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Characterization and evolution of the sediments of a Mediterranean coastal lagoon located next to a former mining area

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ABSTRACT

Coastal lagoons are ecosystems that are relatively enclosed water bodies under the influence of both the terrestrial and the marine environment, being vulnerable to human impacts. Human activities, such as mining extraction, are significant anthropogenic coastal stressors that can negatively affect ecosystems and communities. In light of the above, the objective of this research is to examine the influence of metal mining activities on the composition of sediments of a Mediterranean coastal lagoon, named Mar Menor. This paper presents a comprehensive characterization for grain size, mineralogy, geochemistry and organic matter of sediments of this coastal lagoon, investigating their variation along space and time. Sedimentation dynamics are ruling clearly the grain size predominant in each area of the Mar Menor coastal lagoon, determining the existence of entrainment, transport and sedimentation areas. For minerals, elements and organic matter, sedimentation dynamics are also determining their distribution.

1. Introduction

Coastal lagoons are relatively enclosed water bodies under the influence of both the terrestrial and the marine environment. Furthermore, being close to land, they are vulnerable to human impacts (Hodgkin, 1994; Reizopouluo et al., 1996; Fujita et al., 2014). Therefore, environmental characteristics will be conditioned by their immediate surroundings, which will determine both the mineralogical composition of the sediments, and the quality of its waters and the contamination level of the organisms that live inside.

Environmental conditions in coastal lagoons are very changeable due to their confined nature and to their shallowness. Coastal marine systems are particularly vulnerable to the effects of human activities resulting from mining, industry, tourism and urban development. Despite their importance, these systems are among the most vulnerable water environments in the world and they might even be considered as stressed ecosystems. In fact, they are subject to considerable anthropogenic pressures that usually lead to changes in their environmental health (Courrat et al., 2009).

As for other sedimentary environments, the composition of sediments that accumulate within individual coastal lagoons is primarily a reflection of three main factors (Perry and Taylor, 2007): the sediment source, the processes of sediment transport and deposition, and the chemical processes operating within the sediment or water column. Increasingly important in many sedimentary systems are inputs of anthropogenically sourced sediments. These include both sediment grains that come from material that is anthropogenic in origin and sedimentary materials that have been heavily impacted by anthropogenic activity.

Human activities, such as mining extraction, are significant anthropogenic coastal stressors that can negatively affect ecosystems and communities through the alteration or loss of littoral habitats, increased pollutant inputs, loss of allochthonous material and changes in food availability (Peterson et al., 2000; Sanger et al., 2004; Seitz et al., 2006). Concerning this, sediment composition may differ significantly with the distance to neighbouring mining areas. This results in the generation of different sediment mineralogy inside the coastal lagoon according to a distance gradient to mining areas, which can produce a specific pollution of water and sediments, as well as a specific composition of flora and fauna (Bilkovic and Roggero, 2008).

Heavy metals and metalloids can be toxic at high concentrations and can affect aquatic organisms, as well as adversely affect human health (Nor, 1987; Silva et al., 2000). These elements usually have dynamic distribution and behaviour in lagoon sediments and their sources can be natural or anthropogenic (Kouassi et al., 2015). High metal content in fauna and flora in lagoons may impart a very important impact on human health, reproduction and, consequently, our survival (Abdallah and Mohamed, 2015; Kouassi et al., 2015).

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On the other hand, marine and coastal lagoon sediments not only support a variety of living organisms that are important for maintaining ecosystem structures and functions, but are also a reservoir for insoluble contaminants such as metals (Chapman and Wang, 2001; Kouassi et al., 2015; Renzi et al., 2015). The bioavailability of sediment-bound contaminants is determined by sediment constituents, overlying and interstitial water chemistry, and the behaviour of organisms (Loring, 1991), and so should be considered as a dynamic process. For this reason, sediment quality and mineralogy assessment in coastal lagoon areas can be an issue of interest for these ecosystems.

In light of the above, the objective of this research was to examine the influence of mining activities on the composition of sediments in a Mediterranean coastal lagoon, as well as discuss the possible causes and mechanisms of the sediment redistribution. These wastes were deposited on the bottom of the lagoon, to the extent that the lagoon itself came to be regarded as a mining deposit (Simonneau, 1973). These mining wastes were initially deposited in the southern basin of the lagoon, although the marine currents and other factors, such as wind, may have generated a redistribution of these sediments across the lagoon. We hypothesized that marine sediment distributions were not uniform across the lagoon's seabed, and those sediment grain size, mineralogy and geochemistry were expected to change over time and between different areas inside this ecosystem.

2. Material and methods

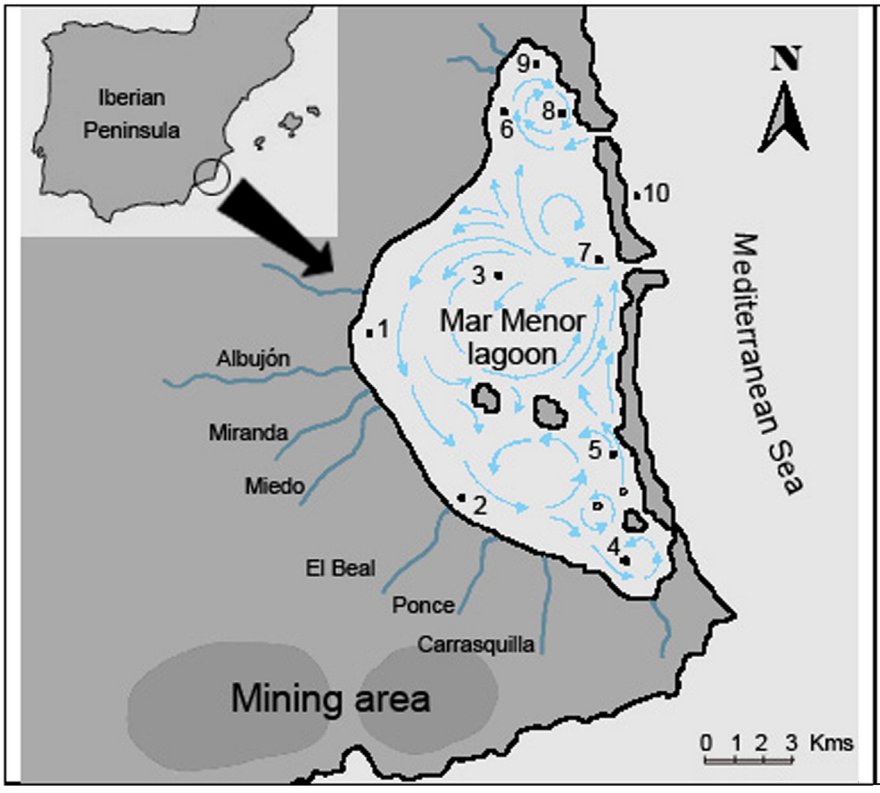
2.1. Study area

This study is focused in a coastal lagoon named Mar Menor that is placed on the southeastern Iberian Peninsula, Spain (Fig. 1). This water body is one of the largest coastal lagoons in the Mediterranean Sea.

The Mar Menor is a hypersaline coastal lagoon of 135.5 km^2, with a maximum length of 21 km and an average width of around 14 km, with a mean depth of 4.5 m and a maximum of 7 m (Martinez-Alvarez et al., 2011). It is separated from the Mediterranean Sea by a long sandy bar called La Manga, which has up to five narrow channels that connect it to the open sea. The lagoon shows a salinity range of 39–45 ppt and the temperature varies from 10 °C in winter to 32 °C in summer (Perez-Ruzafa et al., 2005). Its coastline is densely populated, supporting a large tourist population during summer months of about half a million people.

The mining district of Cartagena-La Union is located at the South of the lagoon (Fig. 1), and belongs to the eastern part of the Betic Ranges. Mining activities in the mining district date back to many centuries ago, because remains of exploitations belonging to ancient civilizations, including Iberians, Phoenicians, Carthaginians and Romans, have been found. At that time, they extracted mainly gold, silver, lead, zinc, iron and copper (Oen et al., 1975). The Carthaginians extracted large amounts of metals, besides silver, that contributed to increase their power in the war against Rome. Mining in Cartagena revived in the nineteenth century, with the start of underground mining through smallholding exploitations. The mining district of Cartagena-La Union becomes in the late nineteenth century one of the largest producers of lead (Vilar and Egea Bruno, 1990). In 1957 the open pit mining started with the opening of the Emilia quarry (Vilar et al., 1991), while in 1968 underground mining ended, which made way for “open pit” mining, although some isolated mines followed barely subsisting. This prolonged activity has caused quite a visual impact on the area due to the presence of numerous accumulations of mining waste. Between 1957 and 1987 more than 360 million tons of rocks were mobilized. Mining ceased in 1991 due to economic, environmental and social pressures (García, 2004).

The bed sediment grain size composition of the lagoon is predominantly muddy and sandy, with some areas with natural rocky bottoms



Sampling Stations	X	Y
SS1	689256	4177307
SS2	693137	4171401
SS3	694786	4179275
SS4	699320	4169386
SS5	698662	4172949
SS6	694229	4185186
SS7	698443	4180232
SS8	696812	4185342
SS9	695575	4187341
SS10	698730	4182574

Fig. 1. Location, on the left side, of Mar Menor lagoon, internal currents and different sampling stations 1 to 10 (adapted from Díaz del Rio and Somoza, 1993 and Bautista et al., 2007). Coordinates, on the right side, presented in UTM ETRS89 for different sampling stations (SS); X = longitude and Y = latitude.

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