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Heavy Metals Concentrations and Risk Assessment in Atlantic Tarpon (*Megalops atlanticus*) from Coastal Water of Ondo State, Nigeria

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ABSTRACT

The presence of heavy metals in the aquatic environment is an indication of ecological risk due to their persistent nature in the environment and also their bioaccumulation in aquatic organisms that can be deleterious on aquatic organisms. This study therefore investigated the concentrations and the associated risks of Zinc, Lead, Cupper, Chromium, Cadmium, Nickel and Cobalt in *Megalops atlanticus* from coastal water of Ondo State. A total of 168 fish with total length and body weight ranged from 21cm - 45cm and 74g – 788g respectively were collected using cast net. Heavy metals in fish tissues were analyzed with GBC Savant AA Sigma flame atomic Absorption Spectrometer (AAS). The statistical tool SPSS 25.0 version was used to analyze the data collected. While One-way ANOVA and Duncan post hoc test were used to determine levels of significances. The results of the mean concentrations of heavy metals in the fish tissue Zn (15.74±7.05mg/kg), Pb (0.35±0.22mg/kg), Fe (15.30±6.62mg/kg), Cu (2.11±1.32mg/kg), Cr (0.25±0.09mg/kg), Cd (0.27±0.09mg/kg), Ni (0.48±0.30mg/kg) and Co (0.55±0.29mg/kg), indicated that the concentrations of these heavy metals fall within their respective Word Health Organization permissible limits. Risk assessment analyses however revealed that *Megalops atlanticus* poses some ecological, carcinogenic and non-carcinogenic risk to the environment and consumers respectively because the values for both ecological, carcinogenic and non-carcinogenic risk are beyond the permissible threshold values. The calculated Ecological risk quotient (ERQ) for Cu (1.24), Cr (2.25) and Ni (1.02) are greater than one (ERQ >1) from the analysis as compared to other investigated trace metals. Also, the Target Health quotient risk (THQ) and the Target cancer Risk (TR) showed no risk as values are less than one in all metals, and which indicates that *Megalops atlanticus* from Coaster Water of Ondo State, Nigeria did not pose both non carcinogenic and carcinogenic threats to the consumers of the fish. However, periodic monitoring of both the aquatic environment and the fish sp are recommended to forestall potential future ecological and health risks due to bioaccumulation and biomagnification of these heavy metals in the fish and their consumers.

Keywords:

Food safety, hazard, pollution, aquatic environment, monitoring

Introduction

Aquatic pollution has become a serious global concern due to industrial activities, agricultural and domestic application (Yi *et al*., 2008; Tiwari *et al*., 2015). This issue arises as a result of the quality of coastal waterbodies and aquatic environment being destroyed due to human or anthropogenic activities. The major sources of pollution of the coastal waters are land-based. These land–based sources of

pollution could be transported to the coastal creeks through drainages, ditches, shallow pits, as run-off and the direct dumping of wastes (Onyema, 2009). It has been estimated that 100 million people are at risk of toxic pollution at levels that exceed international health guidelines (Otachi *et al*., 2015). Heavy metals are among the most harmful contaminants to the environment and particularly sensitive indicators of changes in the aquatic environment (Ajima *et al*., 2015: Loto *et al*., 2022). Their toxicity and ability to accumulate in living organisms thereby causing a major problem with significant ecological implications cannot be overlooked (Jaishankar et al., 2014; Ajibare et *al*., 2018). Trace metals can be accumulated via both food chain and water bodies in fish (Balakrishnan and Ramu, 2016).
Fish are one of the most important and the largest groups of vertebrates in the aquatic system. Fish have been considered good indicators for heavy metal contamination assessment in aquatic systems because they occupy different trophic levels with different sizes and ages (Olawusi-Peters *et al*., 2019).

Fish that have bio-accumulated heavy metals may pose chronic health problems to its consumers. For example, there is a link between Lead (Pb), cardiovascular, muscular, and renal problems. Lead may also cause reproductive disorders in adults as well as developmental and cognitive deficiencies in children (Omobepade *et al*., 2020). Copper (Cu) on the other hand is an essential mineral needed for various body activities and functions in humans, but may cause kidney, liver and brain disorders when concentration is above the recommended limit (Ajibare *et al*., 2018).

Atlantic Tarpon (*Megalops atlanticus)* are large migratory elopomorph fish (Emmanuel *et al*., 2011). It belongs to the Family Megalopidae. They occur in tropical, subtropical, and temperate waters of the Atlantic Ocean (Crabtree *et al.*, 1997). *M. atlanticus* are widely distributed in warm temperate, subtropical and tropical waters (Zerbi, 1999; Emmanuel and Ross, 2019). *M. atlanticus* usually spawn at the beginning of raining season in ocean and their larvae (leptocephali) are transported shoreward from offshore spawning grounds by ocean currents to coastal nursery habitats and creeks where they grow and are harvest by fishermen (Crabtree *et al.*, 1992, Shenker *et al*., 2002).

Tarpon, or *Megalops atlanticus*, is an economically significant fish due to its great source of protein and high nutritional value (Kurth *et a*l., 2019). For light-tackle fishermen, it is also a well-liked game fish for recreational purposes (Dingle and Drake, 2007). Megalops atlanticus has ecological significance in addition to its economic and social worth, especially because of its unique leptocephalus larval stage (Quaeck-Davies *et a*l., 2018). This species has a distinct larval stage, in contrast to most fish, which do not go through metamorphosis after hatching (Smith, 1989). Because it needs low-salinity water to develop (Shenker *et al*., 2002), the leptocephalus larval stage is susceptible to the negative impacts of urban sprawl Quaeck-Davies *et a*l., 2018).

The study area is a hub of high economic activity with active oil exploration, fishing, agriculture, trading, and boat making. Boat transportation is the primary means of moving people and goods in the area. These activities, along with other municipal uses, contribute to water and sediment pollution. Mangrove swamps dominate the vegetation, particularly the red mangrove (*Rhizophora racemosa*) and the white mangrove (*Avicennia spp.*), typical of swamps. A notable feature of the area's vegetation is the desiccation caused by marine water incursion into about 10,000 hectares of freshwater swamp forest (Olorunlana, 2013). The area is typified by gently rising marsh flats in the creek that are almost at sea level. The area is drained by many perennial streams and rivers that traverse several coastal settlements and empty into the open ocean through the estuary, facilitating water exchange between the ocean and the coastline (Loto *et al*., 2022).

Global research interest in food safety concerning the accumulation of these hazardous chemicals in food, especially fish, has increased due to the numerous health impacts linked to heavy metals and other toxic substances (Balakrishnan and Ramu, 2016). A number of techniques have been put forward for evaluating the potential adverse health effects that heavy metals in fish may bring to humans. These hazards can be divided into effects that are carcinogenic and those that are not. Dose-effect relationships are used to assess the threshold for harmful effects of carcinogenic pollutants in relation to the observed or projected exposure concentration (Enuneku *et al.*, 2018).

Therefore, using Megalops atlanticus as an indicator species, the objective of this study is to assess the heavy metal concentrations and potential ecological and health concerns associated with heavy metals through the ingestion of fish from the coastal creeks of Ondo State.

2. Materials and Methods

2.1. Study area, samples collection and preparation

Study Area

The coastal area of Ondo State lies on Latitude 5º 50'N – 6º 09'N and Longitude 4º 45'E – 5º 05'E (Ajibare, 2014). The area is occupied by the Ilajes community in linear settlements along the coast with a fast-growing population, most of whom utilize the water for various purposes (Agunbiade *et al.* 2010). Four (4) major fishing communities, Rewoye, Ojumole, Ikorigho, and Odonla were selected in Ilaje Local Government Area of Ondo State. The site selection was based on the population/aggregation of fishing families/possible anthropogenic inputs, geographic distribution, catch volume and species diversities of the fish catches in the area. The fish were caught using cast net.

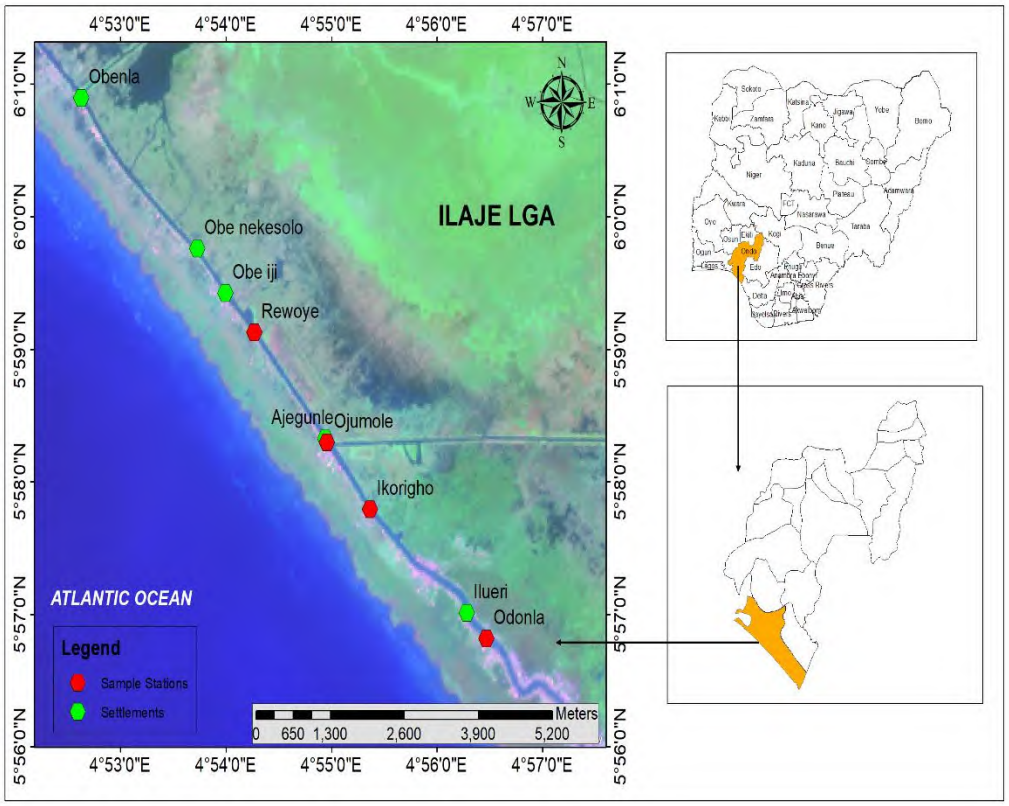

Figure 1: Map of the sampling stations

2.3 Sampling collection

The fish used for this study were collected from a coastal creek between February and April 2023. Each sampling day, fish samples were gathered along the creek sides from 0700 to 0900 hours using a cast net with a 0.5 mm mesh size. To prevent decomposition before laboratory examination, the fish were stored in an ice chest.

2.3.1 Determination of heavy metals

In the laboratory, fish samples were thawed in the open air in the laboratory and body wiped dry. After slicing the muscle into smaller pieces with a knife, it was dried in a 60°C oven for 48 hours. Using a mortar and pestle, the dried muscle was mashed and pulverized into a powder. Four grams (4g) of ground muscles were digested with 10 ml of nitric acid (HNO3) and 4 ml of perchloric acid. On a hot plate, the mixture was cooked to 85°C for 30 minutes. The residue was filtered into a 50 ml volumetric flask after being allowed to cool following digestion. The flask was filled to the 50 ml mark with distilled water. After that, the filtrate was put into a sample vial that had already been cleaned and kept at room temperature in preparation for additional examination with a standard scientific model of flame atomic absorption spectrophotometer (FAAS) for heavy metals, according to Thomas and Mohaideen, (2015).

2.3.2 Health risk determination

2.3.3. Target hazard quotient

This computation determines the non-carcinogenic risk limit related to pollutant exposure. It was determined using the USEPA (2021) region III risk-based level table to estimate human health risk of ingesting metal-contaminated fish species. The calculation was done using the equation below:

$$THQ = \frac{EF \times ED \times FIR \times M}{RfD \times BW \times ATn} \times 10^{-3}$$

Where:

THQ = Target hazard quotient; EF = Exposure frequency (365 days/year); ED = Exposure duration (54 years, equivalent to the average life expectancy of the Nigerian population); FIR = Fish ingestion rate (48 g/person/day (Abalaka *et al*., 2020); Cf = Conversion factor (0.0208) to convert fresh weight (Fw) to dry weight (Dw) considering 79% of moisture content in fish; CM = Concentration of heavy metals in fish species (mg/kg d. w.); WAB = Mean body weight (bw) (70 kg); ATn = When describing non-cancer risk, the average exposure time for non-carcinogens (19710); RfD = The reference dose of the metal (an estimate of the amount of exposure per day to which the general public might be constantly exposed for a lifetime without a detectable risk of adverse effects).
A THQ below 1 implies that the fish can be considered safe for consumption with no potential associated risks (Salam *et al*., 2019).

2.3.4 Hazard index

The total of the hazard quotients is used to determine the hazard index (HI) from THQs (USEPA, 2005).

HI = $HI = \sum_{n-1}^{n} THQ$

Where:

HI = The hazard index

2.3.5. Target cancer risk

The target cancer risk (TR) was used to denote concerns over carcinogenic issues. The technique for measuring TR is also presented in the USEPA Region III Risk-Based Concentration Table (USEPA, 2021). The following is the model for estimating TR (Enuneku et al., 2018):

$$TR = \frac{M \times FIR \times CPSo \times EF \times ED}{Bw \times ATn} \times 10^{-3}$$

Where:

TR = Target cancer risk; CM = Concentration of heavy metals in fish species (ng/g); FIR = Fish ingestion rate (g/day); CPSo = The carcinogenic potency slope, oral (mg/kg bw/day); ATc = The averaging time, carcinogens (365 days/year for 70 years as used by Ref. (USEPA, 2021). TR categories are described as, if TR ≤ 10^{-6} = Low; 10^{-4} to 10^{-3} = moderate; 10^{-3} to 10^{-1} = high; ≥10^{-1} = very high.

3.3.4 Ecological Risk Quotient (ERQ)

Ecological Risk Quotient (ERQ) (which numerically evaluates the associated risks in quantification and interpretation of the concentration of chemicals in aquatic environment) was determined using the following formula as cited by Olawusi-Peters *et al.*, (2019);

$$EQR = \frac{Eci}{Rli}$$

Where:
Ec: = Environmental concentration (mg/kg),
Rl = Recommended limit (mg/kg)

2.3.4. Statistical analysis

The statistical tool SPSS 25.0 version was used to analyze all the data collected. The mean heavy metal concentrations in fish species and standard deviations were calculated. One-way ANOVA was used to determine the significant differences between heavy metal concentrations in the fish tissues while Duncan post hoc test was used to determine the significance in the concentration of heavy metals in fish across the sampling stations. Probability level at p = 0.05 was used to indicate statistical significance. Mean of each value were presented in table and figures.

3.0 RESULTS

3.1. Heavy metals concentrations in fish

The mean heavy metals concentrations in the tissues of *M. atlanticus* are shown in Table 1. The levels of heavy metals in the tissue are in the following sequence; Zn < Fe < Cu < Ni < Pb < Cr < Cd. The one-way ANOVA shows that there was no significant difference ($p > 0.05$) in the level of heavy metals in the fish tissues. There was no significant ($p > 0.05$) difference between the mean heavy metals concentration of *M. atlanticus* across the sampling stations, except for Iron and copper that showed significant ($p<0.05$) different across the stations (Table 1.) The concentration of heavy metals recorded in *M. atlanticus* were lower than WHO permissible limits, except for Cr and Ni with higher values.

Table 1: Heavy metals in *M. atlanticus* from Ondo state coastal creeks

Parameters	Sampling Stations				MEAN	WHO
	Rewoye	Ojumole	Ikorigho	Odonla		Limits
Zinc (mg/kg)	11.82±6.51^{A}	15.56±7.70^{A}	13.63±5.80^{A}	16.20±7.57^{A}	**14.30±6.94**	75
Lead (mg/kg)	0.33±0.13^{A}	0.45±0.25^{A}	0.37±0.11^{A}	0.37±0.17^{A}	**0.38±0.17**	2
Iron (mg/kg)	11.16±1.77^{A}	14.44±8.03^{AB}	10.08±2.30^{A}	17.85±7.52^{B}	**13.38±6.30**	100
Copper (mg/kg)	1.43±1.05^{AB}	1.73±1.00^{AB}	1.01±0.87^{A}	2.29±1.07^{B}	**1.61±1.08**	13
Chromium(mg/kg)	0.30±0.12^{A}	0.28±0.10^{A}	0.45±0.35^{A}	0.33±0.12^{A}	**0.34±0.20**	0.1
Cadmium (mg/kg)	0.32±0.14^{A}	0.31±0.10^{A}	0.31±0.11^{A}	0.34±0.13^{A}	**0.32±0.12**	2

Nickel (mg/kg)	0.48 ± 0.21^{A}	0.53 ± 0.31^{A}	0.45 ± 0.30^{A}	0.59 ± 0.36^{A}	**0.51±0.30**	0.5
Cobalt (mg/kg)	0.46 ± 0.26^{A}	0.50 ± 0.36^{A}	0.64 ± 0.25^{A}	0.65 ± 0.37^{A}	**0.56±0.31**	NA

Mean value with same superscripts along the row were not significantly different (p>0.05).

3.2. Assessment of health risks

To calculate the target hazard quotient, assumptions were used in the health risk assessment. The excess likelihood of acquiring cancer over a 70-year period life expectancy as stated by USEPA (2005), was used to express the health risk associated with non -carcinogenic and carcinogenic impacts of investigated heavy metals. In this study, by analyzing the consumption of each heavy metal, the target hazard quotient (THQ) values of each metal were presented in Table 2, with mean values for each metal: Zn (0.04), Pb (0.07), Fe (0.01), Cu (0.03), Cr (0.00), Cd (0.25), Ni (0.02) and Co (1.44). Among all the metals, only Cobalt has the value greater than one. The Hazard Index (HI) for *M. atlanticus* were significantly higher than one, which suggest potential hazard associated with the fish species (Table 2). The target cancer risk (TR) values of *M. atlanticus* as presented in Table 3 revealed an increasing order from Pb (2.62×10^{-06}) > Cr (1.29×10^{-04}) > Cd > (1.47×10^{-04}) > Ni (6.67×10^{-04}). All the values showed that there was no cancer risk associated with consumption of *M. atlanticus* from the coastal creek of Ondo State.

Table 2: Target Hazard Quotient (HQ) and Hazard Index (HI) of *M. atlanticus* from Ondo State coastal creeks

Stations	Zinc	Lead	Iron	copper	Chromium	Cadmium	Nickel	Cobalt	**HI**
1	0.03	0.06	0.01	0.03	0.00	0.25	0.02	1.19	**1.59**
2	0.04	0.09	0.02	0.03	0.00	0.24	0.02	1.28	**1.72**
3	0.03	0.07	0.01	0.02	0.00	0.24	0.02	1.63	**2.02**
4	0.04	0.07	0.02	0.04	0.00	0.26	0.02	1.66	**2.12**
Total	**0.04**	**0.07**	**0.01**	**0.03**	**0.00**	**0.25**	**0.02**	**1.44**	**1.86**

Table 3: Target cancer Risk of *M. atlanticus* from Ondo State coastal creeks

Metals	Station 1	Station 2	Station 3	Station 4	**Mean**
Pb	2.26×10^{-06}	3.07×10^{-06}	2.57×10^{-06}	2.57 X 10-^{06}	**2.62×10^{-06}**
Cr	1.13×10^{-04}	1.09×10^{-04}	1.71×10^{-04}	1.25×10^{-04}	**1.29×10^{-04}**

Cd	1.49X 10^{-04}	1.42 X 10^{-04}	1.42 X 10^{-04}	1.57 X 10^{-04}	**1.47 X 10^{-04}**
Ni	6.22 X 10^{-04}	6.93 X 10^{-04}	5.87 X 10^{-04}	7.67 X 10^{-04}	**6.67 X 10^{-04}**

3.3 Ecological Risk Quotient (ERQ)

The Ecological Risk Quotient (Figure 1) shows decreasing order of investigated heavy metals from Cr (2.25) > Cu (1.24) > Ni (1.02) >Co (0.56) > Zn (0.19) > Pb (0.19) >Cd (0.16) > Fe (0.13). This indicated that *M. atlanticus* may constitute some ecological threat to the coastal creeks since some of the values of ERQ were greater than one (ERQ>1).

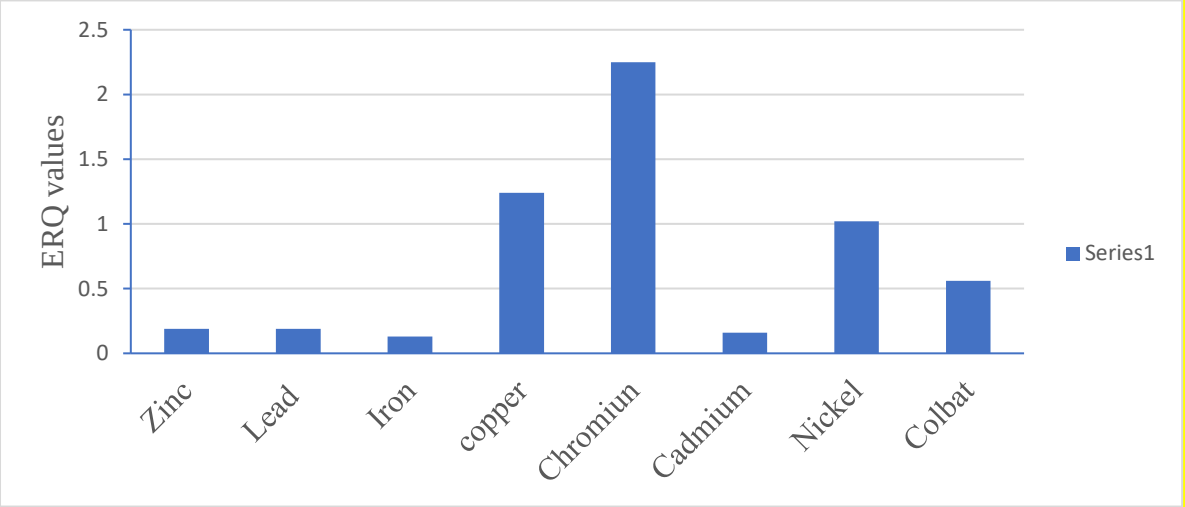

Figure 1: Ecological Risk Quotient of heavy metals in *M. atlanticus*

DISCUSSION

The concentration of heavy metals in *M. atlanticus* was generally within the permissible limits set by the World Health Organization (WHO, 2003), with the exceptions of chromium (Cr) and nickel (Ni). These levels were lower than those found in *Nematopalaemon hastatus* from the coastal waters of Ondo State, Nigeria, and in *P. obscura* from the Owan River, Edo State, as reported by Ajibare *et al*. (2018) and Oboh and Okpara (2019), respectively. However, these results contrast with those of Mustapha *et al*. (2021), who linked higher levels of heavy metals in fish from Epe lagoon to the use of agrochemicals and industrial activities, and Loto *et al*. (2022), who investigated *Sarotherodon melanotheron* and *Tilapia guineensis* from the Mahin lagoon, South Western Nigeria.

The average iron (Fe) concentrations in fish in this investigation fell within the 0.5 and 50 mg/kg recommended by the WHO and FEPA for fish foods. As noted by Asaolu and Olaofe (2004), iron is a micronutrient that is necessary for a variety of biological processes in marine creatures, despite the fact that it can become hazardous when it surpasses this limit. Myoglobin, hemoglobin, and certain enzymes are all produced with iron, and an iron shortage can result in weakness, impaired concentration, and heightened susceptibility to infections. Although it can be dangerous at high doses, copper (Cu) is another element that is necessary for the manufacture of hemoglobin and the activity of enzymes

(Sivaperrumal *et al*., 2007). According to this study, the fish tissue had Cu levels that were below both the FEPA (2003) permitted limit of 1.00 mg/kg and the FAO (2007) guideline of 3 mg/kg. Lower pH values are associated with increased Cu accumulation in aquatic species, according to Sivaperrumal *et al*., (2007).

There were no discernible variations in the levels of lead (Pb) in the fish tissue between stations ($p>0.05$). Even though several fish species had elevated Pb levels, they were still within the allowed ranges of 0.01 mg/l established by FEPA (2003) and 2 mg/kg established by FAO (2007). Due to its high toxicity, lead can cause delayed embryonic development, impaired growth, decreased reproduction, increased mucous formation, neurological problems, inhibition of enzymes, and kidney dysfunction at sublethal amounts (Akan *et al*., 2012). While too much chromium (Cr) can be fatal to fish and other creatures, it is a necessary trace element for humans and some other animals (Akan *et al.*, 2009). Cr concentrations in fish tissue were found to be high in this investigation, while they were still below the maximum value of 12–13 mg/kg recommended by the USFDA (1993).

The Target Health Quotient (THQ) for heavy metals (Zn, Fe, Pb, Cu, Cr, Cd, Ni, and Co) indicated that all metals had THQ values less than one ($THQ<1$), except for cobalt (Co). However, the hazard index (HI) suggested a potential health hazard, with values greater than one ($HI>1$). This is consistent with the findings of Akoto *et al.* (2014), who reported a potential non-carcinogenic risk from heavy metals in fish from the Fosu Lagoon, Ghana. The Target Cancer Risk (TCR) showed that the future cancer risk was low ($TCR \leq 10^{-6}$) for all heavy metals, similar to findings by Enuneku *et al*. (2018) and Olawusi-Peters and Adejugbagbe (2020).

The Ecological Risk Quotient (ERQ) for copper, chromium, and nickel suggested a potential ecological risk ($ERQ>1$), corroborating Ajibare and Loto (2023). This contrasts with Olawusi-Peters et al. (2019), who reported an ecological risk of heavy metal exposure in fish to be less than one.

Conclusion

This study revealed considerable concentrations of heavy metals in *Megalops atlanticus*, generally within recommended limits. The Target Health Quotient (THQ) indicated no possible non carcinogenic health risk for fish consumers. However, the Hazard Index (HI) suggested potential non carcinogenic health hazards with regular consumption. The Target Cancer Risk (TR) confirmed no carcinogenic risk associated with *M. atlanticus* in the study area. The Ecological Risk Quotient (ERQ) indicated ecological risks, particularly from Cu, Cr, and Ni, with ERQ values greater than one ($ERQ > 1$). Given the presence of Zn, Pb, Cu, Cr, Cd, Ni, and Co in the studied fish, there is need for routine monitoring and stringent regulation to mitigate heavy metal pollution in this ecosystem and to ensure food security and safety in the studied area.

Reference

Agunbiade, F.O., Olu-Owolabi, B.I. & Adebowale, K.O. (2010). Seasonal and spatial variations analysis of pollution status of Ondo coastal environment Nigeria using principal component analysis. *Geochemical Journal* 44: pp. 89-98.

Ajibare A. O. (2014). Assessment of Physico-Chemical Parameters of Waters in Ilaje Local Government Area of Ondo State, Nigeria. *International Journal of Fisheries and Aquatic Studies*, 1(5), 84-92.

Ajibare, A. O. & Loto, O. O. (2023**).** Risks Assessment of Copper Cu), Lead (Pb), Mercury (Hg) and Zinc (Zn): A case study of Tilapia guineensis in Lagos Lagoon. *Ghana Jnl Agric. Sci***.** 58 (1), *77–84*

Ajibare, A.O., Olawusi-Peters, O.O. & Ayeku, P.O. (2018) Bio-accumulation of some heavy metals in the cephalothorax and abdomen of *Nematopalaemon hastatus* in the coastal waters of Ondo State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, **11**(6), 32–38.

Ajima, M. N. O., Nnodi, P. C., Ogo, O. A., Adaka, G. S., Osuigwe, D. I., & Njoku, D. C. (2015). Bioaccumulation of heavy metals in Mbaa River and the impact on aquatic ecosystem. *Environmental monitoring and assessment*, *187*, 1-9.

Akan, J.c., Mohmoud, S., Yikala, B.S. and Ogugbuaja, V.O. (2012). Bio-Acucuulation of some Heavy metals in Fish Samples from River Benue in Vinikilang, Adamawa State, NNnnigeria. *American Journal of Analytical chemistry*, 3: 727 – 736.

Akoto, O., Bismark, E. F., Darko, G., & Adei, E. (2014). Concentrations and health risk assessments of heavy metals in fish from the Fosu Lagoon. *Int. J. Environ. Res*., 8(2),403-410.

Asaolu, S.S., And Olaofe, O. (2004). Bio-Magnification of Some Heavy and Essential Metals In Sediments, Fish And Crayfish From Ondo State Coastal Region. *Biological Science Research6:13-39.*

Balakrishnan, A. & Ramu, A. (2016). Evaluation of Heavy Metal Pollution Index (HPI) of Ground Water in and around the Coastal Area of Gulf of Mannar Biosphere and Palk Strait. *J. Adv. Chem. Sci*., 2(3), 331–333.

Crabtree, R.E., E.C. Cyr, D.C. Chacon—Chaverri, W.O. McLarney, and J.M. Dean. 1997. Reproduction of tarpon, *Megalops atlanticus*, from Florida and Costa Rican waters and notes on their age and growth. *Bulletin of Marine Science* 61:271–285.

Dingle, H., & Drake, V. A. (2007). What is migration? *Bioscience*, *57*(2), 113-121.

Emmanuel, B. E., & Ross, Y. R. (2019). Morphometric characteristics, food of Tarpon atlanticus and water quality trends in the Ogudu creek Lagos, Nigeria. *Ife Journal of Science*, *21*(3), 1-11.

Emmanuel, B. E., Oshionebo, C., & Aladetohun, N. F. (2011). Comparative analysis of the proximate compositions of Tarpon atlanticus and Clarias gariepinus from culture systems in South-Western Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, *11*(6), 5344 – 5355.

Enuneku, A., Omoruyi, O., Tongo, I., Ogbomida, E., Ogbeide, O., & Ezemonye, L. (2018). Evaluating the potential health risks of heavy metal pollution in sediment and selected benthic fauna of Benin River, Southern Nigeria. *Applied water science*, *8*, 1-13.

Federal Government Protection Agency (FEPA, 2003). Guidelines and Standards for Environmental Pollution Control in Nigeria. 238p.

Food and Agricultural Organization (FAO). (2007). Fishery profile. The Federal Republic of Nigeria. Pp 24.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary toxicology*, *7*(2), 60.

Kurth, B. N., Peebles, E. B., & Stallings, C. D. (2019). Atlantic Tarpon (Megalops atlanticus) exhibit upper estuarine habitat dependence followed by foraging system fidelity after ontogenetic habitat shifts. *Estuarine, Coastal and Shelf Science*, *225*, 106248.

Loto O. O., Samuel, O.B. and Chukwu, L.O. (2022). Heavy Metals Concentration and Enzymatic Biomarker of Two Commercially Important Cichlid Species (Sarotherodonmelanotheron and Tilapia guineensis) From the Mahin lagoon, South Western, Nigeria. *Ethopian Journal environmental studies & Management 15(4):474- 485.*

Oboh, I. P., & Okpara, B. C. (2019). Bioaccumulation of heavy metals and assessment of the human health risk of consumption of Clarias gariepinus and Parachanna obscura from the Owan River, Edo State, Nigeria. *Biologija*, *65*(3).

Olawusi-Peters, O. O., & Adejugbagbe, K. I. (2020). Health Risk Assessment of Heavy Metals in Clarias gariepinus (Burchell, 1822) from Fish Mongers within Akure Metropolis, Ondo State, Nigeria. *International Journal of Animal and Veterinary Sciences*, *14*(5), 55-59.

Olawusi-Peters, O.O., Ajibare, A.O. & Akinboro, T.O. (2019) Ecological and health risk from heavy metal exposure to fish. *Journal of Fisheries Research*, 3(2), 10–14.

Olorunlana, F.A. (2013). Evaluation of erodibility indices in Akoko region of Ondo State, Nigeria. *Global Journal of Biology and Health Sciences* 2(2): pp. 86-89.

Omobepade, B.P., Akinsorotan, A.M., Ajibare, A.O., Ogunbusola, E.M., Ariyomo, T.O., Jimoh, J.O., Odeyemi, K.M., Okeke, O.S., Falabake, M.A., Adeniji, S.M. & Adedapo, A.M. (2020) Heavy Metal Concentrations in the White Shrimp *Nematopalaemon hastatus* and their Associated Ecological and Health Risk in the Nigerian Continental Shelf. *Egyptian Journal of Aquatic Biology and Fisheries*, 24(2), 301–316.

Onyema, I. C. (2009). Pollution and the ecology of coastal waters of Nigeria. Dolps & Bolps Investments. . 216pp.

Otachi, E. O., Plessl, C., Körner, W., Avenant-Oldewage, A., & Jirsa, F. (2015). Trace elements in water, sediments and the elongate tigerfish Hydrocynus forskahlii (Cuvier 1819) from Lake Turkana, Kenya including a comprehensive health risk analysis. *Bulletin of environmental contamination and toxicology*, *95*, 286-291.

Quaeck-Davies, K., Bendall, V. A., MacKenzie, K. M., Hetherington, S., Newton, J., & Trueman, C. N. (2018). Teleost and elasmobranch eye lenses as a target for life-history stable isotope analyses. *PeerJ*, *6*, e4883.

Salam, M. A., Paul, S. C., Noor, S. N. B. M., Siddiqua, S. A., Aka, T. D., Wahab, R., & Aweng, E. R. (2019). Contamination profile of heavy metals in marine fish and shellfish. *Global Journal of Environmental Science and Management*, *5*(2), 225-236.

Sani, A., Idris, K. M., Abdullahi, B. A., & Darma, A. I. (2022). Bioaccumulation and health risks of some heavy metals in Oreochromis niloticus, sediment and water of Challawa river, Kano, Northwestern Nigeria. *Environmental Advances*, *7*, 100172.

Shenker, J.M., Cowie-Mojica, E., Crabtree, R.E., Patterson, H.M., Stevens, C., Yakubik, K., 2002. Recruitment of tarpon (*Megalops atlanticus*) leptocephali into the Indian river lagoon, Florida. Contrib. Mar. Sci. 35, 55–69.

Sivaperrumal, P., Sankar, T.V. and Viswanthan-Nair, P.G. (2007). Heavy Metal concentration in Fish, Shellfish and Fish Products from Internal Market of Indian vis-à-vis international standards. Food chemistry, 21: 225 – 234.

Thomas, S. & Mohaideen, J. A. (2015). Determination of some Heavy metals in fish, water and Sediments fromBay of Bengal. *Int. J. Chem. Scie.*, 13(1),53-62.

Tiwari, A.S. Kushwaha, A.C. Dwivedi, (2015). Accumulation of heavy metals in liver, muscle and gill of Cyprinus carpio from the Ganga River at Varanasi, Uttar Pradesh Accumulation of heavy metals in liver, muscle and gill of Cyprinus carpio from the Ganga River at Varanasi, Uttar Pradesh, Journal of the Kalash Science 3 (1): 47–51.

United States Environmental Protection Agency, USEPA (2005). Supplementary Guidancefor Conducting Health Risk Assessment of Chemical Mixtures. Risk Assessment ForumTechnical Panel, Washington, DC.

United States Environmental Protection Agency, USEPA (2021). Regional Screening Level (RSL) Summary Table: November 2021. 2020, p. 82.

World Health Organization, (WHO, 2003). Guidelines for Drinking Water Quality. Vol 1. Recommendation WHO. Geneva 130p.

Yi, Y., Wang, Z., Zhang, K., Yu, G. and Duan, X. (2008). Sediment pollution and its effect on fish through food chain in the Yangtze River, Int. J. Sediment Res. 23 (4):338–347.

Zerbi, A., Aliaume, C., Joyeux, J.-C., 2001. Growth of juvenile tarpon in Puerto Rican estuaries. ICES (Int. Counc. Explor. Sea) J. Mar. Sci.58, 87–95.

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