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Trace Metal Elements Contents of the Waters and Fish on El-Kala Coastline (El-Tarf- Eastern Algeria)

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ABSTRACT

The purpose of this study was to examine the quality of water and fish meat of *Sarpa salpa* and to determine the water pollution index based on the physicochemical parameters in El-Kala waters, Algeria. The sampling of water and fish was carried out in 2020 at three stations (New Harbor, Maudite Islands, and Messida). The results of pollution index “PIj” calculation at coastal waters El-Kala were classified as lightly polluted (New Harbor and Messida waters) with the pollution index values of 3.24 to 1.33, respectively. It was important to notice that the levels of Cd, and Pb had exceeded the International Security standards in the coastal areas. The values of the bioconcentration factor “BCF” of the whole and of the dosed ETMs oscillate were between 18.31 and 175.41. At the three stations, the distribution of ETMs according to their BCF values were sequenced in the following decreasing order: cadmium> lead> zinc. The average concentrations of TME in water and fish meat decreased in the following order of stations: New Harbor> Messida> Maudite Islands, regardless of the metal. The analyses carried out made it possible to identify the samples from the New Harbor and Messida stations as the most contaminated with cadmium found in fish and cadmium and lead found in water. The high levels of cadmium and lead in water and fish tissues can be a real indicator of the degree of contamination of the site by these metals.

INTRODUCTION

Contaminants found in coastal waters can accumulate in marine organisms through the food chain, degrading the resilience of ecosystems and threatening the health of humans who consume contaminated seafood. Industrialization and urban, agricultural or tourist development of coastal areas are the main causes of the increase in pressure exerted on these environments **(Bandowe *et al.*, 2014; Amara *et al.*, 2019)**.

Most major biological groups have been used to characterize and monitor the marine environment. Fish inhabit almost all aquatic environments and occupy vast distribution areas and highly diverse habitats. Their degree of evolution and their advanced level in food webs give them integrative properties of fluctuating environmental parameters and make them particularly interesting as a biological and ecological model. In addition, fish have a longer lifespan, and therefore integrate pollution signals unlike spot measurements of water chemistry.

Fish consumption has changed considerably over the last fifty years. Overall, consumption per person per year has increased steadily. On a global scale, it increased from 9.9kg on average in the 1960s to 16.4kg in 2005 and 19.2kg in 2012 **(FAO, 2014)**, while reaching 20.3kg in 2016 **(FAO, 2018)**. However, the consumption of halieutic products, and more specifically that of fish, due to their nutritional quality and their beneficial effects on health, can be a significant source of exposure to numerous chemical contaminants present in the environment **(Storelli, 2008)**. Metallic contamination of aquatic environments has thus become a worldwide concern due to its toxicity, bioaccumulation, and effects on aquatic life and human health, as reported in the study of **Deniseger *et al.* (1990)**. Metallic trace elements (TMEs) represent a dangerous group for the aquatic environment due to their persistence, their toxicity, and tendency to bioaccumulate. Some of these elements (Zn, Cu) are essential for life, however, others (Cd, Pb) have; to date, no known biological role has proven toxicity **(Altindag *et al.*, 2005)**. It is therefore important to assess the health risks associated with consuming fish potentially contaminated with these trace metals via the alimentation regym. To limit the potential impact of these pollutants on human health, several agencies and organizations such as the European Union have established maximum limits for Cd and Pb in fish. Although the law relating to the protection and development of the coastline, No. 02-02 of February 5, 2002, prohibits harm to the natural state of the coastline and the discharge of chemical and organic pollutants into coastal waters, such discharges still occur.

The Algerian State is a signatory to several international agreements containing important obligations relating to the protection of these natural environments against pollution, specifically the convention for the protection of the Mediterranean Sea against pollution signed in Barcelona in 1976 and amended on June the 9th, 1995 **(UNEP, 2007)**. Like the European countries, Algeria, through national institutions, must develop its coastal water monitoring system. Over the last two decades, numerous works have been carried out concerning the assessment of marine pollution in Algeria **(Belabed *et al.*, 2013; Belhaouari *et al.*, 2014; Bensafia & Khati, 2018; Ouali *et al.*, 2018; Derbal., 2019; Zeghdoudi *et al.*, 2019)**, but much remains to be achieved.

The present work aimed to evaluate the level of contamination of the waters column and a marine organism of commercial interest, the *Sarpa salpa* fish populating the El-Kala coasts strongly anthropized (harbor activities and agricultural, urbanization) by the determination of metals such as cadmium, lead, and zinc.

MATERIALS AND METHODS

1. Study area and sampling strategy

The El Kala coastline extends over approximately 50km between Cape Segleb (or Cape Roux) and Cape Rosa. It is made up of coral formations sheltering several species of fish. The seabed is infiltrated by currents of fresh water rich in nutrients coming from coastal lakes and which, over time, have shaped an underwater world of incomparable beauty where aquatic life abounds which distinguishes the shores of the El Kala reserve. Similar to various Mediterranean coastal areas, the town of El Kala is characterized by strong demographic growth; at the last census **(RGPH, 2019)**, the population was estimated at 481,136 inhabitants with an average density of 165 inhabitants/km^2. In terms of image and landscapes, these spaces are considered one of the key tourist destinations in the regions of Algeria.

The locations for measurement and sampling of seawater and fish include 3 stations: (S1) New Harbor, (S2) Maudite Island, and (S3) Messida (Fig. 1).

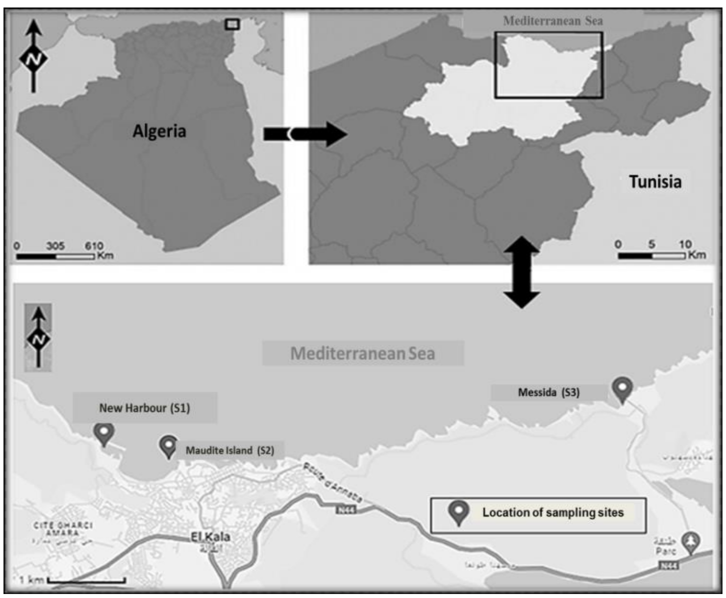

Fig. 1. Location of sampling sites along the El-Kala coasts (El-Tarf City- Northeast Algeria). (Google Maps edited)

The GPS Coordinates of sampling stations and station characteristics are presented in the following table:

Table 1. Sampling stations (water, fish) and sources of contamination (El-Kala coasts - year 2020)

Locality	GPS Coordinate	Pollution source
New Harbor (S1)	36.89950° N, 8° 42255° E	Domestic wastewater Urban water coming from the habitations located in the city of El-kala -Harbor traffics.
Maudite Islands (S2)	36.8983° N, 8.4329° E	This station is supposed to be far from any source of pollution, apart from accidental pollution caused by maritime traffic. This is a reference station for this study.
Messida (S3)	36.90780° N, 8.51622° E	This station receives inputs from the bay of Mesida River, which carry waste of agricultural origin and domestics. the Messida River collects untreated water from the main urban outfall of the city Oum Teboul Souarekh and several municipal sewers discharge domestic wastewater directly into the open sea from homes.

2. Determination of physic-chemical parameters of water

Physic-chemical parameters were measured during 2022. Temperature, pH, dissolved oxygen, and the salinity of water of the two sites were measured in duplicate *in situ* using a multi-parameter U-50 (HORIBA, water quality monitor).

3. Measurement and analysis of waters and fish quality

During the year 2022 (hibernal season) and for the three stations under study, surface waters of each station were sampled using standard sampling procedures. Water samples were conducted at a depth of 50cm in deep water current or at semi-depth in shallow waters (**Rodier *et al.*, 1996)**.

Water samples (50ml) were collected in decontaminated glass bottles. When measurements were not carried out immediately, samples were preserved at 4°C. Water samples were acidified using HNO3 (D = 1.4g/ cm3) to reach a pH lower than 2.

Samples were filtered with a whatman membrane of 0.45µm porosity and then preserved at 4°C prior to trace metals analysis.

For the tissues of fish from the El-Kala coastline: 41 fish from the salema were captured, with St1 (n =17); St2 (n=16), and St3 (n=8), in each sampling station, fish specimens were rinsed with distilled water and were put in plastic bags and stored in a freezer (-40 °C) with a view to their mineralization. After dissection, the dorsolateral muscle without the skin was recovered for metal analysis based on the reference methods for marine pollution studies (UNEP/FAO/IA EA, 1994). In the Teflon bombs, using a precision balance, a slice of the salema muscle (0.5g)- as a dried powder- was added to 2.5ml of concentrated sulfuric acid and 4mL of concentrated nitric acid. Then, the mixture was heated slowly, using a hot-plate during 20min at 130°C. As a result, the double distilled water content was filtered by Whatman filter (0.45mm), and thereafter, the solution was completed to a final volume of 100ml.

The levels of contaminations by Cd, Pb, and Zn contained in the samples (fish tissues and water) were determined using an atomic absorption spectrophotometer (AAS) with an acetylene flame (Shimadzu model AA- 6200, Shimadzu Corp., Kyoto, Japan). The metal contents of the samples represent the average values obtained from replicate samples and were expressed in micrograms per gram of dry weight. The concentrations (Cem) of the metallic elements were obtained using the formula of **Joanny *et al.* (1983)**.

4. Data processing and statistical analysis

Concentrations of all metallic elements (Pb, Cd and Zn) in the muscle of *S. salpa* were afterward expressed as $\mu g.\ g^{-1}$ of dry weight according to the following formula:

$$C_{me}\ (\mu g/g) = (CE \times V) / M$$

Where, CE is the concentration based on the calibration curve ($\mu g.ml^{-1}$); V is the volume of the final solution after digestion (mL), and M is the mass of the mineralized muscle (g).

5. Calculation of the bioconcentration factor (BCF)

The bioconcentration factor used by **Lewis *et al.* (2007)** is based on the concentration of trace metals in seawater samples and in the organism:

$$BCF = Ca/Cb$$

Where, Ca: the metal concentration in the organism ($\mu g.g^{-1}$ dry wt), and Cb: the metal concentration in seawater ($\mu g.g^{-1}$ dry wt).

6. Water pollution index

The pollution index is a useful tool to provide information about the water quality using the following forumla **(Nemerow & Sumitomo, 1970)**:

$$PIj = \sqrt{\frac{(Ci/Lij)^2M + (Ci/Lij)^2R}{2}}$$

Where, L_{ij}: standard water quality parameter for each parameter for a specified water quality purpose (j); C_i: measured water quality parameters I; PI_j: the pollution index for a specifed j water quality purpose (j); $(C_i/L_{ij})_M$: maximum value of C_i/L_{ij}, and $(C_i/L_{ij})_R$: average value of C_i/L_{ij}.

The relation between the level of water pollution and the pollution index criteria based on the Decree of the Minister of Environment No. 115 year 2003 about Determination of Water Quality Status is as follows:

$0 \leq PI_j \leq 1$: meets the standard/good quality
$1 \leq PI_j \leq 5$: lightly polluted
$5 \leq PI_j \leq 10$: moderately polluted
$PIj > 10$: heavily polluted

7. Principal component analysis (PCA)

A study of interdependence relationships was carried out by the principal component analysis (PCA) on a centered and reduced data matrix, the aim of which is to understand the mechanisms of enrichment of the waters of the El-Kala coastline.

The analysis was carried out on a matrix of 3 samples (stations) and seven variables: pH, T°C, salinity, dissolved O2, Cd, Pb, and Zn. To carry out this analysis, we used the R software for statistical computing (2022) using the following packages: “ggplot2”; “FactoMineR”; “factoextra”; “corplot”; “grid” and “ggbiplot”.

RESULTS

1. Water quality

The evaluation of the quality of the marine environment (El-Kala coastline) through the analysis of the physical and chemical parameters of seawaters allowed us to establish a preliminary diagnosis of the state of metal pollution of this ecosystem coastal. The results of measurements on site and laboratory analysis of the quality of El-Kala waters are presented in Table (1).

The results of seawater temperature, salinity, pH, and dissolved O2 levels are consistent with the Algerian standards in cold period and in agreement with the averages observed in the Mediterranean Sea CE (1975). The waters are well oxygenated (6.6-9.05mg/ L), with a neutral to slightly alkaline pH (7.6-8.4), stable salinity (36.1-37.4g/ L), and temperatures ranging from 13.9 to 15.8°C (Table 2).

Cadmium levels measured in the coastal waters of El-Kala vary from 0.008 to 0.031mg/ l; average cadmium concentrations vary depending on the station; they are high at S1 (0.0231± 0.005mg/ l), low at S2 (0.0102± 0.006mg/ l) and intermediate at S3 (0.0188± 0.006mg/ l). Maximum concentrations are noted at New Harbor; the minimum values are noted at Maudite Islands (Table 2). This metal is then encountered in Harbor stations such as New Harbor and to a lesser extent in Messida and Maudite Islands. The results of the Pb determination show average contents of the order of 0.1188± 0.022mg/ l in New Harbor, 0.0297± 0.006mg/ l in Maudite Islands and 0.0917± 0.014mg/ l in Messida. Zinc, in the marine waters of the El-Kala coast, shows concentrations varying from 0.0351 to 0.597mg/ l. The average zinc contents are of the order of 0.0557± 0.013mg/ l in New Harbor and 0.1565± 0.018mg/ l in Maudite Islands and 0.519± 0.052 in Messida; However, it is in Messida that the highest zinc contents were noted. However, the minimum contents of Cd, Pb and Zn were recorded in Maudite Islands (Table 2). If we take into account the average levels of cadmium and lead recorded in the waters of the coast of El-Kala, we can establish a classification of the stations according to the following descending order: New Harbor > Messida > Maudite Islands. For the concentrations of zinc at the sites under study, the sites are sequenced as follows: Messida> Maudite Islands> New Harbor.

2. Heavy metals in fish

From the figures below which represent the contents of metallic elements studied in fish, it is noticed that the content of heavy metals varies with the element and station. The contents of Cd, Pb and Zn found in the sub-samples (41 samples) show concentrations varying from 0.75 to 1.97µg.g-1 dry wt for cadmium and 0.23 to 1.58µg.g-1 dry wt for lead, and 23.38 to 75.57µg.g-1 dry wt for zinc (Fig. 3). At each site, the average concentrations of lead and zinc are 1.27±0.17 and 64.51±4.97µg.g-1 dry wt fot the New Harbor; 0.55± 0.16 and 45.77± 5.39µg.g-1 dry wt for Maudite Islands; 0.91± 0.14 and 45.77± 5.39µg.g-1 dry wt in Messida, respectively (Table 1). These Pb and Zn contents are well below the guideline values accepted by **WHO (2004)** set at 2 and 100µg. g-1 dry weight, respectively.

Table 2. Physicochemical parameters analyses *in situ* of and average concentrations of trace elements (µg.g^{-1} dry wt) in the muscle of *S. salpa* and water collected at the three sites on El-Kala coasts during the year 2022 (St1 n= 17; St2 n= 16 ; St3 n= 8; mean ± standard deviation)

Parameter	Min-Max	New Harbor (S1)	Maudite Islands (S2)	Messida (S3)	International security standards
	Physicochemical parameters measured				*(CE.1975)*
Temperature (°C)	13,9-15,8	15,2±0,26	14,2±0,26	15,26±0,35	-
Salinities (g/l)	36,1-37,4	37,2±0,13	36,2±0,13	37±0,13	
pH	7,6-8,4	7,8±0,13	8,2±0,13	7,8±0,06	6-9
Dissolved Oxygen (mg/l)	6,6-9,05	6,8±0,15	8,8±0,2	6,8±0,2	80-120%
	Concentrations of water chemical elements analyzed (mg/l)				coastal areas (Martin and Whitfield, 1983)
Cadmium	0,008-0,031	0,0231±0,005	0,0102±0,006	0,0188±0,006	0,01
Lead	0,0211-0,152	0,1188±0,022	0,0297±0,006	0,0917±0,014	0,03
Zinc	0,0351-0,597	0,0557±0,013	0,1565±0,018	0,519±0,052	2,5
	Concentrations of fish chemical elements analyzed (µg.g-1 dry wt)				Fish muscles (WHO, 2004)
Cadmium	0,75-1,97	1,75±0,09	1,45±0,19	1,66±0,11	1
Lead	0,23-1,58	1,27±0,17	0,55±0,16	0,91±0,14	2
Zinc	23,38-75,57	64,51±4,97	45,77±5,39	55,63±5,21	100

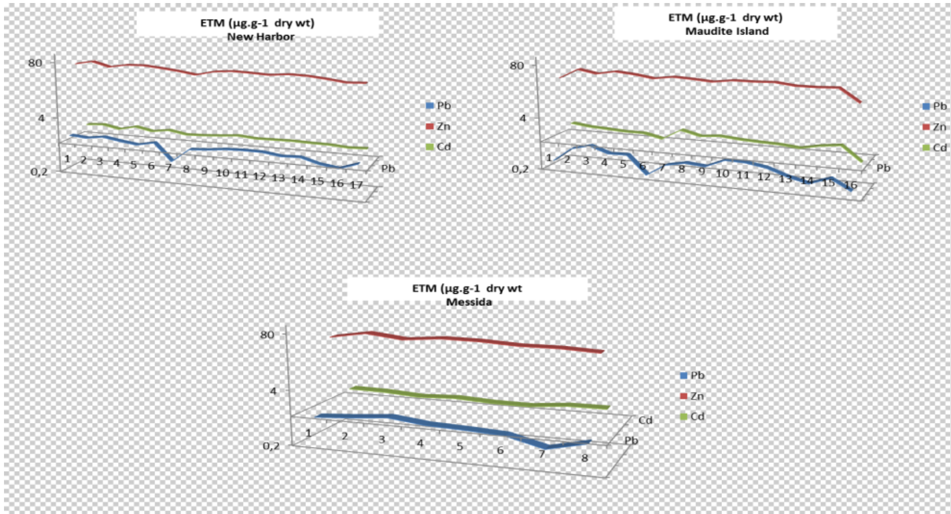

Fig. 2. Variations of heavy metal concentration (µg .g-1dry wt) in muscle of *S. salpa* (El-Kala coasts)

3. PIj

According to the results of the pollution index calculation in Fig. (2), it can be seen that all stations studied are characterized by low to not polluted conditions, where only the waters of New Harbor and Messida were categorized as lightly polluted with pollution index values of 3.24 and 1.33, respectively. The Maudite Islands fall into the "not polluted" category, with a pollution index value of less than 1. This condition has become an issue for ecosystems, as high concentrations of toxic elements such as Cd and Pb accumulate and increase in marine waters, leading to bioaccumulation in marine organisms.

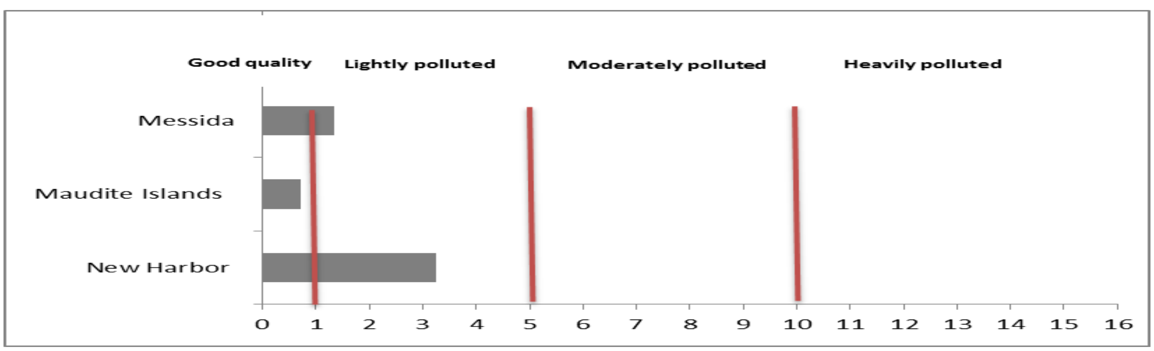

Fig. 3. Water pollution index (PIj) in the coastal waters of El-Kala, Algeria

4. FBC

The values of the bioconcentration factor of the whole and of the dosed ETMs oscillate between 18.31 and 175.41. In the three studied stations, the distribution of ETMs according to their BCF values follows the following decreasing order: cadmium > lead > zinc (Fig. 4).

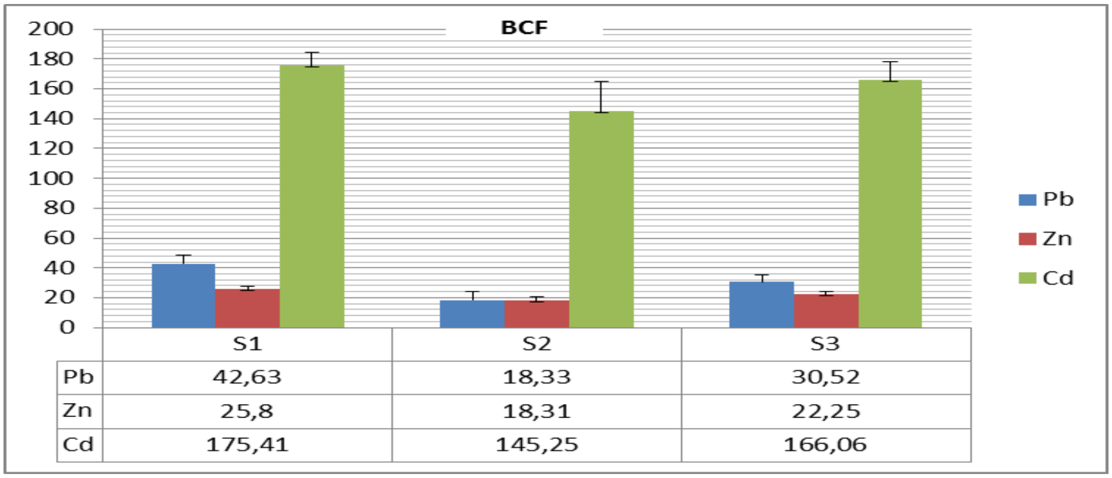

Fig. 4. Variations of the bioconcentration factor (BCF) in fish

5. Results of statistical analysis

5.1. Variables and individuals -PCA

The distribution of variables on the Dim.1 axis (72.7% of the variance) shows the existence of two distinct groups, the first with positive values: T°C, S, and Cd water- Pb water, Cd fish, Pb fish and Zn fish, and the second group with negative values: pH, O2 and Zn water (Fig. 5). The Dim.2 axis (12.3% of the variance) is represented only by a variable with a positive value: Zn water. The first group explains the phenomenon of transfer of heavy metals from water to fish. These values indicate the phenomenon of pollution by cadmium and lead, which is represented at most stations during the study period (Fig. 5a).

The analysis of the projection of individuals in the factorial plan 1 and 2, made it possible to visualize a clear difference between station 2 (Maudite Islands) and stations 1 and 3 New Port and Messida, respectively (Fig. 5b)

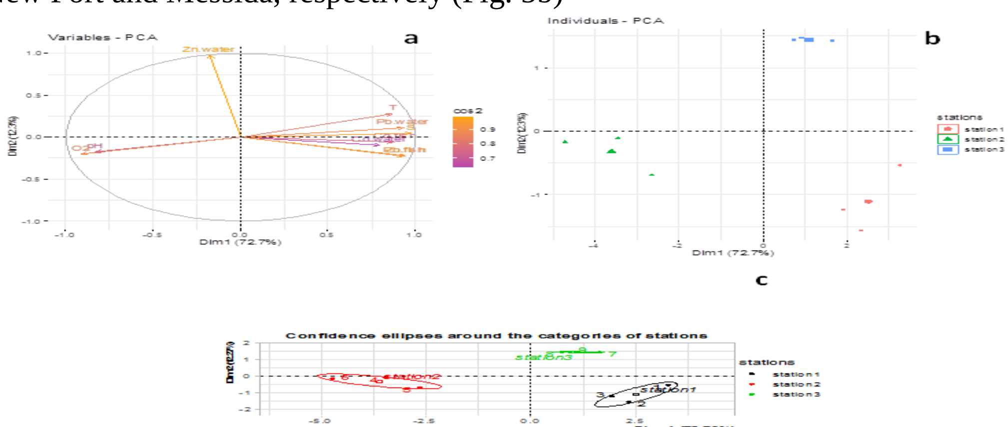

Fig. 5. Principal component analysis in the Dim1-Dim2 factorial design (Variables-PCA (a); individuals-PCA (b) and Confidence ellipses around the categories of stations (c))

5.2. Correlation matrix

The results of the analysis of the correlation matrix to search for possible correlations between the TME and the physical parameters of the coasts' water of El-Kala, show the existence of significant positive correlation between pH- O2(r = 0.74) ; S-T°C (r= 0,81) ; Cd water- T°C (r=0,53) ; Cd water- S (r=0,86) ; Pb water-T°C (r=0,91) ; Pb water et S (r=0,90) ; Pb water- Cd water (r=0,67) ; Cd fish-T°C (r= 0,66) ; Cd fish-S (r= 0,89) ; Cd fish -Cd water (r= 0,89) ; Cd fish-Pb water (r= 0,68) ; Pb fish-T°C (r= 0,82) ; Pb fish-S (r= 0,85) ; Pb fish- Cd water (r= 0,63) ; Pb fish -Pb water (r= 0,87) ; Pb fish-Cd fish (r= 0,76) ;Zn fish- T°C (r= 0,77) ; Zn fish-S (r= 0,87) ; Zn fish-Cd water (r= 0,65) ; Zn fish-Pb water (r= 0,87) ; Zn fish-Cd fish (r= 0,76) et Zn fish- Pb fish (r= 0,97).

Table 4. Correlation matrix of physical and chemical parameters

	pH	O2	T	S	Cd.water	Pb.water	Zn.water	Cd.fish	Pb.fish	Zn.fish
pH	1.00	0.74	-0.71	-0.81	-0.48	-0.72	[illegible]	-0.70	-0.76	-0.80
O2		1.00	-0.79	-0.86	-0.71	-0.89	-0.04	-0.76	-0.80	-0.84
T			1.00	0.81	0.53	0.91	0.09	0.66	0.82	0.77
S				1.00	0.86	0.90	-0.12	0.89	0.85	0.87
Cd.water					1.00	0.67	-0.18	0.89	0.63	0.65
Pb.water						1.00	-0.09	0.68	0.87	0.87
Zn.water							1.00	-0.17	-0.40	-0.40
Cd.fish								1.00	0.76	0.76
Pb.fish									1.00	0.97
Zn.fish										1.00

DISCUSSION

The degree of pollution of the marine environment and the biological quality are strongly influenced by the hydrological and metallic parameters of the latter. Furthermore, anthropogenic activities are the cause of modifications in the physicochemical parameters of marine waters. A growing number of studies **(Holmstrup *et al.*, 2010; Laskowski *et al.*, 2010)** have sought to evaluate the effects of a number of environmental factors on the toxicity of pollutants, including pH, salinity, temperature, dissolved oxygen. The sources of pollution are linked to the urban discharges in the harbor, agricultural and domestic in the Messida River in addition to the washing water from trawlers and sardine boats, which is a potential source of pollution of sites 1 with Cd and site 3 with both Cd and Pb.

One of the objectives of this study was to measure the trace metals contained in the fish meat of the salema, *Sarpa salpa* caught along the El-Kala coastline, in order to highlight possible transfers of micropollutants from the environment to the fish. We also focused on trace metal levels in fish muscle due to their importance for human consumption. Regarding cadmium, the average levels contained in the fish meat of *Sarpa salpa* populating the coast of El-Kala are of the order of 1.75±0.09µg.g-1 dry wt in New Harbor ; 1.45± 0.19µg.g-1 dry wt at Maudite Islands; and 1.66± 0.11µg.g-1 dry wt in

Messida. With reference to the guide values accepted for cadmium (1µg.g-1 dry wt) by **WHO (2004)**, we can consider the fish caught at all stations as unfit for consumption. Even if this species is not popular for consumers, it represents a real danger for human health when consumed regularly. The high levels of cadmium in fish muscle tissues can be a real indicator of the degree of contamination by this metal for the site. Lead and cadmium are non-essential metals which are not subject to regulation; their concentration increases in the tissues depending on the levels of the environment. Mean metal concentrations in *S. salpa* muscles (regardless of sampling station) decreased in the following order: Zn> Cd> Pb. The results obtained lead us to also establish the enrichment orders of the stations for all metals, providing the following sequencial order: New Harbor> Messida> Maudite Islands; However, it is at the New Harbor that the highest contents of all the metallic elements studied are noted.

Contrary to our results, fish meat of the same species worldwide has lower levels of Cd, Pb and Zn **(Canli & Atli, 2003; Afonso *et al.*, 2017)**. On the other hand, the quantities of lead recorded in the salema fish inhabiting the Gulf of Skikda by **Zeghdoudi *et al.* (2018)** are significantly higher (43.95µg/ g) compared to those found in this investigation (Table 3).

Table 3. Concentration levels of trace metal elements in the muscle of the salema (*Sarpa salpa*) from different locations of the world (µg .g-1dry wt)

Area		Cd	Pb	Zn	Reference
Northeast Mediterranean Sea	Salema	0.45	2.98	16.48	Canli & Atli (2003)
Coast of the island of Gran Canaria (Canary Islands).	Salema	0.0021	0.029	10.18	Afonso *et al*. (2017)
Skikda Bay (µg/g)	Salema	1.16	43.95	14.87	Zeghdoudi *et al.* (2018)
El-Kala coastline(µg/g)	Salema	1.62	0,91	55.30	**The present study**

The PIj values are distributed in the following descending order: New Harbor > Messida > Maudite Islands. The water pollution index provides a unique assessment score on environmental parameters and it is analyzed to interpret water quality of coastal areas **(Popovic *et al.*, 2016; Dunca, 2018)**.

The BCF is a parameter used to describe the transfer of trace metal elements (TME) from the biotope (water, sediments, air, soil) to organisms. It comes from the relationship between the concentration of a trace metal element in an organism in a state of equilibrium and its concentration in the biotope **(Asante *et al.*, 2014)**. The bioaccumulation of zinc is actively controlled by various metabolic processes and their rates are most often relatively independent of ambient concentrations, which is not the case for cadmium and lead which are not essential to life **(Pattee & Pain, 2003)**. A large difference in the bioaccumulation of different micropollutants is reported in the same species fished in different regions around the world, which means that the intrinsic factors are identical; we can blame in this case the changes in the extrinsic factors.

The correlation coefficients between these different variables then suggest a common evolution and origin; the three ETM (Cd, Pb and Zn) are indicators of an anthropogenic contribution of heavy metals from port traffic and urban and domestic discharges from the town of El Kala carried by the Messida River toward the sea (Table 4). The presence of trace metals in the fish and waters of El-Kala coasts is closely linked to the physicochemical parameters of the environment, in particular salinity and temperature. Many experiments have demonstrated that the accumulation of metals in many organisms through ingestion from surrounding water could be a cause of metal bioaccumulation **(Marin-Guirao *et al.*, 2008)**. It has been shown that assimilation remains linked to water, food and sediment, to ecological needs and water concentration gradients and also to other factors such as salinity and temperature **(Pagenkopf, 1983; Ouali *et al.*, 2018)**. Temperature is a "key" environmental factor that affects the physiology and behavior of ectothermic organisms, such as fish; in the majority of studies, an increase in temperature leads to an increase in the bioaccumulation and toxicity of pollutants of aquatic organisms **(Schiedek *et al.*, 2007; Holmstrup, 2010)**. The multifactorial analysis through the use of principal component analysis confirms this situation on the diagram of variables-PCA (Fig. 5a).

CONCLUSION

This study is a contribution to knowledge of the degree of pollution of the El-Kala coastline with a particular interest in metal contamination via a biological model (the fish species *S. salpa*). During this study, two approaches were maintained: the first was the monitoring hydrological parameters (T°C, pH, S g/l and dissolved O2) of the seawater, where values are in agreement with the averages observed in the Mediterranean Sea and with those usually measured on the Algerian coasts. The second approach was devoted to measure the trace metals in the water affecting the fish meat of the salema. According to the principal component analysis (PCA), there clearly appears an effect of temperature and salinity on the bioaccumulation and assimilation of trace metals.

Our average values for trace metals turned out to be very heterogeneous, and vary significantly depending on the parameters considered in the present study: abiotic (water, station) and physiological taken into consideration (muscle). The correlations between compartments (water/fish) supports the hypothesis of the transfer of contaminants (environment/organisms) and the bioaccumulation of the micropollutants studied. This study confirms that species from El-Kala coastline have been submitted to lightly polluted environment.

REFERENCES

Afonso, A. ; Gutiérrez, A.J. ; Lozano, G. ; González-Weller, D. ; Rubio, C. ; Caballero, J. M. ; Hardisson, A. and Revert, C. (2017). Determination of toxic metals, trace and essentials, and macronutrients in *Sarpa salpa* and Chelon labrosus: risk assessment for the consumers. Environmental Science and Pollution Research., 24 (11) :10557 – 10569.

Altındag, A. and Sibel, Y. (2005). Assessment of heavy metal concentrations in the food web of lake Beysehir, Turkey. Elsevier, Chemosphere., 60: 552 – 556. https://doi.org/10.1016/j.chemosphere.2005.01.009.

Asante, F.; Agbeko, E.; Addae, G. and Quainoo, A.K. (2014). Bioaccumulation of Heavy Metals in Water, Sediments and Tissues of Some Selected Fishes from the Red Volta, Nangodi in the Upper East Region of Ghana. British Journal of Applied Science and Technology., 4(4): 594 – 603

Belabed, B.E.; Laffray, X.; Dhib, A.; Fertouna-Belakhal, M.; Turki, S. and Aleya, L. (2013). Factors contributing to heavy metalaccumulation in sediments and in the intertidal mussel *Perna perna* in the Gulf of Annaba (Algeria). Marine Pollution Bulletin., 74: 477 – 489. https://doi.org/10.1016/j.marpolbul.2013.06.004.

Belhaouari, B. ; Rouane-Hacene, O. ; Bendaha, M. and Zitouni, B. (2014). Effects of Metal Sulfates on Catalase and Glutathione-S-transferase of Marine Gastropod : *Osilinus turbinatus*. Journal of Applied Environmental and Biological Sciences., 4 (9) : 191–196.

Bensafia, N. and Khati, W. (2018). Seasonal variations in four trace metals (Cu, Zn, Pb, Cd) in sponges *sarcotragus spinosu*lus of the Gulf of Annaba, Northeast Algeria. AACL Bioflux., 11 (3). http://www.bioflux.com.ro/aac.

Canli, M. and Atli, G. (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environmental pollution., 121(1): 129 –136. https://doi.org/10.1016/S0269-7491(02)00194-X.

Deniseger, J.; Erickson, J.; Austin, A.; Roch, M.; Clark, M.J.R. (1990). Water Research., 24: 403– 416.

Derbal, F.; Bensafia, N.; Khati, W. (2017). Sponges (Porifera) as bioindicator species of environmental stress from de Gulf of Annaba (Algeria). Biodiversity Journal., 9 (4): 319–324. . https://doi.org/10.31396/Biodiv.Jour.2018.9.4.319.324.

Dunca, A.M. (2018). Water pollution and water quality assessment of major transboundary rivers from Banat (Romania). Journal of Chemistry., 1–8. https://doi.org/10.1155/2018/9073763.

FAO. (2014). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2018). Ethiopia: report on feed inventory and feed balance. FAO, Food and Agriculture Organization of the United Nations, Rome, Italy.

Holmstrup. M; Bindesbøl. A.M; Oostingh. G.J; A. Duschl. A; Scheil. V; Köhler. H.R; S. Loureiro; Soares. A.M.V.M; Ferreira. A.L.G; Kienle. C; Gerhardt. A; Laskowski. R; Kramarz. P.E; Bayley. M; Svendsen. C and Spurgeon. D.J. (2010). Interactions between effects of environmental chemicals and natural stressors: A review, Sci., 408 (18): 3746 –3762. https://doi.org/10.1016/j.scitotenv.2009.10.067.

Laskowski. R; Bednarska. A. J; Kramarz. P.E; Loureiro. S; Scheil. V; Kudłek. J and Holmstrup. M. (2010). Interactions between toxic chemicals and natural environmental factors - A meta-analysis and case studies, Sci., 408 (18): 3763–3774. https://doi.org/10.1016/j.scitotenv.2010.01.043.

Martin, J.M. and Whitfield, M. (1983). The significance of the river input of chemical elements to the ocean. In: Trace metals in seawater.

Ouali, N; Belabed, B.E; ZEGHDOUDI, F. and Rachedi, M. (2018). Assessment of metallic contamination in sediment and mullet fish (*Mugil cephalus* Linnaeus, 1758) tissues from the East Algerian coast. Journal of water and land development., 38 (VII–IX): 115–126. https://doi.org/10.2478/jwld-2018-0048.

Pagenkopf, G.K. (1983). Gill Surface Interaction Model for Tracemetal Toxicity to Fishes: Role of Complexation, pH, and Water Hardness. Environmental Science & Technology., 17: 342–347. http://dx.doi.org/10.1021/es00112a007.

Popovic, N.Z.; Diknic, J.A.; Atlagic, J.Z.C.; Rakovic, M.J.; Marinkovis, N.S.; Tubic, B.P.; Paunovic, M.M. (2016). Application of the water pollution index in the assessment of the ecological status of rivers: a case study of the Sava River, Serbia. Acta zoologica bulgarica., 68 (1): 97–10.

PNUE. (2007). Convention sur la protection du milieu marin et du littoral de la Méditerranée et ses protocols, éd. Programme des Nations Unies pour l'environnement Athènes (Grèce)., 175 p.

Joanny, M.; Chaussepied, M. and Corre, F. (1983). Presentation of oceans results. Oceanological Center of Brittany (CNEXO/COB)., 49 pp.

R, Development Core Team. (2022). A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Zeghdoudi, F; Larbi, M.T; Ouali, N.; Haddidi, I.; and Rachedi, M. (2019). Concentrations of trace-metal elements in the superficial sediment and the marine magnophyte, *Posidonia oceanica* (L) Delile, 1813 from the Gulf of Skikda (Mediterranean coast, East of Algeria). Cah. Biol. Mar., 60 : 223–233. https://doi.org/10.21411/CBM.A.BBC0ABC8.

WHO. (2004). Guidelines for Drinking-Water Quality (3rd edition). World Health Organization, Geneva.

Pattee, O.H. and Pain, D.J. (2003). Leadin the environment. In: Hoffman :373–408.

Rodier, J. ; Bazin, C. ; Broutin, J.P. ; Chambou, P. ; Champsaur, H. and Rodi, L. (1996). Analysis of water: natural waters, wastewater and seawater., 7: 738.

Schiedek, D.; Sundelin, B.; Readman, J.W. and Macdonald, R.W. (2007). Interactions between climate change and contaminants, Mar. Pollut. Bull., 54 (12): 1845–1856. https://doi.org/10.1016/j.marpolbul.2007.09.020.

Storelli. (2008). Potential human health risks from metals (Hg, Cd, and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs**).** Food and Chemical Toxicology., 46 (8): 2782 –2788. https://doi.org/10.1016/j.fct.2008.05.011.