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# Research Article

# Assessment of Metallic Trace Elements Using the Seagrass *Posidonia oceanica* and the Surface Sediment from North Eastern of Algeria

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## Abstract

**Background and Objective:** In recent years, like many other Mediterranean coasts, the Gulf of Annaba, located in the North Eastern coast of Algeria and extreme South Eastern of the Mediterranean has been subjected to significant urban, agricultural and industrial extension that might have affected the exploitation of its maritime resources and contaminated its coastal environments. The objective of this study was to follow a seasonal assessment of contamination by trace metals (zinc, copper, nickel and chromium) was made using the tissues of seagrass *Posidonia oceanica* and the superficial sediment. **Methodology:** Sampling was conducted seasonally from October, 2009 to September, 2010 in two sites from the Gulf of Annaba (Lacaroube and Lehnaya), individuals harvest were dissected (roots, rhizome and mature leaves) and 500 g to 1 kg of superficial sediment were harvested. Therefore, analyses were carried out by atomic absorption spectrophotometry (Air acetylene). **Results:** From the results obtained, the Metal Pollution Index (MPI) demonstrated that sediment and seagrasses in the urban site of Lacaroube had the most abundant metal concentrations. There was obvious seasonal variation of these metals in compartments of seagrass (roots, rhizome and mature leaves) and superficial sediments with higher concentrations of Zn and Ni especially in winter. **Conclusion:** The study of the biological response of this marine plant to chemical pollutants and in particular to metallic elements in the marine environment, represents a new tool that is not intended to duplicate or replace chemical monitoring but integrated into the monitoring programs of this environment. In addition to physicochemical analysis, the biological indicator can act as an early warning system for a contamination whose effects are still reversible.

Key words: Metal contamination, *Posidonia oceanica*, bioaccumulation, bio-indicator, MPI

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The marine phanerogam *Posidonia oceanica* (L.) Delile, an endemic species in the Mediterranean sea. The complex vegetable structure of these meadows contains a large number of sensitive biological systems that are of fundamental importance to the Mediterranean marine ecosystem. They are the principal contributor to the great biological diversity of the marine ecosystem, because a remarkably high number of species colonies these meadows[1].

The seagrasses are a primary food for many animals (e.g., manatee, dugong and green sea turtle) and form a critical habitat for thousands of other animal and plant species. In shallow-marine ecosystems seagrasses also play critical roles in the ecology and economy stabilizing sediment and carbon and nutrient cycling[2,3]. Furthermore, hundreds of planktonic, epibenthic and in faunal species depend on seagrass beds for survival with approximately 70-90% of commercial fish inhabiting seagrass during their life[4]. However, several seagrass habitats in the world are now vulnerable and in degradation.

Many seagrasses have been completely destroyed by development of human populations in these coastal areas[5]. In many areas of the Mediterranean coast, the *Posidonia* seagrass experienced significant regression due to many factors[6-9]: Coastal development (right of hydrodynamics and sedimentation), pollution (hydrocarbons, pesticides and heavy metals)[10] organic matters, suspended solids, macro-wastes, anchors, the negative influence of human impacts[11,12] and all practices that can cause a tear leaves or shoots of *Posidonia.* In Algeria, the few existing studies were old, which were devoted to that species, indicated the fragmentary state[13]. The herbarium of the Bay of Algiers is a gradient herbarium, located in a semi-closed site, well protected, which receives terrestrial emissions from nearby valleys and urban effluents[14].

Worldwide, seagrass such as *Posidonia oceanica* has been recommended as bio-indicator of environmental conditions especially those in Mediterranean areas[15,16]. *Posidonia oceanica* is a slow-growing species endemic of the Mediterranean sea, where it is the dominant seagrass. Several studies have indicated that seagrass habitat is declining worldwide[17].

Several studies showed that this seagrass specie suffers mainly from the accumulation of heavy metals levels in the Mediterranean sea[18-23]. Unlike pesticides and acid rain, trace metals exist naturally in marine environments, some of which (e.g., Cu and Zn) are essential micronutrients to organisms. However, at higher concentrations (10.5-10.4 mol $L^{-1}$) of these metals including those essential micronutrients can be toxic to seagrasses[24-26]. To date, there are few studies on seagrass from Algeria and of those previous studies, they are mainly concentrated on morphology, taxonomy and spatial distribution[27].

To our knowledge there is no reliable information on the levels of trace metals in seagrasses *Posidonia oceanica* and their habitats in North Eastern of Algeria. In this study, the concentrations of four trace metals (Cr, Cu, Ni and Zn) was determined in the "*Posidonia oceanica*" seagrass from gulf of Annaba (North Eastern Algerian sea) and the relationship between these metal concentrations and their environmental compartment (superficial sediment) were examined.

## MATERIALS AND METHODS

**Study location:** This study was performed in the Gulf of Annaba located in extreme Eastern of the Algerian coast. About 600 km from Algiers and 100 km from the Tunisian border, the Gulf of Annaba is a wide-mouthed bay, open to the Mediterranean sea on the North, extending from Cape Rosa (8°15'E and 36°58'N) in the East, to Cape Garda (7°47'E and 36°58'N) in the West, with a distance of 40 km in between. Seybouse is the second longest river in Algeria (with a catchment basin of about 6470 $km^2$) and important source of heavy metals measured in the Gulf of Annaba[28]. The watershed "Mafregh" (with 2252 $km^2$ of surface) is also an important source of heavy metals in the Gulf of Annaba. The samples were collected from two stations selected based on their location in the Gulf of Annaba. This is the Lehnaya and the Lacaroube stations (Fig. 1, Table 1).

During sampling periods in the Gulf of Annaba, the measured bay water temperature ranged from 12.50±0.34 to 24.35±0.41°C, dissolved oxygen from 26.00±1.3 to 76.00±3.60%, salinity from 35.22±0.34 to 38.06±0.54 and pH from 7.18±0.17 to 8.80±0.21.

**Sampling:** At each station, 10 complete beams of *Posidonia oceanica* and 500 g to 1 kg of superficial sediment were harvested. The marine plant *Posidonia oceanica* was randomly collected from individual diving by hand and at a rate of 30 complete shoots per station and per season at a depth ranging between 5 and 15 m depending on the station. Shoots collected were divided into three repetitions (N = 10). Superficial sediments (of the two stations) were brought to the laboratory to be analyzed.

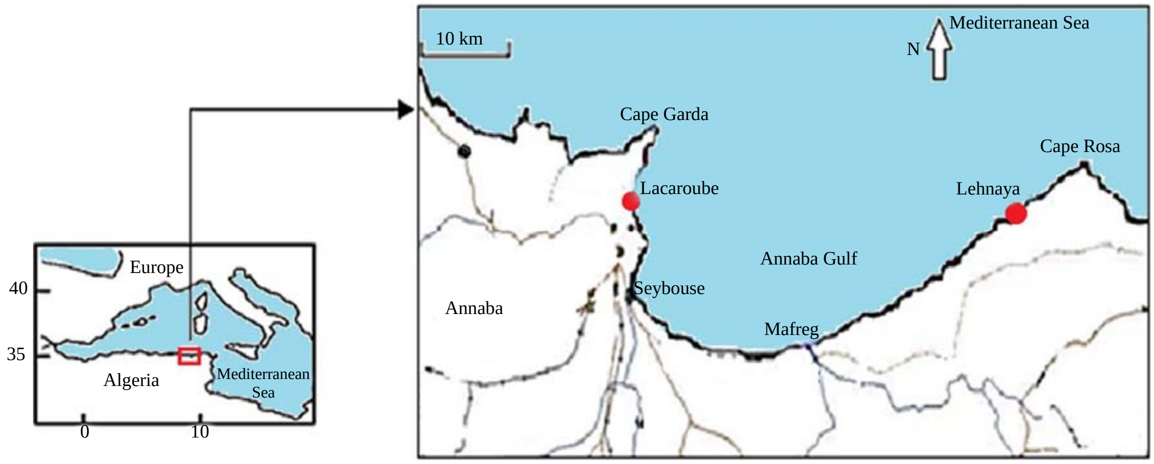


Fig. 1: Map of the Gulf of Annaba and sampling stations (Lacaroube and Lehnaya)

Table 1: General information on the sampling stations situated in Gulf of Annaba (North-Eastern of Algeria coast)

| Stations | GPS coordinates | Depth (m) | Nature background | Other features |
|---|---|---|---|---|
| Lehnaya | 36°54'18" N<br>8°07'30" E | 08 | Meuble | Busy in the summer period |
| Lacaroube | 36°55'56.64" N<br>7°45'54" E | 05 | Meuble | Urban waste |

**Samples preparation:** *Posidonia oceanica* samples were dissected in the laboratory to separate their roots (ra), rhizomes (rh) and leaves, these last have been separated using the Giraud method[29] in juvenile leaves (Jl), intermediate (Il) and mature ones (Ml). Only mature leaves have been cleaned of their epiphytes by a plastic ruler and rinsed with distilled water. All tissues of plant were then dried at 105°C until a constant weight, then mashed and wet-mineralized. This consisted in adding the nitric acid and hydrogen peroxide ($HNO_3$ and $H_2O_2$ in an amount of 5/2 mL) to the mash and heating them at 100°C until a clear solution was obtained. The latter was then filtered through a filter paper (Whatman No. 41) and the filtrate obtained was transferred to the volumetric flasks and made up to 25 mL with 2% $HNO_3$. The resulting product was stored in polyethylene bottles tightly sealed until analysis.

The amount of superficial sediment collected was cleared of boulders and debris and then dried in an oven at 105°C for 48 h. After drying, the sediment was placed on a sieve in order to recover only the fine fraction (to $\leq$63 µm) for mineralization.

**Metals determination in sediments and plants:** The concentrations of metallic trace elements (Zn, Cu, Ni and Cr) contained in the samples (tissues of plant and sediments) were determined using an Atomic Absorption Spectrophotometer (AAS) with air acetylene flame (Shimadzu model AA-6200). The metal contents of the samples represent the average values obtained from three replicas and were expressed in micrograms per gram dry weight.

**Statistical analysis:** The results obtained by various tests were analyzed statistically using descriptive metric methods by giving the mean and standard deviation of mean (SEM). They have been subjected to a comparison by "Kruskal-Wallis test" at the level of significance $\alpha$ = 0.05 via XL.Stat 2009 software.

**Metal Pollution Index (MPI):** The MPI values which indicate the Metals Pollution Index (MPI) from each site were also calculated in this study. The "MPI" modified by Usero *et al.*[30] was used to compare total metal contents of seagrass between different sites. It was modified using the following Eq. 1:

$$MPI = (C1 \times C2 \ldots C_n)^{1/n} \quad (1)$$

where, $C_n$ is the concentration of the metal n in seagrass or environmental compartments (sediment) and n is the total number of metals.

## RESULTS

The metal concentrations of Zn, Cu, Cr and Ni found in superficial sediments from the different locations and seasons are given in Table 2. In both stations, the mean seasonal concentrations for Zn and Ni follow the order winter>fall>spring>summer (Table 2). The concentrations of these two metals were higher in Lacaroube station. For all seasons, the metal concentrations of Cu and Cr were more important in Lacaroube (Table 2). The content of sediment metals was significantly different in the two study sites ($p = 0.0002$, $p<0.0001$), zinc rate remained the highest (Table 2).

The heavy metal content was always more important in Lacaroube station. The concentrations of zinc were highest in seagrass roots of the two stations followed by nickel, chromium and copper. As in superficial sediments, in both stations, the seasonal mean concentrations for Zn and Ni follow the order winter>fall>spring>summer (Table 3). The "Kruskal-Wallis test" indicated highly significant differences in the content of the root metals according season and metal dose (Table 3).

Highest metal concentrations (Zn, Cu, Cr and Ni) in rhizomes were observed at Lacaroube station. As with the two previous compartments, the metal concentrations recorded in winter were the most outstanding and in all stations, the high concentrations were observed at "Zn" metal (essential micronutrients to organisms). The "Kruskal-Wallis test" indicated highly significant differences in the content of the rhizomes metals according season and metal dose (Table 4).

Even in mature leaves of *Posidonia oceanica*, recorded heavy metal content also varies with the seasons and stations of study. At both stations, statistical analysis showed that there are highly significant differences between the concentrations of the four metals assayed. The concentrations of zinc and nickel were the most important in all four seasons of study, the higher were obtained in adult leaves of *Posidonia oceanica* collected in Lacaroube station (Table 5).

Statistical analysis indicated the correlation between the ETM content in sediments and in different analyzed compartments. A positive correlation was recorded for zinc which entered its content in sediments and other plant parts (Table 6).

A correlation was also recorded between zinc and the different assayed metals. It showed a positive correlation on zinc content and nickel contents in most compartments analyzed except mature leaves of Lehnaya station. At Lacaroube station, is nickel is correlated to most metals measured in the three parts of the seagrass. In all compartments studied in Lacaroube station

Table 2: Trace Eelement (TE) concentrations (Mean±SME, μg g$^{-1}$ dry weight) in superficial sediments sampled between years 2009 and 2010 in two stations situated in Annaba Gulf (North-Eastern of Algeria coast) compared by "Kruskal-Wallis test" at the level of significance α = 0.05

| Location | Season | Zn | Cu | Cr | Ni | $H_{obs}$ | p-value |
|---|---|---|---|---|---|---|---|
| Lehnaya station | Fall | 18.09±0.98 | 5.11±0.64 | 27.60±0.66 | 70.85±1.21 | 42.04 | 0.0002*** |
| | Winter | 20.58±1.33 | 1.54±0.30 | 17.20±0.59 | 13.35±1.45 | | |
| | Spring | 12.74±0.63 | 7.44±1.40 | 14.75±1.50 | 10.42±0.95 | | |
| | Summer | 40.78±0.31 | 6.58±0.73 | 13.54±1.27 | 90.39±0.38 | | |
| Lacaroube station | Fall | 50.36±3.18 | 2.73±0.40 | 16.53±1.64 | 30.81±4.64 | 44.74 | <0.0001*** |
| | Winter | 55.76±3.35 | 20.90±3.73 | 17.89±3.38 | 30.74±2.35 | | |
| | Spring | 47.09±3.31 | 6.91±0.88 | 26.37±3.30 | 16.64±2.56 | | |
| | Summer | 26.17±1.18 | 9.36±1.90 | 16.61±3.42 | 16.00±2.98 | | |
| $H_{obs}$ | | 4.39 | 4.85 | 5.41 | 3.43 | | |
| p-value | | 0.22 | 0.18 | 0.14 | 0.33 | | |

***Very highly level of significance

Table 3: Trace Element (TE) concentrations (Mean±SME, μg g$^{-1}$ dry weight) in *Posidonia* roots sampled between years 2009 and 2010 in two stations situated in Annaba Gulf (North-Eastern of Algeria coast) compared by "Kruskal-Wallis test" at the level of significance α = 0.05

| Location | Season | Zn | Cu | Cr | Ni | $H_{obs}$ | p-value |
|---|---|---|---|---|---|---|---|
| Lehnaya station | Fall | 28.38±3.31 | 1.70±0.34 | 20.16±3.93 | 14.98±0.95 | 43.76 | 0.0001*** |
| | Winter | 31.56±3.33 | 1.95±0.35 | 28.97±0.86 | 26.88±1.70 | | |
| | Spring | 12.31±0.66 | 1.77±0.37 | 14.09±0.38 | 13.23±1.31 | | |
| | Summer | 50.28±0.69 | 5.84±0.55 | 12.43±0.62 | 40.98±1.81 | | |
| Lacaroube station | Fall | 61.62±2.85 | 4.15±0.84 | 15.32±0.86 | 22.77±2.59 | 44.54 | <0.0001*** |
| | Winter | 66.78±3.23 | 5.52±1.24 | 16.87±0.62 | 33.48±3.63 | | |
| | Spring | 41.85±3.22 | 7.25±3.28 | 11.40±0.70 | 20.30±1.11 | | |
| | Summer | 18.06±3.33 | 5.59±0.94 | 20.63±3.36 | 13.52±2.16 | | |
| $H_{obs}$ | | 12.05 | 6.19 | 11.90 | 16.05 | | |
| p-value | | 0.007** | 0.10 | 0.008** | 0.001** | | |

**Highly level of significance, ***Very highly level of significance

Table 4: Trace Element (TE) concentrations (Mean±SME, µg $g^{-1}$ dry weight) in *Posidonia* rhizomes sampled between years 2009 and 2010 in two stations situated in Gulf of Annaba (North-Eastern of Algeria coast) compared by "Kruskal-Wallis test" at the level of significance α = 0.05

| Location | Season | Zn | Cu | Cr | Ni | $H_{obs}$ | p-value |
|---|---|---|---|---|---|---|---|
| Lehnaya station | Fall | 23.05±2.66 | 1.75±0.21 | 15.37±1.45 | 16.95±1.43 | 43.54 | 0.0001*** |
| | Winter | 32.33±3.35 | 3.37±0.25 | 25.23±2.91 | 28.66±1.89 | | |
| | Spring | 22.39±3.69 | 1.97±0.07 | 16.56±1.21 | 14.83±1.05 | | |
| | Summer | 22.02±3.18 | 6.29±1.21 | 19.00±3.37 | 6.54±1.58 | | |
| Lacaroube station | Fall | 33.14±3.15 | 4.54±1.35 | 20.48±2.20 | 30.23±1.52 | 41.96 | 0.0002*** |
| | Winter | 77.88±0.95 | 7.99±0.22 | 36.81±4.15 | 39.04±1.26 | | |
| | Spring | 20.24±0.31 | 5.60±0.61 | 22.50±3.40 | 31.86±1.50 | | |
| | Summer | 25.30±3.34 | 5.69±0.48 | 22.04±2.33 | 22.63±2.55 | | |
| $H_{obs}$ | | 11.99 | 6.73 | 9.89 | 9.41 | | |
| p-value | | 0.007** | 0.08 | 0.02* | 0.02* | | |

*Significant, **Highly level of significance, ***Very highly level of significance

Table 5: Trace Element (TE) concentrations (Mean±SME, µg $g^{-1}$ dry weight) in *Posidonia* mature leaves sampled between years 2009 and 2010 in two stations situated in Annaba Gulf (North-Eastern of Algeria coast) compared by "Kruskal-Wallis test" at the level of significance α = 0.05

| Location | Season | Zn | Cu | Cr | Ni | $H_{obs}$ | p-value |
|---|---|---|---|---|---|---|---|
| Lehnaya station | Fall | 21.95±0.01 | 0.83±0.08 | 0.20±0.10 | 15.02±0.35 | 46.35 | <0.0001*** |
| | Winter | 25.31±0.05 | 0.87±0.07 | 16.47±0.11 | 26.92±0.32 | | |
| | Spring | 10.67±0.24 | 0.96±0.14 | 14.40±0.10 | 19.18±0.43 | | |
| | Summer | 70.67±0.01 | 6.54±0.31 | 12.02±0.13 | 15.57±0.23 | | |
| Lacaroube station | Fall | 87.53±0.25 | 0.76±0.08 | 15.76±0.05 | 40.70±0.40 | 46.50 | <0.0001*** |
| | Winter | 16.50±0.31 | 6.45±0.30 | 15.63±0.54 | 43.39±0.33 | | |
| | Spring | 16.64±0.10 | 4.02±0.23 | 25.95±0.23 | 38.58±0.24 | | |
| | Summer | 49.60±0.34 | 4.56±1.14 | 17.74±0.63 | 30.35±1.05 | | |
| $H_{obs}$ | | 7.62 | 11.39 | 4.56 | 3.93 | | |
| p-value | | 0.05 | 0.01* | 0.21 | 0.27 | | |

*Significant, ***Very highly level of significance

Table 6: Correlation coefficient calculated between different compartments analyzed for all metals

| | Lehnaya station | | | | Lacaroube station | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | Sediment | Roots | Rhizomes | Mature leaves | Sediment | Roots | Rhizomes | Mature leaves |
| **Zinc (Zn)** | | | | | | | | |
| Sediment | 1 | | | | 1 | | | |
| Roots | 0.84 | 1 | | | 0.91 | 1 | | |
| Rhizomes | 0.57 | 0.65 | 1 | | 0.44 | 0.53 | 1 | |
| Mature leaves | -0.16 | 0.03 | -0.33 | 1 | 0.92 | 0.95 | 0.52 | 1 |
| **Copper (Cu)** | | | | | | | | |
| Sediment | 1 | | | | 1 | | | |
| Roots | -0.05 | 1 | | | 0.27 | 1 | | |
| Rhizomes | 0.68 | -0.13 | 1 | | -0.04 | 0.91 | 1 | |
| Mature leaves | 0.67 | 0.26 | 0.61 | 1 | 0.35 | 0.92 | 0.8 | 1 |
| **Chromium (Cr)** | | | | | | | | |
| Sediment | 1 | | | | 1 | | | |
| Roots | -0.57 | 1 | | | 0.29 | 1 | | |
| Rhizomes | 0 | 0.16 | 1 | | -0.3 | 0.45 | 1 | |
| Mature leaves | 0.66 | -0.59 | -0.35 | 1 | -0.85 | 0.1 | 0.51 | 1 |
| **Nickel (Ni)** | | | | | | | | |
| Sediment | 1 | | | | 1 | | | |
| Roots | 0.7 | 1 | | | 0.58 | 1 | | |
| Rhizomes | 0.46 | 0.69 | 1 | | 0.6 | 0.98 | 1 | |
| Mature leaves | 0.71 | 0.81 | 0.87 | 1 | 0.81 | 0.83 | 0.82 | 1 |

nickel is negatively correlated to the presence of copper against its presence is positively related to the presence of zinc and chromium at *Posidonia oceanica* collected in Lacaroube station (Table 7).

Factor analysis also shows that the copper dosed in *Posidonia oceanica* is different and has individual groups relative to other elements assayed. The first group is formed of copper dosed in the four seagrass compartments of Lacaroube

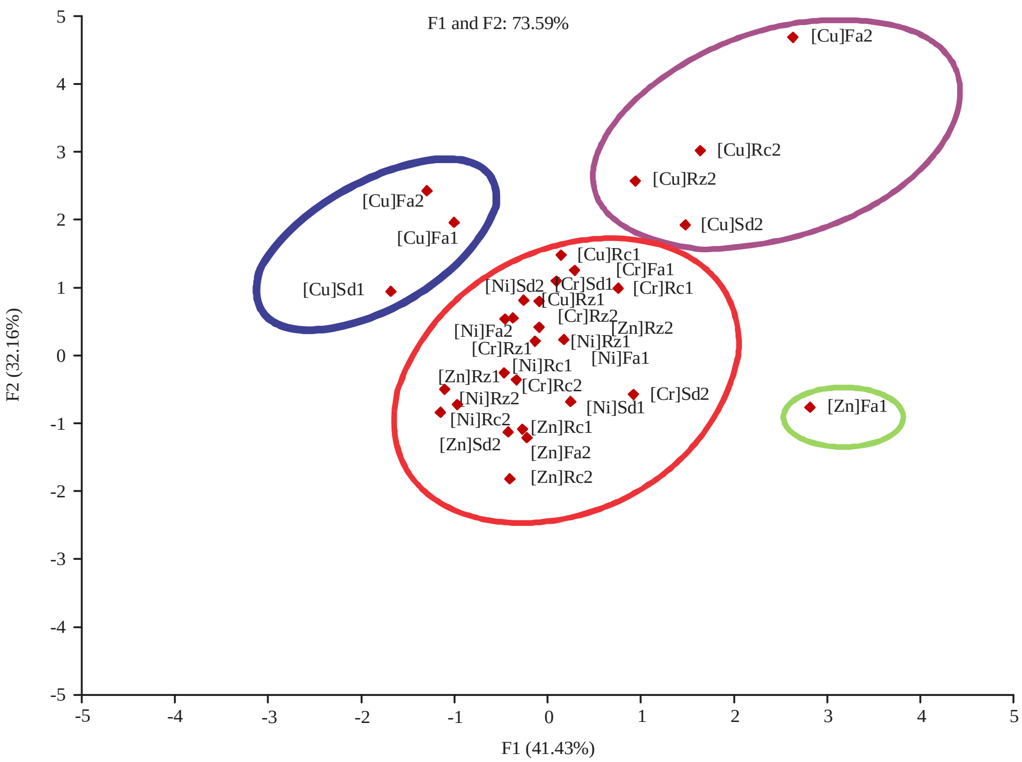


Fig. 2: Factor analysis of various heavy metals measured in *Posidonia oceanica* sampled in Annaba Gulf (North-Eastern of Algeria coast)

1: Lehnaya station, 2: Lacaroube station, Fa: Mature leaves, Rc: Roots, Sd: Sediment and Rz: Rhizomes

Table 7: Correlation coefficient calculated between different metals analyzed for all compartments (sediment superficial and three tissues of *P. oceanica*)

| | Lehnaya station | | | | Lacaroube station | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | Zn | Cu | Cr | Ni | Zn | Cu | Cr | Ni |
| **Sediments** | | | | | | | | |
| Zn | 1 | | | | 1 | | | |
| Cu | 0.2 | 1 | | | -0.66 | 1 | | |
| Cr | 0.18 | -0.06 | 1 | | 0.56 | -0.23 | 1 | |
| Ni | 0.65 | 0.22 | -0.45 | 1 | 0.26 | -0.51 | -0.45 | 1 |
| **Roots** | | | | | | | | |
| Zn | 1 | | | | 1 | | | |
| Cu | -0.24 | 1 | | | -0.68 | 1 | | |
| Cr | -0.25 | -0.22 | 1 | | 0.78 | -0.46 | 1 | |
| Ni | 0.78 | -0.03 | -0.07 | 1 | 0.84 | -0.63 | 0.87 | 1 |
| **Rhizomes** | | | | | | | | |
| Zn | 1 | | | | 1 | | | |
| Cu | 0.65 | 1 | | | 0.09 | 1 | | |
| Cr | 0.76 | 0.51 | 1 | | 0.35 | 0.09 | 1 | |
| Ni | 0.68 | 0.36 | 0.53 | 1 | 0.6 | -0.39 | 0.57 | 1 |
| **Mature leaves** | | | | | | | | |
| Zn | 1 | | | | 1 | | | |
| Cu | -0.8 | 1 | | | -0.69 | 1 | | |
| Cr | -0.49 | 0.02 | 1 | | -0.21 | 0.13 | 1 | |
| Ni | -0.15 | 0.06 | -0.16 | 1 | 0.55 | -0.43 | 0.69 | 1 |

station while the second compound is copper mature leaves and copper sediment of Lehnaya station and chromium mature leaves of Lacaroube station (Fig. 2).

The ranges of MPI at both stations of superficial sediment, *Posidonia oceanica* roots, rhizomes and mature leaves were 7.95-28.29 and 6.61-21.36 and 10.12-30.75 and 2.72-18.68,

Table 8: Spatiotemporal variations of the Metal Pollution Index (MPI) calculated for all compartments (sediment superficial and three tissues of *P. oceanica*)

| Location | Season | Superficial sediment | *Posidonia* roots | *Posidonia* rhizomes | *Posidonia* mature leaves |
|---|---|---|---|---|---|
| Lehnaya station | Fall | 11.09* | 10.99* | 10.12** | 2.72** |
| | Winter | 9.23 | 14.80 | 16.75* | 9.94* |
| | Spring | 10.99 | 7.98 | 10.20 | 7.29 |
| | Summer | 7.95** | 6.61** | 11.45 | 9.84 |
| Lacaroube station | Fall | 16.27 | 17.28 | 17.47 | 14.37** |
| | Winter | 28.29* | 21.36* | 30.75* | 16.39 |
| | Spring | 19.44 | 16.28 | 16.88 | 16.09 |
| | kummer | 15.97** | 12.95** | 16.37** | 18.68* |

*Maximum, **Minimum

respectively and the maximum MPI was located at Lacaroube station (Table 8). In most compartments, the calculations of MPI index show that maximum values were obtained during winter season.

## DISCUSSION

Like many magnoliophyte, *Posidonia oceanica* has both a strong concentration of power in trace elements, proportional to the concentrations present in the environment[31-34] and a good resistance to metal contamination because the species remains in the vicinity of important sources. Also, *Posidonia oceanica* is often seen as a bio-indicator of metal contamination for many years[15,35-37].

In the Mediterranean, the seagrass is a powerful integrator of global marine water quality[33]. Widely distributed all along the coast, particularly "Receptive" to pollution[31,38] and assault related to human activities[39,40], secured to the bottom, it realizes, by its presence and vitality (or its regression materialized by "Dead matte"), to the quality of water derived.

*Posidonia oceanica* seagrass is organized into numerous complex food webs, most of which begin with the consumption of *P. oceanica* leaves and the epiphytes which are associated with them[41]. Since marketed species are among the known or potential grazers of *P. oceanica*, the study of metals in this species is not only of ecotoxicological interest but also of public health concern.

The foliar tissue analysis of these organisms allows us to determine the mean pollution levels over a limited time interval, whereas an analysis of the roots provides an indication of environmental contamination over a much longer period[42]. This phenomenon may be due to the long lifespan of the roots and the slow regeneration levels of these structures compared with foliar structures[41,43,44].

It is known that sediments can act as a source of contaminants for organisms[45]. In fact, marine macrophytes absorb metals in two ways: By direct absorption from water through the leaf surface or from the sediment and interstitial water through the roots[46].

In sediment, the capacity to retain heavy metals is controlled by all factors related to sediment characteristics that are determinant in heavy metal accumulation processes. One of the most decisive factors acting on heavy metal accumulation processes is grain size[47]. The decreases heavy metal concentrations in sediment are strongly and positively correlated to increased grain size[48,49].

The assays of heavy metals show that there is a station of a seasonal effect on the distribution of these elements at *P. oceanica*. The ETM dosed in this study are part of the trace elements essential for living organisms, therefore their contents will vary according to certain biological activities of the biocenosis populating the sediment. Copper is a trace essential element for cellular metabolism may become extremely toxic for aquatic animals as its concentration in water increases. At equilibrium, there are few free copper ions in natural waters, since most copper are associated with inorganic ions or organic substances[50]. In both stations, the roots of *P. oceanica* are directly related to sediment in which they develop and have, therefore, ETM concentrations in proportion to that found in the latter.

Adult leaves contain zinc concentration more than copper. This result was similar to Luy *et al*.[51], which explained the specification of their photosynthetic tissues. For Cu, its low concentration in mature leaves can be explained by its use in metabolic activity during the growth period of the other sheets (intermediate sheets and juvenile) therefore Cu is used where one needs[52].

The concentration of these trace elements (Zn and Cu) follows a descending order by always placing before copper, zinc (Zn>Cu)[36,53]. These observations come to consolidate the results obtained in this study. Lehnaya station in the copper values found in the sediment and the roots are quite close and it is in the leaves that the content of this ETM is less.

The maximum MPI were observed at Lacaroube station. This site is more likely to be affected by anthropogenic activities in summer. In Lehnaya station, the rate of ETM is higher in mature leaves. The latter receive the metals from sediment but also those of the water with which they are in contact.

MPI mature leaves (14.34-18.68) of the study exceed those recorded in the *Posidonia* leaves of Corsica (0.66-2.24)[18] where the concentrations measured ETM, represent the "Background noise" of the Mediterranean sea. Khaled *et al.*[54] showed high values of MPI (11.73-18.46) in *P. oceanica* harvested Marsa Matrouh beaches that approximate the MPI Lacaroube station of this study. Marsa Matrouh and Lacaroube are both overcrowded and summer use location.

## CONCLUSION

In the present study, trace metal levels were evaluated in the sediment and in *Posidonia oceanic* harvested in two locations in the Gulf of Annaba (Lacaroube and Lehnaya). Results have shown that sediment presented the highest concentrations of Zn and Ni. These levels, however, don't exceed the limit values set by the sediment quality guideline. The different parts of *Posidonia oceanica* exhibit high values of Zn in winter season. Therefore, the investigation of trace metal concentrations in the tissues of these species may provide useful information on the transfer of potentially toxic elements from abiotic compartment (sediments) to higher consumers. Seagrass which are widely distributed in the aquatic environment could be selected as monitoring network.

## SIGNIFICANT STATEMENTS

The findings of this study validated the traditional use of the seagrass *Pocidonia oceanica* and the superficial sediments in the monitoring of the metallic pollution of the marine ecosystem as it demonstrated:

- The Gulf superficial sediments with higher concentrations of Zn and Ni especially in winter
- The contents of each metallic trace element show variations according to the location of the herbarium and the tissues (roots, rhizomes and matures leaves) of the seagrass
- The concentration of MTE varies according to the graduating season

Other study can be done on these species of marine magnoliophyta in order to qualify the state of a marine ecosystem with respect to other pollutant.


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