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Bioaccumulation of heavy metals in the *Cyprinus carpio* organs of the El Izdihar dam (Algeria)

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ABSTRACT

The objective of this study is to determine the bioaccumulation of heavy metals in different organs of *Cyprinus carpio* of El Izdihar dam, Sidi Abdelli (Wilaya of Tlemcen) in northwestern Algeria. This latter is an important water resource for drinking water and irrigation in the region. The Zn, Pb, Fe, Ni, Cu, and Cd elements were analyzed using the Rayleigh WFX-130 atomic absorption spectrophotometer after wet digestion by Malayandi and Barette method. The results are given in mg/kg dry weight. One way ANOVA and principal component analysis (PAC) were used to compare the data among months (levels of 0.05). Mean concentrations were found to decrease in *C. carpio* samples in sequence in gills and gonads as Zn > Fe > Pb > Ni > Cu > Cd, in fillets as Zn > Pb > Ni > Fe > Cu > Cd. For Zn and Fe, bioaccumulation in the gills is higher than in the gonads and fillets. For Cu and Cd: fillets > gills > gonads, and for Pb and Ni: fillets > gonads > gills. In fish samples, the concentrations of zinc, lead, and cadmium exceed the FAO/WHO values. The results for all metals were statistically significant at $p < 0.05$ between different months and different organs.

Keywords: Heavy metals; *Cyprinus carpio*; El Izdihar dam; Tlemcen; Algeria

1. Introduction

Pollution of the aquatic environment by heavy metals remains a serious problem. In a country like Algeria, where water resources are limited, the impact of pollution remains an obstacle to sustainable development. Effluents released into the environment are often untreated and metals are found in all stages of the aquatic ecosystem. Since they are not biodegradable, they accumulate along the food chain and reach the man who is its last link.

From aquatic environments, we are interested in dams. El-Izdihar dam of Sidi Abdelli (Wilaya of Tlemcen) is one of the largest dams in western Algeria. It is primarily intended to supply drinking water to the city of Oran, Sidi Bel-Abbès and secondarily for irrigation of different downstream agricultural areas [1].

In 2006, the Wilaya of Tlemcen Fisheries Department carried out, in this dam, fry carp release and then

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found mortality rates [2]. We chose the carp (*Cyprinus carpio*) to monitor pollution by heavy metals. It belongs to the Cyprinidae family. This is a freshwater species tolerant to temperature changes (18 and 30˚C). It is resistant to climate change in our region and is a good water quality indicator. This is an excellent farmed fish consumed by a large population as in other regions/ parts of the world [3–11].

2. Materials and methods

The El Izdihar dam is located on Isser Wadi. It is located about 33 km from the capital of the province, at an altitude of 467 m. It is an area of 669.15 hectares. It is fed mainly by that wadi. Sidi Abdelli station is located in semi-arid level with chilly winter and a dry period that spans 6 months from April to October. It contains a volume of water perfect for fish farming, which is about 106 Hm^3 and an average depth of 45 m allowing carp farming (Fig. 1).

Samples were collected each month by fishing using a motorized boat and a three mesh net sorting during the period from March 2008 to February 2009. Seventy-nine individuals of carp were caught. Fish samples collected were stored in a cooler and transported to the laboratory.

Each individual was weighed and its total length (L) was measured (Table 1). After the measurements, we determined the age of the fish by its size and gonad weight, and then we recovered three parts: the gills, gonads, and fillets separately. They were kept in Petri dishes. Mineralization was performed according to the Malaiyandi and Barette method [12]. One gram of each organ was placed in a flask containing a volume of nitric acid (HNO_3, concentrated 1 N). The flask was placed at a temperature of 95˚C for 1 h 30 min. Once the mineralization completed, the contents of the cooled flask was filtered using swinex and a 0.45 μm porosity membrane. The filtrate was adjusted to 20 mL with bidistilled water, than stored in pots in the refrigerator until analysis. The number of repetitions is according to the number of individuals caught (Table 1). Metal determination was realized using a Rayleigh WFX-130 flame atomic absorption spectrophotometer and standard solutions were prepared in their specific batch solutions to avoid analytical deviation. The potential contamination of samples was evaluated analyzing one acid blank in every batch. This analysis was performed at the Laboratory for human actions valuation and application on public health, University of Tlemcen. Metals that were analyzed are: Zn, Pb, Cu, Fe, Ni, and Cd. All data were computed on a milligram per kilogram dry weight basis. The accuracy of the analytical procedures for total metal determinations was checked using DORM-2 (certified standards) provided by the National Research Council of Canada. The later was analyzed under the same experimental conditions. Replicate analysis of these reference materials showed good accuracy with recovery rates for metals between 96%. The absorption wavelengths and detections limits were 213.9 nm and 0.0059 ppm for Zn, 283.3 nm and 0.0042 ppm for Pb, 248.3 nm and 0.0046 ppm for Fe, 232 nm and 0.015 ppm for Ni, 324.8 nm and 0.007 ppm for Cu, and 228.6 nm and 0.001 ppm for Cd. Statistical analysis was performed using Minitab 15 software. One way ANOVA test was used to compare the data among months at the level of 0.05 and also we performed principal component analysis (PAC) on the mean of weight, length, and metal concentrations in carp's organs of each months.

3. Results and discussion

Table 1 shows numbers of fishes sampled, length, weight ranges, and their relationships. Fig. 2 shows the temporal variations of the mean content of the various metallic elements in the different organs obtained from samples analyzed by atomic absorption spectrophotometry (AAS). We did not obtain samples during the months of January and February 2009. The horizontal line in each graph indicates the recommended values for each metallic element in fish according to FAO/WHO [13]. In general, different tissues showed different capacities for accumulation of heavy metals.

According to the results, the average accumulation of zinc is, respectively about 70.43 ± 38.80 mg/kg, 101.33 ± 26.80 mg/kg, and 37.23 ± 35.33 mg/kg in the gonads, gills, and fillets. The maximum accumulation of zinc is measured during the month of June in the gills (115.71 ± 23.17 mg/kg), while the minimum is measured during the month of December in the fillets (13.51 ± 5.15 mg/kg). These average concentrations in gonads and gills exceed tolerable values (50 mg/kg) throughout the study period [13]. Zinc is an essential trace element for life, but at low concentrations for living organisms, its accumulation is mainly concentrated in the gills. The Zn has a role as a cofactor in many enzymatic systems involved in the utilization of almost all nutrients. High concentrations cause various tissue lesions to fish. They also retard growth and disrupt their reproduction [14].

The accumulation of lead is also important. The results show, whatever the organ, that it was high

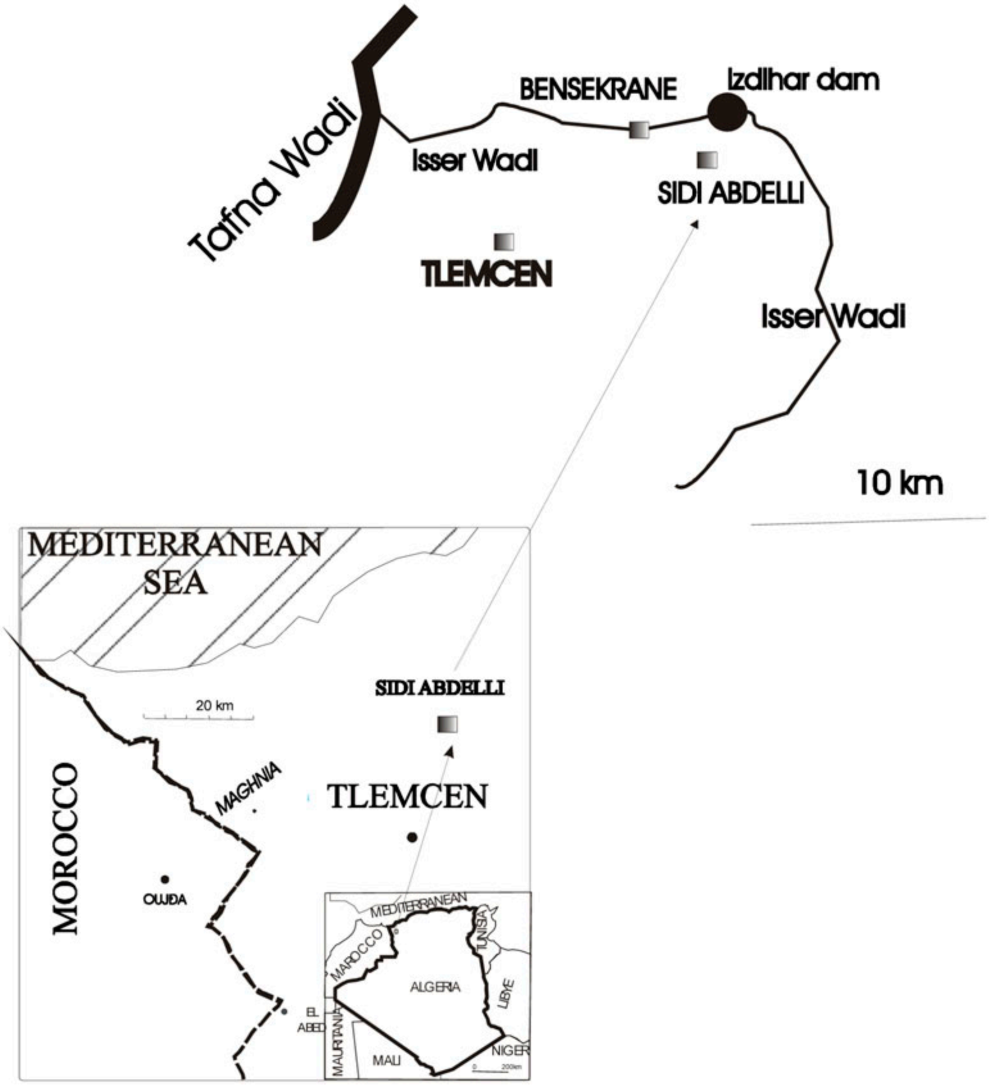

Fig. 1. Location of the sampling site.

during the study period. The average concentrations are 8.96 ± 2.05, mg/kg, 6.33 ± 4.22 mg/kg, and 10.81 ± 2.74 mg/kg, respectively in the gonads, gills, and fillets. The highest maximum concentration is observed in the fillets (13.02 ± 3.13 mg/kg) and the lowest (2.35 ± 2.79 mg/kg) in the gills during the month of March. Lead is not essential to the life of living beings. Lead concentrations show significant variability over time that exceeds the recommended values 0.5 mg/kg [13].

The mean levels of iron are, respectively 12.94 ± 7.85 mg/kg, 20.13 ± 11.66 mg/kg, and 5.28 ± 0.10 mg/kg in the gonads, gills, and fillets. The highest maximum concentration is observed in the gills (41.22 ± 27.91 mg/kg) during the month of December and the lowest in the fillets (5.36 ± 2.03 mg/kg) during the month of November. Iron is essential for the synthesis of haemoglobine and involved in numerous enzymatic reactions linked to oxido-reduction (catalyze, cytochrome oxidase, and peroxidase).

The mean levels of nickel are, respectively 6.89 ± 1.26 mg/kg, 5.67 ± 1.13 mg/kg, and 7.46 ± 1.74 mg/kg in the gonads, gills, and fillets. The highest maximum concentration is observed in the fillets (9.73 ± 1.43 mg/kg) during the month of June and the lowest in the gills (4.35 ± 0.38 mg/kg) during the month of December. These concentrations recorded do not exceed the tolerable value, 10 mg/kg [13].

Monitoring, in time, the evolution of copper in carp showed the presence of this element during the study period probably due to the fact that it is an essential element for the conduct of biological processes [15]. It is involved in many metabolic

Table 1
Size ranges and the relationship between weight (W) (g) and total length (L) (cm) of *C. carpio* caught during the study period

Months	Number of fish	W ranges	L ranges	Equation[a]	*R* value
March	9	516.44 ± 336.84 154–1.061	36.71 ± 9.13 25.3–52	$y = 0.0295\ X + 21.591$	1.00
April	8	486.38 ± 248.95 187–788	35.25 ± 6.60 26.9–45	$y = 0.0296\ X + 21.569$	1.00
May	9	400.67 ± 335.51 218–1.280	33.26 ± 7.36 28–58	$y = 0.0277\ X + 22.846$	0.99
June	9	284.33 ± 259.22 78–951	28.24 ± 7.17 23–48	$y = 0.0293\ X + 20.665$	0.99
July	10	395.70 ± 326.68 225–1.310	32.89 ± 7.45 26.5–59	$y = 0.0285\ X + 22.295$	0.99
August	6	388.67 ± 100.24 291–579	34.48 ± 2.51 31.7–38.8	$y = 0.0231\ X + 25.496$	0.93
September	8	315.13 ± 50.49 239–390	32.13 ± 1.70 28.9–34.4	$y = 0.0272\ X + 23.542$	0.81
October	10	272.70 ± 38.41 234–353	29.45 ± 1.61 27.8–33.1	$y = 0.0385\ X + 18.96$	0.92
November	7	349.57 ± 76.16 233–451	31.36 ± 1.93 28.4–35	$y = 0.0308\ X + 21.04$	0.99
December	3	249.33 ± 156.95 196–426	26.37 ± 6.13 25.2–33	$y = 0.0285\ X + 20.635$	0.98
Means	79	372.61 ± 238.99 78–1.310	32.30 ± 6.32 23–59	$y = 0.0291\ X + 21.875$	0.99

[a]y is total fish length (cm) and X is total weight (g).

pathways, including the formation of hemoglobin. Concentrations of this element fluctuates around 5.25 ± 0.06 mg/kg in the organs studied and do not exceed the tolerable value, 10 mg/kg [13]. Like iron, Cu is involved in electron transport. The activity of numerous enzymes (Cu–Zn-superoxide dismutase, catalase, tyrosinase etc.) depends on the presence of Cu.

Over time, the concentrations of cadmium are important. The mean levels are around 3.29 ± 3.13 mg/kg in the different studied organs, thus exceeding the recommended value, 0.1 mg/kg [13]. The maximum concentration is recorded in the gills (6.47 ± 2.90 mg/kg) during the month of July and the minimum in the gonads (0.40 ± 0.76 mg/kg) during the month of September. In fish, cadmium is absorbed through the respiratory gill or through food [16]. Cadmium is toxic to aquatic invertebrates and freshwater plants. Its toxicity depends on the parameters of the water quality. It can disrupt the ionic balance by altering the cell membranes permeability.

All metals concentrations varied significantly ($p < 0.05$) from month to month and from organ to another of all carp samples. The gradient of accumulation in gills and gonads is the same and is as follows: Zn > Fe > Pb > Ni > Cu > Cd. On the other hand, in the fillets, it is as follows: Zn > Pb > Ni > Fe > Cu > Cd. In organs, Zn and Fe have the following gradient: gills > gonads > fillets. For Cu and Cd: fillets > gills > gonads, and for Pb and Ni: fillets > gonads > gills.

Table 2 summarizes our results and the various data from the literature [9,17–19] to highlight the level of contamination compared to tolerable values [13].

The Zn in our samples is lower than that reported in the literature [8,17–19] in contrast to Pb and Cd, but exceed the tolerable values. The Cd and Pb were higher than the limits human consumption of the fish samples from the study area [13]. The Cu and Ni are higher than those reported in the literature [8,17–19], but not exceed the tolerable values. The Fe, Cu, and Zn are essential, with considerably higher concentrations in metabolic organs than in muscle tissue, presumably due to their function as cofactor for the activation of number of enzymes. Our iron values in the tissue sample were lower than the literature. The Fe is found in organisms in compounds like hemoglobin or myoglobin, as well as ferritin and hemosiderin in fishes.

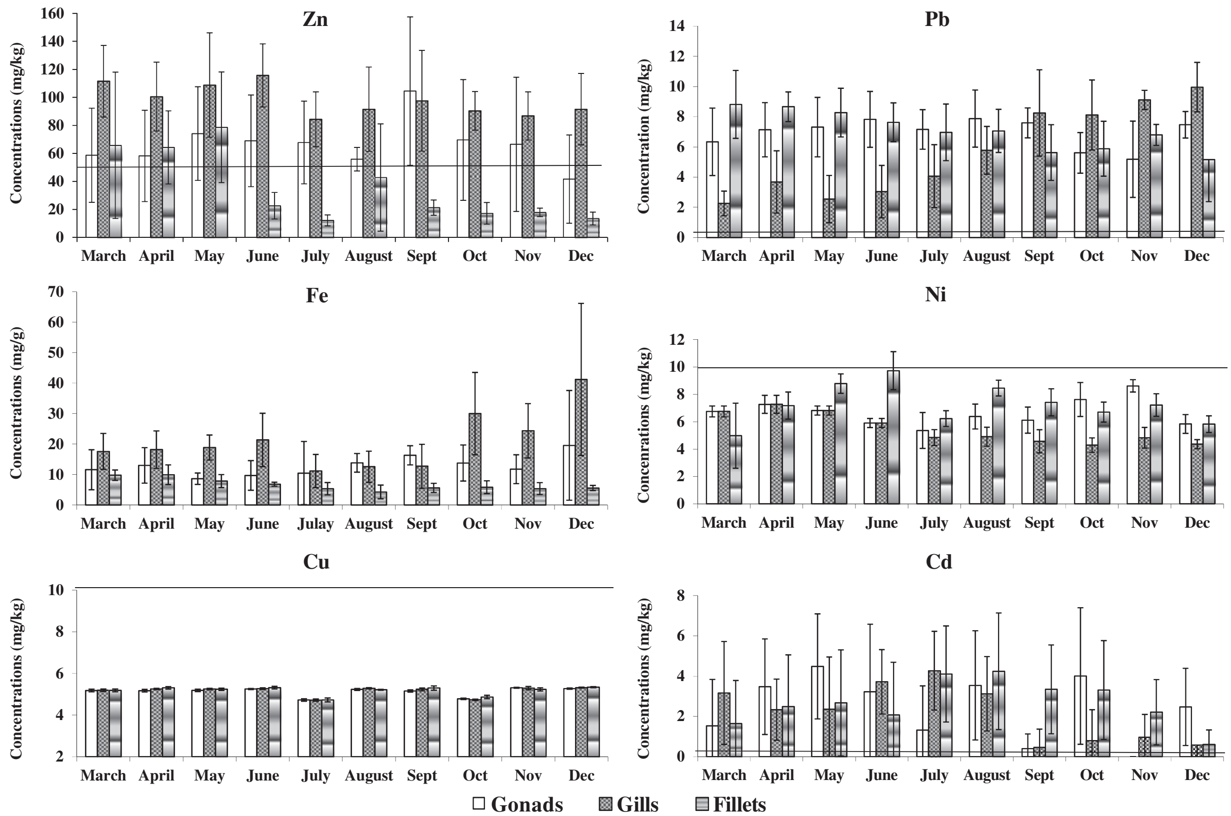

Fig. 2. Temporal variations in the concentration of Zn, Pb, Fe, Ni Cu, and Cd in the gonads, gills, and fillets.

The target organs, such as gills have tendency to accumulate heavy metals in high values, as shown in many species of fishes in different areas [20]. In this study, highest concentrations of Zn were observed in gills followed by gonads and fillet. The concentrations of metal in gills reflect the concentrations of metal in waters where the fish species live [21]. Their accumulation in gills could be due to element complexion with the mucus, which is impossible to be completely removed from the lamellae, before tissues are prepared for analysis. The adsorption of metals onto the gills surface, the first target for pollutants in water, may also influence the total metal levels of the gill [22]. Heavy metal concentrations were lower in the muscle compared to gonads and gills. Similar results were reported from a number of fish species that the muscle is not an active tissue in accumulating heavy metals [23]. The metal concentrations in tissues of *C. carpio* depend on age, length, and weight altogether. The relationships between heavy metal levels in tissues and fish sizes were generally supported in the literature [20,24]. Authors showed that accumulation of metals (Ni and Pb) decreased with an increase in the length of fish *Labeo umbratus*. Al-Yousuf et al. [25] found that the average metal concentrations in tissues of female fish were higher than those in male fish, indicating the differences in metabolic activities of the two sexes. It is also known that the metabolic activity of a young individual is normally higher than that of an older one [26]. One explanation for relationships between metal concentration and fish size found in this study may be the difference in metabolic activity between younger and older fish. High metal concentrations in water can also slow fish development [27]. Dietary habits may also have an impact on metal concentrations in different fishes. Previous studies have suggested that Zn may be biomagnified in a variety of aquatic foods and lake types [28]. Strong relationships were also found between Zn concentrations in zooplankton and fish [29]. In our study, fish feeding mostly on algae display higher concentrations of Zn. It seems that Zn concentrations are inversely related to the trophic status of the fish. These results are in agreement with those of Amundsen et al. [30] regarding trophic status and heavy metal contamination in different freshwater fish species. Although there is no clear evidence about Cu dietary transfer [31], many studies have demonstrated that diet is the most important route of copper accumulation in aquatic animals, and food choice influences body burden

Table 2
Comparison of heavy metals concentrations (mg/kg) in *C. carpio* gills, gonads and fillets with literature

Refs.	*C. carpio*	Concentrations (mg/kg) Organs	Zn	Pb	Fe	Ni	Cu	Cd
[17]	Kasumigaura lake (Japan)	Gonads	108	0.031	185	0.042	1.263	0.009
		Gills	–	–	–	–	–	–
		Fillets	5.433	0.037	2.729	0.041	0.249	0.009
[18]	Almus lake (Turkey)	Gonads	–	–	–	–	–	–
		Gills	–	–	–	–	–	-
		Fillets	33.6	1.0	96.6	2.0	2.6	0.3
[19]	Kizilirmak river (Turkey)	Gonads	874	0.25	198	0.53	5.56	0.20
		Gills	1.036	0.16	480	0.26	3.30	0.16
		Fillets	8.50	1.79	37	3.90	1.1	0.12
[8]	Bafra lake (Turkey)	Gonads	101.82	–	3.89	0.062	0.62	0.094
		Gills	242.84	–	4.72	0.053	0.36	0.096
		Fillets	11.46	–	2.87	0.045	0.30	0.089
This study	Sidi Abdelli dam	Gonads	70.43	8.96	12.94	6.89	5.23	2.3
		Gills	101.33	6.33	20.13	5.67	5.25	2.5
		Fillets	37.23	10.81	6.87	7.46	5.28	2.7
[13]	Other fishes		50	0.5	–	10	10	0.1

of copper [32,33]. According to Eisler [31], little or no biomagnification of copper is evident in freshwater food chains.

PCA was applied using as variables the mean of weight (W) and length (L), and the metal concentrations in organs of carp caught monthly, in order to verify possible bioaccumulation patterns in organs and to detect possible different contamination levels among months in the area of study. PCA indicated that both organs and months explained significantly 62.25% of the total variance (34.33% for factor 1 and 27.91% for factor 2) of sizes and the metal concentrations (Fig. 3).

4. Conclusion

We have demonstrated the bioaccumulation of metals (Zn, Pb, Cu, Ni, Cd, and Fe) in organs of carp, a bioindicator species for pollution, and very widespread and widely consumed by the population.

The dam's water which was potable before 2006, has been observed to deteriorate in quality very rapidly because of the anthropogenic activities. Agricultural wastes are additionally discharged to dam. These may be the possible causes of the high metals, mainly dam sediment and biotic components. Levels of heavy metal varied depending on different tissues. In this study, the Pb and Cd levels in fishes were found to be high in all organs. These would pose health hazards to the consumers.

In this study, the effects of heavy metal accumulation in organs of *C. carpio* were determined. In general, the concentration of zinc was observed to be higher in all months. We found also zinc, lead, and cadmium concentrations higher than the FAO/WHO values [13], except of Zn in fillet. In general, metal concentrations varied from month to another. This depends on the size, sex, age of individuals, and dietary habits. The present data showed that Zn and Fe concentrations in gills were generally higher than in gonads than muscles. From above-mentioned result, it is clear that the concentrations of Pb and Cd of Izdihar dam are high. We can conclude that there should be effort to protect dam from pollution to reduce environmental risks. A potential danger may occur in the future depending on the agricultural and industrial development in this region. It is imperative that solutions must be taken for the El Izdihar dam water treatment.

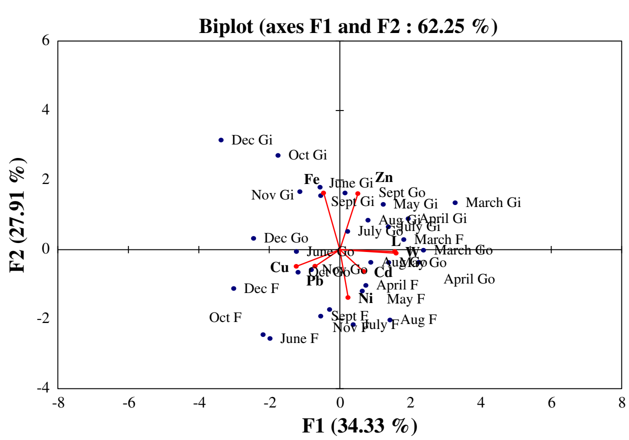

Fig. 3. Biplots for first- and second-axis of the PCA bases on weight (W), length (L), and concentrations (Zn, Pb, Cu, Fe, Cd, and Ni) in organs of *C. carpio* from Sidi Abdelli dam, Algeria (Go: gonads, Gi: gills, F: fillets).

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