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Human Health Risks Associated with Trace Element Contamination of *Crassostrea gasar* (Dautzenberg, 1891) from Lake Zowla-Aného Lagoon Hydrosystem (Southern Togo)

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Abstract Trace element pollution in aquatic ecosystems is one of the most important threats of human health and food chain. In order to assess the concentration of trace element in soft tissues of *Crasostrea gasar* and the human health risk associated with its consumption, seven trace elements (As, Hg, Pb, Cd, Zn, Cu and Cr) were analyzed by Atomic Absorption Spectrometer coupled to a hydride and cold vapour generator. *C. gasar* were collected at Zowla and Zalivé in the Lake Zowla-Aného Lagoon hydrosystem. The results showed a significant inter-site variation of trace elements concentrations. The highest concentrations (mg kg^{-1} dry weight) were obtained at Zalivé (0.69, 40.61, 246.47, 13.34, 10.13, 908.57 and 0.31) and lower concentration at Zowla (0.48, 34.26, 165.1, 10.4, 6.43, 766.3 and 0.2) respectively for As, Cd, Cu, Cr, Pb, Zn and Hg. The estimated daily intake (EDI) of each trace element in children is greater than the EDI for adults. The target hazard quotient (THQ) for children is higher than that for adults. For children, only Hg had a THQ < 1 at Zalivé, but at Zowla only As, Hg and Pb had THQ < 1. For adults, As, Hg, Pb, and Zn had THQ < 1 at Zalivé while in Zowla it was As, Cr, Hg, Pb and Zn which had THQ < 1. Considering the cumulative effect of all trace elements, these levels of trace elements in oysters can be toxic for consumers (TTHQ > 1). Also, the cancer risk (CR) for As and Cr were higher than 10^{-4} indicating that the onset of carcinogenic effects related to As and Cr in children and adults is probable. This study, therefore, suggests that the current environmental levels of trace metals are potential threats to the health of regular consumers of *C. gasar* of this hydrosystem.

Keywords: *Cassostrea gasar, trace metals, oyster consumption, health risks, Aného Lagoon*

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1. Introduction

Human activities such as agriculture, energy production, industry, transport, wastewater treatment, urban and industrial waste incineration, generate all kinds of chemical pollutants which were detected in the aquatic environment. Among pollutants, trace element which are normally found in low concentrations in the earth's crust can, under the action of anthropogenic factors, be found in high concentrations in the waters and sediments of the affected region. They are then considered as major elements in the studied environment. Increased metal concentrations in the environment could be transferred to organisms in the food chain, posing a threat both to the biodiversity of the ecosystem and to the sustainable and continued use of its resources [1].

Lake Zowla-Aného Lagoon hydrosystem located in the coastal area of Togo Is of great ecological interest; it Is an important source of fisheries and tourism industry. Regrettably, due to its position downstream from the city of Aného and the Hahotoé-Kpogamé phosphate mining area, this aquatic ecosystem Is currently undergoing severe degradation by wastewater discharges resulting from the processing plant and the discharge of domestic wastewater, household and hospital waste incineration [2,3,4,5,6]. There Is also information about the presence of different pollutants in certain organisms in the hydrosystem, for example fishes (tilapias, catfishes), crustaceans (Callinectes, Cardisoma), diatoms, and some halophyte species [4,5,7]. This indicates that the transference of several heavy metals occurs between abiotic and biotic components which represent a real threat to human health.

Bivalve mollusks mainly feed upon phytoplankton but other sources such as detritus, bacteria, microphytobenthos and zooplankton can also constitute an important component of their diet [8]. Hence, feeding with a wide range of food sources added to sedentary or even sessile lifestyle makes these organisms to be very exposed to risk of contamination by trace metals [9]. It was established that bivalves are excellent bioaccumulators since any contaminants in the water, from natural sources or pollution, are easily concentrated in their flesh, particularly trace elements [10,11,12,13,14].

The inter tidal mangrove oyster, Crassostrea gasar was an extractive resource of great socio-economic relevance in the West African sub-region, mainly for the traditional populations, who use them for their own consumption and exploitation [15,16]. Oysters have very high essential vitamins and minerals such as protein, omega three fatty acids, calcium, zinc, iron, vitamins B and E and poses no danger to the cholesterol levels in human [17]. In Togo, C. gasar Is mainly found on the roots and lowest branches of the mangroves trees bordering lakes and the network of channels of the Lake Zowla-Aného Lagoon complex [18]. However, the possible association between the consumption of oysters and human exposure to the various contaminants found in the Lake has not been studied. Thus, the objective of this study Is to assess the human health risks related to the consumption of contaminated oysters' soft tissue collected in the Lake Zowla-Aného Lagoon hydrosystem.

2. Material and Method

2.1. Study Area

Oyster sampling Is carried out at two sites (Zalivé and Zowla) of the hydrosystem Lake Zowla-Aného Lagoon (Figure 1). This hydrosystem includes Lake Zowla (6.55 km2), the Zalivé Channel and the Aného Lagoon in the south-east which consists of a network of narrow and shallow channels (4 to 11 m). This lagoon system Is part of the Togolese coastal zone which Is located between latitudes 6° 17'37" and 6° 14' 38" North and longitudes 1° 23' 33" and 1° 37'38" East. The waters of the Lake Zowla-Aného Lagoon system communicate downstream with the sea through the Aného pass (mouth), which has been open continuously since 1969. The hydrological regime of the lagoon system depends mainly on the regimes of the Zio, Haho, Boco and Mono Rivers [2,3,5].

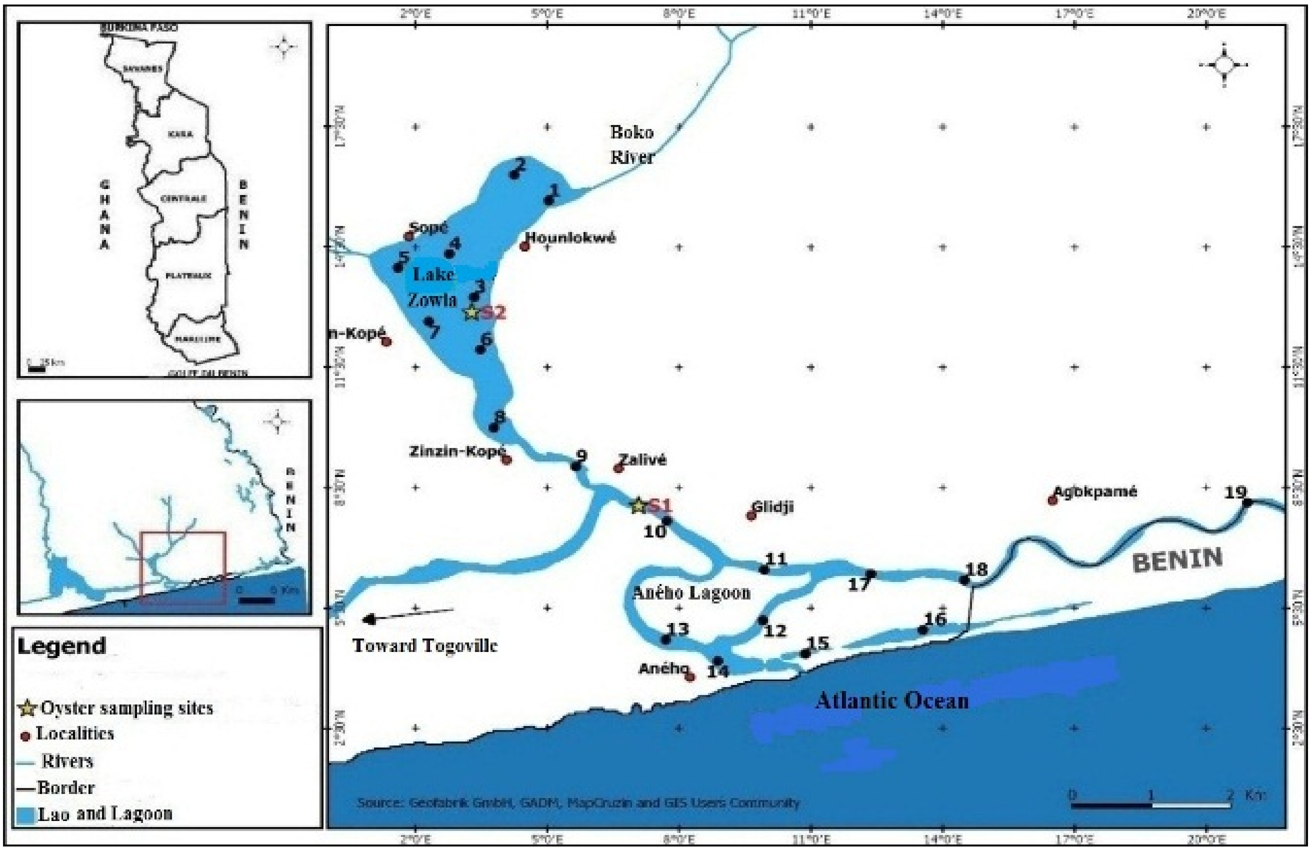

Figure 1. Map of the study area showing the sampling sites (S1 = Zalivé site; S2 = Zowla site)

2.2. Sampling of Oysters and Laboratory Analysis

Ninety (90) Oysters were sampled using a simple random sampling method at two localities (Zowla and Zalivé) during three months (January, April and July) at a rate of thirty (30) per month. These sampling sites were selected according to the suggestion performed in our previous studies [4]. This technique was chosen according to Scherrer [19], who mentioned that the preparation of the sampling unit selection protocol does not a priori require any information on the size, structure and behavior of the population. The sampling period corresponds to the period of oyster harvesting in the lagoon system (January to July). The oysters were transferred to the laboratory on ice and then stored at -20°C until required.

After washing, the oysters were kept in tap water for 72 hours to allow depuration of gut contents and of particulate material present in the mantle cavity. Then they were shelled using a clean stainless steel scalpel, avoiding damage to the shellfish and limiting the loss of intra-tissue fluid. After shelling, the soft tissue was dried in an oven at 70°C and digested in nitric acid (2 to 4 ml of pure HNO3 for 0.05 to 1 g of sample) in borosilicate glass tubes in a pressurized medium and heat to near dryness [20]. Then, the residue was diluted to 15 ml with distilled water and filtered. Samples intended for the determination of mercury were digested with the same reagents without heating. Cd, Cu, Pb, Cr and Zn were analyzed using a Thermo Electron flame atomic absorption spectrometer (AAS) while Hg and As were analyzed using AAS coupled to a Thermo Scientific hydride and cold Vapour generator (VP100) with a flame for As and no flame for Hg.

2.3. Quality Control

The validity of the analytical methods was verified by internal control. A procedural blank was prepared simultaneously with the same acid (68% HNO3) as for the other samples under the same experimental conditions and measured for each 10 samples batch. Standard solutions of each element were analyzed under the same conditions as before. This made it possible to highlight possible contamination of the sample, to eliminate quantification errors and to verify the accuracy of the method. In addition, in order to verify the repeatability of the results, multiple duplicates were incorporated into the analytical batch in a random manner.

2.4. Health Risk Assessment Procedure

The assessment of health risks followed four (04) successive stages according to [21,22,23].

2.4.1. Identification of the Danger

This step consists in identifying the substances studied as well as the undesirable effects which their presence in humans may cause. The available literature will be used for this step.

2.4.2. Dose-Response Relationship

It is based on the Toxicological Reference Values (TRV) which are indices characterizing the link between human exposure to a toxic substance and the occurrence or the severity of an observed harmful effect. The TRV which were Oral Reference Dose (RfDo) and Oral Cancer Slop Factor (CSFo) will be chosen through available database of different environmental and health care agencies [24,25].

2.4.3. Exposure Assessment

The methodology consists of the calculation of the Estimated Daily Intake (EDI). The exposure scenario in which the individual is most exposed (i.e. maximalist hypothesis) will be used. In this scenario, the following assumptions are considered: (i) there will be a certain amount of discrepancy in health risks between age groups (children vs adults) and the locality of the inhabitants; (ii) the average quantity of oyster consumed per person depends on the period of harvest (7 months) and the minimum quantity available on the local market. It was further assumed that cooking has no effect on the toxicity of heavy metals in seafood.

There have been no prévois estimates of the total volume of oysters harvested from the Lake Zowla-Aného Lagoon hydrosystem to date, or how much of the fishery they are consuming. To evaluate the oyster consumption rate (Qi), subjects were personally interviewed with a questionnaire. Hundred and ten (110) consumers were sampled from the two (2) coastal fishing communities namely Zalivé (36 adults and 22 children) and Zowla (30 adults and 28 children). In the study area, oysters are generally fried or grilled then packaged in small plastic bags intended for sale or home consumption. The survey asked respondents to indicate the pack and how often they consume the oyster meat. We also identified the average weight of a pack of oyster and then averaged all of the respondent’s answers. The average oyster intake was calculated for children and adults using the following formula (Eq.1):

$$Q = \frac{\Sigma\left[Q_i \times \% \text{ of adults or children}\right]}{100} \quad (1)$$

With Q = Average quantity, Q_i = quantity corresponding to a given percentage.

The EDI was determined by the following equation (Eq. 2) according to [23]:

$$EDI = \frac{C \times Q \times F}{W} \quad (2)$$

EDI: Estimated Daily Intake linked to the consumption of oyster soft tissue (mg/kg/d); C: Exposure concentration relative to oyster soft tissue expressed in mg/kg. In this study, the average trace element concentrations in *C. gasar* from each site will be used; Q: Quantity of oyster soft tissue ingested per day (kg/d); F: Frequency of exposure: fraction of days per year or fraction of hour per day. The frequency of consumption in this study is considered to be 180 days per year according to the oyster harvest period (January to July) without considering holidays and weekends; W: Target body weight (kg).

In the coastal area of Togo, the average body weight of children aged 3 to 17 is 28.7 kg [26] whereas that of adults (18 to 70 years old) is estimated at 67.6 kg [27].

Table 1. Oral Reference Dose (RfDo) and Oral Cancer Slop Factor (CSFo) of trace elements

	As	Cd	Cr	Cu	Hg	Pb	Zn
RfDo (mg/kg/d)	3×10^{-4}	1×10^{-3}	3×10^{-3}	4×10^{-2}	3×10^{-4}	$3{,}5\times10^{-3}$	3×10^{-3}
CSFo $(mg/kg/d)^{-1}$	1.5	-	0.42	-	-	8.5×10^{-3}	-

2.4.4. Risk Characterization

It was done according to the effects produced after oyster consumption. For effects occurring above a threshold, the result is expressed as a Target Hazard Quotient (THQ). The THQ, a ratio between exposure to a potentially hazardous element and its reference dose was determined using the formula (Eq.3):

$$THQ \frac{EDI}{RfDo} \quad (3)$$

Where EDI is Estimated Daily Intake (mg/kg/d); RfDo is Oral Rference Dose (mg/kg/d). If THQ < 1, the occurrence of a toxic effect is very unlikely; whereas THQ > 1 indicates that the occurrence of a toxic effect cannot be excluded.

Based on the literature, exposure to two or more pollutants may cause additive and/or interactive effects, and hence, the total or combined target hazard quotient (TTHQ) may be calculated. The TTHQ gives an overview of health risks of the seven studied metals together through oyster consumption.

For non-threshold effects (carcinogenic effect), the cancer risk (CR) was calculated as follow Eq.4:

$$CR = EDI \times CSFo \frac{T}{Tm} \quad (4)$$

With EDI: Estimated Daily Intake (mg/kg/d); CSF_o: oral Cancer Slope Factor (mg/kg/d)-1; T: exposure duration; Tm: Average period of entire life (in year) generally equal to 70 years. The carcinogenic risks were not considered for Cd, Cu, Hg and Zn due to unavailability of corresponding carcinogenicity slope factors.

The RfDo and CSFo values chosen from the available database of different environmental and health care agencies USEPA (United States Environmental Protection Agency) and OEHHA (Office of Environmental Health Hazard Assessment) are presented in Table 1.

2.5. Statistical Analysis

Student's t-test was used to compare average concentrations between sampling sites. For this purpose, STATISTICA version 6 was used.

3. Results

3.1. Daily Consumption of Oysters

Results revealed that oyster consumption is heavily favoured in the communities sampled. It showed that all respondents (100%) sampled had consumed an oyster before. However, only respondents who say eating oysters every day during the collection period were retained. Table 2 shows the oyster consumption rates among fishermen and highly exposed individuals in and around Zalivé and Zowla. Results also revealed that oyster consumption rates were 30 and 75 g/day for typically and maximally exposed adults respectively and 20 and 50 g/day for exposed children. In addition, it should be noted that the highest intake of adults is almost twice that of the average child.

Table 2. Estimated oyster consumption rate among adults and children respondents in coastal area of Togo

Frequency of consumption	Adults		Children	
	Respondents (%)	Qi (g/d dw)	Respondents (%)	Qi (g/d dw)
Once a day	0	20	48	20
	35	30	40	30
	51	40	7	40
	10	50	5	50
	3	60	0	60
	1	75	0	75
	0	100	0	100
Average quantity (Q) in g/d dw)		38.45		26.90

Table 3. Variation of trace element concentrations in soft tissues of oyster *C. gasar*

Localities		Hg	As	Pb	Cd	Zn	Cu	Cr
Zalivé	Average	0.31	0.69	10.13	40.31	908.57	246.47	13.34
	S D	0.17	0.35	6.23	15.68	377.3	110.54	5.53
	Min	0.035	0.2	0.96	9.97	339.35	57.48	4.07
	Max	0.67	2.24	23.72	79.22	2448.1	599.44	33.21
	%CV	54.84	50.72	61.5	38.9	41.53	44.85	41.45
Zowla	Average	0.2	0.48	6.43	34.26	766.3	165.1	10.4
	S D	0.17	0.36	5.34	17.53	378.76	99.36	4.16
	Min	0.026	0.08	0.71	8.98	291.04	44.76	3.29
	Max	0.8	2.05	29.05	98.9	2617.05	746.71	25.32
	%Cv	85	75	83.05	51.17	49.43	60.18	40
WHO		0.5	0.1	2	1	100	30	50

SD= Standard Deviation; Min= Minimum; Max= Maximum; Cv = Coefficient of variation.

3.2. Concentrations of Heavy Metals in Oysters

Variations of Hg, As, Pb, Cd, Zn, Cu and Zn in soft tissues of C. gasar from the two sampling locations (Zalivé and Zowla) during the sampling periods are listed in Table 3. Among the seven trace metals tested, Zn concentration was the highest (in soft tissue of C. gasar and Cu concentration was the second elements found to be highest in the bivalve. At both locations, the order of magnitude of metal levels is Hg <As <Pb <Cr <Cd <Cu <Zn.

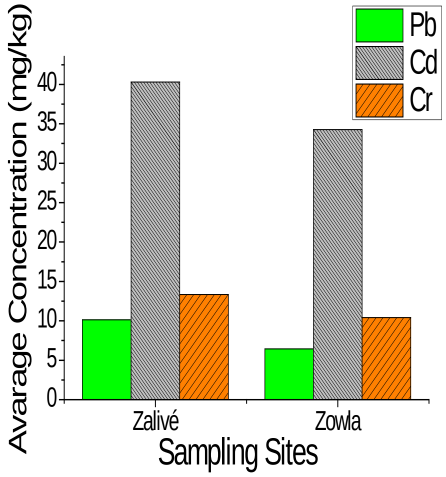

Figure 2. Inter-site variation of average concentrations of Pb, Cd and Cr in *C. gasar* soft tissue

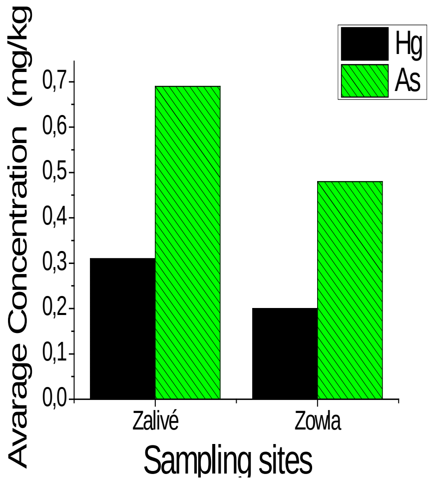

Figure 2. Inter-site variation of average concentrations of Hg and As in *C. gasar* soft tissue

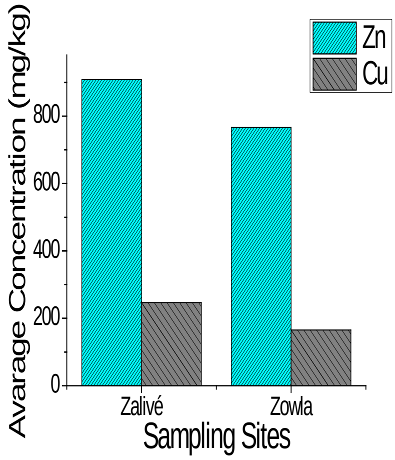

Figure 4. Inter-site variation of average concentrations of Zn and Cu in *C. gasar* soft tissue

From the perspective of spatial distribution of metals in oysters, Student's t test showed that the average concentrations found in Zalivé were higher than those found in Zowla fishing ground. Results of the test gave t-values of 4.06, 4.04, 4.14 and 4.27 for As, Cr, Hg and Pb respectively with p-values < 0.0001. For Cd and Zn, the t-values were respectively 2.44 and 2.52 with p-values < 0.05. Regarding Cu, its t-value was 5.19 with $p < 0.00001$. The inter-site comparison of the average trace element concentrations is depicted in Figure 2, Figure 3 and Figure 4.

3.2. The Target Hazard Quotient (THQ).

Table 4 shows the mean daily estimated intake amounts of observed trace metals in oysters. Generally, a higher intake of trace metals is shown for children. Zn showed the highest EDI with 0.254 mg/day/kg for an adult and 0.406 mg/day/kg for children at Zalivé. The least intake was for Hg with 5.6×10^{-5}mg/day/person for adults and 8.9×10^{-5} mg/day/kg for children at Zowla. It can also be observed that for the ingestion of oysters by children, the daily dietary intakes of studied metals were significantly higher than those of adults.

Calculated results for noncarcinogenic hazard index for children and adults in Zowla and Zalivé, assessed by considering the exposure to trace metal contaminated oysters via ingestion are presented in Table 5. As you would expect, target hazard quotients for children were higher than those of adults. Results also indicated that the maximum THQ is for Cd, followed by Cu, Cr, and Zn. Overall, the combined target hazard quotients for the seven studied trace metals were well above 1.

Table 4. Estimated daily dietary intake of trace metals; exposure per day/(mg/(kg d))

		EDI						
		As	**Cd**	**Cr**	**Cu**	**Hg**	**Pb**	**Zn**
Zalivé	**Children**	3.1×10^{-4}	1.8×10^{-2}	6×10^{-3}	0.11	1.4×10^{-4}	4.5×10^{-3}	0.406
	Adults	2×10^{-4}	1.1×10^{-2}	3.7×10^{-3}	6.9×10^{-2}	8.7×10^{-5}	3×10^{-3}	0.254
Zowla	**Children**	2×10^{-4}	1.5×10^{-2}	4.6×10^{-3}	7.4×10^{-2}	8.9×10^{-5}	2.3×10^{-3}	0.342
	Adults	1.3×10^{-4}	9.6×10^{-3}	2.9×10^{-3}	4.6×10^{-2}	5.6×10^{-5}	1.8×10^{-4}	0.215

Table 5. Non-carcinogenic risk (target hazard quotient, THQ) and combined toxic risk (TTHQ) of oysters

		THQ							TTHQ
		As	Cd	Cr	Cu	Hg	Pb	Zn	
Zalivé	Children	1.03	18	2	2.75	0.47	1.29	1.35	20.89
	Adults	0.67	11	1.23	1.73	0.29	0.86	0.85	16.63
Zowla	Children	0.67	15	1.53	1.85	0.3	0.66	1.14	21.15
	Adults	0.43	9.6	0.97	1.15	0.19	0.51	0.72	13.57

Cancer risk (CR).

Carcinogenic risk (CR) exposures to As, Cr, and Pb were evaluated for adults and children and presented in Table 6. It could be clearly seen that the CR of Cr are the highest and those of Pb are lowest. Additionally, compared to children, trace metals values are lower in adults. The carcinogenicity ranking obtained increased following the order adults at Zowla> children at Zowla > adult at Zalivé > children at Zalivé.

Table 6. The metals carcinogenic risk for adults and children pose by As, Cr and Pb according to location

Location		As	Cr	Pb
Zalivé	Children	$2x10^{-4}$	$1.1\ x10^{-3}$	$1.64\ x10^{-5}$
	Adults	$1.3\ x\ 10^{-4}$	$6.7\ x10^{-4}$	$1.09\ x10^{-5}$
Zowla	Children	$1.3\ x10^{-4}$	$8\ x10^{-4}$	$8.4\ x10^{-6}$
	Adults	$8.4\ x10^{-5}$	$5\ x10^{-4}$	$6.6\ x10^{-6}$

4. Discussion

The present study confirms the occurrence and variability of trace metal levels in living organisms in Lake Zowla-Aného Lagoon, a large coastal ecosystem in Togo. The trace metal concentrations in oysters in our study are relatively high. In effect, compared with results in previous literatures, the concentrations of investigated metals were much higher than those recorded in oyster collected elsewhere in Africa [10,11,14,28,29,30]. High levels of trace elements in oysters appear to be related to the pollution status concerning the metals of the area where the bivalves are collected. Indeed, various studies conducted on the Togolese coast have revealed that the dumping of phosphorite mine tailings into the sea has led to very elevated concentrations of Cd, Cr, Cu, Ni, Sr, V, Zn, Ti, Fe and Mn in aquatic ecosystems and soils [2,3,31]. For example, [32] investigated the degree of pollution in marine sediments and adjacent aquatic ecosystems and found that the contamination is extremely severe for Cd, severe for Cr and Ni. Nevertheless, to this main source, should be added the pollution by agricultural inputs (fertilizers and pesticides) used in the watersheds of the Zio, Haho and Boco rivers.

The average concentrations of As, Cd, Cr, Cu and Zn in this study are higher than WHO standards [11,14,30]. This result is consistent with the findings that in highly contaminated aquatic habitats, the concentrations of metals in the tissues of shellfish, usually exceed the permissible limits for human consumption and involve serious health threats [33].

In the current study, the target hazard quotients (THQ) associated with the consumption of oyster soft tissue for children were all higher than the THQ for adults. In general, studies have shown that children are still the most exposed to trace elements because of their low body weight and physiological fragility since contaminants are easily absorbed into their bodies. Children's bodies potentially absorb more contaminants and are unable to eliminate them as easily as adults because their elimination systems are less well developed [49].

The occurrence of arsenic-related toxic effect in adults following the consumption of Zalivé and Zowla oysters is unlikely (THQ = 0.67 and THQ = 0.43). The same conclusion can be drawn for adult consumers living in Zalivé (THQ = 0.67). Contrariwise, the occurrence of a toxic effect linked to the consumption of Zalivé oysters by adults cannot be excluded (THQ = 1.03). [4] reported that the amount of arsenic in the edible saltwater clam (Senelia senelis) was 12.84 times and 32.10 times higher than the Oral Reference Dose (RfDo) for the maximally exposed adults and children respectively. Therefore, they suggested that moderate consumption of that bivalve and other seafood from Lake Aného (Togo) is advisable to avoid health risks to consumers. Similarly, another study in abandoned gold mines in Ghana reported a significant health risk in children due to As contamination in the area [34]. It has been shown that outside the workplace, exposure to arsenic is mainly due to the ingestion of contaminated food and water. Foods that mainly contribute to this dietary inorganic arsenic intake in the population are vegetables, fruits and fruit juices, and rice. However, in coastal regions, regular consumption of seafood is the main source of inorganic arsenic [35].

With regards to cadmium, risk indices found in children and adults in Zalivé (THQ = 18 and THQ = 11 respectively) and Zowla (THQ = 15 and 9.6 respectively) show that the occurrence of a toxic effect following oyster's consumption is very likely in both adults and children. [36] reported that, in the case of regular local consumers, the levels of Cd in Cassostrea corteziensis are a possible health risk in six of seven coastal lagoons of NW Mexico. Cd is a cumulative toxicant with a biological half-life of about 20 to 30 years. Chronic exposure to cadmium leads to the onset of irreversible nephropathy which can progress to renal failure [37].

The occurrence of toxic effects related to Cu, following the consumption of both Zalivé and Zowla oysters, cannot be excluded. The THQ found in both children and adults in Zalivé (2.75 and 1.73 respectively) and Zowla (1.85 and 1.15 respectively) are greater than 1. Nevertheless, these values are lower than those of C. angulate and C. hongkongensis in Taiwan [38]. Copper is an essential element required as a cofactor and/or structural component of numerous metalloenzymes. However, perturbations in Cu (II) homeostasis can be highly toxic to cells and have been linked to the development of neurodegenerative diseases such as Alzheimer's, Parkinson's, Menkes and amyotrophic lateral sclerosis [39,40,41]

The consumption of Zalivé oysters can cause Cr-related toxic effects in children and adults (THQ = 2 and THQ = 1.53 respectively). Concerning the consumption of Zowla oysters, the occurrence of toxic effects linked to Cr is only possible in children (THQ = 1.23). According to [42,43] hexavalent Cr (Cr VI) has no biological role and is more toxic than trivalent Cr (Cr III) which plays a biological role in the organism. Toxicological studies showed that the ingestion of low doses of Cr (VI) (< 0.1 mg/l) would pose no risk of toxicity because of the rapid reduction of Cr VI to Cr III in the stomach [43]. It would then be important to carry out other chemical analyses to identify the nature of Cr found in the soft tissue of the studied oysters. The occurrence of toxic effects related to Hg is unlikely (THQ < 1) for the consumption of oysters in the study area by both children and adults.

With respect to Pb, the appearance of toxic effects following consumption of Zalivé oysters is only possible in children (THQ = 1.29). However, lead is a non-essential element that can have numerous adverse health effects including neurotoxicity and nephrotoxicity [44]. Lead poisoning can lead to reduced cognitive development and intellectual performance in children. In adults, high levels of Pb in the blood can cause subtle changes such as effects on sperm quality, insomnia, tiredness, loss of memory and coordination, hearing loss and weight loss, increased blood pressure and cardiovascular disease [44]. Regarding zinc, the occurrence of toxic effects linked to this element is only likely in children following the consumption of Zalivé and Zowla oysters. In adults, the occurrence of effects is unlikely (THQ = 0.85 in Zalivé and THQ = 0.72 in Zowla). Zinc (Zn) is an essential component of human nutrition (Mertz, 1981). It is one of the most important trace elements in metabolic processes in the human body, as it is a key part of cells, and enzymes depend on it as a cofactor. However, ingesting food with high levels of Zn can cause serious health problems, such as damage to the pancreas, disruption of protein metabolism, arteriosclerosis, poisoning, nausea, acute abdominal pain, diarrhea and fever [45].

Most studies have examined the risks posed by fish which, admittedly, constitutes the major source of animal protein among many communities. Nonetheless, a comparison of our results with the limited number of THQ values reported in the literatures indicated that the target hazard quotients in Zowla and Zalivé were comparable to or higher than those reported from other contaminated areas of the West Africa sub region. [7] determined the THQ of Cd, Fe, Hg, Mn, Pb and Zn of the freshwater clam (Galatea paradoxa) from River Mono (Togo). With the estimated THQ found to be lower than 1 for the majority of samples, it was concluded that there was no long-term health risk for the consumption of the said shellfish for residents of the river. Similar studies conducted in the Volta River and Diebu Creek in Niger Delta have reached the same conclusions for the aforementioned species [30-46]. Reference [29] assessed the potential health risk from consuming contaminated oyster (C. virginica) from different markets in Port Harcourt, Nigeria. They found that EDI values were within tolerable limit. Nonetheless, THQ and TTHQ calculated indicated likely risk since the values were above the threshold of 1 for lead, Cobalt and Cadmium. Reference [38] estimated the health risks of heavy metals such as Cd, Cu and Zn via consumption of two severely contaminated oysters (Cassostrea angulae and C. hongkongensis) in Taiwan. They found that 50% (12 THQs) of the THQs far exceeded 1 for the maximally exposed individuals consuming oysters collected from Machu Island, Taiwan.

Long term exposure to low amounts of toxic metals could, result in many types of cancers [47]. Reference [48] suggested that the safe limit for cancer risk is TR < 10-6 and threshold or unacceptable cancer risk limit is TR > 10−4 (1 chance in 10,000 lifetime exposure) [22]. In the current study incremental lifetime CR for Cr violated the threshold risk limit in all the studied oysters, As violated the risk in oyster at Zalivé, whereas none of the oyster crossed the designated risk limit for Pb. It also emerges from this study that the CR linked to the consumption of Zalivé oysters remains higher than the CR linked to the consumption of Zowla oysters. Results also confirmed a potential cancer risk for the children as a highly exposed population to the carcinogenic elements via oyster consumption. Overall, the carcinogenicity ranking obtained in the present study decreased following the order children in Zalivé > children in Zowla > adult in Zalivé > adult in Zowla.

5. Conclusion

In the present study, the concentrations of trace elements (Cr, Cu, Zn, As, Cd, Hg and Pb) in oyster (C. gasar) from Lake Zowla-Aného Lagoon hydrosystem were analyzed and their potential health risks were estimated. The results showed that the levels of the concerned trace metals were higher than the maximum limit of normal recommended values. The estimated exposures and risk indices indicated that that oysters' consumption might bring significant potential non-carcinogenic and carcinogenic health risks to the public of the study area. Nevertheless, health risks via consumption of oyster are more significant for children than adults. Also, the consumption of Zalivé oysters presents a greater risk than the consumption of Zowla oysters. On the basis of the results obtained, measures must be put in place to limit the risks of children's exposure to trace metals via the ingestion of contaminated oysters. For example, a limited consumption of C. gasar meat and other seafood from the Lake Zowla-Aného Lagoon hydrosystem should be considered. Besides, government should enforce laws that require mining industries to use standard waste treatment plants for the treatment of their waste before it is discharged into the sea and inland water bodies.

Conflicts of Interest

The authors declare no conflict of interest.

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