

Comparative assessment of heavy metals concentrations in the muscles, gills and guts of croaker, *Pseudotolithus senegalensis* from coastal waters of Nigeria and South America

Ayo-Olalusi, C. I.^{1*}, Omoboye, H. Y.² and Ozor, P. A.³

¹Department of Biotechnology, Nigerian Institute for Oceanography and Marine Research, Victoria Island, PMB 12729, Lagos, Nigeria.

²Department of Zoology, Obafemi Awolowo University, Ile-Ife, Nigeria.

³Department of Science, Lagos State University, Ojo, Lagos, Nigeria.

*Corresponding author: Caroline I. Ayo-Olalusi. ireti.ayoolalusi@yahoo.com

Received: 18 November, 2025

Revised: 17 June, 2026

Accepted: 25 June, 2026

Keywords: Heavy metals, *Pseudotolithus senegalensis*, tissues, coastal waters, health risk



© 2026 Zoological Society of Nigeria



This is an Open Access article distributed under the terms of Creative Commons Attribution License 4.0 (CC BY-NC-SA)

Abstract

Heavy metals pollution of aquatic ecosystems is a major environmental challenge because of its adverse effect on aquatic organisms and human health. This study investigated heavy metals accumulation in *Pseudotolithus senegalensis* obtained from Nigerian waters and imported from South America. Heavy metals concentrations were determined using Atomic Absorption Spectrophotometry. Zinc, Fe, Cu, Pb, Mn and Cr values were 1.49-11.31 $\mu\text{g/g}$, 3.70-43.52 $\mu\text{g/g}$, 0.6-2.72 $\mu\text{g/g}$, 0.19-2.09 $\mu\text{g/g}$, 0.02-4.47 $\mu\text{g/g}$ and 0.83-6.01 $\mu\text{g/g}$, respectively. In the American samples, Zn and Fe were highest in the gut (11.31 \pm 0.387 $\mu\text{g/g}$) while Fe was highest in the gills (22.26 \pm 0.014 $\mu\text{g/g}$) of Nigerian specimens. Muscle tissues consistently had the lowest Zn and Fe concentrations in both groups. Copper and Cd were not detected in the muscles of the South American samples whereas Cd and Cr were absent in the gills and gut, respectively. Cluster analysis grouped Zn and Fe together whereas Cu, Cr, Cd, Pb and Mn formed a separate cluster. Principal Component Analysis identified two principal components that accounted for 98.89% of the total variance. Overall, gills and guts accumulated higher concentrations of heavy metals than muscles. Heavy metals levels in the Nigerian samples were within WHO limits whereas elevated Pb concentration in the South American samples may pose health risk to consumers.

Introduction

Heavy metals pollution of aquatic ecosystem is recognised as a major environmental challenge. Aquatic environments are increasingly polluted by heavy metals discharged from residential, commercial, and other anthropogenic sources (Briffa *et al* 2020). These contaminants can alter the community structure of the aquatic organisms in the affected environment (Madesh *et al* 2024). Heavy metals are taken up by fish through various routes, including the gills, guts and muscles, depending on their availability in the aquatic environment. They accumulate in different fish organs at varying concentrations (Ray and Vashishth, 2024; Rao and Padmaja, 2000; Bervoets *et al* 2001). While some heavy metals, like lead, cadmium, and mercury, have no known positive function in biological systems, others, like copper, iron, and zinc, are essential for fish metabolism (Kumar *et al* 2024). These essential metals are required in trace amounts and are obtained through food and water to support healthy physiological function; however, excessive accumulation could result in toxic effects (Zahran *et al* 2025; Yousafzai 2004).

Petroleum exploration, processing, mining, and poor wastewater management are the most frequent sources of

heavy metal pollution. Natural disasters, including cyclones, tornadoes, earthquakes and landslides, have also been linked to heavy metals pollution. (Das *et al* 2023). Furthermore, accidents involving nuclear reactors and solid weapons can release heavy metals contaminants, which could alter the ecosystem. For example, Chernobyl, radioactive metal pollution in Ukraine 1986 resulted in widespread radioactive contamination of the environment, while thousands of people were exposed to radiation and many were placed at an increased risk of developing thyroid cancer, particularly in Ukraine, Belarus and parts of Russia (Folkers and Gunter 2022). Also, many lives were lost after consuming fish tainted with methyl mercury from an industrial effluent dumped into the Jitney River in Japan (Hong *et al* 2012). Heavy metals pose serious dangers to the environment because they are not readily detoxified by metabolic activities and consequent accumulate in biological systems (Zaynab *et al* 2022).

In Nigeria, the most populous country in Africa with over 200 million inhabitants (Adesola *et al* 2024), fish is widely consumed as one of the most affordable sources of animal protein. The increasing demand for fish has resulted in a substantial influx of imported seafood into Nigerian markets. Therefore, it is of interest to contribute

to the available information on the level of heavy metals in fish consumed within the country. This study was aimed at identifying the levels of heavy metals (Zn, Fe, Mn, Cr, Cu, Cd, and Pb) in different tissues of *Pseudolithus senegalensis* (Valenciennes, 1833) to ascertain whether the fish is safe for human consumption.

Materials and methods

Sample collection

Pseudolithus senegalensis (croaker) specimens from Nigeria were obtained directly from Seafood Limited, Ijora, Lagos. Specimens of the same species imported from South America by the same company were also procured for comparative analysis. The samples were labelled, placed in coolers containing ice flakes at approximately -4°C , transported to the laboratory of the Physical and Chemical Oceanography Department of the Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos, Nigeria and subsequently stored in the refrigerator until analysis. Prior to analysis, samples were thawed at room temperature, and the guts, gills and muscle were carefully excised for heavy metal determination. Each matrix was subjected to acid digestion. Trioxonitrate (V) acid, Tetraoxosulphate (VI) acid and hydrogen peroxide were used as oxidising reagents in various combinations and proportions following the method of AOAC (2005)

Sample preparation and analysis

Each fish specimen was descaled and dried for 36 hours at 80°C in an electric oven and pulverised using a dry homogeniser. The fish was further dried, stored in dry plastic bottles and digested using the method of Capon as described by Obodo (2002). Briefly, 1.0g of fish powder was measured into a Kjeldahl's flask, 20ml of a mixture of 10ml HClO_4 and 100ml HNO_3 was added. Digestion was carried out in a fume cupboard for 3 hours until the brown NO_2 fumes disappeared. After cooling, the digest was transferred into a 50ml volumetric flask and made up to volume with 0.7% HNO_3 solution.

Determination of metal concentration

Atomic Absorption Spectrophotometer model 929 SOLAR was used to determine the concentration of metals in the samples at specific wavelengths following the procedure outlined by AOAC (2005). Air acetylene flame was used.

Data analysis

Data analysis was performed using the statistical package, SPSS 16.0. The data generated were subjected to descriptive statistics and t-test. Heavy metals from the same source were grouped using cluster analysis (CA). Also, Principal Component Analysis (PCA) was used to identify the associations among heavy metals in the fish tissues from South America and Nigeria.

Results

The levels of trace metals obtained in various parts of *P. senegalensis* from Nigeria and South America are

presented in Table 1. The maximum concentrations of Zn ($11.31 \pm 0.387 \mu\text{g/g}$) and Fe ($22.26 \pm 0.014 \mu\text{g/g}$) was observed in the gut of *P. senegalensis* from South America while in Nigerian *P. senegalensis*, the peak of Fe ($43.52 \pm 0.65 \mu\text{g/g}$) was in the gill. The muscle had the lowest Fe concentrations among the examined tissues in both countries. However, the Fe concentration in the Nigerian samples ($3.7 \pm 0.03 \mu\text{g/g}$) was lower than that of the South American samples ($4.53 \pm 0.20 \mu\text{g/g}$). Copper and cadmium were not recorded in the muscle, Cd and Cr were also absent in the gills and guts of samples from South America. In the Nigerian samples, lead was not observed in the muscle and gut while cadmium was not observed in the tissues of *P. senegalensis*.

The concentration of heavy metals varied in the gills and guts of *P. senegalensis* in South America (Table 1). Overall, the muscle exhibited the lowest levels of Zn, Fe and Cu in South America and Nigeria (Table 1). In South America samples, higher concentrations of Zn, Fe and Pb (11.31 ± 0.39 , 22.26 ± 0.01 and $0.19 \pm 0.05 \mu\text{g/g}$, respectively) were recorded in the gut, whereas Cu, Mn and Cr were higher in the muscle of Nigeria samples (0.6 ± 0.02 , 0.47 ± 0.06 and $0.55 \pm 0.02 \mu\text{g/g}$, respectively) than in South America samples (Figure 1). The gills of South America fish had higher concentrations of Mn, Cr and Pb (4.47 ± 0.07 , 6.01 ± 0.05 and $1.08 \pm 0.05 \mu\text{g/g}$, respectively) while Fe and Cu were higher in the gills of Nigeria specimens (43.52 ± 0.65 and $1.66 \pm 0.07 \mu\text{g/g}$, respectively) (Figure 2). Fe concentration in the gut was similar in both locations, while Pb showed the lowest concentration across all tissues in both samples (Figure 3).

In both samples, the concentration of Mn was higher in the gills (4.47 ± 0.07 and $2.22 \pm 0.40 \mu\text{g/g}$) than in the muscles and gut (Table 1). Pb concentration in the muscle ($2.09 \pm 0.29 \mu\text{g/g}$) was higher in South American samples than in Nigerian samples. The concentration of Fe, Zn, Cd and Cu in the tissues of *P. senegalensis* from both locations were below WHO standards but Pb, Mn and Cr were above the permissible limits. Lead ($0.23 \pm 0.05 \mu\text{g/g}$) was only recorded in the gills of *P. senegalensis* in Nigeria. The t-test analysis revealed that only Cu showed significant variation ($p < 0.05$) among the tissues studied in both locations (Table 1).

Cluster analysis (CA) grouped the heavy metals in the fish tissues from South America into two: Zn and Fe in Group 1 while Cu, Cr, Cd, Pb and Mn made up Group 2 (Figure 4). Also, two groups were formed among trace metals in the tissues of *P. senegalensis* collected in Nigeria. Zn and Fe made a Group while Cu, Cr, Cd, Pb and Mn made the other group (Figure 5). PCA gave two major components, PC1 and PC2, accounting for 98.89 % of the total variance. Fe and Zn contributed more to the variations in the group of metals examined.

Discussion

The present study revealed that heavy metals concentrations were higher in gills and guts compared to the muscle tissue of *P. senegalensis*. This pattern is consistent with previous reports (Afolabi *et al* 1988;

Sadik 1990). Fish gills are recognised as the main site for the uptake of waterborne pollutants, whereas the liver plays a key role in detoxification. Therefore, the higher concentrations of heavy metals in the gills may result from their direct contact with contaminated water. The earth's soil is rich in iron, which is found naturally in aquatic environments (Cadmus *et al* 2018) and had the highest concentration in many tissues in the present study. Thus, prolonged exposure to elevated iron levels can cause it to build up in many fish tissues, increasing

tissue problems in essential parts (Avenant-Oldewage and Marx 2000). This is consistent with the study of Singh *et al* (2019), which identified excess iron in the *L. rohita*. Except for lead in the muscle and Mn and Cr in the gills of croaker imported from South America, the levels of every metal identified were within the WHO recommended limits (WHO, 1996). Given that these fish species are consumed protein source, the observed levels of manganese and chromium suggest possible contamination that could be injurious to human health.

Table 1: Heavy metal concentration (µg/g) of various tissues of *P. senegalensis* from Nigeria and South America

Metal (µg/g)	South America			Nigeria			t-test p value	WHO/EPA STANDARD
	Muscle	Gill	Gut	Flesh	Gill	Gut		
Zinc	4.7±0.33	10.20±0.02	11.31±0.39	1.49±0.04	7.86±0.04	10.5±0.04	0.09	58-150
Iron	4.53±0.20	21.39±0.04	22.26±0.01	3.70±0.03	43.52±0.65	22.34±0.45	0.44	4-48.0
Copper	BDL	0.77±0.29	1.46±0.37	0.6±0.02	1.66±0.07	2.72±0.03	0.04	4-10.0
Lead	2.09±0.29	1.08±0.05	0.19±0.06	BDL	0.23±0.05	BDL	0.20	1.5
Manganese	0.02±0.0	4.47±0.07	0.04±0.02	0.47±0.06	2.22±0.40	0.51±0.02	0.67	0.0025-0.005
Cadmium	BDL	BDL	0.01±0.01	BDL	BDL	BDL	0.00	0.0 – 0.2
Chromium	BDL	6.01± 0.05	BDL	0.55±0.02	BDL	0.83 ± 0.05	0.56	0.1-0.15

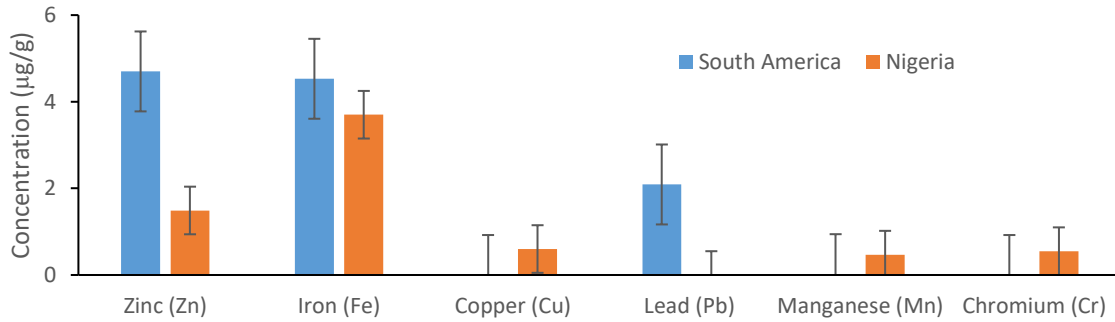


Figure 1. Concentration (µg/g) of heavy metal in the muscle of *P. senegalensis* from Nigeria and South America

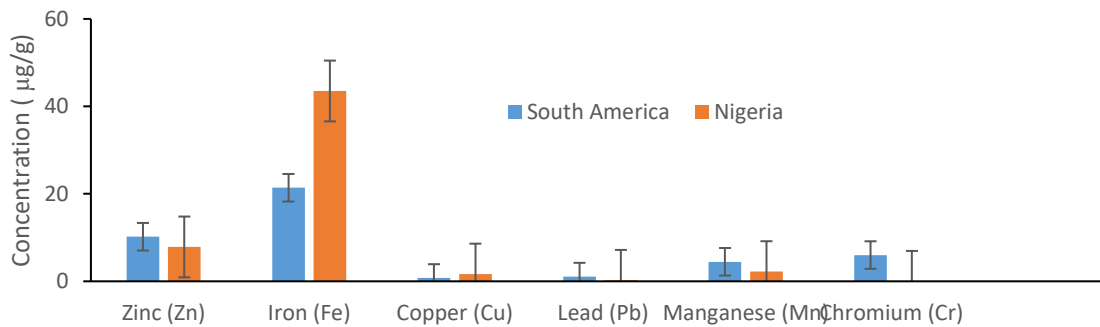


Figure 2. Concentration (µg/g) of heavy metal in the gill of *P. senegalensis* from Nigeria and South America

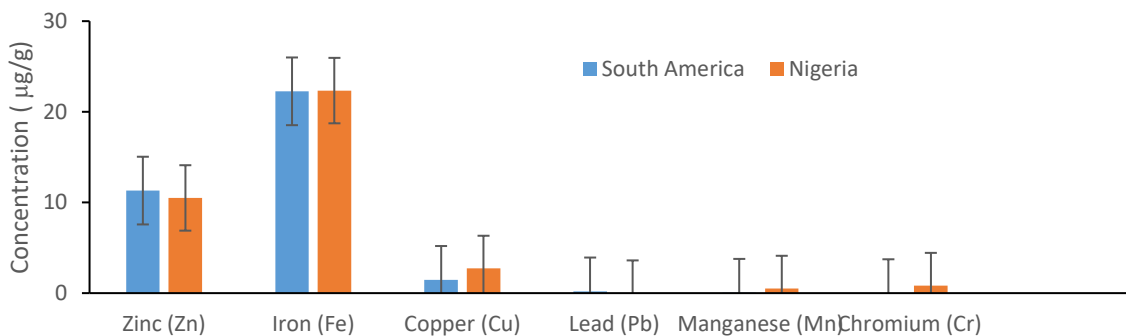


Figure 3. Concentration (µg/g) of heavy metal in the gut of *P. senegalensis* from Nigeria and South America

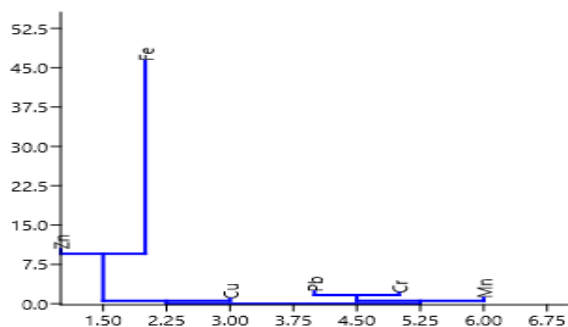


Figure 4. Cluster Analysis of heavy metals in *P. senegalensis* from S. America

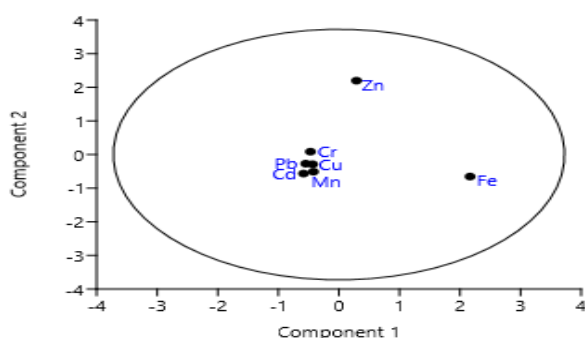


Figure 5. Principal Component Analysis (PCA) of heavy metals in *P. senegalensis* from Nigeria

Most rocks naturally contain heavy metals such as Mn, Pb and Cr, and weathering of these rocks could cause high concentrations of these metals in aquatic environment (Ali *et al* 2005). In fish, the liver, spleen, kidney, and gills are the main organs affected by lead bioaccumulation. The lethal lead concentration for fish is between 10 and 100mg/l (Garai *et al* 2021). At sublethal levels of lead exposure, fish exhibit behavioural abnormalities, impotence, and delayed development (Emon *et al* 2023). The absence of cadmium in organs of fish specimens from Nigeria is consistent with the findings of Fufeying 1994, who reported undetectable levels of cadmium in fish from Ikopba Reservoir, Benin City, Nigeria.

Since muscle serves as a location for energy storage and for movement and swimming activities rather than as a site for metabolic reactions, the levels of these metals in muscle were generally reduced (Ray and Vashishth, 2024). This is comparable to the Buriganga River investigation, where the muscle contained comparatively mild quantities of heavy metals (mg/g dry weight) in several *H. fossilis* tissues (Begun *et al* 2013).

Conclusion

The heavy metal concentrations of *P. senegalensis* were considerably higher in the gills than in the muscle. The concentrations of heavy metals in croakers from Nigeria were within WHO standards. However, the high level of lead found in croakers from South America could constitute a health hazard. Regular assessment of the concentrations of heavy metals in fish is necessary for public safety.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

The authors gratefully acknowledge Nigerian Institute for Oceanography and Marine Research (NIOMR) for its support.

References

- Adesola R.O, Opuni E, Idris I, Okesanya O.J, Igwe O, Abdulazeez M.D, Lucero-Prisno D.E. 2024. 3rd. Navigating Nigeria's Health Landscape: Population Growth and Its Health Implications. *Environ Health Insights*. 18: 1-18. <https://doi.org/10.1177/11786302241250211>
- Afolabi, B.C.O. 1988. Heavy metal levels in local and imported smoked fish in Nigeria. 4th FAO Expert Consultation on Fish Technology in Africa, Abidjan. 21-30.
- Ali, N., Oniye, S.J., Balarabe, M.I. and Anta, J. 2005. Concentration of Fe, Cu, Cr, Zn and Pb in Makara-Drain, Kaduna, Nigeria, *Chemclass J. 2*: 69-73.
- AOAC. 2005. Official Method of Analysis of the Association of AOAC International (18th ed.). AOAC. Maryland, USA.
- Avenant-Oldewage, A. and Marx, H. M. 2000. Bioaccumulation of chromium, copper and iron in the organs and tissues of *Clarias gariepinus* in the Olifants River, Kruger National Park. *Water South Afr.* 26(4):569-582.
- Begum, A.I. Mustafa, M.N. Amin, T.R. Chowdhury, S.B. and Quraishi, N. B. 2013. Levels of heavy metals in tissues of shingi fish (*Heteropneustes fossilis*) from Buriganga River, Bangladesh, *Environ. Monit. Assess.* 185. <https://doi.org/10.1007/s10661-012-2959-4>
- Bervoets, L., Blust, R. and Verheyen, R. 2001. Accumulation of metals in the tissues of three Spined Sticklebacks (*Gastrosteus aculeatus*) from natural fresh waters. *Ecotoxicol. Environ. Saf.* 48(2): 117-127.
- Briffa, J. Sinagra, E. and Blundell. R. 2020. Heavy metal pollution in the environment and their toxicological effects on humans, *Heliyon*. 6(9). <https://doi.org/10.1016/j.heliyon.2020.e04691>
- Cadmus, P., Brinkman, S.F and May, M.K. 2018. Chronic Toxicity of Ferric Iron for North American Aquatic Organisms: Derivation of a Chronic Water Quality Criterion Using Single Species and Mesocosm Data. *Arch. Environ. Contam. Toxicol.* 74(4):605-615. <https://doi:10.1007/s00244-018-0505-2>.
- Das, S., Sultana, K.W., Ndhlala, A.R., Mondal, M. and Chandra, I. 2023. Heavy metal pollution in the environment and its impact on health: exploring green technology for remediation. *Environ. Health Insights*. <https://doi: 10.1177/11786302231201259>
- Emon, F. J., Rohani, M.F., Sumaiya, N., Tuj Jannat, M.F., Akter, Y. and Shahjahan, M. 2023. Bioaccumulation and bioremediation of heavy

- metals in fishes: A review. *Toxics* 11 (6). <https://doi.org/10.3390/toxics11060510>.
- Folkers, C. and Gunter, L.P. 2022. Radioactive releases from the nuclear power sector and implications for child health. *BMJ Paediatr.* 6(1): <https://doi.org/10.1136/bmjpa-2022-000001>.
- Fufeying, T.P. 1994. 'Heavy metal concentration in water, sediment and fish species of Ikpobo reservoir, Benin City, PhD Thesis University of Benin, Benin City, Nigeria, 167pp.
- Garai, P., Banerjee, P., Mondal, N., Mahavidyalaya, H. and Arambagh. 2021. Effect of heavy metals on fishes: Toxicity and bioaccumulation. *J. Clin. Toxicol.* 11(18). 1-10.
- Hong, Y., Kim, Y. and Lee K. 2012. Methylmercury exposure and health effects. *J. Prev. Med. Public Health.* 45(6): <https://doi.org/10.3961/jpmph.2012.45.6.353>
- Kumar, M., Singh, S., Jain, A., Yadav, S., Dubey, A. and Trivedi, S.P. 2024. *J. Trace Elem. Med. Biol.* 83. <https://doi.org/10.1016/j.jtemb.2023.127377>.
- Madesh, S., Gopi, S., Sau, A., Rajagopal, R., Karthick, S., Namasivayam, R. and Arockiaraj, J. 2024. Chemical contaminants and environmental stressors induced teratogenic effect in aquatic ecosystem – A comprehensive review. *Toxicol. Rep.* 13. 2214-7500. <https://doi.org/10.1016/j.toxrep.2024.101819>.
- Obodo, G.A. 2002. The bioaccumulation of heavy metals in fish from the lower reaches of River J. *Chem. Soc. Nig.* 27(2): 173-176.
- Rao, L.M. and Padmaja, G. 2000. Bioaccumulation of heavy metals in *M. cyprinoids* from the harbor waters of Visakhapatnam. *Bull. Pure Appl. Sci.* 19. 77-85.
- Ray, S. and Vashishth, R. 2024. From water to plate: Reviewing the bioaccumulation of heavy metals in fish and unraveling human health risks in the food chain. *Emerg. Contam.* 10(4). <https://doi.org/10.1016/j.emcon.2024.100358>.
- Sadik, A.O., 1990. Heavy metal contamination in some Nigerian marine fishes of commercial importance. NIOMR-Technical Paper No 63.
- Singh, M., Barman, A.S., Devi, A.L., Devi, A.G. and Pandey, P.K. 2019. Iron mediated zehmatological, oxidative and histological alterations in freshwater fish *Labeo rohita*, *Ecotoxicol. Environ. Saf.* 170: 87-97. <https://doi.org/10.1016/j.ecoenv.2018.11.129>
- World Health Organization 1996. Health criteria other supporting information in Guideline for drinking water quality (2nd ed.). WHO Geneva, 900pp.
- Zahran, E., Mamdouh, A.Z. and Elbahnaswy, S. 2025. The impact of heavy metal pollution: bioaccumulation, oxidative stress, and histopathological alterations in fish across diverse habitats. *Aquacult. Int.* 33(371). <https://doi.org/10.1007/s10499-025-02045-1>
- Zaynab, M., Al-Yahyai, R., Ameen, A., Sharif, Y., Ali, L., Fatima, M., Khan, A.K. and Li, S. 2022. Health and environmental effects of heavy metals. *J. King Saud Uni. Sci.* 34(1). <https://doi.org/10.1016/j.jksus.2021.101653>

ORCID

Caroline I. Ayo-Olalus: <https://orcid.org/0009-0003-8928-6999>