Journal of Environment Pollution and Human Health, 2023, Vol. 11, No. 1, 13-20
Available online at http://pubs.sciepub.com/jephh/11/1/3
Published by Science and Education Publishing
DOI:10.12691/jephh-11-1-3

Health Risks Assessment Associated with Two Fish Species (*Sarotherodon melanotheron, Chrysichthys nigrodigitatus)* Consumption, Contaminated with Trace Metals in Taabo Lake

SIDIBE Adama[1,*], Yapo Habib KPIDI[1], Yapoga Jean SEKA[2], Ossey Bernard YAPO[1,3]

[1]Laboratory of Environmental Sciences (LES), UFR of Environmental Sciences and Management, NANGUI ABROGOUA University, 02 Po Box 801 Abidjan 02 - Côte d'Ivoire
[2]Institute of Agropastoral Management, Peleforo Gon Coulibaly University of Korhogo, Po Box 1328 Korhogo, Côte d'Ivoire
[3]Laboratory of the Central Environment, Ivory Coast Anti-Pollution Center (LCE-CIAPOL), Côte d'Ivoire
*Corresponding author: sidibeadama568@gmail.com

Received February 02, 2023; Revised March 10, 2023; Accepted March 19, 2023

Abstract Objective: To assess the health risks associated with the consumption of the muscles of two fish species, *Sarotherodon melanotheron* (Rüppell, 1852) and *Chrysichthys nigrodigitatus* (Lacépède, 1803), contaminated by trace metals (TMEs) in Taabo Lake. For this purpose, the levels of four (4) TMEs, zinc (Zn), lead (Pb), cadmium (Cd) and mercury (Hg) were investigated, according to standard methods, in the muscles of 30 fish of each species caught in Taabo Lake. Once this basis was established, the assessment of the health risks associated with the consumption of the muscles of these fish contaminated by these trace elements in children and adults in the study locality was carried out. The results show that with hazard quotients greater than 1 for Cd, Hg and Pb exposure related to the consumption of the muscles of two fish species studied, the probability of a carcinogenic effect is high in children and adults in the study area. Also, for RC values greater than 10^{-4} for Cd, Hg and Pb exposures in children and adults, a carcinogenic risk remains evident in these parts of the population in the study area.

Keywords: *Sarotherodon melanotheron, Chrysichthys nigrodigitatus, TME, hazard quotient, cancer risk*

Cite This Article: SIDIBE Adama, Yapo Habib KPIDI, Yapoga Jean SEKA, and Ossey Bernard YAPO, "Health Risks Assessment Associated with Two Fish Species (*Sarotherodon melanotheron, Chrysichthys nigrodigitatus)* Consumption, Contaminated with Trace Metals in Taabo Lake." *Journal of Environment Pollution and Human Health*, vol. 11, no. 1 (2023): 13-20. doi: 10.12691/jephh-11-1-3.

1. Introduction

In recent years, the consumption of fisheries resources, specifically fish, has been in the spotlight because they are exposed to certain toxic environmental contaminants such as trace metals (including cadmium, mercury, lead, etc.) which accumulate in their tissues and are transferred through the food chain to humans [1]. The problem of the transfer of metal contaminants from the environment to the food chain is a source of concern and a subject of much research [2].

Indeed, the development of major activities for human needs has transformed the various environmental compartments, particularly water bodies, into receptacles for anthropogenic (domestic, industrial, agricultural, etc.) and/or natural discharges loaded with toxic metallic elements (Pb, Cd, Hg, etc.) which are accumulated there. Previous studies on the bioaccumulation of trace metals in fish [3] as well as the degree of TME contamination in sediments [4,5] have highlighted the existence of metallic contamination of these different matrices and their probable transfer to humans who is the last link in the food chain. This trace element contamination of the food chain is a risk to human health. Indeed, long-term or chronic exposure to trace elements can pose serious health threats, such as permanent intellectual and developmental disabilities, behavioural disorders, cardiovascular and kidney diseases, liver disorders, irregular blood composition [6]. Several studies [6,7] have also shown that exposure to TMEs is involved in physical, muscle and neurological degenerative processes.

The contamination of the fisheries resource (crabs, fish, etc.) by trace metals as a result of discharges from anthropogenic activities in Côte d'Ivoire has been extensively documented [5,8,9,10,11]. However, very little attention has been paid to human health risk assessment in these numerous studies.

The objective of this study is to assess the health risks associated with the consumption of two species of food fish, *Sarotherodon melanotheron* (Rüppell, 1852) and *Chrysichthys nigrodigitatus* (Lacépède, 1803) contaminated with zinc (Zn), lead (Pb), cadmium (Cd) and mercury (Hg) in Taabo Lake.

2. Materials and Methods

2.1. Presentation of the Study Area

Taabo, 6°13´60"N et 5°7´60"W, located 187 Km from Abidjan and 90 Km from Yamoussoukro, is situated in the Agnéby-Tiassa region. This is the site of a hydroelectric scheme on the Bandama River. Taabo Lake covers an area of 69 km^2 at the normal impoundment coast. It has an elongated NW-SE shape with a single eastern diverticulum [12]. Taabo Lake catchment area is 64% cultivated and forested, 27% bare land and housing, 2% banana plantation and 7% watercourse. Figure 1 shows the occupation of the Taabo Lake catchment area by the above anthropogenic activities.

2.2. Biological Materials

Two fish species most commonly caught by fishermen in Taabo Lake and commonly consumed by the population were purchased at the landing stage of the lake. These are *Sarotherodon melanotheron* and *Chrysichthys nigrodigitatus*.

2.3. Methods

2.3.1. Sampling

Three seasonal sampling campaigns, from August 2018 to June 2019, of *S. melanotheron* and *C. nigrodigitatus* adult specimens of approximately identical sizes were carried out. A batch of about twenty-five (25) fish per species and per campaign was collected for this study. In all, 150 fish, including 75 per species, were collected, kept in a cooler at 4°C and transported to the laboratory for physicochemical analyses. Before analysis, all laboratory glassware was cleaned with detergent and tap water and rinsed thoroughly with double-distilled water before use.

2.3.2. Muscle Pretreatment

After fish dissection, the tissues or muscles were removed and dried at 60°C in a Memmert U50 oven for 48 hours until a constant weight was obtained. The ground and homogenised tissues were stored in hermetically sealed pillboxes. A 0.4 g test sample was placed in a Teflon tube with 5 mL of ultra pure nitric acid (HNO_3, 67%). This preparation was first kept at room temperature for 12 hours and then mineralised at 150°C for 2 hours. The resulting mineralization was filtered with 0.45 µm porosity Whatman filter paper. The filtrate was completed with a 2% nitric acid solution to reach a final 25 mL volum.

The method's effectiveness and equipment used's cleanliness were checked for each sample with a nitric acid solution (pure HNO_3). This blank underwent the same mineralisation and dilution steps [13].

2.3.3. Trace Metals Analysis

Varian Atomic Absorption Spectrometry (AAS) method has been used for zinc, lead, cadmium determination and the CV-AAS has been used for the mercury determination. These are simple, more sensitive, faster techniques with less interference and the most widely used for trace elements in biological tissue determination.

AAS principle is to vaporise the liquid sample and heat it with a flame or an oven. Radiation defined by a frequency specific to the element analysed is sent out, the radiation absorption by the atoms present is proportional to the concentration of the element considered. The results are expressed in $mg.kg^{-1}$ of the trace element according to the following equation:

$$C=(C1*V)/(m*F) \quad (1)$$

With:
C, final Sample concentration in $mg.kg^{-1}$;
C1, sample solution concentration in $mg.L^{-1}$;
m, sample mass in g and,
F, test solution dilution factor.

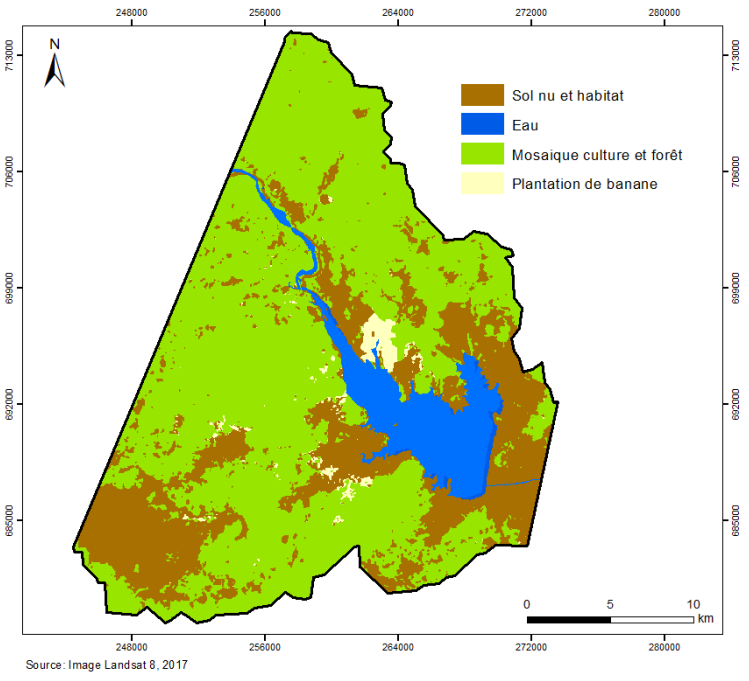

Figure 1. Land use in Taabo Lake catchment (Survey data, 2019)

2.3.4. Health Risk Assessment

Health risk assessment method adopted in this study is that developed by the US Environmental Protection Agency [14]. It can be defined as the probability of occurrence of an incident or adverse effects on human or other animal exposure to environmental hazards 6,15]. In other terms, it is a method that makes it possible to estimate, by calculation, the health risks to which a population is exposed to a particular pollution of anthropogenic or natural origin [16]. This method has four main steps according to [14]. These are:

- chemicals' hazards identification;
- toxicological reference values (TRVs) choice and dose-response relationship evaluation;
- population exposure estimation;
- risk characterisation.

2.3.4.1. Hazard Identification

This step makes it possible to select the substances to be taken into account in the quantitative health risk assessment and to identify the effects that may be derived from them.

In the context, only chronic effects, likely to appear following prolonged exposure to lower doses, were retained for the risk assessment [17]. The chemical elements taken into account are zinc, mercury, lead and cadmium for their non-carcinogenic and carcinogenic effects on human health.

2.3.4.2. Dose-response Assessment

Relationship assessment consists of defining a quantitative relationship between the ingested dose or the inhaled concentration and the incidence of the deleterious effect. This relationship is translated into the Toxicological Reference Value (TRV) or Reference Dose (RfD) which expresses the link between the dose of the toxic substance and the occurrence or severity of the effect studied in the population. In this study, the oral TRVs used are those published by "Environment and Risks National Institute" [18,19] for chronic threshold effects. These databases available in the literature are presented in Table 1.

Table 1. Threshold Toxicological Reference Values ($mg.kg^{-1}.d^{-1}$)

Chemical substances	Fish (ingestion)	Agency and year
Cd	2.10^{-4}	ATSDR, 1999
Hg	3.10^{-4}	ATSDR, 1999
Pb	$3{,}6.10^{-3}$	RIVM, 2001
Zn	0.5	RIVM, 2001

RIVM: Public Health and the Environment National Institut (Rijksinstituut voor volksgezondheid) (Netherlands);
ATSDR: Agency for Toxic Substances and Disease Registry (USA).

2.3.4.3. Estimating Exposures

This step consists of determining the pathways of the substance under study from the source to the human receptor, as well as estimating the frequency, duration and extent of exposure. This leads to the calculation of the Daily Exposure Dose (DDE), calculated as a function of the metal trace elements maximum concentration taken into account (C) and the body mass (P). Its analytical expression (mg/kg/d) is:

$$DDE\ \left(mg.kg^{-1}.d^{-1}\right) = \frac{Q*C*F}{P} \qquad (2)$$

With:
Q, fish consumption quantity: 0.043 $kg.d^{-1}$ [20];
C, maximal, not average trace element concentration in the fish;
F, exposure frequency, without unit (F = 1) and, P, body weight in kg;
P, average children body weight aged 0-15 years is 28 kg and that of an adult is conventionally 70 kg according to US-EPA [21].

2.3.4.4. Risk Characterisation

This step allows an estimation of the incidence and severity of adverse effects likely to occur in a human population due to exposure to all substances. The risk characterisation for threshold effects is expressed by the hazard quotient (HQ), also known as the Target Hazard Quotient (THQ). It is calculated for the oral route of exposure as follows:

$$HQ = \frac{DJE}{TRV} \qquad (3)$$

Where:
DJE: Daily exposure dose (mg/kg/d) ;
TRV: Toxicological Reference Value (mg/kg/d).
If HQ < 1, a toxic effect is unlikely to occur,
If HQ > 1, no toxic effect can be excluded.

This formula applies to each individual substance and does not provide information on the effect resulting from exposure to a mixture of substances.

2.3.5. Cancer Risk Assessment (CR)

Carcinogenic risk (CR) determines the developing cancer probability over a lifetime following exposure to a potentially carcinogenic contaminant [15,22]. This risk, CR, has been estimated for Cd, Hg and Pb classified as possibly carcinogenic to humans according to the International Agency for Research on Cancer report [23,24]. Its assessment, through oral exposure, has the expression:

$$CRor = DJE * FPCor \qquad (4)$$

With:
CRor, the oral cancer risk ;
FPCor, oral slope factor. FPC = 1 $(mg.\ kg^{-1}.day^{-1})^{-1}$.

The oral slope factors values for the different TMEs in this study are given in Table 2.

Table 2. slope factors Values for the trace elements considered

TMEs	FPC Oral $(mg.\ kg^{-1}.d^{-1})^{-1}$	Sources
Hg	1	[7,22,25]
Cd	0,38	
Pb	1,5	

According to the [26,27,28] guidelines for people both categories, children and adults, if:

- $CR < 10^{-6}$, cancer risk is negligible;
- $10^{-4} < CR < 10^{-6}$, cancer risk is acceptable and;
- $CR > 10^{-4}$, risk is not acceptable, hence obvious.

3. Results

3.1. Trace Elements Seasonal Distribution in Sarotherodon Melanotheron and Chrysichthys Nigrodigitatus Muscles

3.1.1. Cadmium

The seasonal median levels vary from 0.06 $mg.kg^{-1}$ to 3.205 $mg.kg^{-1}$ for an overall median of 1.26 $mg.kg^{-1}$ in *C. nigrodigitatus* muscles. Similarly, the seasonal median levels in the muscles of *S. melanotheron* range from 0.027 $mg.kg^{-1}$ to 2.11 $mg.kg^{-1}$ with a general median level of 1.95 $mg.kg^{-1}$. Considering the required limit value for human consumption without harmful effects (0.05 $mg.kg^{-1}$), 83.33% and 90% of the samples taken for *C. nigrodigitatus* and *S. melanotheron*, respectively, have levels that are lower.

3.1.2. Mercury

Seasonal median values from *C. nigrodigitatus* muscles range from 0.102 to 1.19 $mg.kg^{-1}$ with a general median of 0.159 $mg.kg^{-1}$. Similarly, *S. melanotheron* muscles show median levels ranging from 0.175 $mg.kg^{-1}$ to 1.461 $mg.kg^{-1}$ with an overall median of 0.207 $mg.kg^{-1}$.

Of all the samples taken, 73.33% and 73.33% for *C. nigrodigitatus* and *S. melanotheron*, respectively, have concentrations below the limit value (0.5 $mg.kg^{-1}$) for safe human consumption.

3.1.3. Lead

Median seasonal muscle values for *C. nigrodigitatus* range from 0.24 $mg.kg^{-1}$ to 87.09 $mg.kg^{-1}$ with a general median of 0.58 $mg.kg^{-1}$. For *S. melanotheron*, these values are 0.225, 117.94 and 0.272 $mg.kg^{-1}$ for the minimum, maximum and general seasonal medians respectively.

Thus, 23.33% and 36.67% of all samples taken have levels below the recommended limit value (0.2 mg/kg) for human consumption, respectively for *S. melanotheron* and *C. nigrodigitatus*.

3.1.4. Zinc

Muscles of *C. nigrodigitatus* have seasonal median concentrations ranging from 0.254 $mg.kg^{-1}$ to 21.465 $mg.kg^{-1}$ with an overall median of 4.105 $mg.kg^{-1}$. For *S. melanotheron*, these values are 0.254, 12.125 and 4.01 $mg.kg^{-1}$ for the seasonal minimum, maximum and overall medians respectively.

The evaluation of the quality of the samples taken in relation to the permissible limit value for human consumption reveals that 6.67% and 6.67% of *C. nigrodigitatus* and *S. melanotheron*, respectively, have levels below the standards (0.20 $mg.kg^{-1}$).

3.2. Health Risks Related to the Consumption of Fish Contaminated with Trace Elements

Exposure assessment results for Cd, Hg, Pb and Zn from consumption of *C. nigrodigitatus* and *S. melanotheron* flesh (muscle) and corresponding hazard quotients (HQ) for adults and children are presented.

3.2.1. Daily Exposure Dose (DJE)

Figure 2a and Figure 2b show the DJE in children and adults associated with the consumption of *S. melanotheron* and *C. nigrodigitatus* meat (muscle), respectively.

Results show that the daily exposure doses to TMEs in children and adults, at *S. melanotheron* level, are the highest for Pb (0.506 mg/kg/d for children and 0.202 mg/kg/d for adults). This is followed by Zn (0.260 mg/kg/d for children and 0.104 mg/kg/d for adults), etc. The same order of magnitude remains valid for *C. nigrodigitatus* species. However the exposure to TMEs in children is still higher than in adults for both *S. melanotheron* and *C. nigrodigitatus*. Exposure order for TMEs in adults and children is as follows:

$$DJE(Pb) > DJE(Zn) > DJE(Cd) > DJE(Hg).$$

3.2.2. Hazard Quotient (HQ)

Children and adult hazard quotients for *S. melanotheron* (3a) and *C. nigrodigitatus* (3b) are presented.

Table 3 shows the elemental statistics of TMEs analysed in the two fish species, *S. melanotheron* and *C. nigrodigitatus* muscles.

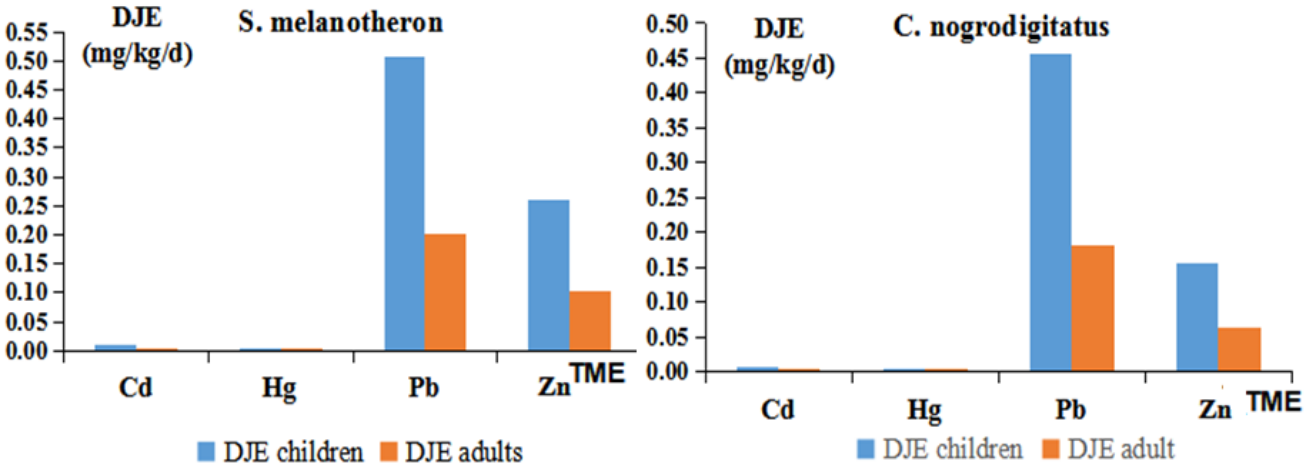

Figure 2. Daily exposure levels in children and adults from eating the flesh (muscle) of *S. melanotheron* and *C. nigrodigitatus*

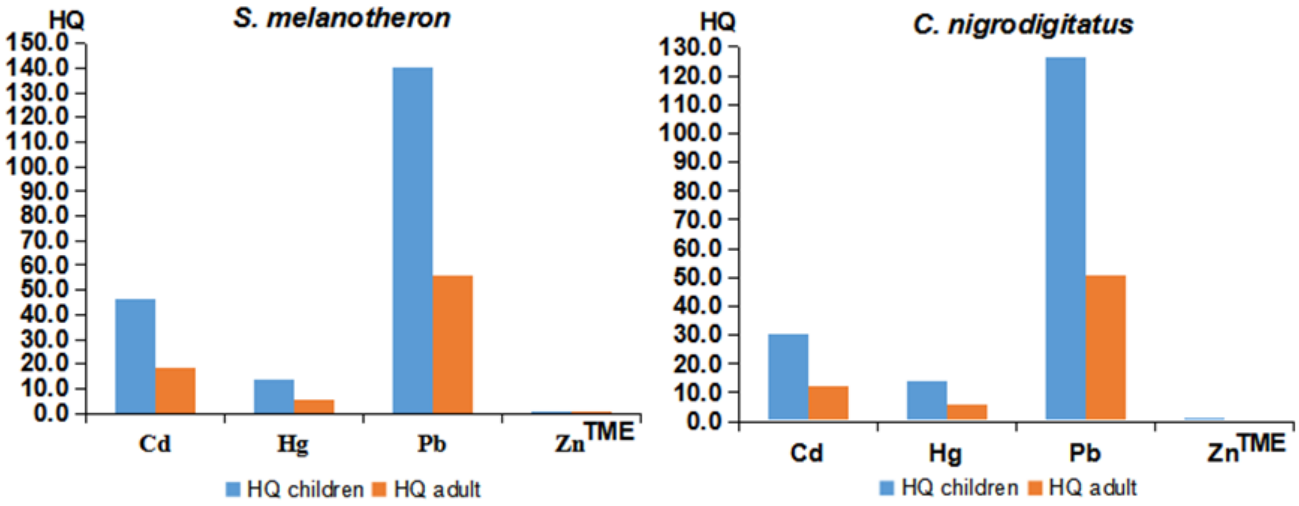

Figure 3. Children and adults Hazard Quotient of *S. melanotheron* and *C. nigrodigitatus*

Table 3. TME elemental statistics of Sarotherodon melanotheron and Chrysichthys nigrodigitatus muscles

		Cd (mg.kg^{-1})			Hg (mg.kg^{-1})			Pb (mg.kg^{-1})			Zn (mg.kg^{-1})		
	Seasons	Min	**Med**	Max	Min	**Med**	Max	Min	**Med**	Max	Min	**Med**	Max
C. nigro-digitatus	**S S**	0.05	**0.06**	0.07	0.825	**1.19**	2.741	0.28	**1.61**	4.22	3.83	**21.465**	102.256
	S P	2.45	**3.205**	3.96	< LD	< LD	< LD	8.6	**87.09**	297.1	0.71	**4.425**	11.92
	S C	< LD	**< LD**	< LD	0.056	**0.102**	0.177	0.226	**0.24**	0.263	0.239	**0.254**	0.303
	Générale	0.05	**1.26**	**3.96**	0.056	**0.159**	**2.741**	0.226	**0.58**	**297.10**	0.239	**4.105**	**102.256**
S. melano-theron	**S S**	0.04	**0.04**	0.04	0.182	**1.461**	2.667	0.25	**0.335**	2.65	2.720	**12.125**	83.490
	S P	1.81	**2.11**	6.07	< LD	**< LD**	< LD	4.01	**117.94**	329.20	0.350	**7.725**	169.570
	S C	0.005	**0.027**	0.049	0.102	**0.175**	0.227	0.205	**0.225**	0.29	0.249	**0.254**	0.275
	Générale	0.005	**1.95**	**6.07**	0.102	**0.207**	**2.667**	0.205	**0.272**	**329.20**	0.249	**4.010**	**169.57**

S S : dry season ; S P : rainy season ; S C : flood season; Min: minimum; Med : median; Max: maximum.

Children and adults hazard quotients for Pb (140.43 and 56.17, respectively), Cd (HQ = 46.61 for children and 18.64 for adults) and Hg (HQ = 13.65 (child) and 5.46 (adult)) are well above 1 for *S. melanotheron* species. Also, the HQs in children and adults for Pb, Cd and Hg remain well above 1 for *C. nigrodigitatus* species. However, the child and adult HQs for Zn (*S. melanotheron*, HQ = 0.87 (child); HQ = 0.35 (adult) and, *C. nigrodigitatus*, HQ = 0.52 (child); HQ = 0.21 (adult)) remain lower than 1.

3.3. Cancer Risks (CR) from Eating Two Fish Species Contaminated with Trace Elements

Figure 4 below shows the evolution of data on cancer risks in children and adults after consumption by *S. melanotheron* and *C. nigrodigitatus* populations caught in Taabo Lake and contaminated by trace metals including Cd, Hg and Pb.

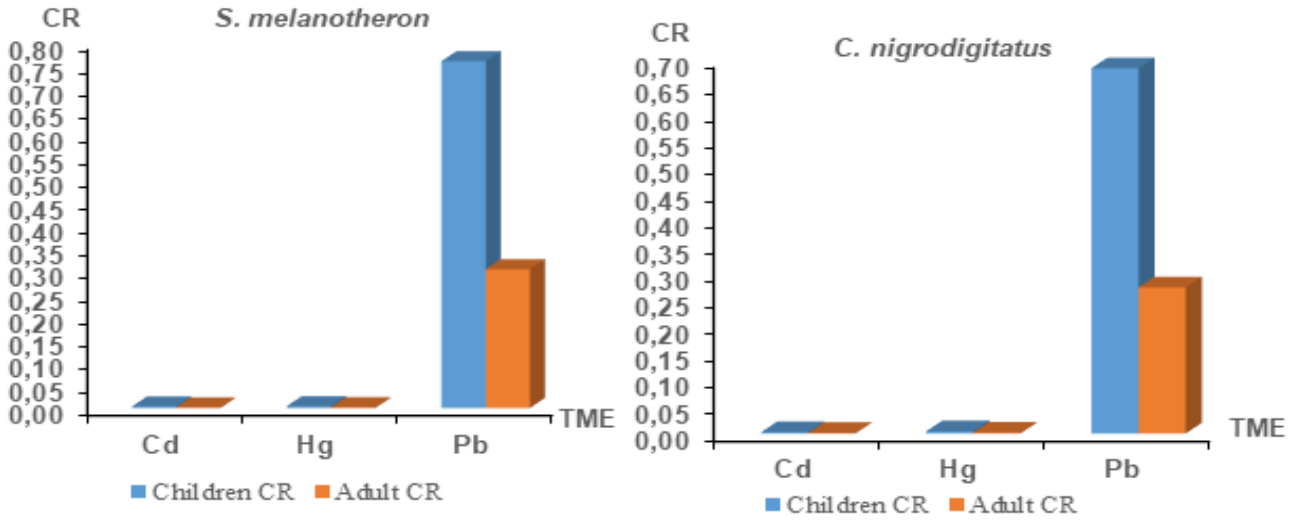

Figure 4. Cancer risk in children and adults after consumption of *S. melanotheron* and *C. nigrodigitatus* muscles caught in Taabo Lake

In *S. melanotheron* muscles, the determined CR values are 4.10^{-3}, 4.10^{-3} and 758.10^{-3} respectively for Cd, Hg and Pb exposure in children. In adults, 10^{-3}, 2.10^{-3} and 303.10^{-3} are the CR values recorded for exposure to Cd, Hg and Pb. Similarly, the *C. nigrodigitatus* muscles consumption reveals cancer risks, in children with values in the order of 2.10-3, 4.10^{-3} and 684.10^{-3} for Cd, Hg and Pb exposure respectively. In adults, the CR values for exposure to Cd, Hg and Pb are 10^{-3}, 2.10^{-3} and 274.10^{-3}, respectively.

Thus, the CR values recorded in the muscles of *S. melanotheron* and *C. nigrodigitatus* for Cd, Hg and Pb exposures in both children and adults are greater than 10^{-4}, defined as an unacceptable cancer risk limit. In sum, the cancer risk from eating the muscles of these two species of fish, both in children and adults, due to these trace elements is quite high and is given in the following order:

$$Pb > Hg > Cd > 10^{-4}.$$

4. Discussion

Toxicological results of fish caught in Taabo Lake revealed the trace metal elements Cd, Hg, Pb and Zn in the muscles of *S. melanotheron* and *C. nigrodigitatus* species at fairly high concentrations. These seasonal median concentrations ranged from 0.06 to 3.205 $mg.kg^{-1}$ and 0.027 to 2.11 mg/kg for Cd, from 0.102 to 1.19 $mg.kg^{-1}$ and 0.175 $mg.kg^{-1}$ to 1.461 $mg.kg^{-1}$ for Hg, from 0.24 $mg.kg^{-1}$ to 87.09 $mg.kg^{-1}$ and 0.225 to 117.94 $mg.kg^{-1}$ for Pb, and from 0.254 $mg.kg^{-1}$ to 21.465 $mg.kg^{-1}$ and 0.254, 12.125 and 0.272 $mg.kg^{-1}$ for Zn, respectively in *C. nigrodigitatus* and *S. melanotheron*. Referring [29] guidelines for fish edibility (Cd: 0.05 $mg.kg^{-1}$; Hg: 0.5 $mg.kg^{-1}$; Pb: 0.2 $mg.kg^{-1}$; Zn: 0.2 $mg.kg^{-1}$), our results show that both fish species studied are contaminated with these TMEs. The trace element concentrations found could be the cause of consumer health problems over time.

The results of analyses by [3,30] corroborate our findings in that they confirm the trace metal elements occurrence in *C. nigrodigitatus* and *S. melanotheron* muscles caught in Taabo Lake. Compared to this work, the present study revealed TMEs higher levels than those reported by [30] in *C. gariepinus* (0.127±0.085 $\mu g.g^{-1}$ for Cd, 0.166±0.081 $\mu g.g^{-1}$ for Pb) and *O. niloticus* (0.150±0.063 $\mu g.g^{-1}$ for Cd, 0.236±0.082 $\mu g.g^{-1}$ for Pb) caught in the Malebo Pool (Congo River, DR Congo). However, Zn levels in the present study are lower than those found by [31] in *C. anguillaris* (35.40±16.04 $\mu g.g^{-1}$) and *S. melanotheron* (57.33±20.11 $\mu g.g^{-1}$) muscles from Lome lagoon, Togo.

Trace elements accumulated in fish muscle can lead to adverse health effects in human populations that consume fish regularly. To assess this exposure to consumption of fish muscle contaminated with trace elements or health risks, the hazard quotient (HQ) calculation is generally used in toxicological studies as outlined by [32-35]. This Cd, Hg, Pb and Zn assessment in the present study identified these elements as human health hazards after consumption of fish muscle from *S. melanotheron* and *C. nigrodigitatus* species in both children and adults. The analysis in Figure 3 shows hazard quotients in children and adults for Cd (46.61/18.64), Hg (13.65/5.46) and Pb (140.43/56.17) greater than 1 for *S. melanotheron* species, respectively. This is also is true for *C. nigrodigitatus* in both children and adults. To this end, [36] determined, in their study, Pb hazard quotients of 64.44 and 161.11 respectively for adults and children who consume *Callinectes amnicola* type crab species. Also, 168.14 for adults and 420 for children HQs consuming the *Cardisoma armatum* type of crab, which are even more exposed at Pb in the lower Ouémé valley, were established. Contrary to these authors, [35] recorded HQs of less than 1 in adults for whom the occurrence of a toxic effect from Pb (HQ = 0.011) or Cd (HQ = 0.009) related to the tilapia muscles consumption is unlikely. Similarly, with less than 1 HQs in children and adults for Hg, Cd and Pb exposures related to *Clarias nigrodigitatus* muscles consumption of from Yinhi, Douhou and Gbeu, streams in the Ity mining area, Zouah-Hounien department, non-cancer toxicological risks are unlikely in this population according to [37]. Thus, in the present study, the results indicate that Zn recorded a HQ of less than 1 for *S. melanotheron* and *C. nigrodigitatus* species muscle consumption in both age categories.

Figure 3 of this study shows that children are more exposed to trace element toxicological risks than adults. This observation was also noted by [32] for the health risks assessed at the level of shrimps (*Metapenaeus affinis*) where children recorded exposure doses in As equal to 14.98 $\mu g.kg^{-1}.week^{-1}$, higher than those of adults. In Togo, [31,38,39] reported higher health risks in children during their health studies on fish species from the lake-lagoon complex and bivalves (*Crassostrea gasar*) from the Aného Lake Zowla-lagoon complex in southern Togo. Also, this children predisposition to toxicological risks related to the fish consumption contaminated by trace elements could be explained by their low body weight, an ease of absorption of contaminants and a less easy detoxification and excretion than in adults.

Calculation results for cancer risk (CR) from exposure to mercury, cadmium and lead in children and adults after consumption of S. melanotheron and C. nigrodigitatus muscles show CR values above 10^{-4} defined as an unacceptable limit for cancer risk in the present study. These results are contrary to those found by Djade [37]. Indeed, according to the author, in children and adults, the CRs recorded on Yinhi Lake are for Cd : $2.64.10^{-6}$ and $1.06.10^{-6}$; Hg: $4.92.10^{-5}$ and $1.97.10^{-5}$ and Pb : $2.87.10^{-6}$ and $1.15.10^{-6}$, respectively. A cancer risk of between 10^{-4} and 10^{-6} is still acceptable and, therefore, without harmful consequences for this population.

5. Conclusion

Median Cd, Pb and Zn concentrations in *C. nigrodigitatus* and *S. melanotheron* muscles are above the WHO recommended limits of 0.05, 0.2 and 0.2 $mg.kg^{-1}$ respectively for safe human consumption. Exposure assessment of Cd, Hg, Pb and Zn related to muscle consumption of these two fish species reveals hazard quotients greater than 1 for Cd, Hg and Pb in children and adults consuming *C. nigrodigitatus* and *S. melanotheron* species muscles. This exposure reflects a high probability

of carcinogenic effects for the population consuming the muscles of these fish caught in Taabo Lake. However, the HQ value for an exposure to Zn of less than 1 indicates an unlikely health risk. Also, it should be noted that children have higher HQ values than adults due to their low body weight, easier absorption of contaminants and less easy detoxification and excretion. The carcinogenic risk values for *S. melanotheron* and *C. nigrodigitatus* muscle consumption related to Cd, Hg and Pb exposures in children and adults are greater than 10^{-4}. Thus, the carcinogenic risk from exposure to Cd, Hg and Pb in both population categories is high and therefore unacceptable.

Conflicts of Interest

Authors declare that they have no conflicts of interest.

References

[1] Chadid, A., Trace metal element quantification (cadmium, lead and total mercury) of some fishery products landed in the Essaouira-Dakhla area: Health risk assessment. PhD thesis, Ibn Zohr University. Morocco, 191 p. 2016.

[2] Falasi, N., N'djili River pollution and soil management constraints Malebo Pool around (Masina agricultural site, case Rail 1/Kinshasa). DEA Memory, Liege University, Belgium, 64p. 2018.

[3] Nzapo, K.H., Ngbolua Koto-te-Nyiwa, Bongema, A.L., Bongo, N.G., Inkoto, L.C., Falanga, M.C., Ashande, M.C., Ndembo, N.J.L., Lokilo, L.E. and Djoza, D.R., Heavy metal bioaccumulation assessment in *Clarias gariepinus* (Burchell, 1822), *Chrysichthys nigrodigitatus* (Lacepède, 1803), *Mormyrops anguilloides* (Linnaeus, 1758) and *Coptodon rendalli* (Boulenger, 1897). *International Journal of Innovation and Scientific Research*, 38(1): 185-191. 2018.

[4] Mata, K.H., Mohammed, M.A.D., Ngweme, N.G., Konde, N.J., Mulaji, K.C., Kiyombo, M.G. and Poté, W.J., Toxique metal concentration and ecotoxicity test of sediments from dense populated areas of Congo River, Kinshasa, Democratic republic of the Congo. *Environemental chemistry and ecotoxicology*, 2: 83-90. 2020.

[5] Sidibe, A., Kpidi, Y.H., Yapi D.A.C., Seka, Yapoga, J., Yapo O.B., Anthropogenic activities and contamination of Taabo Lake sediments by trace metals (cadmium, mercury, lead and chromium). *Australian Journal of Basic and Applied Sciences*, 15(7): 16-24. 2021.

[6] Al-Khatib, I.A., Arafeh, G.A., Al-Qutob, M., Jodeh, S., Hasan, A.R., Jodeh, D. and Valk, V.D.M., Health Risk Associated with Some Trace and Some Heavy Metals Content of Harvested Rainwater in Yatta Area, Palestine. *Water* (Switzerland), 11: 1-16. 2019.

[7] Masok, F.B., Masiteng, P.L., Mavunda, R.D. and Maleka, P.P., An Integrated Health Risk Evaluation of Toxic Heavy Metals in Water from Richards Bay, South Africa. *Journal of Environmental & Analytical Toxicology*, 7(4): 1-7. 2017.

[8] Benoît, K.K., Konan, K.S., Konan, K.F., Boussou, K.C. and Kouassi, K.L., Heavy metals contamination of an aquatic environment and health risks assessment in two fish species: case of the Guessabo Lake, western Côte d'Ivoire. *Oriental Journal of Chemistry*, 35: 1742-1755. 2019.

[9] Kouamé, K.V., Yapi, D.A.C., Kouadio, K.N.G., Djedje, J.-M. and Tidou, A. S., Bioaccumulation of Some Heavy Metals (Pb, Cu, Cd, Zn and Fe) in Crab (Callinectesamnicola) living in Ebrie Lagoon, Jacqueville Sector (Cote d'Ivoire, West Africa). *Research Journal of Chemistry and Environment*, 23(7): 7-12. 2019.

[10] Gbamélé, K.S., Konan, K.S., Kouassi, K.L., Brou, L.A., Konan, K.F. and Bini, K.D., Groundwater chemical contamination assessment by anthropic activities: Case of the Ity-Floleu area, Zouan-Hounien Sub-Prefecture, Western Côte d'Ivoire. *European Scientific Journal*, 16: 247-274. 2020.

[11] Kouamenan, N.M., Coulibaly, S., Atsè, B.C. and Goore Bi, G., Heavy metal bioaccumulation in two Cichlid species tissues (*Hemichromis fasciatus* and *Tilapia zillii* × *Tilapia guineensis*) caught in Ebrié Lagoon western part, Côte d'Ivoire. *Journal of Applied Biosciences*, 148 : 15218–15229. 2020.

[12] Groga, N., Structure, fonctionnement et dynamique du phytoplancton dans le lac de Taabo, Côte d'Ivoire. Thèse de Doctorat, Université de Toulouse, France, 185p. 2012.

[13] Henry, F., Amara, R., Courcot, L., Lacouture, D. and Bertho, M.-L., Heavy metals in four fish species from the French coast of the Eastern English Channel and Southern Bight of the North Sea. *Environment International*, 30: 675-683. 2005.

[14] USEPA (United States Environmental Protection Agency), Risk Assessment Guidance for Superfund Volume 1. Human Health Evaluation Manual (Part A). EPA/540/1-89/002 Office of Emergency and Remedial Response. Washington, DC: U.S. Environmental Protection Agency. 1989.

[15] Liang, Y., Xiaoyun, Y., Zhi, D., Qin, W., Houmei, L. and Jie, T., Heavy Metal Contamination and Health Risk Assessment in the Vicinity of a Tailing Pond in Guangdong, China. *International Journal of Environmental Research and Public Health*, 14: 1557-1571. 2017.

[16] Tanouayi, G., Gnandi, K., Ahoudi, H. and Ouro-Sama, K., La contamination métallique des eaux de surface et des eaux souterraines de la zone minière d'exploitation des phosphates de Hahotoe-Kpogamé (Sud-Togo): Cas du cadmium, plomb, cuivre et nickel. *Larhyss Journal*, 21: 35-50. 2015.

[17] INERIS, Méthodologie d'évaluation quantitative des risques sanitaires relatifs aux substances chimiques. Convention 03 75 C 0093 et 06 75 C 0071 ADEME/SYPREA/FP2E/INERIS, 47p, 2007.

[18] INERIS (Institut National de L'Environnement industriel et des RISques), Fiche de données toxicologiques et environnementales des substances chimiques : Manganèse et ses dérivés. DRC-11-117259-10310B. Version N°2-3 81 p. 2012.

[19] INERIS (Institut National de L'Environnement industriel et des RISques), Fiche de données toxicologiques et environnementales des substances chimiques : Cadmium et ses dérivés. DRC-11-117259-10308B.doc. Version N°3, 111p. 2014.

[20] Food and Agriculture Organisation (FAO), World Fisheries and Aquaculture situation : Opportunities and challenges, Roma, Italy. 275p. 2014.

[21] ASTEE (Scientific and Technical Association for Water and the Environment), Methodological guide for health risk assessment of the impact study of composting facilities subject to authorisation, 65p. 2006.

[22] Johnbul, l.O., Abbassi, B. and Zytner, R., Risk assessment of heavy metals in soil based on the geographic information system-Kriging technique in Anka, Nigeria. *Environmental Engineering Research*, 24(1): 150-158. 2019.

[23] CIRC (Centre International de Recherche sur le Cancer), Agents Classified by the IARC Monographs, Volumes 1-123. 2013. https://monographs.iarc.fr/wp-content/uploads/2018/09/ClassificationsAlphaOrder.pdf.

[24] Mishra, S., Tiwari, A.K.M. and Mahdi, A.A., Impact of Heavy Metal Carcinogens on Human Health. Chapter 13, pp. 277-295. 2018.

[25] USEPA-IRIS, United States Environmental Protection Agency, Integrated Risk In-formation System. 2017. http://www.epa.gov/iris/subst.

[26] USEPA (United States Environmental Protection Agency), Drinking Water Standards and Health Advisories. Office of Water, U.S. Environmental Protection Agency. Washington, DC. 2012.

[27] Cao, S., Duan, X., Ma, Y., Zhao, X., Qin, Y., Liu, Y., Li, S., Zheng, B. and Wei, F., Health benefit from decreasing exposure to heavy metals and metalloid after strict pollutioncontrol measures near a typical river basin area in China. *Chemosphere*, 184: 866-878. 2017.

[28] Shil, S. and Singh, U.K., Health risk assessment and spatial variations of dissolved heavy metals and metalloids in a tropical river basin system. *Ecological Indicators*: 106(27): 1-12. 2019.

[29] WHO/FAO, Liste provisoire des principales espèces de poissons faisant l'objet d'un commerce international (y compris propositions concernant des concentrations maximales de plomb dans différentes espèces de poissons), Trente-septième session, La Haye, Pays-Bas, 4p. 2005.

[30] Nakweti, K.J., Lusasi, S.W. and Tembeni, M.J., Trace metal content assessment (cadmium and lead) in water, sediments and *Clarias gariepinus* (Burchell, 1822) and *Oreochromis niloticus* (Linnaeus, 1758), two fish species in Malebo Pool (Congo River), DR Congo. *European Scientific Journal*, 17(25): 174-192. 2021.

[31] Badassan, T.E-E., Trace element contamination assessment in the waters and sediments of Lomé lagoon and bioaccumulation in two fish species. PhD thesis, Toulouse National Polytechnic Institute (Toulouse-NPI) - Toulouse University, France, 181p, 2021.

[32] Soltani, N., Moore, F., Keshavarzi, B., Sorooshian, A. and Javid, R., Potentially toxic elements (PTEs) and polycyclic aromatic hydrocarbons (PAHs) in fish and prawn in the Persian Gulf, Iran. *Ecotoxicology and Environmental Safety*. 179: 251-265. 2019.

[33] Ramos-Miras, J.J., Sanchez-Muros, M.J., Morote, E., Torrijos, M., Gil, C., Zamani-Ahmadmahmoodi, R. and Rodríguez Martin, J. A., Potentially toxic elements in commonly consumed fish species from the western Mediterranean Sea (Almería Bay): Bioaccumulation in liver and muscle tissues in relation to biometric parameters. *Science of the Total Environment*, 671: 280-287. 2019.

[34] Maurya, P.K., Malik, D.S., Yadav, K.K., Kumar, A., Kumar, S. and Kamyab, H., Bioaccumulation and potential sources of heavy metal contamination in fish species in River Ganga basin: Possible human health risks evaluation. *Toxicology Reports*, n°6: 472-481. 2019.

[35] Diop, C., Diatta, A., Ndiaye, A., Cabral, M., Toure, A. and Fall, M., Trace metal levels in water and fish from five ponds in Dakar and human health risks. *Journal of Applied Biosciences*, 137: 13931-13939. 2019.

[36] Elegbede Manou, B., Atikou, M.I., Sohounnon, M., Labite, H., Deguenon, A.Y., Edorh A.P. and Aina, M.P., Toxic metals (Pb, Cu, Mn) bioaccumulation assessment in crabs species *Callinectes amnicola* and *Cardisoma armatum* consumed with *Abelmoschus esculentus* vegetables in Oueme Bass valley (Benin, West Africa). *Journal of Applied Biosciences*, 154: 15913-15925. 2020.

[37] Djade, P.O.J., Impact assessment of artisanal gold mining on the environment and health: Ity mining area case, Zouan-Hounien Department (West of Ivory Coast). PhD thesis, Félix Houphouët-Boigny University, Abidjan-Cocody, Côte d'Ivoire, 224p, 2021.

[38] Ouro-Sama, K., Régime alimentaire et étude écotoxicologique liée aux éléments traces d'un poisson Siluriforme (*Chrysichthys nigrodigitatus*, Lacépède, 1803) du complexe Lac Togo-Lagune d'Aného. Thèse de doctorat, Université de Lomé, Lomé, Togo, 256p, 2019.

[39] Solitoke, H.D., Dynamique des populations et bioaccumulation des éléments traces chez un Bivalve (Crassostrea gasar, Dautzenberg, 1891) du complexe Lac Zowla-Lagune d'Aného au Sud du Togo. Thèse de doctorat, Université de Lomé, Lomé, Togo. 192p, 2019.