



Tropical Vet. 42 (1) Pages 66 – 78, 2024.

## Health indices of African Catfish (*Clarias gariepinus*) inhabiting selected polluted streams in Ibadan, Oyo State, Nigeria

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### ABSTRACT

Environmental pollutants, such as heavy metal contamination in water sources, especially groundwater and surface water, have been documented to have various health impacts on humans and animals. In the study, samples were collected from forty African catfish (*Clarias gariepinus*) harvested (n=10) from three selected polluted rivers (Eleyele, Oluyole, Dandaru Rivers) and a reference Fish farm (Fol-Hope Limited). Water samples were also collected from all the sites and analyzed for heavy metals. Based on previous findings, the water source of the reference fish farm was free from industrial discharge or contaminants that could cause pollution. Hematology, erythrocyte osmotic fragility test (OFT), heavy metal determination, *in vivo* micronucleus assay, and histopathology were determined.

The results showed significantly lower RBC, PCV, and Hb values ( $P<0.05$ ). In contrast, MCV and MCH values increased in blood samples of catfish from the Oluyole and Eleyele Rivers relative to the reference Fish farm (Fol-Hope). Likewise, an increase in the erythrocyte osmotic fragility of the RBC was observed in blood samples of fish inhabiting the polluted water, coupled with a significant rise in the activities of AST, ALT, and ALP. However, fish from the Dandaru River had higher PCV, Hb, and RBC values than those from the reference Fish farm. Samples of water from the river sources and the liver and gills of fish samples there were observed to be contaminated with heavy metals such as Cd and Mn. Genotoxicity assay displayed a significantly higher frequency of micro-nucleated polychromatic erythrocytes (MnPCEs) in the fish collected from the polluted sites compared to the reference site. The histopathological lesions in the fish liver from the contaminated sites showed marked and severe disseminated congestion involving the vessels and sinusoids. The Kidney revealed severe distortion of the architecture, characterized by outright loss of tubular structure, desquamation, atresia, and degeneration.

In conclusion, the study revealed plausible fish health complications in fish inhabiting polluted streams with toxicities resulting in anaemia, liver damage, DNA damage, and possibly cancer. Thus, caution must be exercised when consuming fish from polluted rivers because they could be potentially harmful to humans thereby constituting a public health risk.

**Keywords:** Environmental pollution, Heavy metal contamination, Toxicity, DNA damage

## INTRODUCTION

About 70% of the earth's surface comprises water from seas and oceans, the major contributors to the global food supply (Alvariño *et al.*, 2023). Unfortunately, these ecosystems are constantly threatened by contamination due to various anthropogenic activities that result in pollutants. Environmental pollutants, such as heavy metal contamination in water sources, especially ground and surface water, have been documented to have various health impacts on humans and animals, such as liver failure, kidney damage, gastric and skin cancer, mental disorders, and adverse effects on the reproductive system (Zhang *et al.*, 2023).

In many low-income countries, including the African continent, wastewater discharge into water bodies with little or no treatment is expected due to the limited availability of treatment facilities (Khalid *et al.*, 2017). This untreated municipal and industrial wastewater into water bodies often contributes to the rapidly growing deoxygenated dead zones. It has been estimated that wastewater disposal into water bodies affects about 245,000 km<sup>2</sup> of marine ecosystems, fisheries, livelihoods, and food chains (Corcoran and Sick, 2010).

Documented data indicated that wastewater and sanitation-related diseases are extensive and growing precariously in countries where untreated wastewater is commonly used for crop irrigation. Ellis *et al.* (2017) reported that about 842,000 deaths in 2012 in middle- and low-income countries were linked to sanitation services, contaminated drinking water, and

inadequate hand-washing facilities. Fishes have been widely used as biological indicators of metals, metalloids, and non-metals contamination (Simionov *et al.*, 2023). Fish muscle tissue is used for analysis due to metal storage capacity (Huang *et al.*, 2022). Hence, various studies have also been conducted globally on the contamination of different fish species by heavy metals (Salam *et al.*, 2021).

Some elements have been found not to have essential roles in metabolism. These potentially toxic elements (PTE) include but are not limited to mercury (Hg), cadmium (Cd), lead (Pb), aluminium (Al), copper (Cu), iron (Fe), nickel (Ni), zinc (Zn), and chromium (Cr) as previously reported (Rajkumar *et al.*, 2023; Simionov *et al.*, 2023). The PTE in natural aquatic ecosystems has been reported to cause algal proliferation, oxygen deficiency, and even the death of fish and other water-dwelling organisms (Bashir *et al.*, 2020). More so, PTE is known to negatively impact ecosystem health with concomitant disruption of the food chain and these environments (Shiry *et al.*, 2021). Previous studies reported the toxicity of arsenic (As), cadmium (Cd), and lead (Pb), causing visceral cancer, liver and bladder cancer, cognitive decline, kidney disorders, hyperactivity, fatigue, anaemia, and decreased intelligence quotient (IQ) in fish (Jeong *et al.*, 2020; Fallahzadeh *et al.*, 2017; Sanders *et al.*, 2015). The present study sought to understand the interactions between PTE in the aquatic environment and its impact on fish ecosystem health.

## MATERIALS AND METHODS

### Sample collection

Forty samples of African catfish (*Clarias gariepinus*) were collected from three selected polluted streams (Eleyele, Oluyole, and Dandaru); and a reference Fish farm (Fol-Hope Limited, Ibadan, Nigeria). The streams were selected based on their impact from human

activity which influenced their physical (light and colour), chemical (organic and inorganic, nutrients), environmental and biological properties. Globally, human activities have been shown to play significant roles in shaping and disturbing ecosystem health (Younger, 2001).

Water samples were also collected from all sites and analyzed for heavy metals. African Catfish (*Clarias gariepinus*) were collected alive from the sites: ten (10) from Fol-Hope farm, which is

the reference site, ten (10) from Dandaru, ten (10) from Eleyele River and (10) from Oluyole River. The physicochemical properties of the water samples from the reference Fish farm (Fol-Hope fish farm) did not reveal the presence of industrial or municipal waste discharge contaminants that could cause pollution.

### Location

Oluyole River (7° 21'N - 7° 22'N; 3° 50'E - 3° 52'E), Dandaru River (7° 48'N; 3° 83'E), Eleyele River (7° 60'N; 3° 60'E) and Fol-Hope Farm (7° 55'N; 3° 88'E).

### Haematology

Blood samples were collected via caudal vein puncture. The needle was introduced on the ventral midline between the anal opening and the beginning of the anal fin to access the caudal vein beneath the vertebral column. The blood was analyzed for full blood count using the method described by Thomas and Merle (2016).

### Osmotic Fragility Test (OFT)

About 5 ml of blood sample was collected from each fish described above into lithium heparinized tubes and then transported to the laboratory for the erythrocyte osmotic fragility (OFT) test as previously described by Azeez et al. (2013).

### Liver function tests

Serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) were determined with Randox kits following the manufacturer's instructions.

### Heavy metal determination

Water samples were collected from Eleyele, Oluyole, and Dandaru Rivers or from earthen ponds at Fol-Hope Limited early in the morning

and transported immediately to the laboratory for heavy metal analysis. After analysis, heavy metals such as Zinc (Zn), Lead (Pb), Cadmium (Cd), Iron (Fe), Manganese (Mn), and Chromium (Cr) contents in the water samples were determined by atomic absorption spectrophotometry (AAS) Buck 211 model.

### *In vivo* micronucleus assay technique

The frequency of micronucleated polychromatic erythrocytes (MnPCE) was estimated in the blood based on the method described by Ola-Davies *et al.* (2019).

### Histopathology

The kidney, liver, gills, and muscles were fixed in 10% formalin and embedded in paraffin wax. Tissue sections of 5-6mm thickness were cut and then stained with hematoxylin and eosin for histopathological examination according to previously described methods (Drury and Wallington, 1976).

### Statistical analysis

All values were expressed as mean  $\pm$  standard deviation (SD) with One-Way Analysis of Variance (ANOVA). Turkey's posthoc test of Graph pad Prism 5.0 was also carried out with p-Values < 0.05 considered statistically significant.

## RESULTS

### Effects of environmental pollution on haematological parameters

Results from Table 1 showed a significant ( $P < 0.05$ ) reduction in RBC, Hb, and PCV values in blood samples from fish collected at Oluyole River compared to fish from other sites. The PCV, RBC, and Hb values of fish from Eleyele River were also lower than the values from Fol-Hope farms, while fish from Dandaru had slightly higher PCV, RBC, and Hb than the

values obtained in fish from the other Rivers, though not significantly. A significant ( $P < 0.05$ ) increase in MCV and MCH values in blood samples of fish from Oluyole River relative to the reference site (Fol-Hope) and other polluted Rivers (Table 1). However, the MCV values of fish inhabiting the Oluyole River increased significantly compared to those from Fol-Hope, while the MCH of fish from the Dandaru River was relatively lower when compared with the MCH values from fish from the Oluyole River (Table 1).

As shown in Table 2, the WBC counts of the catfish from the Dandaru and Oluyole Rivers reduced significantly compared to those from Fol-Hope and Eleyele Rivers. The monocytes, eosinophils, and lymphocyte count of fishes from the Dandaru River were significantly lower in values compared to the other polluted sites and the reference site. On the other hand, the lymphocyte counts recorded in fish from the Oluyole River were significantly lower compared to the Fol-Hope and Eleyele Rivers (Table 2).

#### **Erythrocytes osmotic fragility test**

As shown in Figure 1, the erythrocyte osmotic fragility of the *Clarias gariepinus* from Dandaru River was significantly lower than the values obtained from the reference site and also from Oluyole River at 0.1 and 0.5 % NaCl concentrations, respectively. Similarly, the erythrocyte osmotic fragility of the catfish from the Dandaru River was also lower than the erythrocyte osmotic fragility of those catfish from Fol-Hope Ltd, Eleyele and Oluyole rivers at 0.7% NaCl concentration. The OFT values from Catfish from Oluyole River showed marginally higher values at 0.5, 0.7, and 0.9 % NaCl when compared with the OFT values from the other sites, although were not statistically significant.

#### **Heavy metals concentration (mg/L) in the liver**

The liver tissues of fish from the Dandaru and Oluyole Rivers had a significant amount of Cadmium (Cd) which was observed to be absent from the Fol-Hope and Eleyele Rivers, whereas the concentration of Manganese (Mn) was found to be very high ( $0.280 \pm 0.002$  mg/L) in livers of fish from Oluyole compared to  $0.020 \pm 0.002$  mg/L from fish liver samples from Fol-Hope. Meanwhile, samples from the Eleyele and Dandaru Rivers showed no presence of Manganese in the fish (Table 3). Meanwhile, Copper (Cu) and Chromium (Cr) were not detected in the liver of any fish from all the sites. Traceable Zn levels were detected in the liver of fish from Fol-Hope and Oluyole River (Table 3), while Lead (Pb) was found in all the fish liver samples, in this order viz: Dandaru > Eleyele > Fol-Hope > Oluyole. Hepatic iron (Fe) contents showed Oluyole > Eleyele > Fol-hope > Dandaru, as indicated in Table 3.

#### **Heavy metals concentration (mg/L) in the gills**

There were significantly high levels of heavy metals in the gills of the catfish from all the sample sites, as shown in Table 4. All fish gills demonstrated the presence of Manganese, Copper, Iron, Zinc, Lead, and Chromium, with Iron and Chromium levels being the highest in the gills of those catfish from Dandaru, at 84.70 mg/L and 56.35 mg/L, respectively, followed closely by fish gills from Eleyele which had 18.50 mg/L and (41.85 mg/L). The concentration of heavy metals in the gills of fish in the polluted Rivers and reference site for Mn followed this pattern: Oluyole > Eleyele > Dandaru > Fol-Hope). Iron displayed Dandaru > Fol-Hope > Eleyele > Oluyole), for Cu; Eleyele > Dandaru > Oluyole > Fol-Hope), Zn; Eleyele > Dandaru > Fol-Hope > Oluyole), Pb; Eleyele > Dandaru > Oluyole > Fol-Hope), and Cr; Dandaru > Eleyele > Fol-Hope > Oluyole) as indicated in table 4.

### **Determination of frequency of micro-nucleated polychromatic erythrocytes (MnPCEs)**

The frequency of micro-nucleated polychromatic erythrocytes (MnPCEs) was significantly higher in all the polluted Rivers when compared to the reference site (Fol-Hope). This indicates DNA damage possibly associated with environmental pollution (Table 5). The highest value of  $20.42 \pm 2.07$  MNPCEs/1000PC, which shows the highest level of DNA damage, was obtained in catfish from Oluyole River, followed closely by those fish from Eleyele River ( $14.17 \pm 0.50$  MNPCEs/1000PC) while Dandaru River had fish with  $8.33 \pm 0.77$  MNPCEs/1000PC. Catfish from Fol-Hope had the most minor indicator of DNA damage, at  $1.30 \pm 0.50$  MNPCEs/1000PC.

### **Liver function tests**

The assessment of liver functions (LFTs) revealed that ALT activities in fish inhabiting the Dandaru and Oluyole Rivers were significantly higher than those from Fol-Hope (Table 6). Similarly, the ALP activities in fish from the Eleyele and Dandaru Rivers were also significantly higher than that of the catfish from Fol-Hope Ltd as indicated in Table 6. Furthermore, the hepatic activity of AST in fish from Dandaru River suggested a significant increase in comparison to Fol-Hope and Oluyole River, while the AST activity of the fish from Eleyele River was significantly lower than that of the fish from Fol-Hope Ltd (Table 6).

### **Histopathology**

A mild to severe hepatic steatosis was observed in the liver of Catfish from the reference site; however, histopathological lesions from the polluted Rivers showed marked and severe disseminated congestion involving the vessels and sinusoids, possibly from exposure to

pollutants from these selected sites. The presence of liver steatosis (fat deposit) in fish from the reference site was probably due to a high-fat diet. The liver of fishes from polluted sites, however, exhibited more severe alteration accompanied by congestion involving the vessels and sinusoids,

The histology of the kidneys from the reference site showed some level of desquamation of the tubules and slight disseminated congestion, while the kidney of fish from Eleyele River displayed moderate desquamation of the tubules and tubular necrosis (Figure 3). Similarly, lesions ranging from severe desquamation of tubules with atresia and multifocal patch areas of reddish-brown pigment were observed in resident fish at the Dandaru River. A more advanced distortion of the kidney architecture characterized by outright loss of tubular structure, desquamation, atresia, and degeneration was seen in the kidneys of fish from the Oluyole River.

Results from gill histology revealed some degree of congestion in the secondary lamella and secondary lamella synechia, fusion of secondary lamella, and intra-lamella hyperplasia in fish gills from the reference site. Marked hyperplasia of the primary and secondary lamella, congestion, and mild edema was observed in fish gills at the Eleyele River. In fish from the Dandaru River, marked disseminated intra-lamella hyperplasia and an extensive area of bloated cartilaginous core due to edema were observed. Gills from fish at Oluyole River also showed congestion of the secondary lamella, fusion of secondary lamella, an area of necrosis, edema, and intra-lamella hyperplasia. Hyperplasia, edema, and necrosis were characteristics of the gills from the Dandaru and Oluyole, collaborating a possible hypothesis of direct exposure to contaminants responsible for the structural damage to the fish gills. Conversely, no visible histopathology was observed in the fish muscle from all the sites.

**Table 1: Hematological Parameters of fish samples**

SITES	PCV (%)	Hb (g/dL)	RBC (x 10 <sup>6</sup> /uL)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Platelets (x 10 <sup>3</sup> /uL)
FOL-HOPE	29.60 ± 5.60	9.86±1.61	2.87±0.95	96.75±6.15	32.99±2.99	32.35±0.18	26.76±5.60
ELEYELE	26.00±4.24	8.23±1.54	2.62±0.96	105.50±4.12 <sup>a</sup>	33.36±7.40	31.56±1.06	31.22±5.40
DANDARU	32.50±0.55	10.40±0.27 <sup>b</sup>	3.29±0.10	98.81±1.68	31.24±1.04 <sup>d</sup>	31.67±0.59	23.26±9.16
OLUYOLE	24.40±3.47 <sup>c</sup>	8.08±1.16 <sup>c</sup>	1.88±0.93 <sup>c</sup>	147.30±8.85 <sup>abc</sup>	48.91±14.04 <sup>abc</sup>	29.97±9.36	21.09±6.06

Superscript (a) indicates a significant difference when compared with Fol-hope, superscript (b) indicates a significant difference when compared with Eleyele, and superscript (c) indicates a significant difference when compared with Oluyole. Mean ± SD (n=5).

**Abbreviations:** Packed cell volume (PCV), Hemoglobin concentration (Hb.), Red blood cell counts (RBC), Mean corpuscular volume (MCV), Mean corpuscular haemoglobin (MCH), & Mean corpuscular haemoglobin concentration (MCHC).

**Table 2: White blood cell counts (WBCs) and differentials**

SITES	WBC (x10 <sup>3</sup> )	HET (x10 <sup>3</sup> )	LYMPHO (x10 <sup>3</sup> )	MONO (x10 <sup>3</sup> )	EOSIN (x10 <sup>3</sup> )	BASO (x10 <sup>3</sup> )
FOL-HOPE	25.97±5.81	7.07±2.84	17.61±4.51	0.95±0.04	0.91±0.04	70.80±158.3
ELEYELE	25.01 ±4.89	6.08 ±1.01	17.01±3.36	0.61±0.05	1.10±0.54	78.00±156.0
DANDARU	12.57±5.27 <sup>a, b, d</sup>	2.93±0.86	8.95±1.70 <sup>a, b</sup>	0.51±0.15 <sup>a, b, c</sup>	0.29±0.010 <sup>a, b</sup>	0
OLUYOLE	19.54±6.14 <sup>b, c</sup>	6.55±2.58	11.69±3.91 <sup>a, b</sup>	0.71±0.02	0.62±0.41	51.70±88.3

Superscript (a) indicates a significant difference when compared with Fol-hope, superscript (b) indicates a significant difference when compared with Eleyele, and superscript (c) indicates a significant difference when compared with Oluyole. Mean ± SD (n=5).

**Abbreviations:** White blood cell counts (WBC), Heterophils (HET), Monocytes (MONO), Eosinophils (EOSIN), Basophils (BASO), & Lymphocytes (LYMPHO).

**Table 3: Heavy metals concentration (mg/L) in the liver of fish**

Sites	Cd	Mn	Cu	Zn	Pb	Cr	Fe
Fol-Hope	0.000	0.020±0.002***	0.000	0.010±0.033	0.021± 0.027	0.000	0.135±0.096***
Eleyele	0.000	0.000	0.000	0.000	0.021±0.013	0.000	0.158±0.071
Dandaru	0.020±0.005*	0.000	0.000	0.000	0.032±0.027	0.000	0.032±0.060
Oluyole	0.050±0.003*	0.280±0.002****	0.000	0.0050±0.026	0.005±0.022	0.000	1.124±0.040

\*= p < 0.05      \*\* = p < 0.001      \*\*\* = p < 0.001      \*\*\*\* = p < 0.0001

Cd: Cadmium; Mn: Manganese; Cu: Copper; Zn: Zinc; Pb: Lead; Cr: Chromium; Fe: Iron

**Table 4: Heavy metals concentration (mg/L) in the gills of catfish**

SITES	Mn	Fe	Cu	Zn	Pb	Cr
Fol-Hope	1.30	29.00	0.13	4.60	5.90	1.65
Eleyele	2.30	18.50	0.28	7.26	9.30	41.85
Dandaru	1.60	84.70	0.19	6.50	8.15	56.35
Oluyole	2.40	14.30	0.19	2.93	7.20	1.25

**Table 5: The frequency of micronucleated polychromatic erythrocytes (MnPCEs)**

Sampling stations	Frequency of micronucleated polychromatic erythrocytes (MnPCEs)
FOL-HOPE	1.30±0.50
ELEYELE	14.17±0.50 <sup>a</sup>
DANDARU	8.33±0.77 <sup>ab</sup>
OLUYOLE	20.42±2.07 <sup>abc</sup>

Superscript (a) indicates a significant difference when compared with Fol-hope, superscript (b) indicates a significant difference when compared with Eleyele, and superscript (c) indicates a significant difference when compared with Oluyole. Mean ± SD (n=5). **Abbreviation:** Micronucleated polychromatic erythrocytes (MnPCEs)

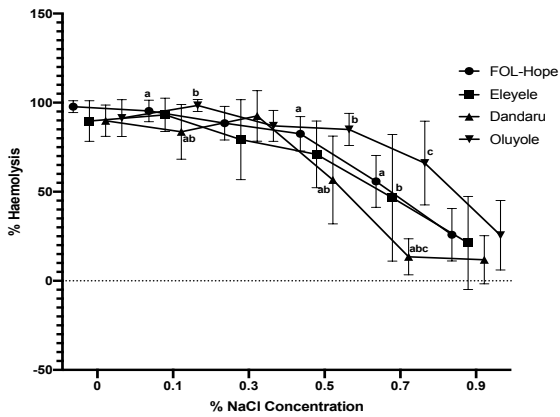


Figure 1: Erythrocytes osmotic fragility of African Catfish from a commercial pond in some polluted rivers in Ibadan. Values with the same superscript alphabet at the same NaCl concentration are significantly different at  $P < 0.05$

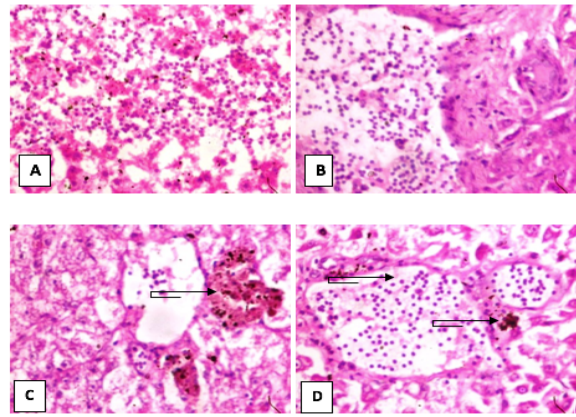


Figure 2: Histology of liver of catfish (*Claria gariepinus*) from Fol-Hope Farm (A), Eleyele stream (B), Dandaru stream (C), Oluyole stream (D). Showing marked deposition of adipose tissue (steatosis) in fish from Fol-Hope farm and congestion of sinusoids and blood vessels in those fish from the polluted river (Black arrow B, C and D). Mag x400.

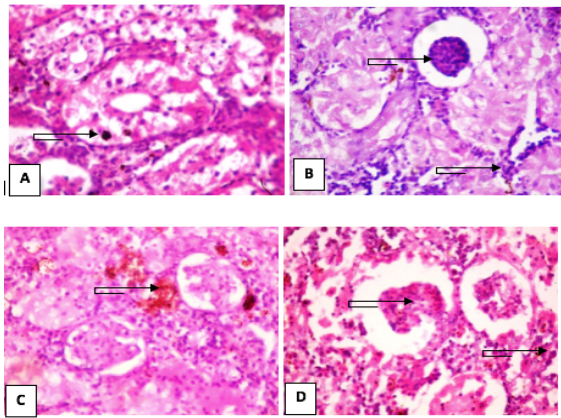


Figure 3: Histology of the kidney of catfish (*Claria gariepinus*) from Fol-Hope Farm (A), Eleyele stream (B), Dandaru stream (C), Oluyole stream (D), showing desquamation of tubules and varied grade of disseminated congestion and necrosis (Black arrow). Mag x400.

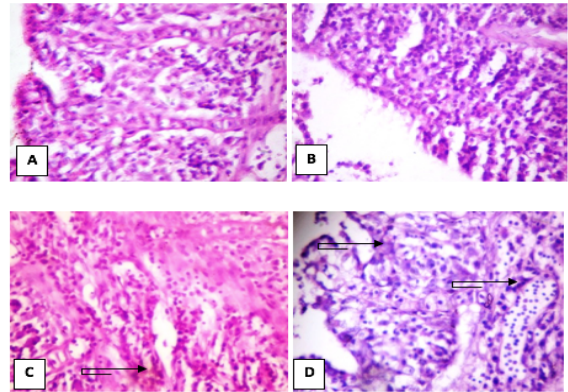


Figure 4: Histology of the gills of catfish (*Claria gariepinus*) from Fol-Hope Farm (A), Eleyele stream (B), Dandaru stream (C), Oluyole stream (D) showing intralamellar necrosis in C and D (Black arrow). Mag x400.

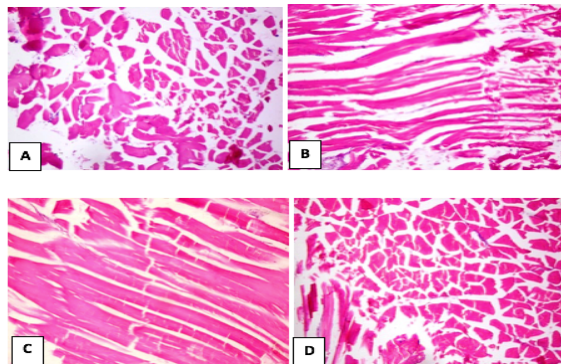


Figure 5: Histology of the muscle of catfish (*Claria gariepinus*) from Fol-Hope Farm (A), Eleyele stream (B), Dandaru stream (C), and Oluyole stream (D). No visible lesion. Mag x400.

## Discussion

In the last three decades, environmental pollution has become a major global challenge for both developed and developing countries (Feng *et al.*, 2024; Seidenath *et al.*, 2021; Niu *et al.*, 2017). The negative impact of environmental pollution on public health could be due to climate change associated with global warming (Alahmad *et al.*, 2023; D'Amato and Akdis, 2020). More recently, climate change has generated hot topics for discussion for governmental and non-governmental

organizations (De Vita *et al.*, 2024; Bornmann *et al.*, 2022). Worthy of note is the fact that human activities have contributed significantly to climate change, exacerbating global warming (Sabir *et al.*, 2024; Zeb *et al.*, 2024). Heavy metal contamination via industrial effluents has continued to worsen the stream condition and its environment. Contamination of dietary substances by environmental pollutants has been reported to have adverse effects on humans and animals (D'Souza and Peretiakko, 2002). Metals escape control mechanisms such as homeostasis, transport, and compartmentalization, thus making them more toxic and lethal (Jan *et al.*, 2015).

In this study, heavy metal contaminants were detected in the liver tissues and fish gills from the polluted streams. These sites were also actively fished and served as water sources for domestic use by locals who consume and sell the fish. Previous studies have documented associated risk factors and public health concerns following fish consumption from polluted rivers (Adams *et al.*, 2020). Different pathological conditions might also arise from exposure to fish and fish by-products from contaminated rivers (Hsu *et al.*, 2022). Industrialization and unregulated disposal of effluents also leach into the ponds, dams, wells, and sources of water in the environment which may ultimately get to the water table.

We observed a significant rise in the activities of some enzymes associated with the liver function of fish from the polluted rivers including higher activities of ALT and ALP. The heavy metals appeared to be a driver for the induction of liver enzymes. Hepatotoxicity has been positively linked to increased activities of the ALT, AST, and ALP, respectively, (Lin *et al.*, 2023; Owagboriaye *et al.*, 2023). Damage to the hepatocyte membrane is a precursor to the leakage of the biomarkers of hepatic injury from the intracellular to the extracellular milieu (Owagboriaye *et al.*, 2023). Hence, the study supports the reports from previous studies that heavy metal contamination of the aquatic environment could be responsible for

hepatotoxicity in aquatic organisms (Khan *et al.*, 2020; Jaishankar *et al.*, 2014). Heavy metal toxicity has been reported to initiate lipid peroxidation, generate reactive oxygen species (ROS), and ultimately induce hepatotoxicity (Mansoor *et al.*, 2023). The accumulation of heavy metals in the liver could also be another pathway causing hepatic dysfunction.

This study also revealed that exposure to potential contaminants in the sampled fish could have precipitated anaemia as revealed by a reduction in PCV, RBC, and Hb concentration. The observed anaemia could be characterized as macrocytic or megaloblastic anemia as evident in the increase in MCV and MCH values. Megaloblastic anaemia had been previously documented in hepatic injury (Yang *et al.*, 2018; Aslinia *et al.*, 2006). Capitão *et al.* (2022) reported heavy metal contamination and the incidence of anaemia in children. This correlates with the hepatic damage associated with heavy metal contamination and accumulation. Excessive deposition of Cr and Pb could cause dysregulation and interference with haematopoiesis by inhibiting key enzymes (Romaniuk *et al.*, 2018). More importantly, increased osmotic fragility recorded for catfish from polluted water undoubtedly contributed to the recorded anaemia as increased erythrocyte osmotic fragility is an indication of the instability of erythrocyte membrane and the possibility of lysis during stress or exposure to contaminants.

Heavy metal contamination could cause anaemia via erythrocyte lysis and the generation of free radicals. The research also observed that the production of WBC and its differentials were significantly altered in fish from polluted water indicating the severity of pollution in the aquatic environment. Generalized leucopenia observed in fish from the Oluyole and Dandaru were possible indicators of reduction in hemopoiesis from the liver, spleen, and bone marrow in the affected fish. Heavy metals, including lead, are prominent destroyers of haemopoietic stem cells, resulting in generalized pancytopenia in chronic and persistent exposure

to heavy metals and other contaminants (Suljević *et al.*, 2021 and Witeska *et al.*, 2023).

Histopathology of the liver of Catfish from polluted waters showed marked and severe disseminated congestion. The kidney tissues from the polluted waters showed desquamation of the tubules and tubular necrosis, severe distortion of the kidney architecture characterized by outright loss of tubular structure, desquamation, atresia, and degeneration. Furthermore, congestion, necrosis, and oedema were observed on the gills. However, histopathology of the muscle of the fish from the reference and the selected streams showed no visible lesion. All the aforementioned pathologies are indicative of organ toxicity, possibly from heavy metals and their attendant pathophysiological consequences. Previous studies have reported arrays of tissue damage and target organ toxicities associated with heavy metal tissue accumulation in aquatic animals (Balali-Mood *et al.*, 2021; Li *et al.*, 2015; Jaishankar *et al.*, 2014). Heavy metal contamination and bioaccumulation in tissues have been known to cause DNA damage and genomic instability (Khan *et al.*, 2020). Many biomarkers can be used to access and monitor damage to nucleic acids (Khan *et al.*, 2020). The micronucleus assay is used to detect genotoxic damage in interphase cells and chromosomal-level DNA damage by environmental pollutants, including heavy metals (Doherty, 2012; Fenech, 2008). The streams were chosen based on the physical observable point source pollution arising as

## References

1. Adams RH, Ojeda-Castillo V, Guzmán-Osorio FJ, Álvarez-Coronel G, Domínguez-Rodríguez VI. Human health risks from fish consumption following a catastrophic gas oil spill in the Chiquito River, Veracruz, Mexico. *Environ Monit Assess.* 25;192(12):783, (2020). doi: 10.1007/s10661-020-08742-z. PMID: 33236254.

effluents from domestic and industrial sources, which may be linked to the detected presence of heavy metals within the tissue of the sampled fish. This may also be responsible for the significant increase in the frequency of micronucleated polychromatic erythrocytes (MnPCEs) observed in the blood of most fish from the polluted sites. Various research findings have reported the association between environmental pollution and chromosomal damage in aquatic and non-aquatic organisms (Mathur *et al.*, 2023; Katalay *et al.*, 2022; Ayhan *et al.*, 2021; Sharma *et al.*, 2021; Çakal Arslan *et al.*, 2015).

## Conclusion

In conclusion, the general use of water from natural sources impacted by human activities for fish farming revealed possible deleterious health impacts on the fish, causing histopathological lesions in the gills and the liver. The presence of heavy metals and induction of genotoxicity means that caution must be exercised when raising fish using water from polluted streams. Ingesting fish from polluted waters such as those assessed in this study might likewise predispose human consumers to toxicity associated with heavy metal and other environmental pollutants intoxication. The use of these biomarkers of exposure proved sensitive to detecting contaminant-induced changes.

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