

Biomonitoring of trace metal contamination in El Mellah Lagoon (Algeria) using cockle *Cerastoderma glaucum* (Bivalvia: Cardiidae)

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Abstract

This work aims to investigate the trace metal contamination of El Mellah Lagoon by assessing their accumulation levels in the tissues of the brackish water cockle *Cerastoderma glaucum* (Bivalvia: Cardiidae). Our findings show that copper (Cu), zinc (Zn), cadmium (Cd), and lead (Pb) concentrations in cockles ranged between 0.81-2.09, 4.12–6.72, 0.09–0.15, and 0.39–0.76 mg/kg soft tissue dry weight respectively, in ascending order of: Cd< Pb< Cu< Zn. Statistical analysis reveals significant seasonal variations in measured metals, with the highest values all recorded in autumn but remaining well below the recommended guide values. Overall, our study excludes the existence of an ecotoxicological threat linked to the presence of essential (Cu, Zn) and toxic (Cd, Pb) metals in the cockles' flesh.

Keywords: Lagoon, *Cerastoderma glaucum*, heavy metals, El Mellah, Algeria.

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1. Introduction

Coastal lagoons are considered transitional zones between continental and marine ecosystems; they are shallow waterbodies partially separated from the sea (Guelorget et Perthuisot, 1983; Kjerfve, 1994). Lagoon ecosystems are habitats with complex dynamics, they are vulnerable, highly unpredictable, and frequently subject to short-term variations in temperature, salinity, and pH. As a result, lagoons are recognised as extreme and unstable environments (Bamber et al., 1992). Currently, coastal lagoons are receiving particular attention worldwide due to their fragility caused by the synergistic effects of climate change and anthropogenic pressures but also in recognition of their multiple uses and services (Basset et al., 2013, Camacho-Valdez et al., 2013). Indeed, due to their high level of primary production, organic matter, and habitat diversity, lagoons are among the most productive aquatic ecosystems. Thus, they provide optimal niches for aquatic species, which many are actively exploited (Costanza et al., 1997). Nevertheless, the stressful conditions that characterize these biotopes have direct impacts on their fauna, especially benthic communities. The latter, composed primarily of sedentary species incapable of moving habitats, are condemned to endure harsh lagoon environments. On the other hand, because macrobenthos plays a crucial role in the characterization and functioning of these ecosystems, it is recognized as a good indicator of their environmental health (Cherkaoui, 2006).

The brackish water cockle *Cerastoderma glaucum* is suspension-feeding bivalve common in the south Mediterranean (Kandeel et al., 2017). It mainly occurs in

estuaries and lagoons where the environments fluctuate at extremes, making the species a specialist of these habitats (Sara, 2007; Derbali et al., 2012; Bamber et al., 1992). However, several studies validated *C. glaucum* as appropriate bioindicator organism according to its biological and ecological characteristics (wide distribution, sessile, filter feeding and high bioaccumulation capacity) (Szefer et Wolowicz, 1993; Arjonilla et al., 1994; Machreki-Ajmi et Hamza-Chaffai, 2006; Machreki-Ajmi et al., 2007; Hamza-Chaffai, 2014; Karray et al., 2015; Velez et al., 2016).

In the present study, we aim to investigate heavy metal contamination in El Mellah lagoon, by evaluating the accumulation of copper (Cu), zinc (Zn), cadmium (Cd), and lead (Pb) in the flesh of *C. glaucum* collected from this waterbody.

2. Materials and methods

2.1. Study area

El Mellah (36° 53' 565° North, 8° 19' 560° East) is the only lagoon in Algeria. This waterbody, situated a few kilometers from the Algerian-Tunisian frontier (Figure 1), is characterized by a rich biodiversity. It is a part of the El Kala National Park's wetland complex and has been designated as a RAMSAR site since 2005. El Mellah covers an area of 865 ha and connects to the sea through a channel of about 900 m. From the hydrological viewpoint, the lagoon receives marine water from a twice-daily tide and fresh water from a limited and sparsely populated watershed area. However, besides its ecological importance, the lagoon is renowned for its artisanal fishing (sea bass, sea bream, mullets, eel, clams, and prawns).

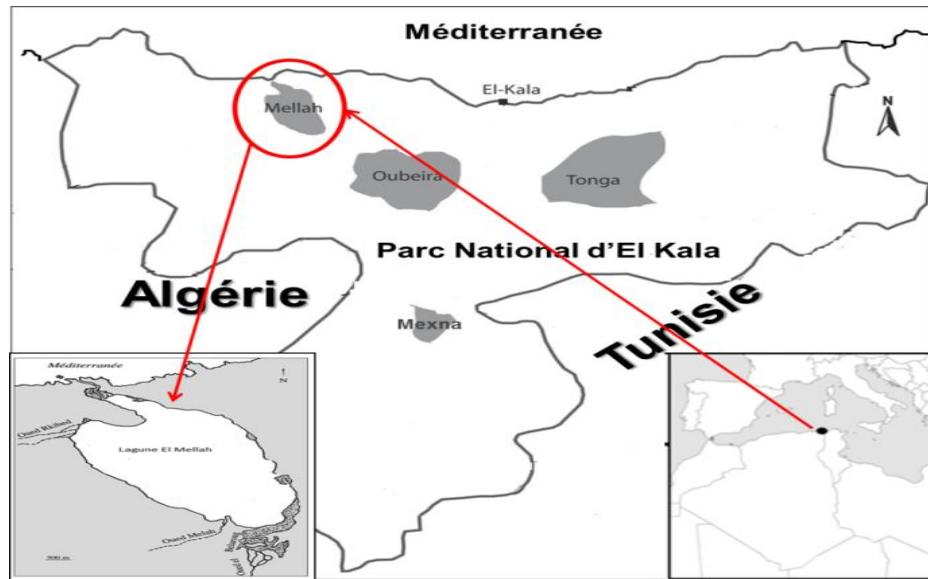


Figure 1. Map showing the study area

2.2. Sample processing

For this study, 50 to 60 specimens of *C. glaucum* measuring 25 to 30 mm in total length (ensuring homogeneous distribution) were sampled seasonally during 2015. In the laboratory, cockles were cleaned with distilled water and measured to the nearest 0.1 mm. Then, they were dissected, and their whole soft parts were taken. The latter were oven dried at 80 °C until a constant weight was achieved. Thereafter, the resulting dry flesh obtained was grounded to powder using a porcelain mortar before proceeding to the mineralization. This step consists in the complete destruction of the organic matter under the combined effect of temperature and concentrated nitric acid (Amiard et al., 1987). We added 1 ml of concentrated HNO₃ (65%) to the dry tissue (1 g) and after two hours at 65 °C, the mixture was brought to 95 °C, where it remained until the solution was clear and the reddish nitrous vapors had disappeared. To quantify trace metal concentrations in the cockle's digest solutions (completed with distilled water), an atomic absorption spectrophotometer (SAA) was utilized (flame for Zn and flameless for Cd, Cu, and Pb).

The results of trace metal concentrations are presented as mean $\pm$ standard deviation and expressed in mg/kg dry weight. The Kruskal-Wallis test was used to compare seasonal Cd, Cu, Zn, and Pb values. Statistical analyses were performed with R software, version 3.1.2. (R Development Core Team, 2014).

3. Results

The concentration levels of heavy metals (Cd, Cu, Zn, and Pb) measured in *C. glaucum* samples from El Mellah lagoon are illustrated in (Figure 2.) Cadmium (Cd) values varied from 0.09 to 0.15 mg/kg, whereas copper (Cu) concentrations ranged from 0.81 to 2.09 mg/kg. Values for zinc (Zn) varied within a narrow range (4.12 to 6.72 mg/kg), and lead (Pb) concentrations, on the other hand, had the lowest values (0.39 to 0.76 mg/kg). Our results revealed significant seasonal variations in analyzed heavy metals ($p < 0.001$). The maximum values for Cd, Cu, Zn, and Pb were all recorded in autumn, while the lowest concentrations were also all observed in spring and summer.

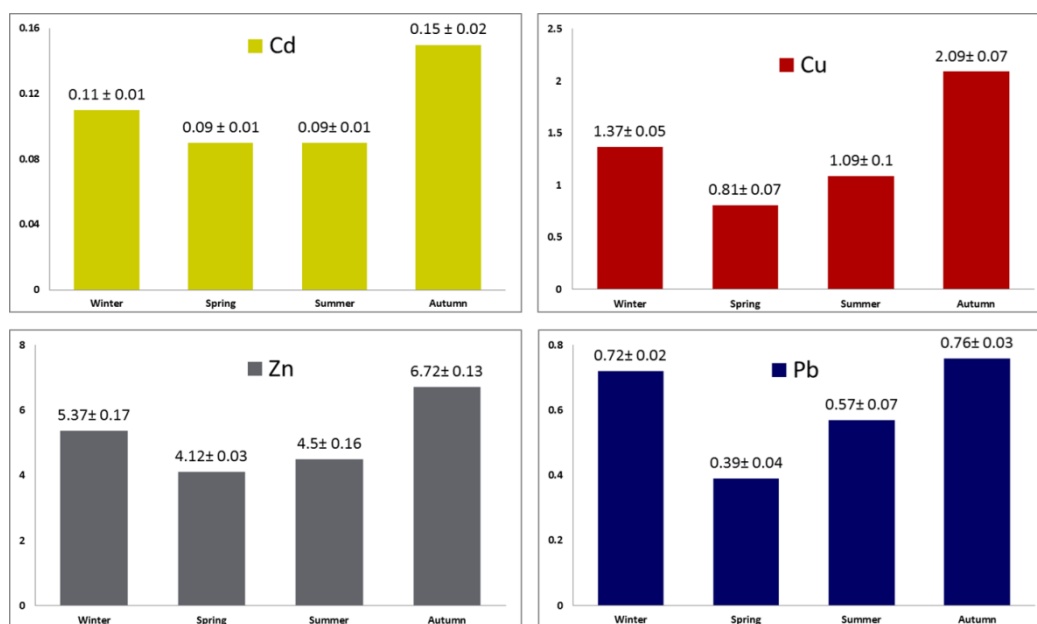


Figure 2. Seasonal variations in heavy metal concentrations (mg/kg) in *Cerastoderma glaucum* collected from El Mellah lagoon.

4. Discussion

In the present study, the objective was to evaluate the contamination level of El Mellah lagoon by the metallic trace elements Cd, Cu, Zn, and Pb via their dosage in the bivalve *C. glaucum* collected from this waterbody. According to Ladhari-Chaabouni (2009), the assessment of metallic bioaccumulation in this species based on an *in toto* analysis provides reliable information on metals' bioavailability in aquatic environment and their assimilation by these organisms. In El Mellah lagoon, our results showed that the order of measured trace metal accumulation potential in cockle tissues occurred in the following sequence: Cd < Pb < Cu < Zn. Copper and zinc are essential heavy metals that accumulate in aquatic organisms as dissolved and adsorbed forms, which could explain their relatively high levels detected in cockles under examination. Additionally, our data show a significant seasonal variability in measured metal concentrations. In fact, the maximum concentrations of Cd, Cu, Zn, and Pb were all recorded in the autumn; these concentration levels remained relatively high in the winter before sharply decreasing in the spring and summer. These variations

might be linked to cockles' ponderal status given that the spawning periods of *C. glaucum* from El Mellah occur between March and October (spring/summer) (Bensaâd-Bendjedid et al., 2018).

Several studies have shown that the seasonal fluctuations in metal concentrations in bivalve tissues are driven by physiological processes related to reproduction (Cossa *et al.*, 1980; Cossa, 1989; Girratano *et al.*, 2011). During gametogenesis, the gonads exhibit considerable development and become an efficient trap for metals' integration into organisms. By contrast, spawning results in a significant fall in their concentration associated with a decrease in the animal's weight (Kaimoussi *et al.*, 2000). Nevertheless, fluctuations in seasonal trace metal concentrations may also result from a combination of various factors either directly correlated with bivalve weight (temperature, food availability, and growth) or related to the biogeochemical cycle and metal bioavailability (Cossa *et al.*, 1980; Paez-Osuna *et al.*, 1995; Langston et Spence, 1995; Okumus et Stirling, 1998; Abdenour *et al.*, 2000; Cheggour *et al.*, 2001; Rainbow *et al.*, 2004; Beldi *et al.*, 2006 ; Taleb et Boutiba, 2007).

On the other hand, our results show that the concentrations of heavy metals in *C. glaucum* at the study site are significantly lower than those reported for a variety of benthic bivalve species in several transitional environments (lagoons and estuaries) at a regional scale (Table 1), as well as the permissible limits set by the international standard (Table 2). However, they remain close to those of Boudjellal et

al. (1998), who measured the same metals (Cd, Cu, Zn, and Pb) in the clam *Ruditapes decussatus* from El Mellah Lagoon despite the significant time interval between both studies. These findings may be explained by the fact that the lake's catchment area is low anthropogenized, supports moderate agricultural activity, and is distant from any source of industrial pollution.

Table 1. Comparison of metal concentrations (mg/kg dry weight) in different benthic bivalve species from lagoon and estuary systems.

Species	Cd			Cu			Zn			Pb			Location	Reference
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean		
<i>Cerastoderma glaucum</i>	0.08	0.15	0.10	0.80	2.14	1.38	4.12	6.97	5.32	0.39	0.76	0.60	El Mellah Lagoon/ Algeria	Present study
	0.02	0.11	0.06	1.35	7.08	3.54	6.37	52.17	27.5	-	-	-	Lac Ganzirri/ Italia	Di Bella et al. (2013)
	< 0.17	< 0.17	-	4.50	14.78	-	-	-	-	1.12	4.05	-	Obidos Lagoon/ Portugal	Valez et al. (2016)
<i>Cerastoderma edule</i>	< 0.004	3.16	1.57	4.9	18.1	8.77	38.5	78.5	58.3	9.3	37.7	18.9	Moulay Bou Selham Lagoon/ Morocco	Cheggour et al. (2001)
	0.095	4.01	2.37	6.45	37.6	22.6	75.4	151	115	8.09	30	16.5	Sidi Moussa Lagoon / Morocco	
	-	-	-	0.15	24.45	7.91	85.55	139.35	117	5.6	32.3	18.75	Bouregreg Estuary/ Morocco	Benmessaud (2007)
<i>Ruditapes decussatus</i>	-	-	0.09	-	-	2.9	-	-	11.4	-	-	0.82	El Mellah Lagoon/ Algeria	Boudjellel et al. (1998)
	-	-	-	0.25	13.75	6.18	71.9	144.7	107.95	8.3	30.7	16.65	Bouregreg Estuary/ Morocco	Benmessaud (2007)
	0.16	0.36	-	5.8	14	-	90	137	-	1.2	8.2	-	Tunis Lagoon/ Tunisia	Chalghmi (2015)
	-	-	0.70	-	-	15.5	-	-	94.7	-	-	13.2	Timsah Lak/ Egypt	EL-Shenawy et al. (2016)
<i>Venerupis aurea laeta</i>	0.41	0.14	1.55	2.98	9.45	5.20	46.46	102.1	65.76	-	-	-	Ganzirri Lake/ Italia	Di Bella et al. (2013)
<i>Scrobicularia plana</i>	-	-	1.34	-	-	32.4	-	-	131	-	-	-	Loukkos Estuary / Morocco	Cheggour et al. (2005)
	-	-	2.3	-	-	51.5	-	-	179	-	-	-	Sebou Estuary / Morocco	
	-	-	2.3	-	-	45.2	-	-	172	-	-	-	Bouregreg Estuary / Morocco	
<i>Paphia undulata</i>	-	-	1.1	-	-	15.5	-	-	73.8	-	-	13.9	Timsah Lak/ Egypt	EL-Shenawy et al. (2016)

Table 2. Maximum levels laid down for regulated heavy metals in the bivalve molluscs flesh (mg/kg).

Country/ Organization	Cd	Pb	References
Algeria	1	1.5	Official Newspaper of People's Democratic Republic of Algeria (n°: 25, 2011)
European Union	1	1.5	European Commission Regulation (EC N° 1881/ 2006)
FAO /WHO	2	0.3	General standard for contaminants and toxins in food and feed Codex Alimentarius (1995)
USA	4	1.7	Center for Food Safety and Applied Nutrition, US Food and Drug Administration (FDA, 2001)

5. Conclusion

The present study contributed to determining the state of El Mellah lagoon contamination with trace metal elements through the analysis of their accumulation in the bivalve mollusc *Cerastoderma glaucum*. Results exclude the existence of an ecotoxicological threat linked to the presence of essential (Cu, Zn) and toxic (Cd, Pb) metals in the cockles' flesh.

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