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ORIGINAL RESEARCH ARTICLE

Seasonal assessment of biological indices, bioaccumulation and bioavailability of heavy metals in mussels *Mytilus galloprovincialis* from Algerian west coast, applied to environmental monitoring☆

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Summary The aim of the present work is to broaden our knowledge on the variability of trace metals in mussel tissues, focusing on seasonal fluctuations in the three different sampling sites of Algerian west coast (Oran Harbor (S1), Ain Defla (S2) and Hadjaj (S3)). For this purpose, the bioavailability (metal indices) and bioaccumulation (metal concentrations in soft tissues) of heavy metals (Zn, Cu, Pb, and Cd), and the physiological characteristics (e.g. biological indices such as condition index (CI)) of mussels *Mytilus galloprovincialis* have been assessed and related to seasons and sites. In S1, the highest levels of metal concentrations and indices were obtained in mussels sampled in winter for Zn, Cu and Cd, but in summer for Pb. The biological indices significantly decreased in winter. In S2, the levels of concentrations and indices of all metals varied whatever the seasons, excepting in summer where the values were the lowest. In summer

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and spring, the biological indices were lower than in autumn and winter. The low growth of organisms in spring and summer might be correlated to the reproductive period and the low trophic level known in S2. S3, considered as a "pristine" area, showed low metal concentrations and indices, and high biological indices, reflecting the favorable physiological conditions for the mussel growth. This approach might be used in the monitoring of the quality of coastal waters and the present work provided a useful data set for Mediterranean monitoring network.

1. Introduction

During the last twenty years, Algeria's population has increased by 50%. About 45% of this population is concentrated on a very narrow strip of the littoral, especially in the industrial and harbor zones (Grimes et al., 2010). This coastal population is still increasing considerably and exerts a great anthropogenic pressure on the coastal marine ecosystem. Worsening conditions can be observed in large sections of the coast, particularly in the gulfs close to the Algerian largest agglomerations, such as Algiers, Oran and Annaba and near the industrial-harbor complexes (Grimes et al., 2010). Algeria participates in the implementation of the Barcelona Convention, which was intended to protect the Mediterranean Sea against pollution (UNEP, 1997). In this context, several biomonitoring studies have been conducted, during the last ten years, along the western coast of Algeria. However, most of these studies were generally limited to the use of a single approach such as dosage of pollutants, monitoring of biomarkers, or determination of biotic indices (Grimes et al., 2010; Rouane-Hacene et al., 2008; Taleb et al., 2007). These studies demonstrated that the industrial and domestic untreated wastewater effluents and run-off water contaminated by pesticides and heavy metals represented a major source of chemical contamination of this coastal area. Heavy metals which are the major anthropogenic contaminants of estuarine and coastal waters may be present in particulate or dissolved forms. Although many metals are essential biological elements, all of them have the potentiality to be toxic to organisms above certain threshold concentrations. Brown and Depledge (1998) showed that these limits should not be exceeded in aquatic environments for the protection of aquatic biota. Thus, coastal waters and sediments of Algerian coast showed high levels of heavy metals especially for Cd, Cr, Cu, Fe, Ni, Pb and Zn (Alomary and Belhadj, 2007; Soualili et al., 2008).

The mussels, in particular the marine *Mytilus* bivalves, are filter feeders widely used as spatial and temporal bio-integrators of marine pollution, for their ability to accumulate and concentrate pollutants (e.g. heavy metals) in their soft tissues at levels higher than those found in the ambient water (Pan and Wang, 2012; Sasikumar et al., 2006; Szefer et al., 2004). Several studies have shown that the variation of biological responses of these organisms to a wide range of contaminants may be caused in part by seasonal and spatial patterns (Fattorini et al., 2008; Pisanelli et al., 2009; Regoli and Orlando, 1994). Furthermore, the metal bioaccumulation may be influenced by the interactions between physiological (growth, weight loss, absorption and accumulation), chemical (metal concentration, speciation and bioavailability) and environmental (temperature and food concentration) factors (Casas and Bacherb, 2006).

In the present study, three sites (Oran Harbor, Ain Defla and Hadjaj) located on the Algerian western coast were chosen because of the distinct nature of the pollution sources present in these areas. The first sampling site was located in the large port of Oran characterized by trade, fishing and marina, receiving untreated sewage effluents from the Oran Metropolis and industrial settlements. The second was located at Ain Defla, in a rural area, near a small fishing port, receiving untreated domestic effluents and agricultural runoffs. Finally, the third was located at Hadjaj, considered as the reference site, because it was far from anthropogenic activities.

The aim of the present study was to establish a seasonal assessment of the marine environment quality and a putative contamination gradient between the three sites. For this purpose, the bioavailability and the bioaccumulation of heavy metals (Zn, Cu, Pb, and Cd), and the physiological characteristics of mussels *Mytilus galloprovincialis* were assessed and related to seasons and sites. The overall results enlighten our knowledge on the influence of seasons when monitoring the potential impact of anthropogenic activities on the water quality of Algerian west coast. The present work provides a useful data set for Mediterranean monitoring network.

2. Material and methods

2.1. Sampling sites

The studied area extends along the western coast of Algeria, from Oran to Mostaganem, as shown in Fig. 1. Three sampling sites were selected with respect to the main identified pollution sources to follow a presumed contamination gradient (Eastwards: sites 1—3): site 1 (S1: 35°42′31.07″N, 0°38′26.76″W) was located in the large port of Oran, site 2 (S2: 35°49′03.66″N, 0°28′55.89″W) at Ain Defla, and site 3 (S3: 36°06′09.59″N, 0°19′11.48″E) at Hadjaj (considered as the reference site).

2.2. Collection and preparation of samples

Coastal waters and mussel samples were collected in 2010, once each season of one annual cycle (February (winter), May (spring), August (summer), November (autumn)), from each of the three studied sites.