Iranian (Iranica) Journal of Energy and Environment 12(1): 61-67, 2021

Iranian (Iranica) Journal of Energy & Environment
Journal Homepage: www.ijee.net
IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Carcinogenic and Non-carcinogenic Risks of Heavy Metals in *Clarias gariepinus* (African Catfish) Obtained from Bariga Section of Lagos Lagoon, Nigeria

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P A P E R I N F O

Paper history:
Received 29 November 2020
Accepted in revised form 09 Febraury 2021

Keywords:
Cadmium
Cancer risk
Hazard index
Soil sediments
Target hazard quotient

A B S T R A C T

The Bariga section of Lagos lagoon is famous in Lagos for fishing activities. However, the safety of edible fishes sold in the place has not been evaluated for a long time. This study determined the safety of *Clarias* gariepinus (African catfish), which is the most frequently patronized fish species in the area. Samples of the fish and soil sediments obtained during rainy and dry seasons were subjected to atomic absorption spectroscopy to determine the levels of cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), and manganese (Mn). Afterward, the daily intake (DI), target hazard quotient (THQ), hazard index (HI), and carcinogenic risks (CR) of the heavy metals were calculated. The results showed that the levels of Cd and Pb in the fish and soil sediments were above the world health organization (WHO) permissible limits, while Zn, Cu, and Mn were normal. The DI of the heavy metals, as well as the THQ and HI, were normal. However, the CR of Cd and Pb were above the recommended limits. The heads of the fishes contained the highest concentrations of the heavy metals, DI, THQ, HI, and CR. Among the heavy metals, Cd had the highest CR. There was no significant ($p > 0.05$) seasonal variation in the accumulations of the heavy metals in the soil sediments. Overall, the results showed that the fish may predispose consumers to health hazards. Consequently, there is a need for heavy metal pollution control in the lagoon, to safeguard the health of fish consumers.

doi*: 10.5829/ijee.2021.12.01.08*

INTRODUCTION

Heavy metal pollution of the aquatic ecosystem is increasingly linked to health and environmental hazards due to increasing applications of the metals in societies. Heavy metals are loosely described as toxic metals with a specific density of 5 g/cm^3 and above [1]. Among heavy metals, lead (Pb), chromium (Cr), nickel (Ni), zinc (Zn), cadmium (Cd), cobalt (Co), titanium (Ti), and iron (Fe) cause more damage to aquatic organisms due to their high bioaccumulative property in water [2]. Heavy metals in an aquatic ecosystem can build up in the food chain and predispose humans to various diseases. Heavy metals can also compromise the nutritional quality of fish, particularly its healthy protein, fats, and cholesterol [2-4]. However, at minute quantities, some of these heavy metals functionally maintain biochemical and physiological processes in living organisms. Sources of heavy metals in aquatic ecosystems are mining operations as well as waste discharges from homes, industries, and farms [5].

In aquatic habitats, fish are more affected by pollution than any organism. This is because fish occupy the top trophic level and so can accumulate enormous quantities of pollutants in their bodies. Thus, most of the times, fish are the causes of health hazards in aquatic habitats and so fish are often used to assess the health status of aquatic environments [6, 7]. Bioaccumulation of heavy metals in fish depends on several factors such as age, size, feeding habits, and body physiology. Other factors include the

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Please cite this article as: T. O. Yahaya, E. O. Oladele, O. R. Abiola, O. Ologe, A. Abdulazeez, 2021. Carcinogenic and Non-carcinogenic Risks of Heavy Metals in *Clarias gariepinus* (African Catfish) Obtained from Bariga Section of Lagos Lagoon, Nigeria, *Iranian (Iranica) Journal of Energy and Environment,* 12(1), pp.61-67. Doi: 10.5829/ijee.2021.12.01.08

level and bioavailability of metals, physicochemical properties of water, among others. The accumulation of heavy metals in various tissues of fish depends on the structure and function of the tissues [5]. Generally, metabolically active tissues such as gills, liver, and kidneys accumulate more heavy metals than other tissues such as skin and muscles [5]. All these put together show that fish are sensitive to xenobiotics and that evaluation of heavy metal levels in fishes is important for the health of humans and aquatic environments.

Lagos lagoon in Nigeria contains several species of fish which were classified into three main ecological groups, namely the marine fishes, freshwater fishes, and euryhaline fishes [8]. The marine fishes use the lagoon for breeding and comprise thirty-one species, while the freshwater fishes dominate the lagoon during the low salinity periods and consist of seventeen species. The euryhaline fishes include twenty-four species and are found in the lagoon all-year-round. These fishes are consumed by the inhabitants and also provide income to fishermen. Unfortunately, studies conducted by Oguguah et al. [9] showed that, over the years, the Lagos lagoon has been contaminated by industrial and domestic pollutants. These pollutants might have caused serious health hazards in the fish and other aquatic organisms in the lagoon, which may pose public health hazards through the consumption of such fishes. Hence, there is a need for periodic evaluation of heavy metals in edible fish species inhabiting the Lagos lagoon. From literature, there is a dearth of such studies on the fishes inhabiting the Bariga section of the lagoon, wherein intense fishing activities and sales take place daily. Among several fish species, African catfish (*Clarias gariepinus*) is the most frequently consumed and sold fish in the area, possibly due to its taste and fleshy body. Therefore, this study evaluated the carcinogenic and non-carcinogenic risks of heavy metals in *Clarias gariepinus* inhabiting the Bariga section of Lagos lagoon.

MATERIAL AND METHODS

Description of the study site

This study was carried out at the Bariga section of Lagos lagoon in Lagos, Southwest Nigeria. Lagos is the capital of Lagos State, on latitude 6°37′N and 6°70′N and longitude 2°70′E and 4°35′E. The state is bordered by the Republic of Benin on the west, Ogun State on the east and north, and the Atlantic Ocean on the south [10]. The city is one of the fastest-growing urban settlements in the world and is the economic hub of Africa. Lagos is the most industrialized city in Nigeria, which, coupled with its high population density, is responsible for high waste generation and environmental pollution in the city. The vegetation of the state is mainly tropic with several water bodies including the lagoon, rivers, and creeks. The climate of the state consists of a long rainy season and a short dry season.

The Lagos lagoon is a continuation of lagoons and creeks that stretches for about 257 km from Cotonou in the Republic of Benin to Niger-Delta in Nigeria. The lagoon borders the forest belt and receives water from numerous big rivers [11]. It also receives wastes from homes, industries, and farms as well as automobile exhausts and leftovers of other anthropogenic activities. It empties into the Atlantic Ocean at Lagos and Cotonou. The Bariga section of Lagos lagoon (the study site) has GPS coordinates of 6° 31′29"E and 3° 23′58"N in Shomolu Local Government Area. It is a highly commercialized environment known for its fishing activities and sales. The residents of Bariga and many other places in Lagos and environs patronize the site for fish for consumption and sales. This necessitates periodic monitoring of heavy metals in the fish, to prevent or reduce unintended health hazards.

Sample collection and preparation

Sixty (60) samples of adult *Clarias gariepinus* with a mean weight of 163.17±3.01 g and a mean length of 27.56±2.01 cm were purchased from Bariga section of Lagos lagoon between January and June 2020 (spanning dry and rainy seasons). The fish were transported to the laboratory in a well-ventilated container, containing the same water obtained from the site where the fishes were caught.

During the period mentioned above, sixty soil samples were also obtained randomly within the top 30 cm of the lagoon sediments into clean and pre-sterilized polyethylene bags. The samples were air-dried at room temperature (28 °C) for 8 days, and later oven-dried until constant weights were attained. The samples were then ground with a mortar and pestle, sieved with a 2-mm mesh sieve, and homogenized [12]. The products obtained were stored in a desiccator before further analyses.

Heavy metal analysis

The levels of Pb, Cd, Zn, Mn, and Cu in the fish and soil sediments were determined using atomic absorption spectroscopy (AAS) as described by Yahaya et al. [13]. The samples were digested by adding 10 ml of HNO_3 to 1 g of each fish and soil sample and the mixture was heated on a heat block. The heating was done gradually, starting from 100 °C to between 250 and 300 °C. The digestion was completed in about 72-83 minutes, indicated by the appearance of white fumes. The mixture was left to cool and then transferred to 50 ml volumetric flasks and distilled water was added to increase the mixture to the 50 ml mark. The solution was transferred to plastic bottles, labeled accurately, and subjected to atomic absorption spectroscopy using a spectrophotometer (UNIAM model 969).

Quality assurance and control
The glassware and plastic materials used for the heavy metal analysis were washed with a detergent solution and rinsed with deionized water. About 10% HNO_3 was then poured into the materials to sterilize them, after which they were rinsed with deionized water again.

Background contamination of the fish and soil samples was checked to ensure the accuracy of the data. Blank samples were analyzed after five samples and all analyses were replicated three times. The reproducibility of the values was found to be at the 95% confidence level. Therefore, the mean value of each heavy metal was used for further analysis. All the chemicals used for the analysis were of high analytical grade.

Health risk assessment
The carcinogenic and non-carcinogenic risks of the heavy metals in the fish samples were used to assess the health risks of daily consumption of the fish. The non-carcinogenic risks were calculated from the daily intake (DI), target hazard quotient (THQ), and hazard index (HI) of the heavy metals as given in equations 1, 2, and 3, respectively [14, 15]. The carcinogenic risks (CR) were calculated using Equation 4 [16].

$$DI=\frac{EF \times ED \times FIR \times CF \times C}{ABW \times AT} \quad (1)$$

$$THQ=\frac{EF \times ED \times FIR \times CF \times C}{ABW \times AT \times RFD} \times 10^{-3} \quad (2)$$

$$HI=\sum THQ \text{ of all heavy metals} \quad (3)$$

In equations 1, 2, and 3, according to Miri [17], ED (exposure duration) is 54.5 years, which is equivalent to the average life span of Nigerians. EF (exposure frequency) is 365 days/year. CF (conversion factor) is 0.208, to convert the dry weight of fish to wet. ABW (average body weight) is 60.7 kg, which is equivalent to the average body weight of adult Nigerians. FIR (fish ingestion rate) is 0.02 g/day. C (concentration) is the concentrations of the heavy metals in the fish tissues. AT (average time) is 365 x ED. RFD (reference dose) of the heavy metals in fish are 0.0035 for Pb, 0.04 for Cd, 0.07 for Cu, 0.14 for Mn, and 0.3 for Zn [17]. THQ and HI values below 1 were considered normal [17].

$$CR = CSF \times DI \quad (4)$$

CSF is the cancer slope factor, which is 0.38 and 0.0085 for Cd and Pb, respectively [16]. CR values greater than 10^{-6} were considered abnormal [18].

Data analysis
The data obtained from the fish and soil samples were subjected to mean and standard deviation (SD). The Student's *t*-test was used to compare the differences between the heavy metals accumulated in the soil sediments in the rainy and dry seasons. The histogram was drawn using the Minitab software version 7.0.

RESULTS AND DISCUSSION

Levels of heavy metals in the fish samples
Lead and Cd were detected in the heads, trunks, and tails of the fish above the world health organization (WHO) permissible limits, while Zn, Cu, and Mn were normal (Table 1). Despite being normal, Zn had the highest concentrations in the fish bodies (2.30±0.020 mg/kg), while Cu had the lowest (0.37±0.500 mg/kg). The head had the highest concentrations of the evaluated heavy metals, followed by trunk and tail. A similar study conducted by Oguguah et al. [9] also detected abnormal concentrations of Cd, Pb, and Mn in fishes obtained from a certain section of Lagos lagoon. Olowu et al. [18]also detected permissible levels of Zn in Epe and Badagary sections of the Lagos lagoon. Contrarily, Abdul et al. [19] did not detect Pb and some other heavy metals in fish samples obtained from Lekki section of Lagos lagoon. Cadmium was not also detected in the fish samples obtained from Oworonshoki section of the Lagos lagoon [20]. Furthermore, Akintade [21] detected permissible levels of Zn, Pb, Cu, Mn, and Cd in fishes obtained from Ologe and Lagos Island sections of Lagos lagoon. Overall, these variations showed that heavy metals are differently distributed along the Lagos lagoon, which could have been influenced by varying anthropogenic activities along the lagoon. In a study by Uaboi-Egbenni et al.[22], a wide variation was observed in the distribution and occurrence of heavy metals at three sampling points along Lagos lagoon. The high concentration of Zn compared to other heavy metals in this study was also observed in Lagos lagoon by Kumolu-Johnson et al. [23] and Olowu et al. [18]. This could be due to the natural abundance of Zn in Nigerian environments, of which the aquatic environment is a major depository [18]. In a study by Ogundele et al. [24], the concentrations of Zn in tested soil samples ranged from 30.8-219.23 mg/kg. Abnormal concentrations of Pb and Cd detected in this study could have resulted from domestic and industrial sewage and acid batteries [5]. It could have also emanated from fertilizers used on the farms around the lagoon as well as oil leaks from ferries and boats. The high concentrations of the heavy metals in the head of the fish compared to the trunk and tail were also reported by Olowu et al. [18] and Olubunmi et al.[26]. Fish heads contain gills, a biologically active organ that requires constant water, which may be laden with heavy metals, hence increased concentrations of heavy metals in the head [5]. Additionally, water, which could be laden with heavy metals, is often egested through the mouth and gills [18].

The detection of the heavy metals in the fish samples suggests that Clarias gariepinus inhabiting the Bariga section of Lagos lagoon may predispose consumers to health risks. Cadmium and Pb, which were detected above the permissible limits, are particularly worrisome. Furthermore, the heads, which contained the highest concentrations of the heavy metals, were at an increased risk for heavy metal toxicities. Cadmium has been implicated in the kidney, respiratory and skeletal diseases [27]. Lead exposure may cause kidney and brain problems, as well as anemia, weakness, infertility, pregnancy loss, stillbirths, and fetal developmental errors [28]. Though Zn, Cu, and Mn were detected within the permissible limits, in strict terms, there are no safe levels for heavy metals. Prolonged exposure to high concentrations of Zn, in particular, may induce apoptosis, especially in the brain [29].

Non-carcinogenic risks of the heavy metals

The DI of Cd, Pb, Zn, Mn, and Cu through the consumption of the fish was within the recommended dietary daily intakes (RDI) (Table 2). Zinc was the most ingested, while Cu was the least ingested. The highest ingestion of Cd was from the trunk, while the highest ingestion of Pb, Zn and Cu were from the head. The ingestion of Cu was jointly highest in the head and trunk. Collectively, these showed that the DI of the heavy metals by the consumers came mostly from the head. The THQ and HI of the heavy metals were less than 1, the upper limit within which a substance could be considered safe for consumption. In the head, Cu had the highest THQ, while in the trunk and tail, Zn had the highest, indicating that Zn had the highest THQ of all the heavy metals and thus posed more non-carcinogenic risks. The HI of the heavy metals was the highest in the head, followed by trunk and tail, suggesting that the heads posed more non-carcinogenic risks.

The normality of the DI, THQ, and HI of the heavy metals suggest that the fish may not pose any serious non-carcinogenic risk. However, since the estimation was based on the average life span of Nigerians, people that live above this age may be at an increased risk. Furthermore, the heavy metals that were not investigated in this study may add to the non-carcinogenic risks and become significant. The results of the current study agree with Oguguah et al. [9], Bawa-Allah et al. [30] and Bassey and Chukwu [31], all of them who reported no non-carcinogenic health risk of heavy metals in fishes collected from different sections of the Lagoon. From the literature survey, no study reported dissenting findings.

Carcinogenic risks of the heavy metals

The CR of Cd in the head, trunk, and tail, as well as Pb in the head and trunk of the fishes, was greater than the permissible limit of 10^{-6} (Table 4). Zinc, Mn and Cu have no cancer slope factor (CSF) and thus have no CR (Table 4). In other words, Zn, Mn, and Cu are non-carcinogenic. On average, the CR of the heavy metals is the highest in the head, followed by the trunk and tail. These imply that the head of the fish posed more cancer risk than the trunk and tail, respectively. Moreover, Cd posed the highest cancer risk, followed by Pb. Both Cd and Pb may induce cancers through several mechanisms. Cadmium may mimic important micronutrients at some binding sites that regulate gene expression and enzyme activity [34]. Cadmium may also damage the DNA by generating free radicals, inducing oxidative stress [35]. Additionally, Cd may induce cell proliferation as well as inhibit apoptosis and DNA repair[36]. Regarding Pb, it can replace Zn in many proteins that modulate transcription. It may also produce free radicals and damage the DNA through

Table 1. Levels of heavy metals detected in the *Clarias gariepinus* (n = 60) obtained from Bariga section of Lagos lagoon

Fish part	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Head	0.92 ±0.006	1.16 ±0.01	2.30 ±0.02	0.84 ±0.015	0.77 ±0.058
Trunk	1.11 ±0.015	0.56 ±0.012	1.92 ±0.015	0.50 ±0.015	0.65 ±0.065
Tail	0.67 ±0.01	0.49 ±0.015	1.51 ±0.007	0.069 ±0.01	0.37 ±0.5
WHO Limit [25]	0.01	0.01	5	9	2.25

Note: Values were expressed as mean ± SD; WHO = World Health Organization.

Table 2. Daily intake (DI) of heavy metals through the consumption of Clarias gariepinus (n = 60) obtained from Bariga section of Lagos lagoon

Fish part	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Head	0.0003	0.0004	0.0007	0.0003	0.0002
Trunk	0.0004	0.00017	0.0006	0.0002	0.0002
Tail	0.0002	0.00015	0.0005	0.0002	0.0001
RDI [32,33]	0.06	0.21	15	5	0.9

Note: RDI = recommended dietary daily intake

Table 3. Target hazard quotient (THQ) and Hazard index (HI) of heavy metals in Clarias gariepinus (n = 60) obtained from Bariga section of Lagos lagoon

Heavy metal	Head	Trunk	Tail
Cd	0.0009	0.0012	0.0006
Pb	0.0003	0.0002	0.0001
Zn	0.0024	0.0020	0.0016
Mn	0.0001	0.00	0.00
Cu	0.0061	0.0002	0.00
HI	0.0098	0.0036	0.0023

Table 4. Carcinogenic risks of heavy metals in *Clarias gariepinus* (n = 60) obtained from Bariga section of Lagos lagoon

Fish part	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Head	1×10^{-4}	3×10^{-4}	-	-	-
Trunk	2×10^{-4}	1×10^{-5}	-	-	-
Tail	8×10^{-4}	0.00	-	-	-

oxidative stress. In addition, Pb may inhibit DNA synthesis or repair [37]. The findings of the current study are similar to Bassey and Chukwu [31] who reported the carcinogenic risk of Pb in some fishes obtained from the Lagos lagoon. Unfortunately, there is a dearth of literature on the carcinogenicity of heavy metals in fishes inhabiting the lagoon to further compare the results of the present study.

Seasonal variations in the levels of heavy metals in the soil sediments

Figure 1 shows the seasonal variations in the levels of Cd, Pb, Zn, Mn, and Cu in the soil sediments of the Bariga section of Lagos lagoon. Except Pb, the levels of the heavy metals were higher during the rainy season than the dry season ($p > 0.05$). The levels of Pb and Cd in the soil sediments were above the WHO permissible limits, while Zn, Cu, and Mn were normal. These findings are consistent with the results obtained by Okoye et al. [38] who detected higher levels of some heavy metals during the rainy season than the dry season in a certain section of Lagos lagoon. The mentioned findings are also in line with Adeyemo et al. [39] who reported higher concentrations of heavy metals during the rainy season than the dry season in the soil sediments of the Lekki-Epe section of the Lagos lagoon. Moreover, Bassey et al. [40] reported abnormal concentrations of Cd, Pb, and Zn in Ologe and Badagary sections of the Lagos lagoon. However, the findings of the current study contradict Akinjogunla and Lawal-Are [41] who reported higher

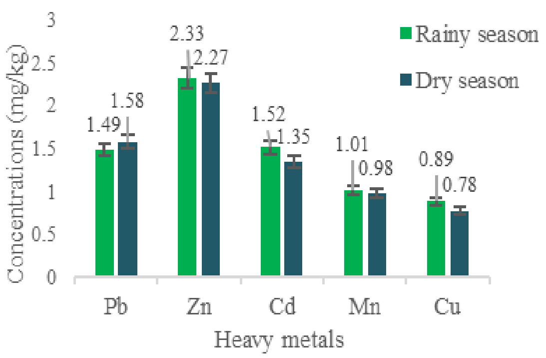

Figure 1. Seasonal variations in the levels of heavy metals in the Bariga section of Lagos lagoon

concentrations of heavy metals during the dry season than the rainy season in the soil sediments of Ebute-Oko, Tomaro, and Agala sections of the Lagos lagoon. The higher concentrations of heavy metals in the soil sediments during the rainy season could be due to increased urban runoff. It could also be attributed to the influx of freshwater during the rainy seasons.

CONCLUSION

The results established that the fishes bioaccumulated non-permissible concentrations of Cd and Pb as well as permissible levels of Zn, Cu, and Mn. Thus, the fishes may pose some health threats to consumers, particularly Cd and Pb toxicity-related diseases. However, the DI, THQ, and HI of these metals were within the permissible limits, suggesting that daily consumption of the fishes may not pose any serious non-carcinogenic health hazards. The heads of the fishes had the highest concentrations of heavy metals as well as the highest DI, THQ, and HI, which indicate that the head may pose more health risk than the trunk and tail, respectively. The CR of Pb and Cd in the fishes were above the allowable limits, indicating that daily consumption of the fishes may predispose consumers to cancers. Among the heavy metals, Cd had the highest CR, thus it may pose the highest cancer risk. Also, the heads of the fishes had the highest CR, which suggests that it poses more cancer risk than trunk and tail, respectively. Collectively, these findings call for close monitoring of heavy metals in *Clarias gariepinus* inhabiting the Bariga section of Lagos lagoon, to safeguard the health of consumers. While we call for more studies to ascertain our claims, agencies in charge of the environment and public health in Lagos State are advised to work towards reducing pollution of Lagos lagoon.

REFERENCES

1. Yahaya, T. O., Oladele, E. O., Fatodu, I. A., Abdulazeez, A. and Yeldu, Y. I. 2020. 'The concentration and health risk assessment of heavy metals and microorganisms in the groundwater of Lagos, Southwest Nigeria', *Journal of Advances in Environmental Health Research*, 8(3), pp. 234-242. https://doi.org/10.22102/jaehr.2020.245629.1183
2. Fatima, M., Usmani, N. and Hossain, M. M. 2014. 'Heavy metal in aquatic ecosystem emphasizing its effect on tissue bioaccumulation and histopathology: A review', *Journal of Environmental Science and Technology*, 7(1), pp. 1. https://doi.org/10.3923/jest.2014.1.15
3. Mansouri, B., Ebrahimpour, M. and Babaei, H. 2012. 'Bioaccumulation and elimination of nickel in the organs of black fish (Capoeta fusca)', *Toxicology and Industrial Health*, 28(4), pp. 361-368. https://doi.org/10.1177/0748233711412425
4. Yahaya, T., Anyebe, D., Adebayo, A., Adebisi, M. and Muhammad, S. 2019. 'Characterization and Toxicological Evaluation of Labana Rice Mill Wastewater in Kebbi State Nigeria', *Uniport Journal of Engineering and Scientific Research*

(UJESR), 4(1), pp. 34-42. http://www.ujesr.org/images/vol4/4.-Yahaya-TO-Anyebe-DA-Adebayo-AO-Adebisi-MA-and-Muhammad-SS-2019.pdf

5. Ali, H., Khan, E. and Ilahi, I. 2019. 'Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation', *Journal of Chemistry*, 2019. https://doi.org/10.1155/2019/6730305

6. Farkas, A., Salanki, J. and Specziar, A. 2002. 'Relation between growth and the heavy metal concentration in organs of bream Abramis brama L. populating Lake Balaton', *Archives of Environmental Contamination and Toxicology*, 43(2), pp. 236-243. https://doi.org/10.1007/s00244-002-1123-5

7. Mansour, S. and Sidky, M. 2002. 'Ecotoxicological studies. 3. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt', *Food Chemistry*, 78(1), pp. 15-22. https://doi.org/10.1016/S0308-8146(01)00197-2

8. Fagade, S., SO, F. and CIO, O. 1974. 'Seasonal distribution of the fish fauna of the Lagos lagoon', *Bulletin de I'L FANT Series A* 36, pp. 244-252. https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCAL7536004468

9. Oguguah, N. M., Onyekachi, M. and Ikegwu, J. 2017. 'Concentration and human health implications of trace metals in fish of economic importance in Lagos Lagoon, Nigeria', *Journal of Health and Pollution*, 7(13), pp. 66-72. https://doi.org/10.5696/2156-9614-7-13.66

10. Yahaya, T., Ogundipe, O., Abdulazeez, A., Usman, B. and Danjuma, J. 2019. 'Bioaccumulation and health risk assessment of heavy metals in three vegetables consumed in Lagos, south-west Nigeria', *Tropical Journal of Natural Product Research*, 3(11), pp. 332-338. https://doi.org/10.26538/tjnpr/v4i1.3

11. Ajao, E. 1996. 'Review of the state of pollution of the Lagos lagoon', *Technical Paper of the Nigerian Institute of Oceanography and Marine Research*, (106), pp. 20. Available at https://www.oceandocs.org/bitstream/handle/1834/2213/NIOMR%20TP-106-1.pdf?sequence=1&isAllowed=y (Accessed November 5, 2020).

12. Yahaya, T. O., Oladele, E. O., Chibs, B., Abdulazeez, A., Nnochiri, K., Stephen, A. O., Ahmed, H. and Daniel, A. 2020. 'Level and Health Risk Evaluation of Heavy Metals and Microorganisms in Urban Soils of Lagos, Southwest Nigeria', *Algerian Journal of Bioesceinces*, 1(2), pp. 51-60. https://doi.org/10.5281/zenodo.4394091

13. Yahaya, T., Doherty, V., Akinola, O. and Shamsudeen, A. 2019. 'Heavy metal profiles and microbial counts of selected sachet water brands in Birnin Kebbi Metropolis, Nigeria', *Ife Journal of Science*, 21(1), pp. 229-234. https://doi.org/10.4314/ijs.v21i1.20

14. Giri, S. and Singh, A. K. 2015. 'Human health risk and ecological risk assessment of metals in fishes, shrimps and sediment from a tropical river', *International Journal of Environmental Science and Technology*, 12(7), pp. 2349-2362. https://doi.org/10.1007/s13762-014-0600-5

15. Miri, M., Akbari, E., Amrane, A., Jafari, S. J., Eslami, H., Hoseinzadeh, E., Zarrabi, M., Salimi, J., Sayyad-Arbabi, M. and Taghavi, M. 2017. 'Health risk assessment of heavy metal intake due to fish consumption in the Sistan region, Iran', *Environmental Monitoring and Assessment*, 189(11), pp. 1-10. https://doi.org/10.1007/s10661-017-6286-7

16. *U.S. EPA. Exposure Factors Handbook*. 2011. 2011 (Final Report) EPA/600/R-09/052F edn. Washington, DC: U.S. Environmental Protection Agency. Available at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252

17. Tepanosyan, G., Maghakyan, N., Sahakyan, L. and Saghatelyan, A. 2017. 'Heavy metals pollution levels and children health risk assessment of Yerevan kindergartens soils', *Ecotoxicology and Environmental Safety*, 142, pp. 257-265. https://doi.org/10.1016/j.ecoenv.2017.04.013

18. Olowu, R., Ayejuyo, O., Adewuyi, G., Adejoro, I., Denloye, A., Babatunde, A. and Ogundajo, A. 2010. 'Determination of heavy metals in fish tissues, water and sediment from Epe and Badagry Lagoons, Lagos, Nigeria', *Journal of Chemistry*, 7(1), pp. 215-221. https://doi.org/10.1155/2010/676434

19. Abdul, W., Oguntuase, K., Omoniyi, I., Bada, S., Adekoya, E., Bashir, A., Ibebuike, L. and Opajobi, G. 2019. 'Dynamics of heavy metal pollution in tropical lagoon of Gulf of Guinea, West Africa', *Journal of Applied Sciences and Environmental Management*, 23(5), pp. 985-993. https://doi.org/10.4314/jasem.v23i5.32

20. Williams, A. B. and Edobor-Osoh, A. 2013. 'Assessment of trace metal levels in fish species of Lagos Lagoon', *Vitamins & Trace Elements*, 2(1), pp. 1-5. https://doi.org/10.4172/2167-0390.1000109

21. Adeboyejo O, A. 2020. 'Heavy-Metals as Environmental Health Indicator of the Lagos Lagoon Complex, Nigeria', *Journal of Marine Science Research and Oceanography*, 3(1), pp. 13-19. https://doi.org/10.33140/JMSRO.03.01.02

22. Uaboi-Egbenni, P., Okolie, P., Martins, O. and Teniola, O. 2010. 'Studies on the occurrence and distribution of heavy metals in sediments in Lagos Lagoon and their effects on benthic microbial population', *African Journal of Environmental Science and Technology*, 4(6), pp. 343-351. https://doi.org/10.5897/AJEST09.139

23. Kumolu-Johnson, C., Ndimele, P., Akintola, S. and Jibuike, C. 2010. 'Copper, zinc and iron concentrations in water, sediment and Cynothrissa mento (Regan 1917) from Ologe Lagoon, Lagos, Nigeria: a preliminary survey', *African Journal of Aquatic Science*, 35(1), pp. 87-94. https://doi.org/10.2989/16085914.2010.466588

24. Ogundele, D., Adio, A. and Oludele, O. 2015. 'Heavy metal concentrations in plants and soil along heavy traffic roads in North Central Nigeria', *Journal of Environmental and Analytical Toxicology*, 5(6), pp. 1. https://doi.org/10.4172/2161-0525.1000334

25. WHO 2011), *'Joint FAO/WHO Food Standards Programme CODEX Committee on Contaminants in Foods', Fifth Session Hague, Netherlands*. Available at: http://www.fao.org/tempref/codex/Meetings/CCCF/CCCF5/cf05_INF.pdf.

26. Olubunmi, O. M., Adewale, O. R., John, A. M., Odunayo, I. S, Jimoh, A. A., Olawunmi, O. C. and Jesuyon, E. 2019. 'Bioaccumulation of Heavy Metals in Parts of the Silver Catfish (*Chrysichthys nigrodigitatus*) Harvested from Badagry Creek and Fish Ponds in Badagry, Lagos, Nigeria', *American Journal of Chemistry*, 9(3), pp. 95-102. https://doi.org/10.5923/j.chemistry.20190903.02

27. Organization, W. H. 2020. *International Programme on Chemical Safety: Cadmium*. Available at: https://www.who.int/ipcs/assessment/public_health/cadmium/en/ (Accessed: November 25th 2020 2020).

28. Wani, A., Ara, A. and Usmani, J. 2015. 'Lead toxicity: a review. ', *Interdisciplinary Toxicology*, 8(2), pp. 55–64. https://doi.org/10.1515/intox-2015-0009

29. Plum, L. M., Rink, L., Haase, H. (2010. 'The essential toxin: impact of zinc on human health', 7(4), pp. 1342-1365. https://doi.org/10.3390/ijerph7041342

30. Bawa-Allah, K., Saliu, J. and Otitoloju, A. 2018. 'Assessment of public health risk associated with consumption of dominant edible animal species of the Lagos Lagoon, Nigeria', *Ife Journal of Science*, 20(2), pp. 355-362. https://doi.org/10.4314/ijs.v20i2.16

31. Bassey, O., Chukwu, L. and Alimba, G. 2019. 'Cytogenetics of Chrysichthys nigrodigitatus as Bioindicator of Environmental Pollution from Two Polluted Lagoons, South-Western Nigeria', *Journal of Genetics and Genome Research*, 6, pp. 047. https://doi.org/10.23937/2572-4061.1510027

32. Rubio, C., Gutiérrez, Á. J., Revert, C., Reguera, J. I., Burgos, A. and Hardisson, A. 2009. 'Daily dietary intake of iron, copper, zinc

and manganese in a Spanish population', *International journal of food sciences and nutrition*, 60(7), pp. 590-600. https://doi.org/10.3109/09637480802039822

33. Ullah, A. A., Maksud, M., Khan, S., Lutfa, L. and Quraishi, S. B. 2017. 'Dietary intake of heavy metals from eight highly consumed species of cultured fish and possible human health risk implications in Bangladesh', *Toxicology Reports*, 4, pp. 574-579. https://doi.org/10.1016/j.toxrep.2017.10.002
34. Waalkes, M. P. 2003. 'Cadmium carcinogenesis', *Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis*, 533(1-2), pp. 107-120. https://doi.org/10.1016/j.mrfmmm.2003.07.011
35. Bertin, G. and Averbeck, D. 2006. 'Cadmium: cellular effects, modifications of biomolecules, modulation of DNA repair and genotoxic consequences (a review)', *Biochimie*, 88(11), pp. 1549-1559. https://doi.org/10.1016/j.biochi.2006.10.001
36. Luevano, J. and Damodaran, C. 2014. 'A review of molecular events of cadmium-induced carcinogenesis', *Journal of Environmental Pathology, Toxicology and Oncology*, 33(3). https://doi.org/10.1615/jenvironpatholtoxicoloncol.2014011075
37. Silbergeld, E. K., Waalkes, M. and Rice, J. M. 2000. 'Lead as a carcinogen: experimental evidence and mechanisms of action', *American Journal of Industrial Medicine*, 38(3), pp. 316-323. https://doi.org/10.1002/1097-0274(200009)38:3<316::aid-ajim11>3.0.co;2-p
38. Okoye, B. C., Afolabi, O. A. and Ajao, E. A. 1991. 'Heavy metals in the Lagos lagoon sediments', *International Journal of Environmental Studies*, 37(1-2), pp. 35-41. https://doi.org/10.1080/00207239108710615
39. Adeyemo, O. K., Ojo, S. O. and Badejo, A. A. 2010. 'Marine Shrimps and Fish as Sediments of Heavy Metal Pollution of Lagos Lagoon', *Global Journal of Environmental Research*, 4(3), pp. 155-160. https://www.idosi.org/gjer/gjer4(3)10/3.pdf
40. Bassey B. O., Alimba C. G. and Chukwu1, O. L. 2019. 'Current Metal Pollution Status and Ecological Risk Impacts on Ologe and Badagry Lagoons In Lagos, Nigeria', *Toxicology and Risk Assessment*, 5(023). https://doi.org/10.23937/2572-4061.1510023
41. Akinjogunla, V. F., Lawal, A. A. 2020. 'Seasonal Assessment of the Impacts of Heavy Metal Deposits in Crassostrea Gasar (Adanson, 1757) from the mangrove swamp of the Lagos Lagoon, Lagos, Nigeria', *Journal of Experimental Research*, 8(2), pp. 21-31. http://www.er-journal.com/papers/Akinjogunla_June_2020_8_2_21-31.pdf

Persian Abstract

چکیده

بخش باریگا در تالاب لاگوس به دلیل فعالیت‌های ماهیگیری در لاگوس معروف است. با این حال، مدت طولانی است که ایمنی ماهی‌های خوراکی فروخته شده در این مکان ارزیابی نشده است. این مطالعه ایمنی *Clarias gariepinus* (گربه ماهی آفریقایی) را که بیشترین گونه ماهی مورد حمایت در منطقه است، تعیین میکند. نمونه‌هایی از رسوبات ماهی و خاک به دست آمده در فصول بارانی و خشک تحت آزمایش طیف سنجی جذب اتمی قرار گرفته‌اند تا میزان کادمیوم (Cd)، سرب (Pb)، روی (Zn)، مس (Cu) و منگنز (Mn) تعیین گردد. پس از آن، میزان مصرف روزانه (DI)، ضریب خطر هدف (THQ)، شاخص خطر (HI) و خطرات سرطان‌زا (CR) فلزات سنگین محاسبه گردید. نتایج نشان داد که میزان Cd و سرب در رسوبات ماهی و خاک بالاتر از حد مجاز سازمان بهداشت جهانی (WHO) است، در حالی که روی، مس و منگنز طبیعی بود. DI فلزات سنگین و همچنین THQ و HI طبیعی بودند. با این حال، CR سی دی و سرب بیش از حد توصیه شده بود. سر ماهیان دارای بیشترین غلظت فلزات سنگین، DI، THQ، HI و CR بود. در میان فلزات سنگین، Cd بالاترین CR را داشت. از نظر تجمع فلزات سنگین در رسوبات خاک، تغییر فصلی و ($p>0.05$) وجود نداشت. به طور کلی، نتایج نشان داد که ماهی ممکن است مصرف‌کنندگان را در معرض خطرات سلامتی قرار دهد. در نتیجه، برای محافظت از سلامتی مصرف‌کنندگان ماهی، نیاز به کنترل آلودگی فلزات سنگین در تالاب وجود دارد