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Health Risk of Exposure to Metal Trace Elements Linked to the Consumption of Fish from the Kalsom Dam in The Didagou Watershed (Dapaong, Northern-Togo)

Pamane KPIAGOU[1*], Sanonka TCHEGUENI[1], Daouda SAMA[1], Kissao GNANDI[1], Tchadjobo TCHACONDO[2]

[1]Laboratoire de Gestion, Traitement et Valorisation des Déchets de la Faculté Des Sciences (GTVD-FDS/UL), 01 BP 1515, Lomé, Togo
[2]Laboratoire des Sciences Biomédicales, Alimentaires et de Santé Environnementale de l'École Supérieure des Techniques Biologiques et Alimentaires de l'Université de Lomé (LaSBASE-ESTBA/UL), 01 BP 1515, Lomé, Togo
*Corresponding author: kpiagoupamane@gmail.com

Abstract In recent years, the Didagou watershed (Dapaong, Togo) has been transformed into a waste disporal site of all kinds by the populations, causing pollution of the Kalsom dam ecosystem. The market gardening intensive use of chemical fertilizers and pesticides around this dam aggravates this situation.

A study of the ichthyofauna of the Kalsom dam carried out in January 2019, permited to inventory eight (08) species of fish distributed in seven (07) genera and four (04) families: Cichlidae, Mormyridae, Clariidae and the Clupeidae. The Cichlididae were the most represented with five (05) species. The presence of Metal Trace Elements (MTE) pollutants in caught fish was also the object of this study. The MTE (Mercury, Cadmium, Lead, and Arsenic) were sought by means of a flame atomic absorption spectrophotometer in fish tissue using.

The results revealed that all collected fish species concentrated levels above the standard set by WHO for cadmium and arsenic. The maximum excess concentration of Arsenic is observed in *Oreochromis niloticus* (24 times the WHO standard). *Marcusenus senegalensis* concentrated in excess all the studied MTE at different rates; Its consumption would cause toxic effects in children from mercury and cadmium which have risk quotients greater than 1 (RQ_{Cd} = 1.40 and RD_{Hg} = 1.81 > 1). Nevertheless, all these fishs are ignorantly consumed by the population.

Keywords Kalsom dam, Bioaccumulation, Excess concentration, ichthyofauna, Risk quotient

1. Introduction

Biodiversity is the earth's natural wealth and provides the essential elements for the life and prosperity of all of humanity. It plays an essential role in the functioning of aquatic ecosystems, the biological basis of fishing and aquaculture and contributes greatly to the economic value of the services rendered by aquatic ecosystems [1].

One hundred and sixty-five million years before man appeared on earth, fish had already left their mark on stone. They were made masters of the rivers, lakes, seas and oceans. The disease affected them little. The food sources they provided seem inexhaustible and man found most of the animal protein there [2].

Nowadays, environmental problems are multiple and concern all the compartments that define the environment. These problems are linked to the development of human activities and have been made worse by immense population growth. This huge population growth in African countries has led to a huge increase in various pollutants in the receiving water bodies and has had adverse effects on the various components of the aquatic environment and on fisheries [3].

In Togo, inland fishing is practiced throughout the territory in rivers, flood zones and dams. These bodies of water provide an estimated production of between 4 000 and 5 000 tonnes per year [4].

The Kalsom dam undergoes in the rainy season, not only a significant and inevitable telluric contribution but also serves as a receptacle for polluted water coming from the city through the Didagou backwater which carries all kinds of waste. Urban and agro-pastoral household waste is a significant source of organic pollution and contribution of Trace Metal Elements (MTE) in the ecosystem; the most toxic are mercury, cadmium, lead, etc. [5]. Moreover, agricultural activities also through uncontrolled use of chemical fertilizers and pesticides are also a source of mineral and organic contamination [6].

MTEs have always been reported as dangerous for the environment when they are found in the air, water, soil, and in food, even at low concentrations. The effect of MTEs on public health and the environment no longer needs to be demonstrated because diseases such as cancers are linked to the presence of certain MTEs in the trophic chain [7]. But the concern is that consumers are very poorly informed about these concerns. The intends of the present study is to determine the level of contamination of fish from the Kalsom dam with metallic trace pollutants and to assess the consequences on human health.

Materials and Methods

Study area

The commune of Dapaong is part of the prefecture of Tône (extreme north of Togo) in the savannah region. With an area of 115 km^2, it is located 650 km from Lomé, the capital of Togo, and 300 km from Ouagadougou, the capital of Burkina Faso. It enjoys a tropical Sudanese climate with a long dry season which strongly handicaps agriculture. The temperatures there are very high, sometimes exceeding 42°C and the cumulative annual rainfall varies between 900 to 1200 mm [8].

In 2016, the population of Dapaong was estimated at 64 800 inhabitants and will reach 85 400 inhabitants by 2030 [9]. This population, although urban, practice a lot of agriculture. The Didagou watershed concentrates the runoff from Mount Monefiago, crosses the center of the city from south to north to flow with all its pollutant load into the Kalsom dam. Located between 10°48'59.0" and 10°51'44.3" North latitude and between 0°09'36.7" and 0°10'23.2" East longitude, this dam is 7 km south- West of the commune of Dapaong, on the Didagou river. With a perimeter of 12 815 m, it covers an area of 286.04 ha and extends over approximately 8 km. Market gardening with intensive use of chemical fertilizers and pesticides is practiced around this dam.

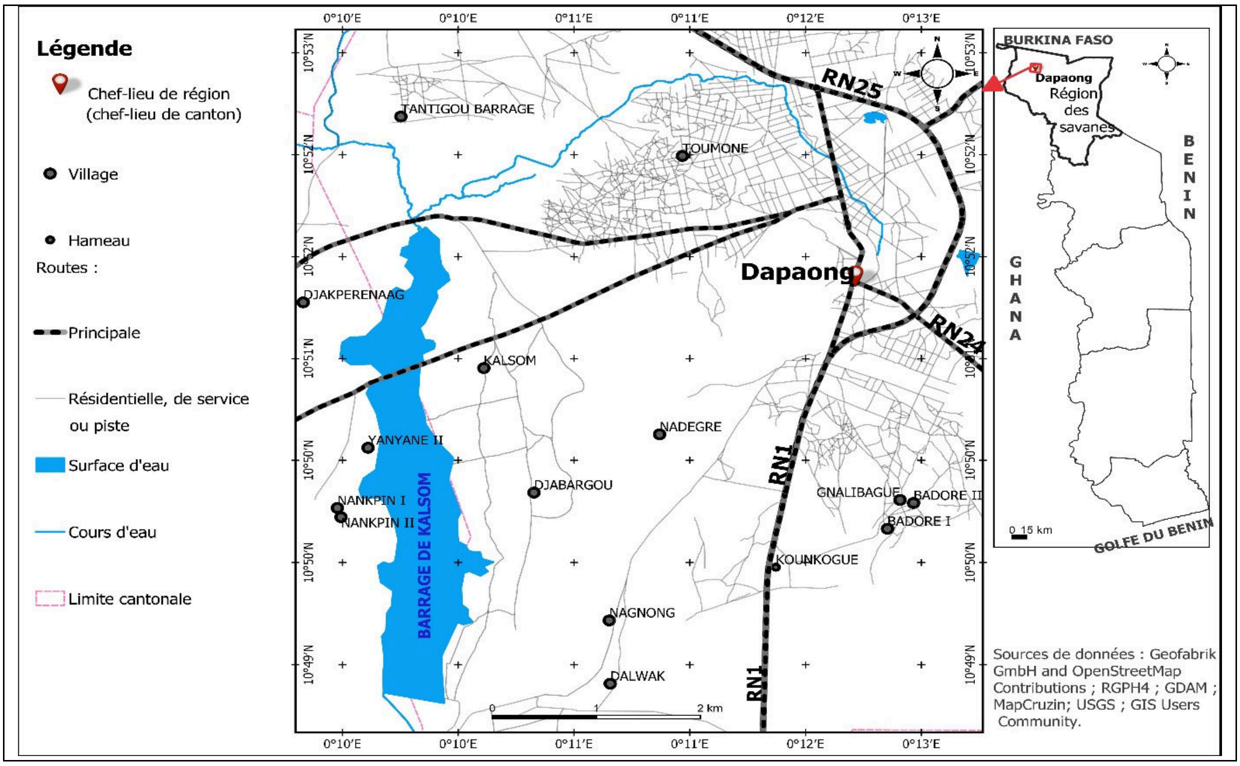

Figure 1: Map of Dapaong city indicating the Didagou backwater and the Kalsom dam

Sampling

Sampling for the inventory of fish species

The choice of fishermen was made by village (Kalsom and Djabargou) and randomly. These fishermen are interviewed at their home and/or at their fishing ground and the answers are noted on a pre-established sheet. Thus ten (10) fishermen, five (05) per village were interviewed. The identification of the fish collected was carried out at the Laboratory of Zoology and Animal Biology of the University of Lomé thanks to the work of [10] and to a previous sampling preserved.

Sampling for chemical analyzes

The fish were taken in early January 2019, just as the fishing boat arrived on the shore, in sterile plastics. Each plastic corresponds to fish of the same species. These various fish samples placed in a cooler containing ice (around 4°C) were transported to the laboratory. Where a photograph has contributed to the identification of different species of fish. Within each species of fish, they are classified in order of size. These different sizes (length (L), width (W)) were determined using a graduated ruler.

The analyzes were made on the five (05) species for which the fishing was substantial (Figure 2).

Tilapia zillii **Gervais, 1848**

Sarotherodon galilaeus **Linné, 1758**

Oreochromis niloticus **Linné, 1758**

Morcusenius senegalensis **Steindachner, 1870**

Clarias gariepinus **Burchell, 1822**

Figure 2: Fish species from the Kalsom dam sampled for analysis

Dosage of MTEs in fishs

The dosage of MTEs was carried out at the Waste Management, Treatment and Valorization Laboratory, called "Laboratoire de Gestion, Traitement et Valorisation des Déchets (GTVD)" of the Faculty of Sciences of University of Lomé (Togo).

The methods used are listed in Table 1.

Table 1: MTE analyzed and methods used

Parameters/Unit	Materials	Method	Standard/ Reference
Mercury (Hg) - mg/L	Flame spectrophotometer « Type Thermo Fischer iCE 3000 Series »	Atomic absorption spectrophotometry	NF EN 1483
Cadmium (Cd) - mg/L			NF EN ISO 5961
Lead (Pb) - mg/L			FD T 90-112
Arsenic (As) - mg/L			NF EN ISO11969

Calculation method for the excess concentration factor (CF) of MTEs: pollution index

$$CF = \frac{\text{Measured concentration}}{\text{Reference concentration}}$$

Methods for assessing the health risk of exposure to MTEs

The method for assessing health risks related to the exposure of populations to toxic substances is a quantitative and qualitative approach, the main stages of which are: characterization of the site, identification of the dangers of chemical substances, and dose-response relationships (Choice of Toxicological Reference Values (TRV)/Dose-Response Estimation, exposure assessment and risk characterization [11].

- **Exposure assessment**

It is a question of determining the ways, the frequency, the duration and the importance of the exposure. This leads to the determination of the Daily Dose of Exposure (DDE) for an adult of body mass (average mass of the adult population) and a child of body mass (average mass of children in the population studied) [11], [12]. In the present study, only the oral and chronic route of exposure via the consumption of fish was considered.

The average quantities of fish ingested per day are expressed according to the following equation [13]:

$$Q = \frac{\Sigma[\text{Amount (g)} \times \text{\% (Adult or Child)}]}{100}$$

Q = average amount of fish consumed in a day; **Amount (g)**: minimum amount of fish consumed in a day; **% (Adulte ou Enfant)**: percentage of adults or children corresponding to the different quantities; **100**: number of individuals surveyed.

The DDEs were expressed for each MTE according to the following equation [14], [12], [15]:

$$DDE = \frac{C\ x\ Q\ x\ F}{M}$$

DDE = Daily Dose of Exposure (to TME) (mg/kg/d); **C** = concentration of TME in fish tissues (mg/kg); **Q** = daily quantity of fish ingested (kg/day); **F** = Frequency of exposure (day/year) (F = 1); **M** = body mass (kg).

Exposure scenarios where the individual is most exposed (maximalist hypothesis) were used. Indeed, by hypothesis, the average annual quantity of fish ingested by a child will be considered equal to that of an adult. The average quantity of fish offered to a Togolese is 9.2 kg/year (0.025 kg/day) [4]. Also, it was considered that the individual consumes this quantity of fish every day (frequency of consumption equal to 365 days/year).

The average body mass of children from 0 to 15 years is 28 kg and that of an adult is 70 kg [15].

- **Risk characterization**

For threshold effects (non-carcinogenic effects), the Risk Quotient (RQ) was determined for each MTE according to the following relationship [16], [15]:

$$RQ = \frac{DDE}{TDD} = \frac{C\ X\ Q\ X\ F\ X\ T}{RfDo\ X\ M\ X\ Tm} = \frac{DDE\ X\ T}{RfDo\ X\ Tm}$$

RfD_O is the reference dose orally in mg/kg/day. This is the TRV; T is the exposure time (year); Tm is the average period of entire life (year). For threshold effects, the duration of exposure is equal to the average lifetime (T = Tm).

TDD = Tolerable Daily Dose (mg/kg/day). According to the report of the National Institute for the Industrial Environment and Risks (INERIS) [17], [15], for chronic threshold effects, the ATSDR (Agency for Toxic Substances and Disease Registry) recommends for Cd 2.10^{-4} mg/kg/day and for As 3.10^{-4} mg/kg/day, the WHO recommends $3.6.10^{-3}$ mg/kg/day for Pb and the American Agency USEPA for Hg 3.10^{-4} mg/kg/day [18].

If RQ < 1, the occurrence of a toxic effect is very unlikely;

If RQ > 1, the appearance of a toxic effect cannot be excluded.

Data traitment

The counting and analysis of the data collected were both manual and computerized. Data entry, auditing and processing were done by the XLSTAT 2021 software (One (01) factor Analysis of Variance (ANOVA). The calculation of indicators and the production of tables were done with the Excel 2013 spreadsheet.

Results & Discussion

Kalsom Dam Fish Inventory

Table 2: Kalsom dam fish species

	Common name	English name	Family	Species
1	Tilapia barbo	Banded jewelfish	Cichlidae	*Hemichromis fassciatus* **Peters, 1852**
2	Nilotica	Nile Tilapia		*Oreochromis niloticus* **Linnaeus, 1758**
3	Ziri point noir	Redbelly Tilapia		*Tilapia zillii* **Gervais, 1848**
4	Ziri	Tilapia (common name)		*Tilapia sp*
5	Tilapia blanc	Mango Tilapia		*Sarotherodon galilaeus* **Linnaeus, 1758**
6	Mormorus	Trunkfish	**Mormyridae**	*Marcusenius senegalensis* **Steindachner, 1870**
7	Silure (blanche et noire)	North African catfish	**Clariidae**	*Clarias gariepinus* **Burchell, 1822**
8	Sardines	Sardinella	**Clupéidae**	*Sardinella sp*

The survey for the inventory of the ichthyofauna of the Kalsom dam in the Didagou watershed in Dapaong made it possible to identify eight (08) species of fish divided into seven (07) genera and four (04) families: Cichlidae, Mormyridae, Clariidae and Clupeidae. The Cichlidae family contains most of the identified species; five (05) of the species encountered belong to this family. The other families are represented by only one species each. These fish are often found in other fresh waters of West Africa [10]. Moreover, this ichthyological diversity of the Kalsom dam is lower than that of a fairly similar body of water in Togo, the Nangbéto dam (180 km2) where in addition to the families of fish species identified, other families have been identified, namely claroteidae, schilbeidae and mochokidae [19]. Also, for a freshwater body, the Ouemé River (Benin) where one hundred and twenty-two (122) species have been counted, divided into fifty (50) families. But all the time the order in the different families is quite the same: ten (10) species of Cichlidae against five (05) species of Clariidae [20]. It should be noted that the current catches are of lower quantity and quality than previous catches and are essentially made up of fry (especially sardinella which are quite non-existent). This represents a significant danger for the fish stock of the Kalsom dam. The growing intensification of the exploitation of fresh and brackish water fish populations in Africa by permanently increasing local populations and above all the alarming acceleration of all the processes of degradation of the natural environment raises the major risk of regression and species extinction [21], [22].

MTE concentration in the water of the Kalsom dam

Table 3: Results of physico-chemical analyzes of water samples from the Kalsom dam according to the seasons

Parameters	pH		Cond (µs/cm)		Hg (mg/L)		Cd (mg/L)		Pb (mg/L)		As (mg/L)	
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS
Dam water	8.04	7.1	116.7	136.3	0.0004	0.0020	0.0011	0.0052	0.0004	0.0100	0.055	0.0240
Norme WHO(*) - EU	**6.50 – 8.50**		**400**		**0.001***		**0.003***		**0.01***		**0.01***	

DS: Dry Season **RS: Rainy Season**

The results reveal that the water from the Kalsom dam contains excess MTEs with maximum levels of Hg (0.020 mg/L), Cd (0.0052 mg/L), Pb (0.010 mg/L), As (0.055 mg/L) above the maximum limits accepted by the WHO. In addition, MTE concentrations in the rainy season are higher than those during the dry season, except for arsenic (Table 3). The two water samples contain, in descending order, arsenic, lead, cadmium and mercury.
The life of fish in this water or consumption presents risks of contamination of fish and the human body with the consequences of the prevalence of various diseases and physiological disorders within the target population [23], [13]. Indeed, the contamination of aquatic ecosystems by MTEs represents a threat to aquatic life because of their bioaccumulation in the tissues of living species [15].

Bioaccumulation of MTE in fish tissue from the Kalsom dam

The results show that the different species of fish sampled concentrate more mercury, cadmium, arsenic and lead in decreasing order. These results are in agreement with those of [7] who mentioned that the concentration of cadmium and lead in fish is ten times lower than that observed in molluscs, crustaceans and annelids, but fish concentrate more mercury. Also, Marcusenus senegalensis followed by Tilapia zillii concentrated more mercury than the other MTEs, while Sarotherodon galilaeus followed by Clarias gariepenus concentrated more cadmium. As for Oreochromis niloticus, it concentrated more arsenic (almost in the same way as cadmium) than the other MTEs. The bioaccumulation of MTE by the aquatic biocenosis would depend on two (02) factors: the bioavailability of the elements concerned and the physiology of the species [7].

Table 4: Average concentrations of metallic trace elements measured in fish from the Kalsom dam

Scientific name	Mercury		Cadmium		Lead		Arsenic	
	Conc. mg/kg	CF	Conc. mg/kg	CF	Conc. mg/kg	CF	Conc. mg/kg	CF
Tilapia zillii	0.322	0.644	0.2175	**4.35**	0.1875	0.9375	0.02425	**2.425**
Oreochromis niloticus	0.01775	0.0355	0.2375	**4.75**	0.1825	0.9125	0.2425	**24.25**
Sarotherodon galilaeus	0.014	0.028	0.27	**5.4**	0.18	0.9	0.01775	**1.775**
Marcusenus senegalensis	0.60725	**1.2145**	0.3125	**6.25**	0.2175	**1.0875**	0.0255	**2.55**
Clarias gariepenus	0.01867	0.03734	0.26	**5.2**	0.185	0.925	0.015	**1.5**
WHO Norme	0.5	1	0.05	**1**	0.2	1	0.01	**1**

In terms of pollution (Table 4), all fish species sampled in the Kalsom dam were polluted by cadmium and arsenic. High pollution by arsenic was observed in Oreochromis niloticus which concentrated more than 24 times the standard accepted by the WHO for this metal. Marcusenus senegalensis was polluted by all the ETMs studied at different rates. He concentrated Mercury with an excess concentration factor of 1.21, cadmium with an excess concentration factor of 5.20, lead with an excess concentration factor of about 1.09 and arsenic with an excess concentration factor of 1.5. These various findings further confirm the fact that the level of bioaccumulation differs from one MTE to another and varies from one species to another [7].

Analysis of variance (ANOVA)

The results of the one (01) factor ANOVA are recorded in the table below.

Table 5: Analysis of variance (Concentrations of MTEs assayed in fish from the Kalsom dam)

Variable	Mean	Standard deviation	*p-value*
Hg	0.197	0.468	0.290
Cd	0.260	0.079	0.079
Pb	0.191	0.080	0.974
As	0.021	0.006	0.068

The analysis of the results showed that the p-value of all the dosed MTEs is greater than the alpha risk threshold (0.05), i.e. the Null Hypothesis (Ho) is accepted. There is no difference between the average concentrations of the four (04) MTEs measured in the five (05) species of fish. The average concentrations of MTEs do not change according to the species of fish (no significant effect of the species of fish on the average concentrations of MTEs).

Public health risks related to the consumption of fish (*M. senegalensis*) polluted by MTEs

Only *M. senegalensis* concentrated in excess all the measured MTEs. The results of the assessment of exposure to Hg, Cd, Pb and As linked to the ingestion of fish as well as the corresponding risk quotients (RQ) in adults and children are reported in the table below.

Table 6: Assessment of exposure to Hg, Cd, Pb and As linked to the ingestion of *Marcusenus senegalensis*

MTE	Q (kg/day)	C (mg/kg)	M (kg)		DDE (mg/kg/day)		TDD	RQ	
			Child	Adult	Child	Adult		Child	Adult
Hg	0.025	0.607	28	70	$5.4.10^{-4}$	$2.2.10^{-4}$	3.10^{-4}	**1.81**	0.72
Cd		0.313			$2.8.10^{-4}$	$1.1.\ 10^{-4}$	2.10^{-4}	**1.40**	0.56
Pb		0.218			$2.0.10^{-4}$	$7.8.\ 10^{-5}$	$3.6.10^{-3}$	0.05	0.02
As		0.026			$0.2.10^{-4}$	$9.3.\ 10^{-6}$	3.10^{-4}	0.07	0.03
			ΣRQ					**3.34**	**1,33**

According to the exposure scenarios mentioned above, the occurrence of a toxic effect from mercury and cadmium linked to the consumption of fish from the Kalsom dam is unlikely (RQ_{Cd} = 0.56 and RQ_{Hg} = 0.72 < 1) in the adults. Whereas, toxic effects in children (RQ_{Cd}=1.40 and RQ_{Hg}=1.81 > 1) can be expected due to their low body weight. There is no risk of toxic effects linked to lead and arsenic with regard to the consumption of Marcusenus senegalensis from the Kalsom dam in both adults and children (RQ_{Pb} and RQ_{As} < 1).

Our results are contrary to those of [15] who, in a similar study on fish from the Togolese lagoon system (South Togo) recorded arsenic hazard quotients for adults (17.64) and for children (44.11) which are all well above 1; this could lead to arsenic-related toxic effects on the population consuming these fish. Thus, children pay a double price for this pollution because, not only are they more exposed, their organism is more fragile. Children are more exposed since they consume, in relation to their mass, more than twice as much food as adults and contaminants are more easily absorbed into their bodies. Ingested contaminants, such as MTEs, can be even more harmful to them. The child's body potentially absorbs more contaminants and cannot eliminate them as easily as adults because their evacuation system is less developed [24].

This study only concerned oral and chronic exposure through fish. However, there are other sources of exposure such as the consumption of other contaminated foods of animal or plant origin [6], [15], [25], contaminated ground and surface water [26] and the inhalation of dust from landfills containing high concentrations of MTE

[27]. Thus, it is essential to carry out regular checks of this ecosystem in order to prevent any public health problem.

In fact, pesticides, like MTEs which are the degradation products of certain pesticides, can reach bodies of water and groundwater through runoff and leaching. According to the report of the Ministry of the Environment and Forest Resources in 1995, the risk is increased when intense rain occurs shortly after spreading. Depending on their concentration in the water, they can affect the different components of the food chain such as fish.

Nowadays, in view of our results, we can say that the level of pollution of the Kalsom Dam has reached a worrying level. Indeed, the problem of pollution from the Kalsom dam is a fundamental problem. The population of Dapaong is only increasing day by day. The amount of sewage and household waste discharged into this dam will therefore also increase in the coming years, it becomes urgent to implement a sewerage network in Dapaong.

Conclusion

The results of this study reveal that in the Kalsom dam, there are eight (08) species of fish divided into seven (07) genera and four (04) families. The Cichlidae family with five (05) species is more represented. All the species of fish analyzed concentrated in levels above the standard set by the WHO for cadmium and arsenic. The maximum excess concentration of arsenic is observed in Oreochromis niloticus (24 times the WHO standard). For cadmium, the maximum excess concentration is observed in Marcusenus senegalensis (6.20 times the WHO standard). The latter species also concentrated in excess all the MTEs dosed at different rates. Its consumption would cause toxic effects in children from mercury and cadmium, which have danger quotients greater than 1 ($RQCd = 1.40$ and $RQHg = 1.81 > 1$).

Thus, the level of contamination differs from one metallic element to another and varies from one species to another.

In view of the degradation of the chemical quality of the fish from the Kalsom dam analyzed, it is essential to take action to reduce the negative impact of this pollution on the health of humans who are at the end of the food chain.

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