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# Bioaccumulation of Lead and Cadmium Residues in Fish and Shrimp at Different Stages of Development in the Nokoué-Channel Lagoon Complex in Southern Benin

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ABSTRACT

At different stages of their development, we studied the bioaccumulation of lead and cadmium residues in fish species *Tilapia guineensis, Sarotherodon melanotheron*, *Hemichromis fasciatus* in Nokoué lake and *Dicentrarchus labrax*, *Selene dorsalus* and shrimp in Cotonou Channel. The methodology adopted was to identify the species and collect the muscles in these different species of fish and shrimp at different stages of their life's development. Fishery products in situ and water samples taken are sent to the laboratory in coolers maintained at 4 ± 5 °C for the quantitative analysis of lead and cadmium residues by spectrophotometry. The results of the analysis show that lead residues are more accumulated in younger species than in adults in *Sarotherodon melanotheron* and *Hemichromis fasciatus*, unlike *Tilapia guineensis*. On the other hand, cadmium is weakly present in water and in aquatic fauna and some traces of cadmium residues are found in the Cotonou Channel, notably at the height of Dantokpa market. The water-based lead bioconcentration factors are significantly greater than the unit showing the predominance of particulate lead exposures of sedimentary origin. The lifestyle of the fish species would be the main factor explaining these results.



## 1. Introduction

The large number of streams, rivers, lakes, etc. form the basis of a fishery whose production is estimated at over 30 000 tons per year in 2007 in Benin. Continental fishing is little known, but it is a very important activity for neighbouring communities because of its job-generating nature and above all as a source of protein for the entire population. But aquatic environments are often degraded because of inadequate sanitation, poor waste management and urban wastewater. The Channel-Nokoué lagoon complex is not immune to this phenomenon, which is taking on ever more worrying proportions (Youssao et al., 2011a). It is indeed, the Nokoué -Channel lagoon complex is the main receptacle of urban effluent discharges contaminated by residues resulting from anthropogenic activities (Soclo et al., 2002, Soclo et al., 2000). However, following the introduction of metallic contaminants into aquatic environments, these are distributed between the water column, the interstitial water covering the sediment and the solid phases consisting of sediments, suspended particles and biota. Depending on the hydrodynamics of aquatic environments, biogeochemical processes and environmental conditions (redox, pH, salinity and temperature), aquatic organisms are more or less contaminated. Sediments are recognized as an important sink for heavy metals in aquatic systems, as well as a potential non-point source that can directly affect overlying waters (Mama et al. 2011). However, water resources are one of the most sensitive and useful environmental components for living things. In spite of the important services that it offers to the human beings and because of its limited capacities, the aquatic environment cannot assure the self-purification of all these toxic discharges of anthropogenic origin in urban environments mainly in the African capitals which do not have not yet sufficiently integrated an efficient system of total waste management (Youssao, 2011). The assessment of the impacts of discharges by the measurement of pollution indicators has in many ways highlighted the threats to the survival of living organisms, creating the loss of the most sensitive species and the degradation of the quality of the resource's fisheries. The tendency of heavy metals to accumulate in living organisms makes them more dangerous for organisms at the top of the food chain including humans. The main purpose of this research is to study the contamination of living aquatic organisms by metals in relation to their living environment (sediments, water) and the stage of their development. Specifically, the aim is to determine the contamination of water and some fish species in the Channel-Nokoué complex with Pb and Cd residues and to evaluate the bio concentration factors with respect to water (BCFw).

## 2. Material and methods

### 2.1. Area of the study

The Channel-Nokoué lagoon complex consists of Lake Nokoué which is located between the parallels 6°20 'and 6°30' North and the meridians 2°20 'and 2°35' East and the channel of Cotonou, located in the South. East of Benin,

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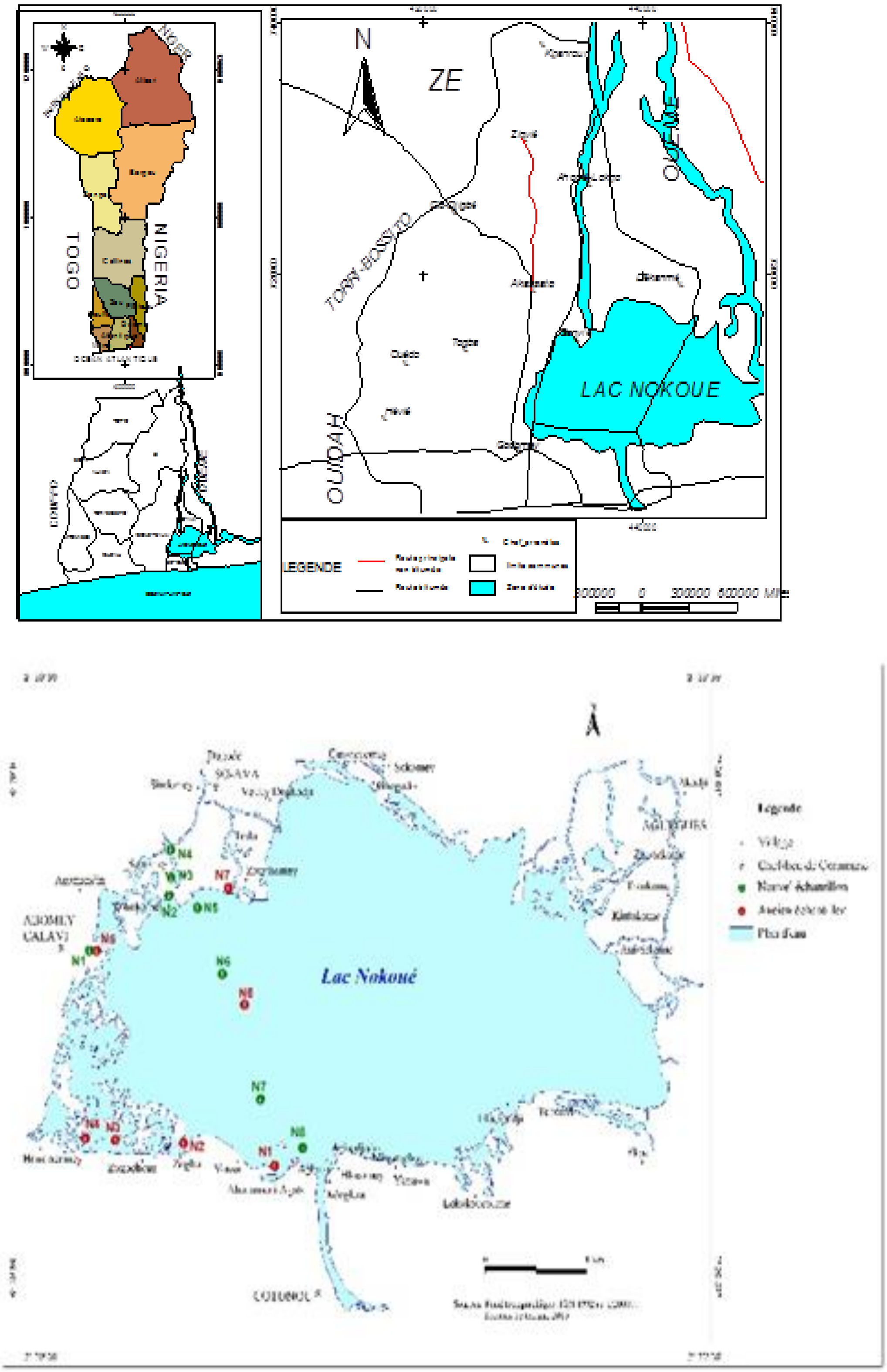
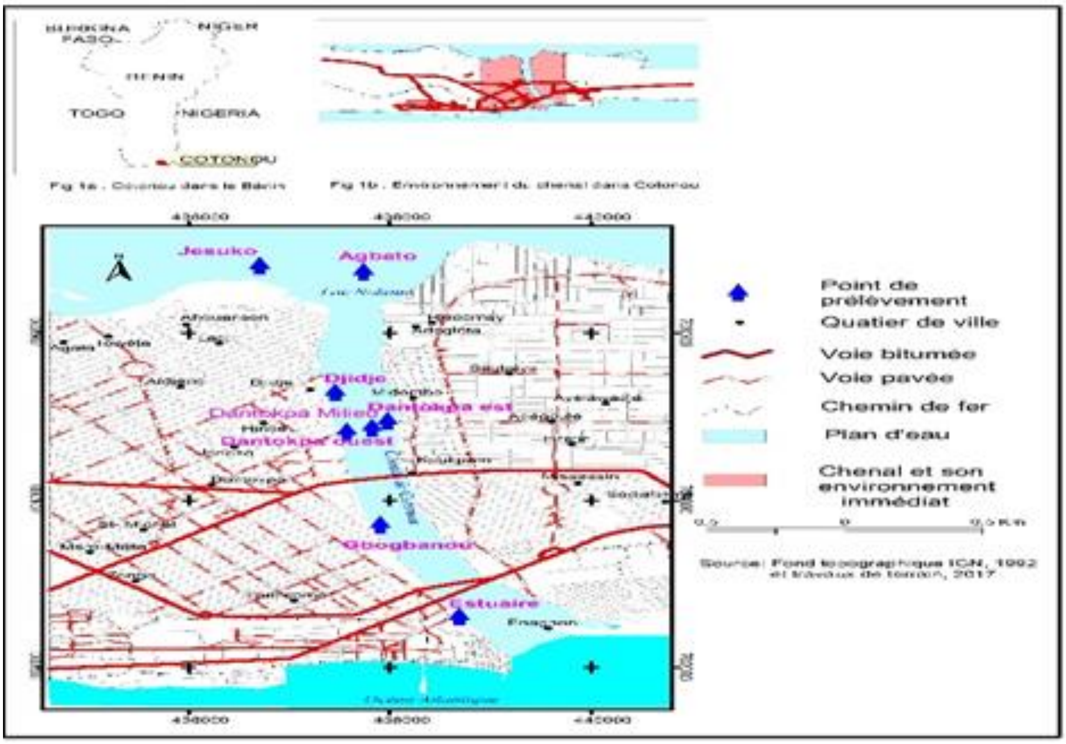
between the parallels 2°26'30 " and 2°26'22 " North and the meridians 6 ° 20 'and 6 ° 23' East. Nokoué Lake stretches from East to West about 12 km length and from North to South 7 km wide parallel to the Atlantic coast from which it is separated by a coastal strip. It is connected to the Atlantic Ocean by the Channel of Cotonou whose whole is designated by complex Nokoué-Channel lagoon. The banks of Lake Nokoué are swampy and its depth does not exceed two (02) meters whereas the Cotonou Channel can reach depths of up to five (5) meters in the central part to the banks. With an area of approximately 160 km2, it covers three departments: Littoral, Atlantique and Ouémé. Nokoué Lake is located in the lower valley of the Ouémé River and the Sô River. The Cotonou lagoon is crossed by three bridges and cuts the city of Cotonou in two parts from which it receives the runoff through fifteen gutters and large collectors whose outlets open there. It is a North-South canal currently 4500 m length with an average width of 300 m (Figure 1). It constitutes an area of 1,35 km2. Its function is to limit the saline intrusion into Lake Nokoué during the dry season while avoiding the flooding of the city of Cotonou during the floods due to the drained waters of the north and those of the city of Cotonou.




**Lake Nokoué**




**Channel of Cotonou**
**(Old sites in red and new ones in green)**
**Figure 1. Location of the study area and sampling points**

The population of the lake and riparian settled in this area is estimated at 90,000 inhabitants with an average density of 282 per $km^2$ (INSAE, RGPH, 2002). The population is mostly fishermen. 80% to 90% of the active people practice traditional fishing with various techniques. Uncontrolled dredging and "acadja" fishing techniques practiced by the Toffin populations of Ganvié and Zogbo have greatly modified the hydrodynamic, physicochemical and ecological conditions of the lake. Today, fishermen no longer earn substantial income from fishing because of the reduction in fish size.

### 2.2. Sampling

The water sampling sites were chosen taking into account the human presence and the activities that take place there. Thus, eight sites were selected at the lake level and seven sites on the Cotonou Channel. These are Calavi (CAL), Ganvié market (GAN_M), Ganvié center (GAN-C), Soava (SO_A) at the mouth of the river Sô and four sites at the central zone of the lake: Middle 1 (M-$LAC_1$ ), Middle 2 (M-$LAC_2$), Middle 3 (M-$LAC_3$) and Jesuko (JES) for Nokoué Lake and Estuary (EST), Gbogbanou (GBO), Dantokpa West (DAN-W), Dantokpa Middle (DAN-M), Dantokpa East (DAN-E ), Djidje (DJI) and Agbato (AGBA) for the Channel of Cotonou. For laboratory analyses, water samples were collected in high density polyethylene containers, washed repeatedly with 2% (v / v) nitric acid in deionized water. Different species of fish and shrimp are collected in the field from fishermen in their fresh catch including *Hemichromis fasciatus*, *Sarotherodon melanotheron* and *Tilapia guineensis* for Lake Nokoué and *Dicentrarchus labrax* (DL), *Selene dorsalus* (SD), marine shrimps of the genus *Penaeidae* (SHR) and an unidentified marine fish species (MFS) in the Cotonou Channel. The water, fish and shrimp samples were kept in a cooler with ice packs and transported to the laboratory at 4 ± 5°C.

### 2.3. Treatment and analysis

Samples of water and living materials are first removed from the refrigerators to bring them back to normal temperature and then mineralized according to the methods used by Youssao (2011). The standard and total lengths of the fish samples were measured and the flesh of the fish samples was taken after dissection and then the muscles were isolated to be pounded in a mortar according to the method used by Youssao et al. (2011a & b). A blank without sample of fish or water is made with the same reagents and under the same conditions. Thus, the solutions obtained are analysed with Spectroquant pharo 100 spectrophotometer in using the kits. The lead residues were tested by a lead kits 1.0971.001. According to the principle of the method, the Pb (II) ions in the mineralized samples form with the (pyridyl -2'-azo) -4-resorcinol (PAR) a red complex which is analysed with Spectroquant Pharo 100 spectrophotometer. Cd was determined by atomic absorption spectrometry after mineralization of water and living material samples**.**

## 3. Results and discussion

### 3.1. Concentration of lead in water of Nokoué Lake

Lead levels in mg/L range from 0.6 to 1.6 in water samples in Nokoué Lake are presented in Table I. The highest and lowest values are recorded in the central area of the lake. These values being higher or lower than those obtained on the other sampling sites, it can be deduced that the metallic pollution is therefore not uniform on this water body.

The contamination of surface waters, sediments and aquatic species by trace metals has become a major concern today (Youssao, 2011).

In the Nokoué-Channel lagoon complex, water and fish resources have been contaminated by lead and concentrations vary according to the sampling sites. The values recorded at Calavi, Ganvié market and Mid Lake2 of the central lake area are significantly high. Water pollution from these heavy metals could be explained by the fuel traffic through this lake over several decades and the drained water from the northern part of the lake.

**Table I. Variation of the lead content in the water of Nokoué lake.**

| Sampling sites | CAL | GAN-M | GAN-C | SO-A | JES | M-LAC$_1$ | M-LAC$_2$ | M-LAC$_3$ |
|---|---|---|---|---|---|---|---|---|
| | N$_1$ | N$_2$ | N$_3$ | N$_4$ | N$_8$ | N$_6$ | N$_7$ | N$_5$ |
| **Pb (mg/L)** | 0,9 | 1,1 | 1,5 | 1 | 0,9 | 1,6 | 0,6 | 0.8 |

**Table II. Concentration of Pb and Cd in the Cotonou Channel.**

| Sampling sites | EST | GBO | DAN-W | DAN-M | DAN-E | DJI | AGBA | Average |
|---|---|---|---|---|---|---|---|---|
| **Pb (mg/L)** | 3.5 | 1.7 | 0.3 | 0.7 | 0.5 | 0.5 | 0.6 | 1.1 |

### 3.2. Concentration of lead in water in Cotonou Channel

Basing on the results in Table II, the average levels of lead residues were estimated at 1.1 mg/L in water. Pb concentrations in water range from 0.3 mg/L at Dantokpa West to 3.5 mg/L at the Estuary.

Suspended matters are the most important sources of dissolved oxygen consumption and are the primary carrier for lead residues that are ingested either orally or through the gills in the body of fish (Youssao 2011). These results are in accordance with the highest values of lead level recorded in the water at estuary and Gbogbanou where there are sandy sediments with low retention capacity of particles (Youssao, 2011). This result explains the asymmetry of contamination levels on the Dantokpa cross-section with greater pollution at the market site (Middle Dantokpa). Indeed, under favorable hydraulic conditions, the particles in suspension with the contaminants they contain can be deposited on the bottom of the lagoon, and thus act as an important source of contamination (Lin et al., 2008).

Different works on water contamination confirm this state of affairs. Traore et al. (2015) assessed Pb in lagoon waters in Côte d'Ivoire. The concentrations found by the latter are lower than ours (19.17 ± 1.93 µg/L) but these values are below the standards that are Pb ≤ 10 µg/L (WHO, 2011). Similarly, from the results obtained in the water of Sitnica and Trepca rivers Kadriua et al. (2017) found levels that ranged from <0.001 to 0.701 mg/L for Pb. These results are well below ours. Similar results are observed with Abdou Khaled et al. (2016) who found values between (0.247 ± 0.120) mg/L and (1.127 ± 0.129) mg/L across several rivers in several districts of the country. Edward et al. (2017) have also studied in the dry and rainy seasons, the evolution of Pb concentrations in the Ureje River in southwestern Nigeria. In the dry season the concentrations were below the detection limit whereas in the rainy season these concentrations ranged from 0.05 to 0.80 mg/L. Similarly, Kabunga et al. (2013) also investigated metal pollution in 74 localities of Zambia for the average concentration the result was 0.03 mg/kg. All these results are inferior to ours. The high values of Pb in water of Nokoué lake and Cotonou Channel are due to the fact that this complex is the place of discharge of the effluents resulting from the activities of dyeing and where daily garbage is dumped and other solid residues. Contrary to the results of this study, Chouti et al. (2010), (Pb: 2.35 mg/L ) report higher levels of heavy metals in this ecosystem than in this study. The variations can be explained by the fact that the sampling periods and the collection stations are not identical and that the Nokoué Lake is a hydrodynamic system influenced by marine and continental inputs bringing about seasonal variations. However, Youssao et al (2011) (Pb: 1.47 mg/L) recorded concentrations in the same body of water in the range of the present study (0.6 to 1.6 mg/L).

### 3.3. Concentration of lead in living species in Nokoué Lake

For the species of Lake Nokoué, the results show that the contents vary between:

-1.6 mg/kg and 1 mg/kg respectively in the species *Hermichromis fasciatus* young and *Hermichromis fasciatus* medium;

-9.7 mg/kg and 10.4 mg/kg respectively in the species *Sarotherodon melanotheron* adult and *Sarotherodon melanotheron young*;

-11.9 mg/kg and 5.4 mg/kg respectively in adult *Tilapia guineensis* and young *Tilapia guineensis*, which are above the international standard of 0.3 mg/kg in fish (EU, 2005; FAO / WHO, 2011).

The average content of lead stored in living materials is 6.64 mg/kg, it is considerably higher than that of Youssao et al. (2011a) which is 1.41 mg/kg. The average value of recorded lead (5.73 mg/kg) for Tilapia guineensis exceeds that obtained by Yèhouénou (2013) which is 0.749 mg/kg for the same species.

In view of the results obtained, it can be confirmed that the fish are more contaminated by sediments since they also live in the benthic compartment. These sediments thus adsorb the lead on sedimentary particles and under the action of the movements of these same fish or dredging sandy activities, the lead particles are released into the water column. Thus, the contamination follows its path along the trophic chain.

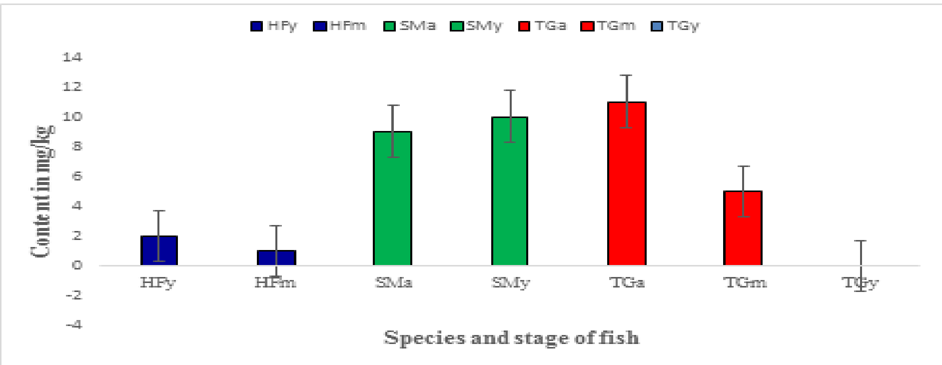



**Figure 2. Concentration of lead in the various fish species of Lake Nokoué at different stages of their development.**
HFy = *Hemichromis fasciatus* young; HFm = *Hemichromis fasciatus* medium. ; SMa = *Sarotodon melanotheron* adult; SMy = *Sarotherodon melanotheron* young. ; TGa = adult *Tilapia guineensis*; TGm = mean *Tilapia guineensis*; TGy = *Tilapia guineensis* young

**Table III. BCFw of Pb in the different fish species of Nokoué Lake and Cotonou Channel.**

| | Nokoué Lake | | | Average | Channel of Cotonou | | | Average |
|---|---|---|---|---|---|---|---|---|
| **Fish species** | HF | SM | TG | | DL | SD | SHR | |
| **BCFw (Pb)** | 1.24 | 9.55 | 8.19 | 6.33 | 1.25 | 1.7 | 3.2 | 2.05 |

- means not determined

According to the results shown in Figure 2, we note that in the species *Hemichromis fasciatus* and *Sarotherodon melanotheron*, the concentration of lead in the flesh of small fish is higher than that in the flesh of large fish. On the other hand, as for *Tilapia guineensis* the lead concentration decreases from large to small. The average value of the concentration of lead in the living mass is 6.64 mg/kg.

Considering the different species and their stages, the lead bioconcentration factors in the flesh of the fish obtained compared to water vary from 0 to 11. The species *Sarotherodon melanotheron* have a higher BCFw value than average as well as adult *Tilapia guineensis*. The BCFw of *Hemichromis fasciatus* is close to that of *Dicentrarchus labrax* which is a brackish water fish. The BCFw average for lead in the living mass is 6.33 for Nokoué Lake species and 2.05 for Cotonou Channel (Table III).

Although Tilapia species are planktonic, they tend to move closer to the benthic zone in search of their food. Thus, they are easily contaminated by sediments that contain large amounts of lead. This could be explained by the fact that these fish also live in the benthic compartment, which is a place where eggs are laid and fertilized. Under the action of the movements of these same fish or the dredging activities by the humans, there is contamination of the water column and through the matter in suspension the contamination of the aquatic beings.

### 3.4. Concentration of lead in living species in Cotonou Channel

The average values of water concentrations in Pb are presented in Table II below and the concentrations of Pb according to the stage of the species are shown in Figure 3.

The mobility of the metal is reduced because it is in a small quantity in the water column. On the other hand, the bioconcentration factor in aquatic fauna compared to water shows that although strongly bound to sediments, a large fraction migrates in the food chain. This means that these species are in direct contact with the sediments either during feeding or by other mechanisms such as the resettlement by water movements due to waves or other factors such as river transport.

As for the different species of fish studied in the Cotonou Channel, the levels of lead in the flesh vary between 0.95 ppm and 1.8 ppm respectively in the young and adult species *Dicentrarchus labrax* whereas the species of *Selene dorsalis* have an average of 1.9 ppm close to these. The highest contamination is obtained in marine shrimp with an average content of 3.5 ppm. BCFs relative to water are relatively low. These concentrations of lead residues in fisheries resources exceed international standards (EU, 2005, FAO / WHO, 2011); this would be favoured by remobilization of the stocks contained in the surface sediments.

Megnon et al. (2012) found a lead content in shrimp of 1.55 mg/kg but a value of 0.09 mg/L in water. The content obtained in this research work is superior to that of Megnon et al. (2012).

Table III above shows the bioconcentration factor of the species studied in relation to water. In general, all species of aquatic fauna accumulated more lead than their living environment because the bioconcentration factor relative to water is on average greater than unity. This phenomenon is more noticeable in marine shrimps than different species of fish. In fish species, we can note a difference in behavior with respect to the metal according to stage; young species have smaller ratios highlighting chronic contamination in *Dicentrarchus labrax*. Samples of the species *Selene dorsalis*, of almost the same stage, have close BCFs. In conclusion, water is not the main source of contamination of aquatic fauna in the study environment. Sediments are a storage tank for large quantities of lead. These species have a lower BCFw than the species of Lake Nokoué except *Dicentrarchus labrax* which has a BCFw equal to that of *Hemichromis fasciatus* which is the least contaminated fish. The two marine species (MF adult and young) sampled in the Cotonou Channel showed Cd contents below the detection limit.

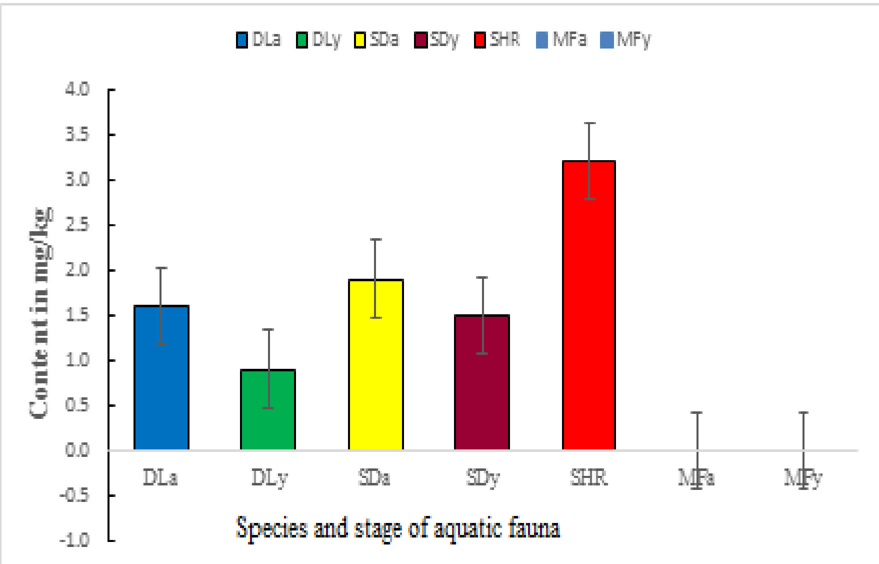



**Figure 3. Concentrations of lead residues in Cotonou Channel fish and shrimp species at different stages of development**. DLa= *Dicentrarchus labrax* adult; DLy = *Dicentrarchus labrax* young.; SDa = *Sarotodon melanotheron* adult; SDy = *Sarotherodon melanotheron* young.; MFa: Marine fish adult; MFy: Marine fish young; SHR= shrimp.

### 3.5. Concentration of cadmium in water

**Table IV. shows the Cd concentrations in the two study areas lagoon complex.**

**Table IV. Cd concentrations (µg/L) in the water of the Nokoué - Chenal of Cotonou.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Lake Nokoué sites** | | | | | | | | |
| | CAL | GAN_M | GANV_C | SO_A | $M\_LAC_1$ | $M\_LAC_2$ | $M\_LAC_3$ | JES |
| Cd (µg/L) | <DL | <LD | <LD | 44.8 | <LD | <LD | <LD | <LD |
| **Sites of Cotonou Channel** | | | | | | | | |
| | EST | GBO | DAN_O | DAN_M | DAN_E | DJI | AGBA | Mean |
| Cd (µg/L) | <LD | 2.8 | 36.8 | 11.2 | <LD | 26.2 | <LD | 11.0 |

<DL: lower than Detection Limit

From this table, it appears that only the water sample of Sô_Ava has a cadmium concentration higher than the detection limit of the device (44.8 µg / L). This point is located at the mouth of the river Sô. On the other hand, in the Cotonou Channel, the average rate is estimated at 11.0 µg/L, neglecting the values below the detection limit. Cd concentrations ranged from <DL at 36.8 µg/L to Dantokpa West at the large market level.

Traore et al. (2015) assessed Cd in a lagoon waters in Côte d'Ivoire. The concentrations found by the latter are higher than ours Cd (0.1 ± 0.03) but these values are inferior to standards which are: Cd ≤ 3 µg/L (WHO, 2011). Similarly, from the results obtained in the water of Sitnica and Trepca rivers Kadriua et al. (2017) found levels that are <0.001 mg/L. These results are close to ours. Similar results are observed with Abdou Khaled et al. (2016) who found values between (0.004 ± 0.001) mg/L and (0.029 ± 0.0006) mg/L for Cd across several rivers in several districts of the country. Kabunga et al. (2013) also investigated metal pollution in 74 localities of Zambia and found nothing for Cd. Contrary to the results of this study, Chouti et al. (2010) (Cd: 0.10 mg/L) report higher levels of Cd in this ecosystem than in this study. The variations can be explained by the fact that the sampling periods and the collection stations are not identical and that the Nokoué Lake (an area close to Porto-Novo) is a hydrodynamic system influenced by marine and continental inputs bringing about seasonal variations.

### 3.6. Concentration of cadmium in fish species

**Table V. Cd Concentrations in Lake Nokoué Fish Species.**

| **Species** | Cd in fish flesh (µg/kg) |
|---|---|
| Sarotherodon melanotheron | 2.5 |

Among all of the fish and shrimp species in the lagoon complex, only Sarotherodon Melanotheron has a cadmium level of 2.5 µg/kg above the detection limit of the method (Table V). Adewumi et al. (2017) also studied three fish species (*C. gariepinus*, *P. obscrura*, *T. zilli*) and the results for Cd vary between ND and 4.9 mg/kg (*C. gariepinus*) and between 0.05 and 161.9 mg/kg (*P. obscrura*). All these results are higher than the values found in this study. Traoré et al. (2015) founded in the shrimp samples Cd concentration ranges from 0 to 0.26 mg/kg, with an average of 0.02 ± 0.01 m/kg. These results are largely higher than that obtained in this research. All these values are higher than the norms**.**

### 4. Conclusion

To sum up, the concentrations of lead residues in fisheries' resources are higher than international standards (EU, 2005, FAO / WHO, 2011) in contrast to cadmium. There are therefore major threats to people's health and the survival of the most sensitive species and their sustainability. These higher values would be favored by remobilization of the stocks contained in the surface sediments by the tidal movements of the water mainly in Cotonou Channel and the mineralization of the organic matter which leads to an acidification of the Nokoué lake environment. The water-based bioconcentration factors (BCFw) show that Pb residues in aquatic fauna are derived from lake waters and sediments, as well as from foods they consume. The accumulation of lead in aquatic organisms depends on the stage of development. The species, the youngest of which are the largest accumulators of lead residues, are missing a development stage (adult for *Hemichromis fasciatus* and medium for *Sarotherodon melanotheron*). The reduction in fish size could be explained by the accumulation of metal residues in the biota. It is necessary to find an appropriate system of waste management, especially in lake human settlement and illegal fuel business.

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