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Possible impact of environmental policies in the recovery of a Ramsar wetland from trace metal contamination

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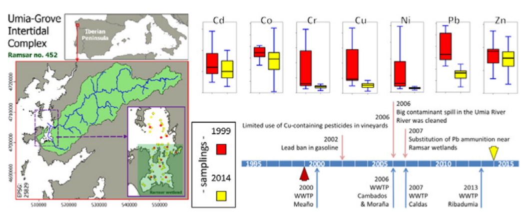
HIGHLIGHTS

- Contamination levels decreased from severe in 1999 to possible/suspected in 2014.
- Recovery due to environmental policies, not by direct cleaning actions
- More effective environmental works are needed to preserve the Ulla-Umia wetland.

GRAPHICAL ABSTRACT



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ABSTRACT

The Umia-Grove Intertidal Complex is located within the Ria of Arousa (NW Iberian Peninsula). Out of its significance for wintering shorebirds it has been included in the Ramsar List of Wetlands of International Importance as well as in international protection networks such as the European Natura 2000 and Important Bird and Biodiversity Areas-BirdLife International. In a sediment analysis conducted in the year 1999, the wetland was found to have been contaminated by potentially toxic trace metals, to wit: Cr, Cu, Ni, and Pb. Sediment samples retrieved in 2014 to make an updated assessment of the condition of the ecosystem showed evidence of the presence of selected trace elements, namely, Cd, Co, Cr, Cu, Ni, Pb, and Zn, within or slightly above the background ranges of local, regional, and general references. In the 15-year time frame between the two samplings there has been noticeable change in the relationship between nature and society as a consequence of the entry into force of a number of regulations aimed at avoiding the emission of contaminants; among others, the ban of Pb in gasoline, the deployment of wastewater treatment plants according to the European Water Framework Directive, and the limitation of the use of Cu pesticides. With the ensuing drop of human pressure, the self-purifying capacity of the ecosystem has effectively contributed to the wetland's recovery. Nevertheless, the application of a normalized enrichment factor to the more recent set of samples suggests the presence of relict low contamination by Cd, Cu, and Ni in localized areas. The compared analysis of the wetland condition in the two years is a sign of the success of the policies and regulations for environmental protection, but further work and more effectiveness are necessary in order to preserve threatened ecosystems of such importance as the Umia-Grove wetland.

1. Introduction

In the year 1972, the United Nations Conference on the Human foresaw a time when technological development would make mankind powerful enough to drastically transform the natural environment at a global level by becoming involved in the origin of disturbances of the natural cycles in the ecosphere having negative effects. The Conference

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highlighted the need to protect the natural environment and improve its condition as the “desire of peoples […] and the duty of all Governments” (United Nations, 1972). As a consequence of this statement, a number of locations around the globe were declared protected areas. According to the definitional statement put forward by the International Union for Conservation of Nature, the IUCN (Dudley, 2008), one of the objectives pursued by this declaration is the long-term conservation of the natural ecosystems that the locations shelter.

Among the several regulatory documents concerning formal protection it is to be singled out The List of Wetlands of International Importance (The Convention on Wetlands, or The Ramsar Convention), which, given its status, is also known simply as “The List”. This is an intergovernmental treaty with the mission to preserve wetlands through a rational use by means of local, national, and international actions performed within the contextual scope of the notion of sustainable development (Ramsar, 2017a). The treaty involves 169 Contracting Parties and the list includes 2290 sites; the 42% of which, up to 953, are marine or coastal wetlands.

One of these areas is the Umia-Grove intertidal complex, located in the estuary of the Umia River and its surroundings, within the Ria of Arousa (Galicia, Spain), in the northwest coast of the Iberian Peninsula. Earlier studies about the Ria of Arousa (see Prego and Cobelo-García, 2003 and references therein) provided evidence of metal contamination in this ria. In particular, the river mouths were identified as risk areas. This is, the estuary of the Ulla River (Belzunce Segarra et al., 1997; Carballeira et al., 2000; Prego et al., 1999; Real et al., 1993) and, to a lesser degree, the mouth of the Umia River (Álvarez-Vázquez et al., 2014; Carballeira et al., 2000), where the aforementioned Ramsar site is located.

Since the beginning of industrialization, especially after the mid-twentieth century, the natural biogeochemical cycles have undergone the effects of dramatic modifications fruit of human action, most commonly in the form of the massive release of chemicals to the environment from municipal and industrial effluents, including some trace elements (TEs) as common contaminants (Gaillardet et al., 2003; Meybeck and Vörösmarty, 2005; Rae, 1997). Early industrialization in the surroundings of rivers, estuaries, and coasts increases the contaminant TEs within the sedimentary registry (Hornberger et al., 1999 and Mil-Homens et al., 2016). It has been observed also, especially in developed countries, that the entry into force of emission-control regulations lead to a decrease in the release of contaminants, facilitating the recovery of the natural contents in the sedimentary registry (Carreta et al., 2002; Fdez-Ortiz de Vallejuelo et al., 2010; and Hosono et al., 2010).

Understanding how the wetlands interact with a rapidly developing world involves the joint consideration of both the positive and negative impacts of such an interaction, and the extent to which contamination control actions have been successful is only seldom addressed in the literature. This is the focus of the present study, which has for its main objective to assess the current quality status and the impact of the environmental actions performed in the early 21st century by considering trace metals as environmental indicators at such a sensitive site as the Umia-Grove Ramsar.

This work is based on samples of surface sediments retrieved in 1999 and 2014, allowing to compare the evolution of contamination in the 15-year time frame with the aim to disclose the possible origins of the observed changes and understand their nature.

2. Study area

In 1990, Spain incorporated the Umia-Grove intertidal complex to the Ramsar list as the site number 452 (Ministerio de Asuntos Exteriores, 1990; Agreement 10259). Together with the endemic flora, “the area is important for waterbirds and supports the largest number of wintering shorebirds (over 10 000) along the Atlantic coast of Spain” (Ramsar, 2017b). This protected area extends over 25.61 km^2 located between the O Grove Peninsula and the mouth of the Umia River, within the Ria of Arousa (NW of the Iberian Peninsula; see Fig. 1). The complex is included also in the Special Area of Conservation (SAC ES114004) “Complexo Ons-O Grove” (Council of the European Communities, 1992; EU Habitats Directive, 92/43/CEE) and in the Special Protection Area (SPA ES0000087) “Complexo Intermareal Umia-O Grove, A Lanzada, Punta Carreirón e lagoa Bodeira” (European Parliament and Council of the European Union, 2009; EU Birds Directive, 2009/147/CE); both in Natura 2000, an EU network of areas of high biodiversity value.

The principal input pathway of freshwater and sediments to the intertidal complex is the Umia River, with an average flow of 16.3 m^3 s^{-1} and a basin surface of 446 km^2 (Río Barja and Rodríguez Lestegás, 1992). The lithology of the watershed is composed mainly of granitic rocks (70.5%), metamorphic rocks (12.8%), and quaternary sediment deposits (16.4%), with a very low presence (not exceeding 0.2%) of filonian and basic-ultrabasic rocks (SITGA, 2017). Ore deposits containing iron (Fe), tungsten (W), and tin (Sn), as well as molybdenum (Mo) and bismuth (Bi) to a lesser degree, were recorded in the river basin (IGME, 2015).

The land use, according to the CORINE Land Cover (SITGA, 2017), is mostly forest and semi natural areas (57.2%) together with agricultural soils (40.1%), artificial surfaces occupying only the 1.9% of the basin area. It is important to highlight that approximately the 12% of the basin is devoted to vineyards and other woody crops (Spanish Information System of Land Use SIOSE, SITGA, 2017).

The population is distributed irregularly, the surroundings of the wetland and the Umia River basin being shared by 15 municipalities with an average population density of 123 people km^{-2}; the absolute figures being 120,589 people in 984 km^2 as of the year 2014 according to INEbase (2017) and SITGA (2017). The most densely populated locations are found in the coast (such as Cambados, with 573 people km^{-2}), and become less densely populated towards the river head (such as Forcarei, with 22 people km^{-2}). In 2014, there were 42 population nuclei with over 2000 people and 5 exceeding 10,000 in the influence area (INEbase, 2017).

The Ria of Arousa, and consequently the surroundings of the Umia Estuary and the O Grove Peninsula, is an important area for fishing, shellfishing and aquaculture; particularly, mussel (*Mytilus*) and oyster (*Ostrea*) cultivation in rafts, the Ria of Arousa being among the richest areas in Galicia (NW Spain) in this trading activity. As an example, consider that in the year 2009 the aquaculture production in the region reached up to about 210,000 t, employing around 25,000 people with a business volume in excess of 165 million euros (FOESA, 2010).

3. Material and methods

A sampling campaign conducted in 1999 in the Ria of Arousa led to the collection of 64 sediment samples, 11 of them from the area of the Umia-Grove Intertidal Complex and its surroundings. The samples were analyzed in the same year and the data retrieved were recovered for the present study from the database of the Marine Biogeochemistry Group (Marine Research Institute-Spanish National Research Council, IIM-CSIC). Since then, several works have been published pointing to metal contamination in the Ramsar wetland (see references cited in the Introduction).

In order to check the current condition of this wetland, 37 sediment samples were collected in 2014 on the location. For proper comparison with the earlier results dating from 1999, the samples were analyzed following the same procedures and methods.

Surface sediments (0 cm to 2 cm) were sampled in 1999 from the R/V Mytilus except in shallow waters, were an auxiliary boat was used. Two Shipeck grabs (with 30 L and 3.5 L capacity) were used in accordance with the boat. In the 2014 sampling, surface sediments were sampled at the same depth from a small boat (approximately 5 m long) using a Van Veen grab of 3.5 L capacity except for shore samples, which were hand-collected with a plastic spatula during the low tide. To avoid contamination, stainless steel grabs were used and the samples