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Distribution of degree of contamination by heavy metals of the gills, muscle, liver and gonads of *Lepomis gibbosus* Linnaeus, 1758 (Centrachide Fish, Percifome, Actinopterygiis)

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Abstract
The purpose of this work is to compare the amounts of eight bioaccumulated metal elements in the gills, muscle, liver and gonads of a fish, *Lepomis gibbosus* Linnaeus, 1758. The individuals analyzed are taken from a living population in the "fouarate" lake which is located in the urban area of the city of Kenitra (Morocco).
The estimation of the concentration of eight metal elements (Fe, Pb, Cd, Cu, Zn, Ni, Mn, Cr) was carried out by atomic absorption in each of the organs. The analyzed sample consisted of three subsamples of different sizes.
The results showed that the importance of the concentration of metal elements differs according to the metal element itself, the organ and the size, otherwise the age, of the fish. In addition, among the eight studied metals, four of them are very common in the organs of the studied fish: zinc, manganese, nickel and copper. The order of the decreasing ranking of the concentrations of the studied metals differs according to the size of the fish, in other words, according to their age. But in older fish, almost always zinc takes first place.

Keywords: *Lepomis gibbosus*- Heavy Metals - Distribution in organs - Lake Fouarate-Morocco

Introduction
Man, to achieve the economic development, is based on the development of its industrial and agricultural activities. These activities are not without negative consequences for the environment. For example, Zaccai (2009) [1] reported that economic growth is an indirect and biased indicator of damage to the environment. Indeed, economic development is accompanied by releases into the environment of polluting and often non-biodegradable substances of various natures that affect the balance of the receiving environment and its environment [2].
Among the toxic elements for the animals, plants and human health, heavy metals [3]. These metals are found mainly in industrial and municipal wastewater (Cd, Cu, Pb, Zn), atmospheric precipitation and water from agricultural activities (Hg, Cu, Pb) [4]. Anthropogenic activity is, therefore, the main source of this type of toxic element and lakes and rivers that often constitute receiving environments for these metals. Thus, hydrosystems are the most threatened by the excessive presence of these metals [5]. Thus, the man, by the consequences of his activities, in particular, those industrial and agricultural, was trapped by his own actions on the environment. Indeed, heavy metals, once present in the biotope of an ecosystem, are absorbed by certain species. Then, by the phenomenon of increasing concentration of these metallic elements along the trophic chain, the threat of these metals can become more and more important [6]. By affecting the abiotic and biotic components of the environment, the degradation of the environment due to heavy metals threatens human life by the manifestation of various cancerous, cardiovascular and respiratory diseases, etc. [7]. Thus, the deterioration of the quality of water resources by proliferation of different sources of pollution threatens the abiotic and biotic balance, and the biodiversity of these resources [8]. As a result, the current state of environmental degradation is one of humanity's greatest concerns [9].
Thus, in this work, we were interested in the quantification of the distribution of eight metal elements in four organs (gills, muscle, liver and gonad) of three size classes of individuals of a Centrachide Fish, Percifome, Actinopterygiis: *Lepomis gibbosus* Linnaeus, 1758.

The sample of the analyzed fish is taken from Fouarate Lake which is part of the urban area of the city of Kenitra (Morocco). This fish is consumed by the riparian human population and by other predators of the ecosystem, hence its threat to the health of the consumer.

Material and Methods

- The living environment of the studied fish: Fouarate lake:

It is located between 35 ° 15 'north latitude and 6 ° 30' longitude north of the city of Kenitra (Morocco). Its impoundment is carried out mainly from atmospheric precipitations, contributions from the Fouarate wadi and the inflow of wastewater. Its waters are used for crop irrigation and livestock watering. Similarly, this lake is located near an urban agglomeration "the city of Kenitra" which knows a very large expansion, generating a large part of wastewater which generates a significant source of pollution and degradation vis-à-vis of this biotope [10,11]. Note that this lake is a source of fishing for several species of fish that are marketed and consumed in the region thus constituting a possible source of danger for the consumer.

In addition, the analyzed water and sediment samples were taken at S1 and S2 (Figure 1). Then, for each metallic element, the given concentration is calculated as the average of the two values recorded in S1 and S2.

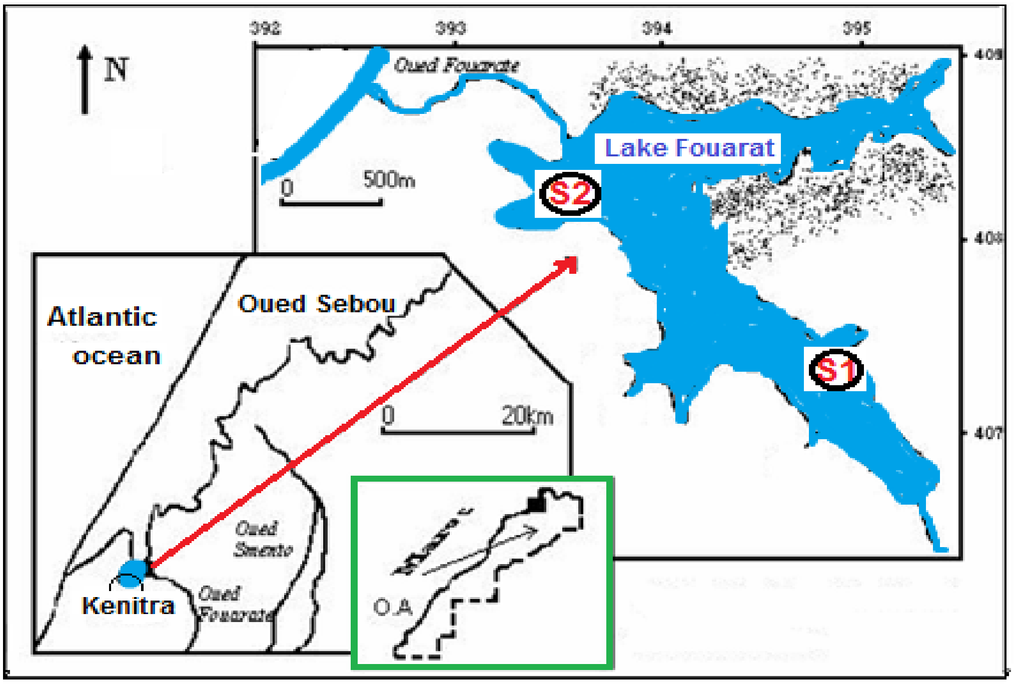

Fig 1: Location in the studied lake of the water and sediment sampling stations

Studied Fish

The sunfish or *Lepomis gibbosus* L. belongs to the Family Centrachidae, Order Perciformes, Class Actinopterygiis. It is primarily carnivorous and feeds on aquatic insect larvae (Tetrichoptera, Coleoptera, etc.), snails, small fish fry and daphnia [12]. It lives in moderately abundant areas of warm, shallow, warm water in slow-moving or stagnant streams [13].

Evaluated Metallic Elements

In the water of the biotope and in the gills of the fish, the muscle, the liver and the gonads we evaluated the contents of 8 metallic elements namely iron, lead, cadmium, manganese, chromium, nickel, copper, and zinc. Note that all elements are potentially toxic once their concentration exceeds a so-called 'critical' threshold. This threshold depends on the species and the metal. For all metallic elements, the notion of toxicity is therefore closely related to that of the limit dose.

The methodology of evaluation of metallic elements

For so-called "bioaccumulative" species, the amount of bioaccumulated metal in the body depends on the age of the individuals. But, often the size of the individual correlates with his size.

Thus, for three size classes, the content of the metal elements in the branches, muscle, liver, and gonads of the fish studied. For each class of tissue, four people were analyzed. It should be noted that the size of the fish has been studied so as to form a sequence of 15 cm and that the growth varies according to the ecological conditions of the environment. The three size classes are such that T1: [8-10[, T2: [10-12[and T3 [12-14].

The evaluation of the contents of the metallic elements carried out by atomic absorption spectroscopy which consists of bringing the elements to their atomic state on the same path of a light ray and to simultaneously make a measurement of the absorption at wavelength specific atoms. The proportionality between the absorption and the concentration makes it possible to calculate the contents of previous mineralized tests.

Results and Discussion

1 Concentration of the studied metals in water and in sediment:

The results of the contents of the studied metallic elements in water and sediment are noted in Tables 1, 2, 3 and 4:

Table 1: Concentration in µg / l of metallic elements in water taken in two stations of Lake Fouarate

Stations	S1	S2	Average concentrations in water	Values quality standards (drinking water) according to WHO	Values Moroccan quality standards (irrigation water)	Decreasing ranking of average metal concentrations in lake water
Copper	10	11	10.5	70	2000	Pb>Fe>Mn>Cd>Zn>Ni> (Cu, Cr)
Zinc	140	2	70.5	3000	2000	
Chromium	10	11	10.5	1000	1000	
Lead	7100	2320	4710	100	5000	
Cadmium	171	10	90.5	3	10	
Nickel	40	52	46	1000	2000	
Manganèse	168	123	145.5	400	200	
Iron	4530	1900	3215	2000	5000	

Tableau 2: Teneurs en µg/g des éléments métalliques dans le sédiment du lac Fouarate

Metal	S1	S2	Mean concentrations in the sediment	Decreasing ranking of average concentrations of metals in sediment
Copper	16.87	52.34	43.60	Fe>Mn>Zn>Pb>Cu>Ni>Cd>Cr
Zinc	192. 65	348.26	270.45	
Chromium	0.07	0.96	0.52	
Lead	15.22	94. 6	55.,91	
Cadmium	12.12	5.98	9.,05	
Nickel	11..3	28.9	20.10	
Manganese	281	524	402.5	
Iron	4974	7942	6166	

Lead

Relative to its concentration in water its concentration in the sediment is very high. Moderately, in water, it is very close to the standard value set for irrigation water. From the point of view of importance, in sediment its concentration comes in third position after manganese and zinc. These high levels can be attributed to the discharge of gas-rich sewage from vehicles in the city of Kenitra and the sewage from service stations supplying these vehicles with fuel; the wash water from roads near the lake is also a potential source of this lead.

Manganese

In water, the concentration of this metal is less important than that of lead but in the sediment, it is the concentration of the latter which is more important. It should be noted that manganese is quite a response in nature, constituting a natural source of pollution. It can also issue from the fertilizers or dyes which are in the effluent of a nearby textile unit.

Cadmium

In water, the concentration noted is high and exceeds the value set by WHO for drinking water and even the value set by Morocco for irrigation water. In the sediment the value noted is low relative to the concentrations of the other metals.

The difference in concentration noted in water and that noted in the sediment could be explained by its degree of solubility of Cd in water its low participation of the sediment.

Zinc

In water, its concentration is average relative to the concentration of other metals. In the sediment it is very high. Wastewater could be a major source of this metal element. The difference in the importance of zinc concentration in water and in the sediment can be explained by the ease with which this metal accumulates on the surface of the sediment [10].

Copper, chromium, and nickel

In water, these elements have very low concentrations. In the sediment, the concentrations of these three are not very high, especially for chromium and nickel.

Industrial wastewater discharged into the lake could be the source of these three metals.

It should be noted that copper deficiency can cause diseases in animals [14, 15].

The iron

In water and sediment, iron concentrations are high, exceed WHO standards and very close to the limit value of the Moroccan standard for irrigation water. In addition, the values noted in the sediment are higher than those in the water. The origins of this metal are the discharges of urban and industrial wastewater discharged into the lake. It should also be noted that iron is very common in nature and is an indispensable element for the functioning of the body of many living beings [16].

Moreover, in the medium studied, the results showed that both in water and sediment the eight metals exist. But, it is the sediment that quantity is more important. This existence is variable in quantity in quality. This difference in concentration between water and sediment could be the result of the low water solubility of metals, the action of certain physicochemical conditions which favors the adsorption of metals on the solid particles of the medium, the action the phenomenon of the release of metallic elements between water and sediment [17,18]. It should be noted that the presence of metals in high quantity or in certain chemical forms can threaten the life of certain living beings. For example, chlorides and sulfates of the zinc or the cadmium, because of their high solubility in water, are compounds that present a danger to certain aquatic animals such as fish in which these elements accumulate easily [10].

2. Concentration of the studied metals in the analyzed organs

Table 3 shows the concentrations of the eight metallic elements in the organs studied in three sizes of fish. These results show that:

These results show that

In the Gills

Lead exists in gills of all sizes of individuals but it is more concentrated in medium-sized individuals. Cadmium is detectable only in small individuals. Nickel is more concentrated in large individuals and to a lesser extent in small individuals. Chromium is more concentrated in medium to large individuals. The concentrations of zinc and manganese do not vary much according to the size of the individuals. Copper and iron are more concentrated in the gills of medium-sized individuals.

In the Muscle

Lead is more concentrated in the muscle of small individuals. The concentration of cadmium is detectable only in large individuals. The concentration of nickel does not vary much according to the size of the individuals. Zinc concentration is very high in medium-sized individuals. Concentrations of manganese, copper, and iron do not vary much according to the sizes of fish.

In the Liver

The concentration of lead is more or less homogeneous in individuals regardless of size. Cadmium levels are lower in medium-sized individuals. Large individuals have less nickel in their liver. Chromium concentrations were not detectable in all sizes of individuals. The importance of zinc concentration increases in proportion to the size of the individual. The concentration of manganese does not vary much according to the size of the individuals. Smaller individuals have less copper and less iron in their liver.

In the Gonads

The concentration of lead is higher in the liver of medium-sized individuals. The concentration of cadmium is not detectable in any size of the studied individuals. The importance of nickel concentration increases in proportion to the size of the individual. Chromium concentrations were not detectable in all sizes of individuals. Zinc contents are higher in small individuals. The concentrations of manganese, copper and iron do not vary much according to the size of the individuals.

Thus, as the results have shown, the importance of the concentration of these metallic elements differs according to the metal element itself, according to the organ and according to the size, otherwise the age, of the fish.

Table 3: Content of the metallic elements in the four studied organs noted in three sizes of *Lepomis gibbosus.*

SIZE I				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Pb	0.21	0.65	0.49	0.21
Cd	0.013	Ld	Ld	Ld
Ni	4.16	1.11	6.32	3.43
Cr	1.18	Nd	Nd	Nd
Zn	2.22	2.21	12.66	24.66
Mn	15.7	2	7.34	5.2
Cu	0.21	1.61	2.29	3.11
Fe	192	30	380	65
SIZE II				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Pb	0.55	0.34	0.47	0.45
Cd	Ld	Ld	0.005	Ld
Ni	2.23	0.75	5.34	6.11
Cr	2.15	Nd	Nd	Nd
Zn	2.09	6.98	17.78	17.23
Mn	13.9	1.81	8.76	4.89
Cu	28.17	1.59	3.62	2.12
Fe	4006	32	1150	74
SIZE III				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Pb	0.18	0.22	0.49	0.2
Cd	Nd	0.013	0.017	Nd
Ni	5.54	1.73	1.2	5.54
Cr	2.11	Ld	Ld	Ld
Zn	2.19	7.02	19.12	19.12
Mn	13.3	0.29	9.23	5.82
Cu	16.19	1.64	3.56	2.19
Fe	2002	51	1994	69

Ld: Less than the limit of detection

On the other hand, in individuals of size I, relative to the other organs, the muscle and the liver accumulate more lead; in those of size II the quantity is high in all the sizes of individuals. Cadmium is not detectable or barely detectable in organs of different sizes of individuals. For nickel, it is higher in the liver of individuals of sizes I and II, in the gonads of individuals of size II and in the gonads and gills of individuals of size III. Chromium is not detectable in organs in small individuals, and detected in small amounts in the gills of individuals of sizes I and II. Zinc is very high in the gonads of individuals of size I and in the liver and gonads of individuals having sizes I and II. Manganese is very high in the gills and elevated in the liver of all sizes of individuals. Copper is very high in the liver and gonads of individuals of size I and in the gills of individuals of other sizes. Iron is very high in the liver and gills of all sizes of individuals.

The results show that three organs are highly affected by high concentrations of heavy metals, liver, gonads, and gills. Muscles are concerned with a high concentration only in small individuals.

Moreover, the heavy metals pollution of the studied environment is attributed to the impact of the pollution sources in this area mainly by discharges of untreated urban and industrial wastewater before being discharged into the lake [11]. As Anna Jakimska *et al*. (2011) [19], heavy metals enter organisms via food, the respiratory tract or the skin. Then, other factors determine their bioconcentration and their bioaccumulation in the organs of the same organism. In *Cyprinus carpio* (Common carp), for example, heavy metals enter the body in three possible ways: by gills, body surface and digestive tract [20]. Once in the body, metals may vary in quantity and quality depending on location, genus, size and tissue [21]. In *Cyprinus carpio* (Common Carp), for example, the estimated accumulation of heavy metals in the liver and gill was in the order of Pb> Cd> Ni> Cr and Cd> Pb> Ni> Cr whereas this order in the cases of flesh and kidney tissues were Pb> Cr> Cd> Ni and Pb> Cd> Cr> Ni [20]. Our results (Table 4) have shown that, as with *Lepomis gibbosus*, this order may vary according to the bioaccumulation organ and that zinc and the most bioaccumulated metal. This latter finding is in part consistent with results from a research conducted on *Mytilus edulis* by Swaleh *et al*. (2016) [21] whose results showed that of all the metals analyzed zinc and iron were the most abundant. We note as well as in the mold, a significant temporal variation was observed for zinc, copper and, lead [22]. For *Sepia spp*. and *Cardium edule*, results obtained by Abdel-Salam and Hamdi (2014) [23] revealed significant variations in Fe, Cu, Zn, Co, Hg, Pb and Cd levels in edible muscles. The phenomenon of the variation of the degree of bioaccumulation of metals in terms of organs was noted in another fish (*Oreochromis niloticus*) as well. According to Taweel *et al*. (2011) [24], in a study conducted in Malaysia to estimate Pb, Cd, Cr, Cu, Ni, and Zn concentrations in the liver, gills, and muscles of the latter fish, the results showed that the concentration of bioaccumulated metals varies a great deal in the tissues according to the type of organ and the concentration has been greater in the gills than in the muscles. For Cadmium and Chromium, a study was conducted to determine heavy metal concentrations in the gills, kidneys, liver, skin, muscles, and scales of three fish species (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) from three stations in the Ravi River, Pakistan [25] showed that concentrations of these metals vary considerably depending on the type of tissues and locations of the fish. However, it should be noted that Koca (2005) [26] reported that the concentration in the aquatic environment of certain organic compounds such as ammonia, nitrite, nitrate, orthophosphate, and sulfate influences the degree of metal uptake by the body. Similarly, Corvi *et al*., (2001) [27] added that in many fish species, the evolution of size-dependent accumulation levels has shown that the higher the size of fish, the higher the levels of cadmium levels are high.

Table 4: Ranking of metals in descending order according to their degree of concentration in the four studied organs

SIZE I				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Classification of metals according to their degree of concentration	Fe>Mn>Ni>Zn>Cu	Fe>Zn>Cu>Ni	Fe>Zn>Ni>Cu	Fe>Zn>Mn>Ni -
SIZE II				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Classification of metals according to their degree of concentration	Fe>Cu>Mn>Ni	Fe>Zn>Mn>Cu	Fe>Zn>Mn>Ni	Fe>Zn>Ni>Mn -
SIZE III				
Metal	**Gills**	**Muscles**	**Liver**	**Gonads**
Classification of metals according to their degree of concentration	Fe>Cu>Mn>Ni	Fe>Zn>Ni>Cu	Fe>Zn>Mn>Cu	Fe>Zn>Mn>Ni -

Note that in some fish bioaccumulation of these toxic elements can cause acute or chronic toxicity [28]. It affects one or more functions of their vegetative life such as damage to the detoxifying organs (kidney, liver), the lesion of the respiratory functions affecting the gills and the neurotoxicosis, the reproductive function affecting the function of the gonads. These effects have serious consequences for the whole body [29]. For example, heavy metal intoxication involves disruption of reproductive functions or affects the physical integrity of the offspring of intoxicated individuals [29]. Similarly, Maüui *et al*. (2000) [30] reported that carbon monoxide and lead, present in the exhaust and detected in the blood of animals exposed to these pollutants, cause sexual, renal and hematological disturbances., and the concentration of lead in the blood was significantly positively associated with developmental delays [31]. In addition, heavy metals are recognized as neurodevelopmental toxins since they can be responsible for fetal damage that leads to neurological abnormalities, developmental delays, learning difficulties and behavioral abnormalities [32]. It should be noted that it has been shown that heavy metals such as cadmium, arsenic, mercury, nickel, lead, and zinc can exhibit endocrine disrupting activity in animal experiments [33]. In fact, by bioaccumulating metals in the gonads, the estrogen receptor can be replaced by several heavy metal molecules such as copper, cobalt, Ni, and Cd. By replacing the Zn atom with Ni or copper, the estrogen receptor binding to the hormone-sensitive elements DNA in the cell the nucleus is prevented [33].

Conclusion

The water and sediment of the studied lake are metallically polluted and this pollution concerns the majority of the metallic elements analyzed. The degree of this pollution varies according to the metallic element. The contamination by metallic elements even touches the biological part of the studied hydrosystem. Indeed, in the four organs of the studied fish (gills, muscles, liver, and gonads) the great majority of the metal elements are bioaccumulated.

The metallic pollution of the various components of the studied lake is attributed to discharges of untreated urban and industrial wastewater before being discharged into the lake.

In addition, the degree of bioaccumulation varies by organ and by size, that is, the age of the fish. However, liver, gonads and gills, muscles are concerned with a high concentration only in small individuals. Similarly, the decreasing order of metal concentrations has shown that moderately five metallic elements often come first in this ranking: Fe> Zn> Mn> Cu> Ni. Almost always iron and zinc both are the first two elements of this classification, but the order of the classification can differ according to the organs.

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