Environmental Pollution 207 (2015) 226–237

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Accumulation of trace metals in sediments in a Mediterranean Lagoon: Usefulness of metal sediment fractionation and elutriate toxicity assessment

Noureddine Zaaboub [a], Maria Virgínia Alves Martins [b], Amel Dhib [c], Béchir Béjaoui [a], François Galgani [d], Monia El Bour [a], Lotfi Aleya [c, *]

[a] Institut National des Sciences et Technologies de la Mer, Salammbô, Tunis, Tunisia
[b] Universidade do Estado do Rio de Janeiro – UERJ, Faculdade de Geologia, Av. São Francisco Xavier, 524, Maracanã, 20550-013 Rio de Janeiro, RJ, Brazil
[c] IFREMER/Laboratoire Environnement Ressources PAC/Corse Imm Agostini, ZI Furiani, 20600 Bastia, France
[d] Université de Bourgogne Franche-Comté, Laboratoire de Chrono-Environnement, UMR CNRS 6249, 16, route de Gray, F-25030 Besançon cedex, France

ARTICLE INFO

Article history:
Received 3 July 2015
Received in revised form
13 August 2015
Accepted 10 September 2015
Available online xxx

Keywords:
Coastal lagoons
Trace metals
Toxicity
Bioassays
Pollution effects

ABSTRACT

The authors investigated sediment quality in Bizerte Lagoon (Tunisia) focusing on geochemical characteristics, metal sediment fractionation and elutriate toxicity assessment. Nickel, Cu, Zn, Pb, Cr and Cd partitioning in sediments was studied; accumulation and bioavailability were elucidated using enrichment factors, sequential extractions, redox potential, acid volatile sulfide and biotest procedures in toxicity evaluation. Results revealed an accumulation for Pb and Zn, reaching 99 and 460 mg kg^{-1} respectively. In addition, the acid volatile sulfide values were high in both eastern and western lagoon areas, thus affecting metal availability. Mean enrichment factor values for Pb and Zn were 4.8 and 4.9, respectively, with these elements as the main contributors to the lagoon's moderate enrichment level. Toxicity levels were influenced by accumulation of Zn in different surface sediment areas. Core sediments were investigated in areas with the highest metal concentrations; metal fractionation and biotest confirmed that Zn contributes to sediment toxicity.

1. Introduction

Anthropogenic activity has dramatically increased the amount of potentially toxic compounds in many ecosystems, threatening human health and causing a decline in species diversity (UNEP/MAP, 2012; Belabed et al., 2013). Coastal lagoons are generally considered to be a sink for trace metals and Bizerte Lagoon, located in northern Tunisia, is no exception as it is strongly affected by its proximity to industrial and urban areas, with three open-dumping type municipal/industrial solid waste landfills (A, B, D) operating in the region and an urban reject zone (C) (Fig. 1) (Lahbib et al., 2010; Fertouna-Bellakhal et al., 2014, 2015). Heavy metal pollution from these landfills and from Tinja Channel, have increased the flow of anthropogenic metals into the lagoon. Adsorbed by the sediments, the bioavailable metal fraction induces potential sub-lethal population-altering dynamics for most of the species in contact with them. For example, toxic biological effects have been reported such as imposex incidence in the muricid gastropod *Hexaplex trunculus* (Lahbib et al., 2010), inhibition of acetylcholinesterase activity in sampled clams and mussels (Dellali, 2001), oxidative damage to DNA in clam gills (Jebali et al., 2007) and substantial vertebral deformities in three *Gobiidae* species (Louiz et al., 2008).

However, no comprehensive study has ever before been conducted on chemical fractionation of sediments (metal fractionation between geochemical phases), nor have any larval toxicity tests been conducted. We therefore hypothesized that the observed heavy metal-mediated toxicity should be evaluated by using metal enrichment in sediments and chemical fractionation of trace elements so as to determine the elements present in the labile fraction that may be readily bioavailable in interstitial water and the water column. With this bioavailable fraction we might improve our interpretation of the known toxicity demonstrated when larvae were directly exposed to elutriates (Geffard et al., 2002). For

* Corresponding author.
E-mail address: lotfi.aleya@univ-fcomte.fr (L. Aleya).

http://dx.doi.org/10.1016/j.envpol.2015.09.033
0269-7491/

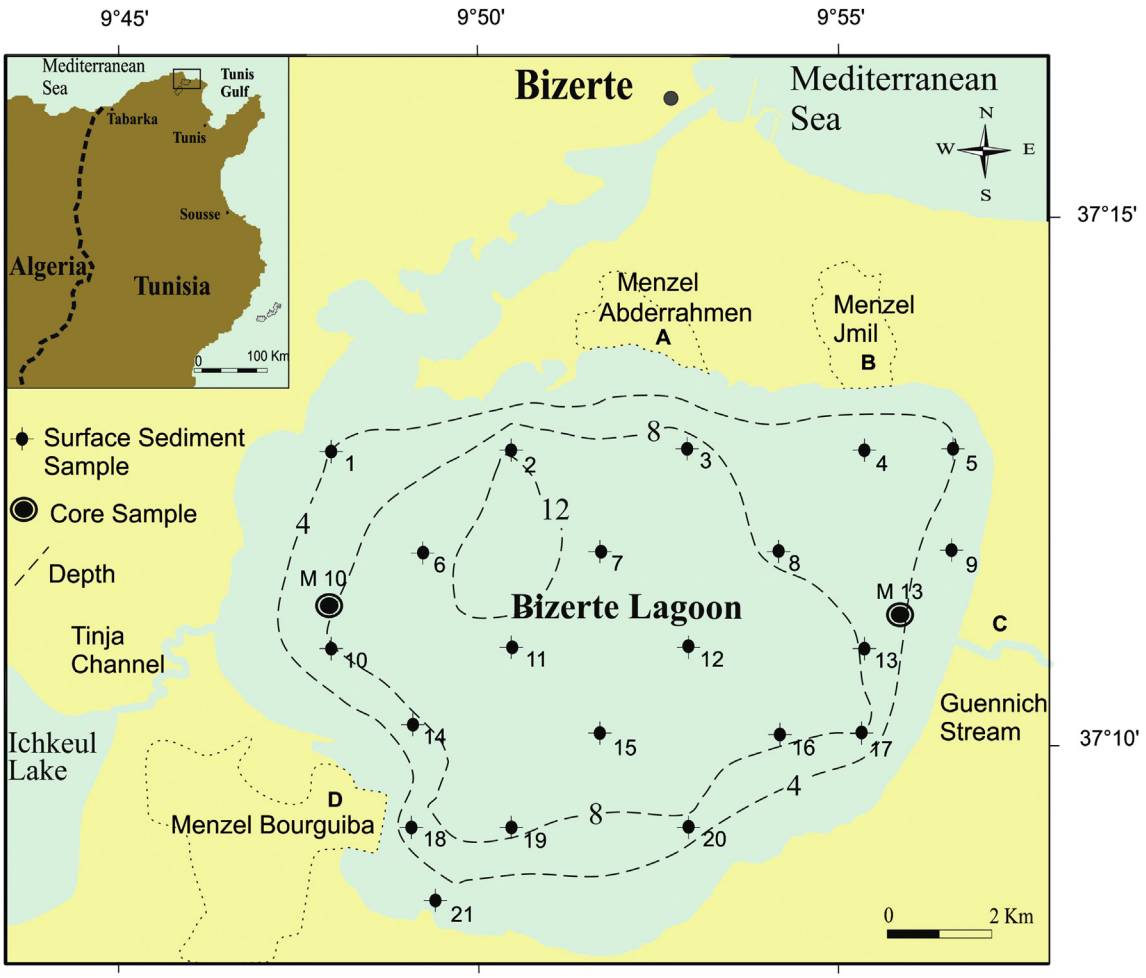

Fig. 1. The Geographical position of the study area and sediment sampling sites in Bizerte Lagoon.

instance, thin toxicity tests have been used to study contamination in larval growth of the oyster *Crassostrea gigas* in coastal regions, the most sensitive environment to pollution (Geffard et al., 2002; Galgani et al., 2009; Mamindy-Pajany et al., 2010), yet they had never been tried in North African lagoons and certainly not in Bizerte Lagoon. Since, according to our hypothesis, (1) acid-volatile sulfides (AVS) are an important carrier phase for trace elements in marine sediments (Di Toro et al., 1990), and (2) trace elements are usually associated with fine-grained sediments because of their high surface-to-volume ratios and adsorption capability (Burdige, 2006; Szava-Kovats, 2008; Belabed et al., 2013), we should obtain enhanced information of the existing trace-element pollution potential by paying more attention to AVS and grain-size sediments. The hypothesis of the possible toxicity of organic pollutants was not tested in our investigation because recent studies prove that these elements are not significant polluters in the sediments of Bizerte Lagoon (Barhoumi, 2014).

The objectives of this study were to quantify Ni, Cu, Zn, Pb, Cr and Cd in sediments from Bizerte Lagoon and to elucidate the sources of environmental degradation. A high resolution sampling was thus conducted during the winter of 2010 to assess the sediments using enrichment factors (EF) and therefore, (1) to determine the difference between the natural versus the anthropogenic presence of trace elements in the sediments and (2) to quantify the relation between trace elements, Eh, AVS and biological toxicity.

2. Materials and methods

2.1. Sampling site

Bizerte Lagoon, situated in northern Tunisia (37°8–37°14′ N and 9°46′–9°56′ E), has a surface area of 128 km^2, a maximum depth of 12 m and a catchment area of 380 km^2. It is connected to Ichkeul Lake through the 5 km-long Tinja Channel (Fig. 1) which is equipped with locks allowing periodic flow between lake and lagoon averaging 165 Mm^3 year^{-1} (Béjaoui et al., 2010). Since construction of several dams on the lagoon's principal tributaries and installation of the channel locks in 1989, this flow has significantly decreased, thereby affecting the lagoon's hydrodynamics as well as its ecological environment (Sellami et al., 2010; Turki et al., 2014). The principal locations affected by human activities (zones A–D) are shown in Fig. 1: (A) affected by urban rejects, (B) urban and industrial rejects area, (C) urban rejects zone and (D) has shipyard activity and an iron factory.

2.2. Sample processing

Surface sediment samples were collected at 21 sites using an Ekman grab sampler (Rickly Hydrological Company, Columbus, Ohio, USA) (Fig. 1). Five to 10 cm of surface sediments were collected and kept in polyethylene flasks at −4 °C for immediate or