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Bioaccumulation of some metal elements and micronutrients in the gills and the muscle of sunfish (*Lepomis gibbosus* Linnaeus, 1758)

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ABSTRACT

With the increasing development of industrial activity and increasing the action of man in nature, the quality of the environment continues to deteriorate. Thus, the assessment of environmental quality, including the water is a necessity.

In the present work we have evaluated the degree of metal contamination of gills and consumable muscle of *Lepomis gibbosus* Linnaeus (Fish, Centrarchidea). To do this the concentrations of seven elements (lead, cadmium, manganese, chromium, nickel, copper, zinc) were measured in three compartments "water-gill-muscle". The study environment is Lake Fouarat which is near the city of Kenitra (Morocco).

The results showed that for these metals, the concentrations recorded either in the gills or in consumable muscle or in both of them the concentrations were higher than those recorded in the water. The degree of concentration of many metals varies depending on the organ type and / or depending on the size or age of the fish.

The results further show that this bioaccumulative fish of metals could be used as a biological tool to assess the metallic quality of the environment. And, its fishing should be prohibited in areas metallically polluted.

KEYWORDS

Metal elements;
Lepomis gibbosus;
Biaccumultion;
Muscle;
Gills;
Morocco.

INTRODUCTION

Heavy metals and micropollutants are likely to accumulate in the bottom sediments of rivers and suspended matter transported by these courses. They are able to disrupt life in the rivers and lakes, either directly (exposure to pollutants) as the case of fish, or indirectly through contamination biocenosis through the trophic chain[1].

Indeed, in the gill of the aquatic breathing species, including fish, heavies metal act biochemical systems of the cell by their specific toxicity; they react specifically with thiol groups (TH) of the enzyme proteins[2].

Moreover, according the growing industrialization, the quality of the environment, especially of this aquatics, decreases. So, the monitoring of these environments has become a necessity. This monitoring is done by estimating the number of physico-chemical parameters or the biological indicators. These are a typical species living in an ecosystem used to assess the environmental conditions. Note that the evaluation of the degree of pollution of an ecosystem by the determination of the level of the pollutants in the body of these bioindicators has several advantages compared to analysis based on the abiotic components of the biotope. Indeed, these creatures incorporate levels of contaminants that have bioaccumulated throughout a period ; it is this phenomenon that gives them a higher importance[3].

Thus, in this work we have evaluated the degree of accumulation of certain heavy metals in the gills and the muscle of *Lepomis gibbosus* (Linneatus, 1978), a fish potentially consumed by the human indigenous population, in a stagnant water, the lake Fouarat, which is near the city of Kenitra (Morocco).

MATERIALS AND METHODS

Studied fish

Lepomis gibbosus L. belongs to Centrachidea family, Perciformes Order Actinopterygiis Class. It lives in the warm waters calm and shallow with a moderately abundant vegetation in streams with low current or stagnant. Its size rarely exceeds 15 centimeters and its growth depends on the environmental conditions. It is primarily carnivorous and feeds on aquatic insect larvae (Trichoptera, Coleoptera, etc..), Snails, daphnia and fish fry. For three size classes (Size I = 6 cm, Size II = 9 cm, ad Size III = 12 cm), corresponding to three age classes, the content of metallic elements was measured in the gills and the muscle of the studied fish. For each class the gills and the muscle of four individuals were analyzed.

Living environment of the studied fish : Lake of Fouarate

It is located between 35 ° 15 ‘north latitude and 6 ° 30’ longitude in the north of the Kenitra city (Morocco). Its impoundment is mainly from precipitation, flows of the river of Fouarat and wastewater. Its waters are used for irrigating crops and watering livestock. In addition, the lake is a source of fishing for several species of fish which are marketed throughout the region providing then a possible feed source. Note also that the lake of Fouarat is located near a major urban center Kenitra city that knows a great expansion, which it generates much wastewater and a significant source of pollution and degradation to the biotope.

The metallic elements evaluated

In the water of the biotope and the gills and the muscle of the fish we evaluated the concentration of seven metallic elements, namely lead, cadmium, manganese, chromium, nickel, copper and zinc in two stations, S1 and S2, of the living environment. Recall that, for all metallic elements, the concept of toxicity is closely related to the dose limit. Thus, all metals can be toxic if the incorporated amount exceeds a certain threshold.

Methodology of assessing metal elements

The evaluation of the contents of metallic elements was carried out by atomic absorption spectroscopy, which is to carry the elements of the atomic state in the same path of a light ray and the simultaneous measurement of the absorption at length wave specific atoms. The proportionality between absorbance and the concentration is used to calculate the contents of previously mineralized samples

RESULTS AND DISCUSSION

Results

Heavy metals in the aquatic biotope

The TABLE 1 shows the concentrations of the studied heavy metals recorded in the water of the environment life of the studied fish.

Lead

The results show very high concentrations of lead,

TABLE 1 : Concentrations (in µg) of the metallic elements in the water of the lake of Fouarate

Stations	S1	S2	Average
Copper	10	10	10
Zinc	140	< limit of detection	70
Chromium	10	10	10
Lead	7100	2300	4700
Cadmium	170	10	90
Nickel	40	50	45
Manganèse	168	123	146

especially at the S1 station. These concentrations, which exceed the Tcified in Moroccan project of the quality standards for surface waters[4] (TABLE 3), could be attributed to the discharge of wastewater containing waters of cleaning service stations of fuel and the water of leaching of roads in the vicinity of the lake which are normally rich in lead that from exhaust emissions from cars.

Manganese

The concentrations of the metal are less important than the lead concentration, but they are even relatively high especially at the F1 station. Note that manganese is an element quite answered in nature which, in turn, provides a natural source of pollution, as it could be of fertilizers or of an effluent of a textile located nearby

Cadmium

The illustrated concentrations were low. These low levels are explained by the fact that, usually, this metal is found in low concentrations in nature. Also, the use of this metal was low because it has not a high quantitative participation in the nearby industrial to the lake. thus, the wastewater does not contain enough of this chemical element.

Zinc

The concentration in the water was high. The wastewater could be a major source of this metal element. In fact, zinc is widely used in industry in various forms: alloy castings, parts, zinc oxide, zinc sulfide, etc. Thus, the wastewater discharged into the lake could be loaded zinc. Also note that the "zinc" products usually contain other metals (e.g, Pb, Cu, Fe, Cd) which strongly influence the profitability of their operations.

In nature, zinc is also found in sediments from the erosion of primary deposits. The main minerals containing zinc are: sphalerite, wurtzite, smithsonite, calamine, willemite, zincite

TABLE 2 : Grid of the quality of the surface water about some heavy metals[4]

Quality class	Pb µg/l	Cr µg/l	Cd µg/l	Ni µg/l
Very good	≤ 10	≤ 50	≤ 3	≤ 20
Good	≤ 10	≤ 50	≤ 3	≤ 20
Average	10-50	≤ 50	3-5	20-50
Bad	> 50	> 50	> 5	< 50
Very bad	-	-	-	-

The copper, chromium, nickel

At both stations, these elements have very lower concentrations than those of other elements. Most likely, the cause of environmental pollution by these metals is anthropogenic

Levels of heavy metals in the gill and consumable muscle

Results are shon in TABLE 3:

Lead

Analysis of lead levels shows that, regardless the size of the fish, lead concentrations in the gill and in the muscle are high. So it seems that at any age, species accumulates, indifferently the organs studied.

Cadmium

The recorded concentrations are low in the gills, especially in the size classes II and III of individuals. So, the young people accumulate more of metallic elements in their gills.

Unlike, in the muscle this toxic metal is accumulated preferentially in the other two size classes II and III. So,there is some correlation between the amount of accumulated metal and the fish size class.

Manganese

The results have shown that the concentrations of

TABLE 3 : Concentrations of metal elements in the gills and the muscle

		Concentrations (in µg / g) of the studied metallic elements in the sunfish of the Lake Fouarte							
		Lead	Cadmium	Iron	Manganese	Chrome	Nickel	Copper	Zinc
Gilles	Size 1	0,22	0,011	182	14,9	1,1	4,08	1,99	23,81
	Size 2	0,53	0	212	14,9	1,1	1,91	1,93	27,02
	Size 3	0,16	0	410	12,7	1,93	5,09	2,01	17,6
Muscle	Size 1	0,65	0	20	2	0	1,1	1,51	5,55
	Size 2	0,34	0,009	19	1,6	0	0,6	1,52	5,34
	Size 3	0,23	0,012	24	0,15	0	1,59	1,54	5,46

manganese in the gills are higher than those noted in the water, and there is no noticeable correlation depending on the size of the fish. Thus, these organs are selective bioaccumulteurs or active manganese.

For muscle, the results show that, for all sizes of fish, manganese concentrations are very low.

Chromium

The accumulation of chromium in the gills was noticeable in all fish size classes but the highest concentration is raised by the sizes II and III of individuals. IN the muscle, we have noted a complete absence of this metal in all analyzed sizes of the fish.

In addition, in the water, the concentrations of chromium were very low and often undetectable. Thus, we can say that the gills are selective bioaccumulators of the chromium with a preferential accumulation in size II and III of individuals. So, these are older people who accumulate more chromium in gills.

Nickel

The concentrations noted in the gills were high. While in the water, these concentrations were low. Thus, the gills are selective Nickel batteries.

For cons=corn, the concentration of Nickel noted in the muscle was weak. So, it seems that the gills are selective accumulators of the Nickel, by against; the muscle is a passive accumulator of this metal.

Copper

In the gills, the recorded concentrations were higher than those observed in the water regardless of the size analyzed by individuals. In contrast, in all sizes studied, the concentrations noted in the muscle are less important, however, they remain higher than those observed in water. Thus, these organs are selective or active bioaccumulteurs of the manganese in the gills and in the muscle.

Zinc

The Zinc accumulates more in the gills than in the muscle. Furthermore, it is the first two fish sizes which accumulate the significant quantities.

Discussion

The absorbed heavy metals persist in the body and they are slowly excreted[5,6]. In many species, if the concentration of these substances exceeds certain limits, it could become toxic. In many fishes, the bioaccumulation of these toxic elements could cause acute or chronic toxicity[7]. They affect one or more functions of vegetative life, such as the detoxifying organs (kidney, liver), they damage the respiratory functions by affecting gills and cause a neurotoxicity, which has the serious consequences on the entire body[2]. In addition, a disruption of reproductive functions affecting the physical integrity of the offspring of intoxicated individuals may be noted[2].

For the studied species, the results have shown that the concentration of most elements measured in the gills or muscle exceeds the levels of these elements in the water. These concentrations can exceed the Moroccan standards which are signaled by the Ministry of Equipment of Morocco[4]. As a result, the consumption of these fish is a threat to human health[8]. Further, note that, for the fish studied the degree of Bioaccumulation may vary depending on the organ and of the metal type (TABLE 4).

The phenomenon of the variation of the degree of biaccumulation of metals according the organ type has been noted in another fish, *Oreochromis niloticus*. According Taweel et al. (2011)[9], in a study conducted in Malaysia to estimate the con-

TABLE 4 : Degrees of bioaccumulation of metals in the studied organs, and the size of analyzed individuals

metallic elements	Gills			Muscle		
	Size I	Size II	Size III	Size I	Size II	Size III
Lead	high	high	high	high	high	high
Cadmium	high	low	low	low	high	high
Manganese	high	high	high	low	low	low
Chrome	high	high	high	very weak	very weak	very weak
Nickel	high	high	high	very weak	very weak	very weak
Copper	high	high	high	very weak	very weak	very weak
Zinc	high	high	low	low	low	low

centrations of Pb, Cd, Cr, Cu, Ni and Zn in the liver, gills and muscle of the fish, the results showed that the concentration of metals which were bioaccumulated in the tissues vary greatly depending on the organ type; the concentration was higher in the gills than in the muscles. For cadmium and chromium, a study was conducted to determine the concentrations of these metals in the gills, kidney, liver, skin, muscles and scales in three species of fish (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) taken from three stations in the river Ravi in Pakistan[10]. The results showed that the concentrations of these metals vary considerably depending on the type of organ, and ecological characteristics the environment of the fish. Thus, these authors noted that for the three species, the concentrations of cadmium and chromium were significantly different among the five organs of fish and according to the three collection sites. Similarly, using the European eel (*Anguilla anguilla*) as associated bioindicator, heavy metals and organic pollutants have been studied in the Adour estuary (South West France) and wetlands[11]. The concentration of copper, cadmium, zinc, lead and silver were measured in the soft tissues of yellow eels. The results showed that concentrations in muscle were consistent with moderately contaminated environments.

These results show that often it is the concentration in the water of the metals which influences the level of the concentration of these in the organs. However, other factors may be involved in this phenomenon. Indeed, for the species we have studied, Koca[12] reported that the concentration of some organic compounds in the aquatic environment, such as ammonia, nitrite, nitrate, orthophosphate, and sulfate influences the absorption degree of the metal by the fish.

Furthermore, for many species of fish, the importance of metal accumulation is a function of size: more the fish is longer, more is the level of cadmium is important[13]. This phenomenon is most visible in the liver and muscle but not in the gills. Indeed, in the present study, we noted that it is the young people who accumulate more cadmium in their gills.

As a hypothesis that explains this phenomenon, we found that at the young individuals of the studied species, the mucus secretion of gills is more intense than at the gills of the elderly ; this abundance of mucus may play as a barrier to an important accumulation of the cadmium in the gills. In contrast, and as Rand and Petrocelli (1985)[14] have reported for other species of fish in older individuals, the inability to produce mucus in abundance promotes the passage of heavy metals in the blood and as a result these metals are less stuck at the gills.

CONCLUSION

We conclude that the studied lake water is metallically polluted. According to the draft standard Moroccan standards of surface water quality, waters are placed in the class of the very bad waters.

For the seven metals studied, the comparing of the recorded concentrations in the three water-gill-muscle compartments has showed that *Lepomis gibbosus* could be considered as a bioaccumultor species of all heavy metals that we have studied. So, it could be considered as a monitoring species of the aquatic environment quality.

Similarly, for many metals, the degree of bioaccumulation in the gills differs from that of the liver. Also, for some element, the size of the fish, is a determining factor of this degree.

For all these results, the consumption of the fish caught in the studied lake should be blocked by prohibiting its fishing.

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