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Environmental and ecological risk assessment of heavy metals in sediments of Nador lagoon, Morocco

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ABSTRACT

Heavy metal assessment in Nador lagoon (Mediterranean coast) was carried out using different environmental indices. In addition, heavy metal concentrations were measured in sediment samples and compared with consensus-based sediment quality guidelines. The spatial distributions of the main contamination sources of heavy metals were identified and described using chemometric and geographic information system methods.

The results show that heavy metals occur in lagoon sediments largely due to the anthropogenic activities in the area (urban effluents). The concentrations of heavy metals found in surface sediments are significantly higher than those from the local background. The potential ecological risk index and other environmental indices produced similar values for the levels of heavy metal pollution in Nador lagoon sediment, thereby confirming each other's results. Pollution indices and statistical analysis show that the heavy metals pose an ecological risk and indicate that Nador lagoon is moderately to considerably pollute.

1. Introduction

With significant natural resources and favorable geographical locations, coastal areas have become centers of human activity worldwide (Pielke, 2005). According to Costanza et al. (1997), "Coastal and estuarine ecosystems are the most productive ecosystems on earth". The functions and processes of an ecosystem can provide services and products that can be used by humans in different ways.

Coastal environments, which are among our most important food sources, are also the ultimate receptacle of pollutants (including heavy metals). The disposal of waste products into rivers and estuaries, especially those in industrial and urban areas, has led to a significant increase in metal contamination (Maanan, 2008). Metals are gradually being concentrated in these water bodies and, at higher concentrations; they are proven toxins for marine biota and humans. Because catastrophic events can cause toxic metals to increase suddenly and have significant effects on human health, at present, there is a great interest in toxic metals from marine environments.

In Moroccan coastal areas, the improper use of land by human activities is a primary factor causing the degradation of water quality and habitat, in addition to local and global climate change (Pielke, 2005). It can also affect the function of heavy metal contaminants in coastal sediments (Mhamdi Alaoui et al., 2010; Maanan et al., 2013, 2014).

Metal contamination of sediments will affect the water, living species and human health (Maanan, 2007, 2008). The direct determination of heavy metals in sediments is an inappropriate means to assess the heavy metal pollution from both natural and anthropogenic sources as they accumulate in sediments in the same way (Zourarah et al., 2007, 2009; Kalloul et al., 2012). The use of heavy metals as indictor of marine pollution has been strongly recommended by international organizations/conventions, such as the 'Barcelona Convention' (Convention for the Protection of the Mediterranean Sea against Pollution) and MEDWET Coast, among others.

The objectives of this study were to (1) determine the spatial and temporal distributions of heavy metals in surface sediments of the lagoon of Nador, (2) define the natural and/or anthropogenic

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sources of these metals using statistical techniques and (3) assess the degree of contamination by heavy metals in the lagoon using indices of contamination.

2. Materials and methods

2.1. Study area

Nador lagoon (34°54′N–02°10′W and 35°17′N–03°05′W) is one of the largest coastal lagoons in the Mediterranean basin. It has an oval shape with an area of 115 km^2, lies in a NW–SE direction, and is separated from the sea by a barrier (25 km long), with an average width between 300 and 400 m and a low height (<20 m) (Ruiz et al., 2006). The average depth of the lagoon is 5 m, with a maximum depth of 8 m. The depths increase from edges (3 m depth) to the middle part of the lagoon (8 m). The salinity range is 33–40 in the extremity of the lagoon where the mixing of the water column is very low (stratification of the water column is very weak). The rainfall is of about 300 mm per year and the prevalent wind come from W–NW and E, which is about the direction of the major axis of the lagoon.

The lagoon system receives three types of water: (a) marine waters through an artificial entrance, which are dominant, (b) hydro-geological contributions of two aquifers: Gareb, located south of the River Selouane, and Bou Areg, located near the southern margin of the lagoon, and (c) surface waters from the periodic flow of 10 small rivers (wadis). Among these, the river Selouane is the largest, in which is dumped the municipal and industrial waste of the village of Selouane (Ruiz et al., 2006).

As in any other part of the coastal world, the Nador coastal region is the active interface between land and sea. Nador lagoon supports many aspects of human life, such as economic, cultural, and community relations. It has been declared a site of ecological and biological interest (SIBE). It is also one of the four Moroccan sites that have been reviewed by the Ramsar Convention for the conservation of wetlands of international importance.

Nador lagoon is also the part of the basin that has undergone the most dramatic alterations due to the rapid change in demographic trends, the new socioeconomic conditions prevailing (which favor a higher consumption of natural resources) as well as new technologies including transport (new roads, new types of ship and therefore new harbors, etc.). The resident population has almost doubled over the last 33 years, exceeding at present 728,634 inhabitants (RGPH 2004) compared to 480,517 inhabitants in 1971.

Nador lagoon was classified as a “hotspot” of Mediterranean pollution by the Action Plan for the Mediterranean. Human pressure has augmented rapidly and has often been poorly planned, marked by an increase in artificialized and agricultural areas to the detriment of natural areas. The anthropogenic activities developed in both its terrestrial and marine parts affect the state of the lagoon environment, as has been detected and demonstrated through the analysis of a large number of physicochemical and biological parameters of marine coastal waters, sediments and biota (Ruiz et al., 2006).

The pressures thus exerted on the environment and natural resources (such as freshwater, soils, forests, etc.) are obvious and are closely linked to “litoralization” and “urbanization” phenomena. The main sources of pollution are related to: (i) system dysfunctions in the collection and treatment of liquid effluents and solid waste in the watershed; (ii) pollution from agriculture, for example the numerous irrigation channels and oueds draining the southern border of the lagoon, carrying the liquid/solid residues of a broad area occupied by farming (Fig. 1) and (iii) pollution related

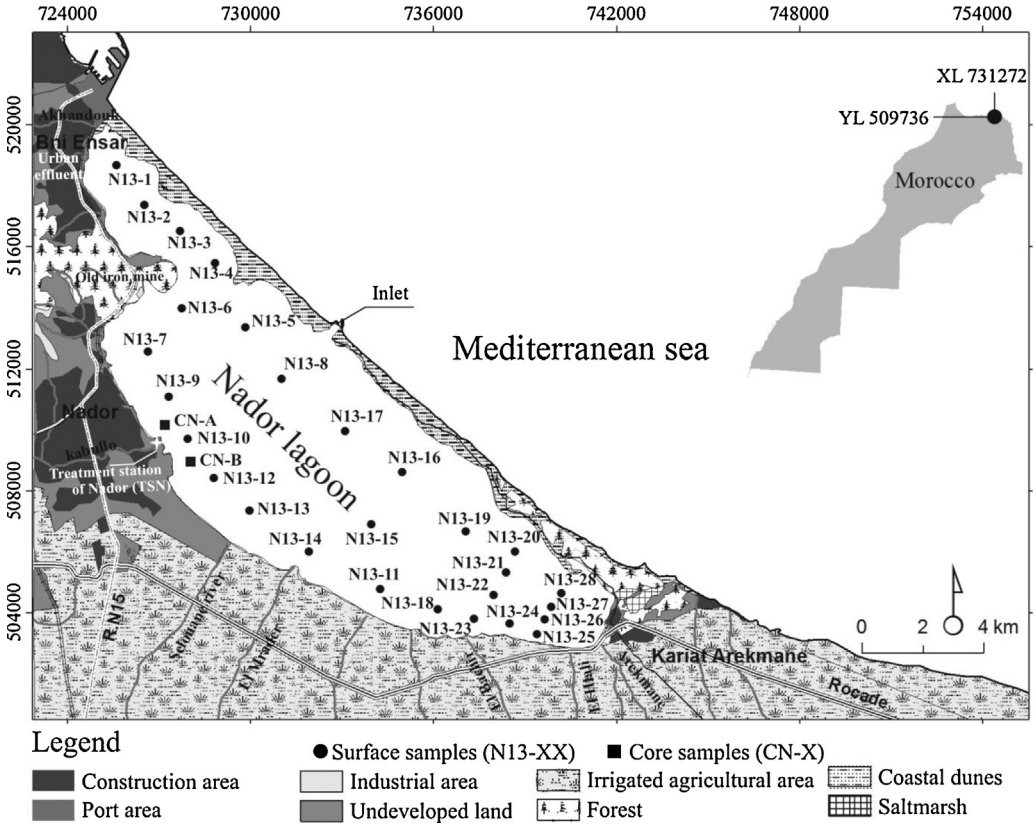

Fig. 1. Map showing land uses and sampling sites.