

Environmental metal pollution in Ria de Aveiro, a coastal lagoon of N Portugal and benthic foraminifera answers

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Grab sediments samples of 49 sites were collected in the main channels of Ria de Aveiro, a coastal lagoon interconnected with the Atlantic Ocean and located in Northern Portugal, under strong anthropic influence. Levels of pollution by heavy metals were analysed by total digestion of the sediments (TDS) by ICP-MS and sequential chemical extraction (SCE) by ICP-OE. SCE was used to evaluate the concentrations of Zn, Pb, Cu, Cr, Ni and Cd as exchangeable cations adsorbed by clay and elements co-precipitated with carbonates (F1), associated with Fe and Mn oxides (F2), linked with sulphides and organic matter (F3).

Sediments grain size, TOC content and mineralogical composition (in total sediment and clay fraction, by XRD techniques), were also determined. During the sampling campaigns, the depth was measured with the boat's sonar and the sites were located with a GPS. Some environmental parameters, such as temperature, salinity/conductivity, pH and Eh, were measured in bottom water and sediment.

The effects of the contamination on biota were evaluated also on benthic foraminifera (living assemblag-

es composition and density), a group of organisms recognized by their high potential as environmental bioindicators.

Laranjo Bay (Murtosa Channel), Aveiro Town Channels and Aveiro Harbours can be considered the most polluted zones of the study area by Zn (72-509 mg kg⁻¹), Pb (23-206 mg kg⁻¹), Cu (16-142 mg kg⁻¹), Cr (5-78 mg kg⁻¹), Ni (8-38 mg kg⁻¹) and Cd (0.03-2 mg kg⁻¹). In these areas high total bioavailable concentrations of these heavy metals, Zn (72-366 mg kg⁻¹), Pb (23-172 mg kg⁻¹), Cu (16-140 mg kg⁻¹), Cr (2-35 mg kg⁻¹), Ni (8-17 mg kg⁻¹) and Cd (0.6-76 µg kg⁻¹), were found. Higher Zn concentrations are mostly associated with SCE phases F1 and F2, Pb and Cd with phase F2 and Cu and Cr with phases F2 and F3.

About 62 living benthic foraminifer species were recognized in this study. Values for foraminifera abundance (<350 n.º/g) and diversity (Shannon Index values: <2.03) are typical of euryhaline systems. Higher total bioavailable concentrations of Zn, Pb, Cu, Cr, Ni and Cd hinder benthic foraminifera of Ria de Aveiro, further reducing their abundance and diversity.

These results suggest that other benthic organisms are also being affected. However, differential sensitivity of different species of foraminifera may exist. For instance *Quinqueloculina seminulum*, spread over many lagoonal areas under tidal currents influence, is tolerant to higher concentrations of heavy metals (F1+F2+F3) but not for phase F1 of Pb, Cr and Cd. This is a suspended feeder species and may be more affected by high concentrations of these metals when they are weakly adsorbed. Species less tolerant to these heavy metals available concentrations

are *Bolivina ordinaria*, *Bulimina elongata*, *Bolivina pseudoplicata*, *Nonionella stella*, *Bolivina striata* and *Fissurina lucida*, found in confined areas near the lagoon mouth, under higher oceanic influence

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