eicosane	14.102	0.82	$C_{20}H_{42}$	282.50
16	Methyl stearate	15.075	0.58	$C_{19}H_{38}O_2$	298.50
17	Ethanol, 2-(tetradecyloxy)-	15.212	0.55	$C_{16}H_{34}O_2$	258.44
18	Octadecanoic acid	15.401	0.93	$C_{18}H_{36}O_2$	284.50
19	5-Eicosene, (E)-	15.641	11.71	$C_{20}H_{40}$	280.50
20	1-Docosene	15.641	0.32	$C_{22}H_{44}$	308.60
21	9,10-Anthracenedione, 2-[4-(acetyl oxy)tetrahydro-2H-pyran-2-yl]-1,3, 6,8-tetramethoxy-, cis-	16.843	0.86	$C_{25}H_{26}O_9$	470.50
22	[1,1'-Biphenyl]-2,3'-diol, 3,4',5, 6'-tetrakis(1,1-dimethylethyl)-	17.106	12.37	$C_{28}H_{42}O_2$	410.60
23	Decanedioic acid, bis(2-ethylhexyl) ester	17.272	6.79	$C_{34}H_{66}O_4$	538.90
24	n-Tetracosanol-1	17.633	8.19	$C_{24}H_{50}O$	354.70
25	Eicosane, 9-cyclohexyl-	18.640	0.33	$C_{26}H_{52}$	364.70
26	Cyclopentane, (4-octyldodecyl)-	18.949	0.57	$C_{25}H_{50}$	350.70
27	Hexadecanoic acid, 2-hydroxy-1-(hy droxymethyl)ethyl ester	19.321	2.30	$C_{19}H_{38}O_4$	330.50
28	Bis(2-ethylhexyl) phthalate	19.572	0.85	$C_{24}H_{38}O_4$	390.60
29	Pentacosane	20.167	0.30	$C_{25}H_{52}$	352.70
30	9-Nonadecene	20.837	4.93	$C_{19}H_{38}$	266.50

Table 6. Identified constituents of extracted water sample from Ikose River

S/N	Identified compound	RT	Area (%)	MF	MW
1	2,4-Di-tert-butylphenol	9.622	0.98	$C_{14}H_{22}O$	206.32
2	2-Tetradecene, (E)-	10.457	6.36	$C_{14}H_{28}$	196.37
3	Hexadecane	10.509	0.72	$C_{16}H_{34}$	226.44
4	1-Nonadecene	12.374	14.07	$C_{19}H_{38}$	266.50
5	Carbonic acid, eicosyl vinyl ester	12.403	1.16	$C_{23}H_{44}O_3$	368.60
6	Phthalic acid, hexadecyl propyl ester	12.941	0.76	$C_{27}H_{44}O_4$	432.60
7	7,9-Di-tert-butyl-1-oxaspiro(4,5)d eca-6,9-diene-2,8-dione	13.364	1.40	$C_{17}H_{24}O_3$	276.40
8	n-Hexadecanoic acid	13.868	2.76	$C_{16}H_{32}O_2$	256.42
9	5-Eicosene, (E)-	14.085	13.88	$C_{20}H_{40}$	280.50
10	Eicosane	14.108	0.79	$C_{20}H_{42}$	282.50
11	Dichloroacetic acid, heptadecyl ester	15.218	0.82	$C_{19}H_{36}Cl_2O_2$	367.40

12	Octadecanoic acid	15.413	1.01	$C_{18}H_{36}O_2$	284.50
13	5-Eicosene, (E)-	15.653	11.75	$C_{20}H_{40}$	280.50
14	Ethanol, 2-(octadecyloxy)-	16.546	0.73	$C_{20}H_{42}O_2$	314.50
15	9,10-Anthracenedione, 2-[4-(acetyl oxy)tetrahydro-2H-pyran-2-yl]-1,3, 6,8-tetramethoxy-, cis-	16.849	0.74	$C_{25}H_{26}O_9$	470.50
16	[1,1'-Biphenyl]-2,3'-diol, 3,4',5, 6'-tetrakis(1,1-dimethylethyl)-	17.123	10.82	$C_{28}H_{42}O_2$	410.60
17	Carbonic acid, dodecyl 2-ethylhexy l ester	17.318	6.43	$C_{21}H_{42}O_3$	342.60
18	Carbonic acid, 2-ethylhexyl hexade cyl ester	17.410	4.90	$C_{25}H_{50}O_3$	398.70
19	n-Tetracosanol-1	17.656	8.87	$C_{24}H_{50}O$	354.70
20	Carbonic acid, but-2-yn-1-yl octadecyl ester	18.966	0.66	$C_{23}H_{42}O_3$	366.60
21	Hexadecanoic acid, 2-hydroxy-1-(hy droxymethyl)ethyl ester	19.578	3.55	$C_{19}H_{38}O_4$	330.50
22	3-Eicosene, (E)-	20.883	0.61	$C_{20}H_{40}$	280.50
23	1-Docosene	20.883	6.24	$C_{22}H_{44}$	308.60

The specific activity of superoxide dismutase (SOD) in the liver tissues (Fig.4) and the gills (5) of fish sampled from Owode river showed the highest significant activity when compared with other samples.

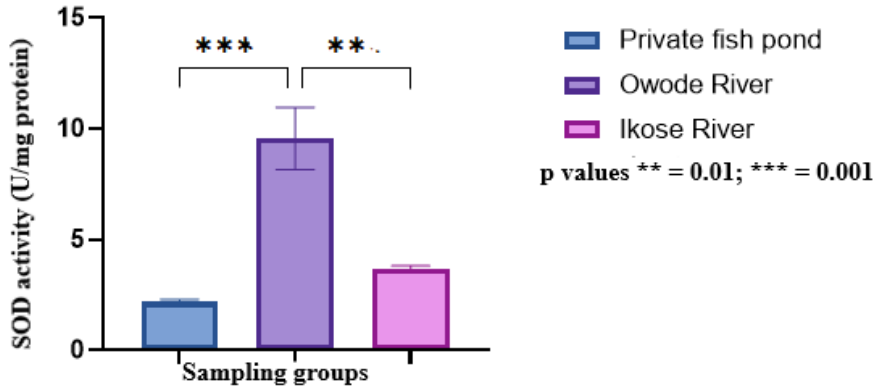

Fig. 1. Superoxide dismutase specific activity in the fish liver homogenates.

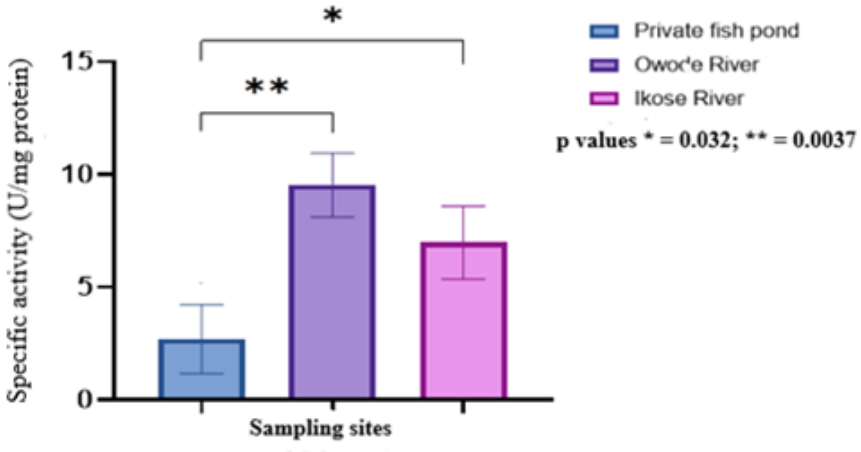

Fig. 2. SOD specific activity in the fish gills

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Overall high concentration of MDA was recorded in the liver of the fish from Ikose river (Fig. 6). However, liver MDA concentrations were not significantly different among the rivers. The concentrations were significantly different from one another in the gills (Fig. 7).

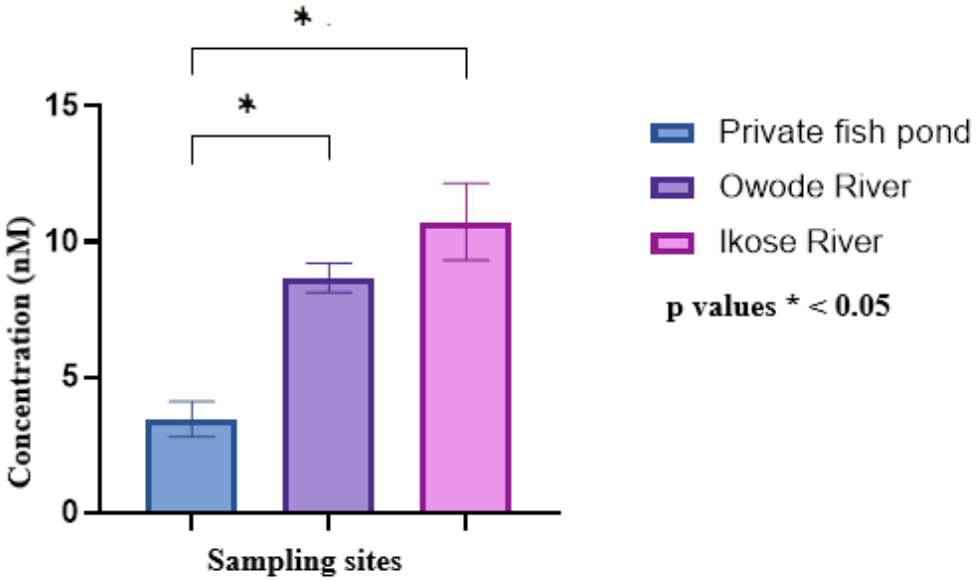

Fig. 3. Malondialdehyde concentration in the liver tissues of the sampled fish

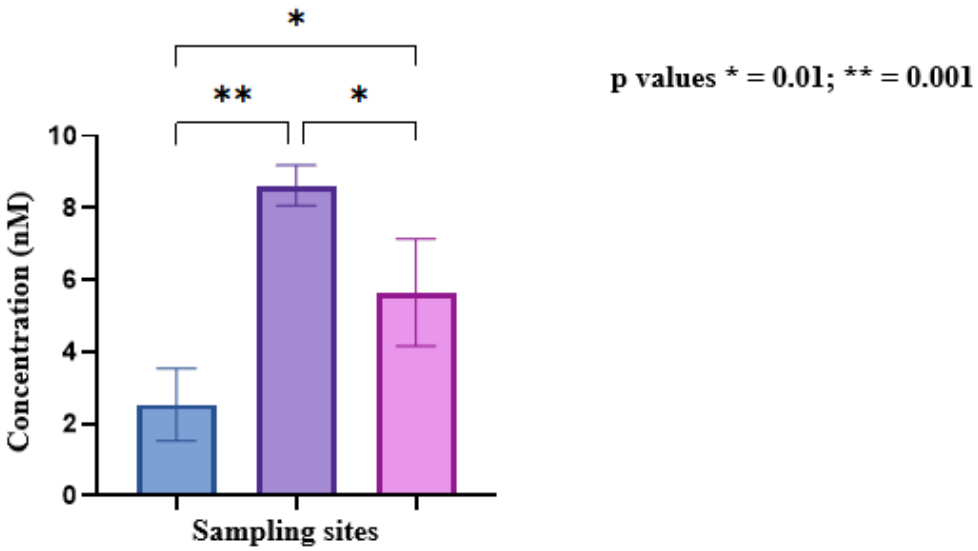

Fig. 4. Malondialdehyde concentration in the gills of the sampled fish

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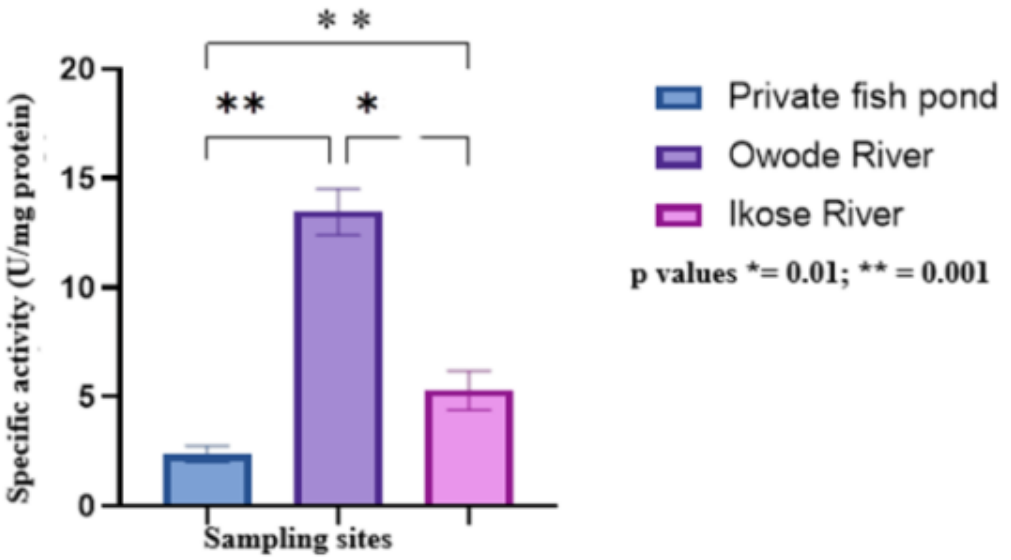

Fig. 5. Acetylcholinesterase specific activity in the liver of the sampled fish

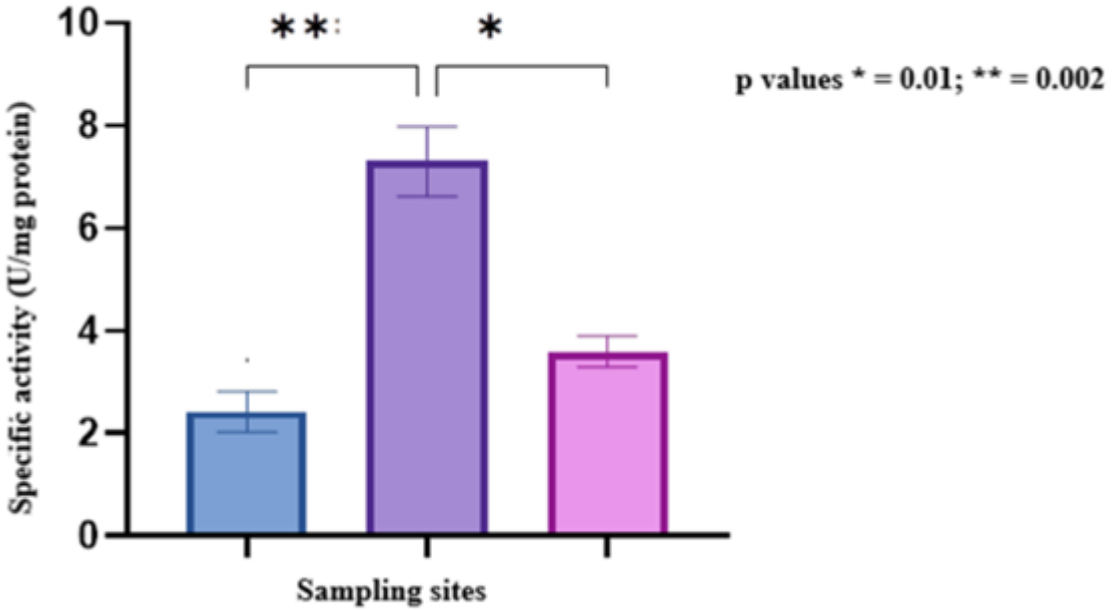

Fig. 6. Acetylcholinesterase specific activity in the gills of the fish samples

The fish liver (Fig. 5) and the gills (Fig. 6) of river Owode recorded high acetylcholine esterase activity when compared with fish samples from Ikose and the commercial farm.

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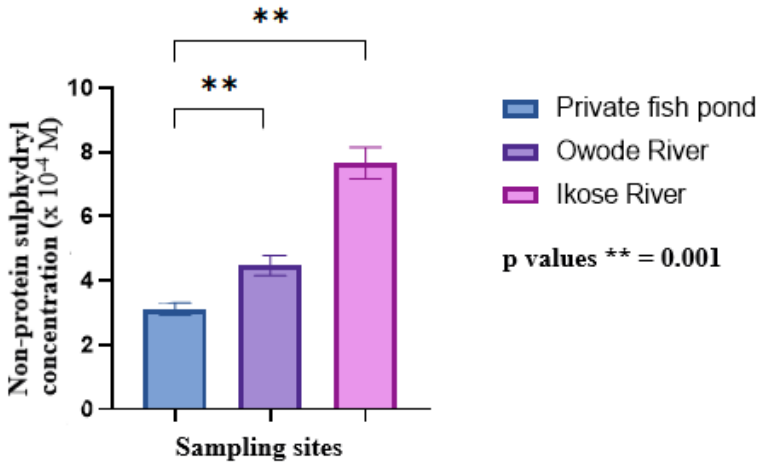

Fig. 7. Non-protein sulphydryl concentration in the liver tissues of fish samples.

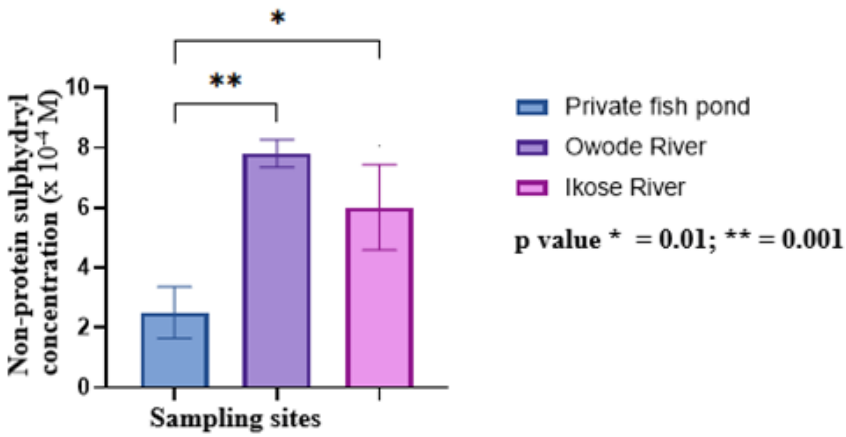

Fig. 8. Non-protein sulphydryl concentration in the gills of fish samples.

Significantly high concentration of non-protein sulphydryl group (NP-SH) was recorded in the liver tissues and the gills of fish sampled from Ikose (Fig. 7) and Owode (Fig. 8) rivers when compared with the fish tissues from commercial farm. The difference in concentration between the two rivers was not significant.

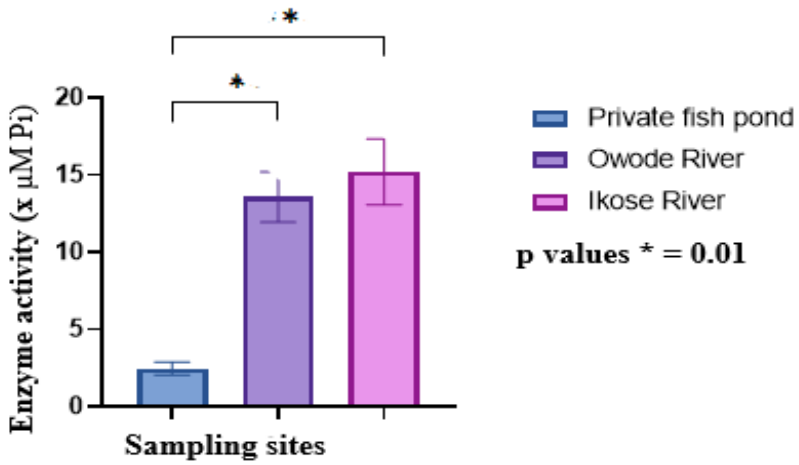

Fig. 9. ATPase specific activity in the liver tissues of the fish samples

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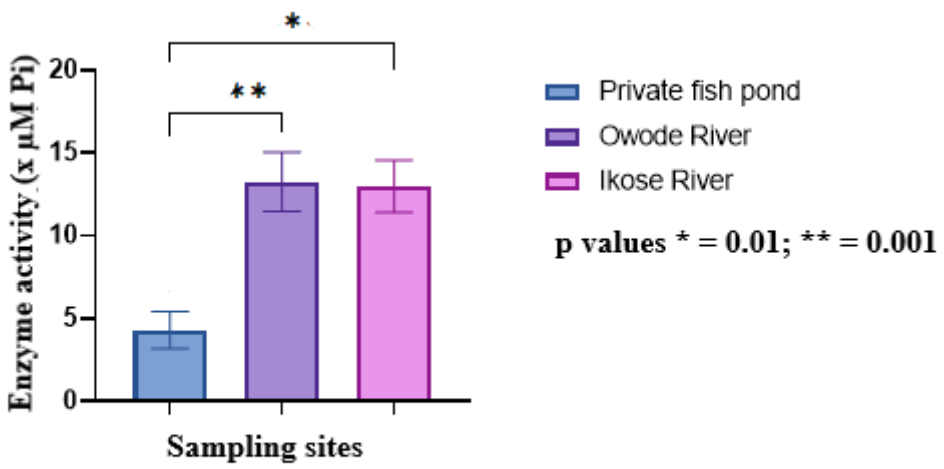

Fig. 10. ATPase activity in the gills of fish samples.

The activity of ATPase in the samples of the liver (Fig. 9) and the gills (Fig. 10) significantly increased in the fish sampled from the two rivers when compared with the commercial fish samples. But the activities of the enzyme in the fish tissues obtained from the two rivers (Owode and Ikose) were not significantly different.

IV. DISCUSSION

Ogbomoso town is located in the South West of Nigeria in West Africa with an estimated population of 655,517 (U N, 2018). Owode and Ikose rivers provide domestic and agricultural uses as well as a source of protein nutrition (fish) for the people. The two rivers were open to indiscriminate dumping of domestic wastes, livestock grazing and agrochemical release from the agricultural catchment. Contamination of the river water by chemical wastes may upset the ecosystem leading to reduction of fertility, changes in sex ratio, developmental alteration and intersex in fish populations as well as cancer cell proliferation in humans (Do et al., 2023; Brander et al., 2013; Pawlowski et al., 2004; Panter et al., 1998). Water quality index (WQI) is a summation of the physicochemical characteristics of water. According to Sinha et al., (2004), the value of WQI (>100) of the water samples including those from the commercial fish farm implied that the water was unsafe for human consumption though the commercial water was less polluted. Chemical profiling of the sampled river water revealed the presence of harmful phenolic compounds such as 2,4 - di-tert-butylphenol and bis (2-ethylhexyl) phthalate (Wang et al., 2025; Gao et al., 2023; Gan et al., 2015) and biphenyl derivative [1,1'-biphenyl]-2,3'-diol, tetrakis (tert-butyl) (Ngoubeyou et al., 2022) are all human carcinogens. The decanedioic acid esters detected in water samples from the commercial fish farm and Owode river are probably originated from industrial wastes such as PVC in lubricants as well as in cosmetics exposures. These esters have the potential to cause chronic toxicity through bioaccumulation (Reddy et al., 2025; Ito et al., 2024). Long-chain hydrocarbons such as 1-nonadecene and 5-eicosene, identified across all sites are petroleum-related alkenes capable of coating fish gills, thereby impairing respiration (Adams et al., 2013). WQI values obtained across all the sampling sites consistently exceeded the threshold of 100 (Sinha et al., 2004), indicating severe pollution. The condition factor (K) and hepatosomatic index (HSI) are integrated bioindicators of contaminant exposure to aquatic ecosystem (Pandit et al., 2019). High HSI value indicates big liver, high metabolic activity, high energy storage and the general health condition of a fish while K also indicates the overall health condition of a fish based on the assumption that heavier fish (at a given length) is healthier than the lighter ones (Ogamba et al., 2014). The higher value of K in commercial fish than those from the rivers implies that the commercial fish were less impacted by the environmental stressors than the fish from the rivers (Ogamba et al., 2014), and driven by controlled water quality and nutrition, contrasting with the rivers' poorer indices occasioned by pollution.

Prakash (2022) has reported a positive correlation between K and HSI. In a poor environment, fish usually have liver with less energy reserved in it. Lower values of K and HSI than the results of the present study have been reported (Tubin et al., 2020). The SOD assay provides valuable insight into oxidative stress responses in the exposed fish (Ofoegbu et al., 2023; Aguilar-Juárez et al., 2020). This antioxidant enzyme catalyzes the dismutation of superoxide radicals into hydrogen peroxide and oxygen, serving as a primary defence against reactive oxygen species (ROS) generated from environmental stressors such as pollutants. The observed significant increase in SOD specific activity in the fish from the polluted rivers relative to the response from the commercial fish samples probably was an adaptive response to oxidative challenge from the pollutants; a compensatory mechanism to mitigate ROS-induced damage (Formicki et al., 2025; Zhang et al., 2022; Aguilar-Juárez et al., 2020). The MDA level elevation in the river samples suggested heightened oxidative stress in the liver and the gills possibly due to exposure to the pollutants in the rivers (Ofoegbu et al., 2023; Rajabiesterabadi et al., 2020). Elevated MDA levels reflect an imbalance where antioxidant defenses, including SOD, catalase, and glutathione peroxidase, are insufficient to neutralize ROS. MDA is a secondary product of polyunsaturated fatty acid peroxidation, initiated by ROS such as superoxide radicals, hydroxyl radicals, and hydrogen peroxide. This peroxidation disrupts membrane integrity by cleaving lipid hydroperoxides, leading to MDA accumulation that is quantified via the thiobarbituric acid reactive substances. Acetylcholinesterase (AChE) is a key enzyme in the cholinergic system that hydrolyzes the neurotransmitter acetylcholine (ACh) into choline and acetate, thereby terminating synaptic transmission at neuromuscular junctions and neuronal synapses. Inhibition of AChE leads to ACh accumulation, causing overstimulation of muscarinic and nicotinic receptors, which can result in neurobehavioral disruptions such as erratic swimming, convulsions, or paralysis. This enzyme is particularly sensitive to neurotoxic pollutants like organophosphate and carbamate pesticides, organotin compounds, heavy metals, and polycyclic aromatic hydrocarbons, making it a widely used biomarker for assessing sublethal toxicity in aquatic organisms (De Carvalho Silva et al., 2025). Increased AChE activity has been reported in fish brain exposed for short period (seven days) to imazapic and imazethapyr herbicides (Moraes et al., 2011; Toni et al., 2010). AChE activity is affected by such factors like temperature, humidity, fish species, size and tissues (Gupta et al., 2022; Menéndez-Helman et al., 2015; Durieux et al., 2010). Fish size appears plausible for the increased AChE activity as fish from the polluted water was remarkably small suggesting that the increased activity was a compensatory response. NP-SH compounds are thiol (SH) compounds consisting of glutathione (GSH), cysteinyl-glycine, cysteine and homocysteine that serve as critical non-enzymatic antioxidants that neutralize reactive oxygen species. Elevated NP-SH levels may indicate an adaptive response to oxidative challenge from environmental pollutants (Chowdhury & Saikia, 2020) reflecting enhanced -SH production to mitigate oxidative damage. Reduction of NP-SH may be due to SH depletion occasioned by oxidative stress. Na^+/K^+-ATPase is a membrane-bound enzyme that maintains cellular ionic gradients by pumping sodium ions out and potassium ions into the cells, utilizing ATP hydrolysis. This process is essential for osmoregulation, nerve impulse transmission, and muscle contraction, and is sensitive to pollutants such as heavy metals, pesticides, and organic compounds that disrupt membrane integrity or energy metabolism. The increased ATPase activity recorded in the gills and the liver samples from the fish of the two rivers probably represented a compensatory mechanism in response to osmotic stress (Abdelkhalek et al., 2015).

V. CONCLUSION

The quality of water from the two rivers was severely polluted probably by chemicals from domestic wastes and therefore the water was not suitable for human consumption. Water samples from the commercial fish farms were not as polluted as the river water. Accordingly, the fish from these rivers are not recommended for consumption.

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