

Short Communication

Characterization of Baker Fjord region through its heavy metal content on sediments (Central Chilean Patagonia)

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ABSTRACT. The spatial distribution of heavy metals content (Ba, Cd, Cu, Pb, Sr and Zn) in sediments of the Baker Fjord and surrounding channels in the central region of the Chilean fjords (47°45'S, 48°15'S) is analyzed. The aim of the study was characterized the patterns of abundance and distribution of these metals in surface sediments. The area corresponds to a poorly studied zone with low human activity. Distribution patterns would be influenced by rainfall conditions (local erosion), fluvial (continental sediments carried by rivers), glacier (glacier flour) and estuarine circulation. Cluster analysis allows differentiation among the sampled sites and group with similar characteristics. Finally, the concentrations found were contrasted with average values of metamorphic rocks and show with some certainty that the values found for calendar for this area and the greatest concentrations are the result of natural enrichment.

Keywords: heavy metals, unpolluted sediments, fjords, Patagonia, Chile.

Caracterización de la región del fiordo Baker en relación al contenido de metales pesados en los sedimentos (Patagonia Central de Chile)

RESUMEN. Se analiza la distribución espacial del contenido de metales pesados (Ba, Cd, Cu, Pb, Sr y Zn) en sedimentos del Fiordo Baker y canales aledaños, en la región central de los fiordos patagónicos chilenos (47°45'S, 48°15'S). El objetivo del estudio fue caracterizar los patrones de abundancia y distribución de estos metales en los sedimentos superficiales. La zona corresponde a un área escasamente estudiada con baja actividad antrópica. Los patrones de distribución estarían influenciados por condiciones pluviales (erosión local), fluvial (sedimentos continentales arrastrados por los ríos), glaciar (harina de glaciar) y circulación estuarina. El análisis de conglomerados permite establecer diferencias entre los sitios muestreados y agruparlos con características semejantes. Finalmente, las concentraciones encontradas fueron contrastadas con valores promedios de rocas metamórficas y muestran con cierta certidumbre, que los valores encontrados corresponden a los naturales para esta zona y las concentraciones mayores son producto de enriquecimiento natural.

Palabras clave: metales pesados, sedimentos no contaminados, fiordos, Patagonia, Chile.

The Baker Fjord is located in the extreme north-eastern zone of the Central Chilean Patagonian Fjords (~48°00'S), in between the Northern and Southern Patagonian Ice Field Glaciers. The basin of the Baker Fjord disrupts the continuity of these two glacier systems, and it receives inflow from the Baker (870 m³ s⁻¹) and Pascua (574 m³ s⁻¹) rivers. This fjord is also in-

fluenced by marine waters coming from the Gulf of Penas generating a two layer estuarine circulation system (Pickard, 1971; Sievers & Silva, 2006).

The scarce population of this region (0.1 inhabitants km⁻²; INE, 2012) minimizes the possible influence of human activity in the area. Therefore the fjord sediment's metal content should be representative of

concentrations due to erosion and the natural lixiviation of the rocks that form the geological landscape (Ospina-Alvarez *et al.*, 2014). The first study concerning sediment metal composition of Baker Fjord area was performed in 1997 during the research cruise CIMAR 2 Fiordos (Ahumada & Contreras, 1999; Ahumada, 2006). In this study the metal content was analyzed only at three oceanographic stations, generating a limited amount of information. In 2009 during the CIMAR 14 Fiordos cruise, new sediment samples were taken at seven oceanographic stations, with the objective of characterizing its surface sediment through the analysis of its metal content. Specific aims were to identify areas of enrichment and the patterns of distribution of six metals (Zn, Ba, Cu, Sr, Pb and Cd) and its association with adjacent continental basins. The sampling was performed on board the research vessel R/V “AGOR Vidal Gormaz” between October 27th and November 26th 2009, where seven oceanographic stations were sampled with a box corer (box size 30x30x40 cm) (Fig. 1). From each box corer, 4 to 6 subsamples were taken with a 30 cm long PVC tube of 10 cm in diameter.

The samples were sealed with PCV lids to keep them humid and stored in a freezer until their physical and chemical analyses, at the Laboratorio de Oceanografía Química of Universidad Católica de la Santísima Concepción (UCSC). From each subsample, the upper 3 cm of the sediment were extracted and divided in four portions or quarters. One was used to analyze sediment texture and the second quarter was used to analyze total organic material (TOM). Texture was determined by means of the wet method and sieved according to the Udden Wentworth grain-size scale (Fütterer, 2000). The TOM content was gravimetrically determined using the weight loss-on-ignition method (Mook & Hoskin, 1982) burning the dry sediment subsample in a furnace at a temperature of 450°C.

The third subsample quarter was used for the metal analysis and the last one was kept as a reference sample. These subsamples were dried and crushed in an agate mortar until very fine dust. 0.5 g were extracted and subjected to acid digestion (HNO₃, HF, and HClO₄), which was carried out in covered Teflon cups at 70°C until the samples were dry. The residue was dissolved in 10 mL of HCl Suprapur® (Merck) and gauged to 25 mL using Milli-Q (EMD Millipore). Following this, 50 µL of the acid fraction were analyzed using thermospray flame furnace atomic absorption spectrometry (TS-FF-AAS) in a GBC 902 atomic absorption spectrophotometer (González *et al.*, 2004). For metal determinations, MESS-3 Certified Reference Materials were used.

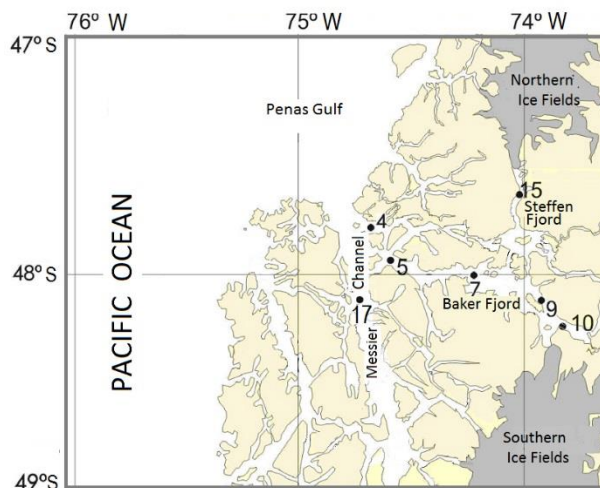


Figure 1. Position of sampling sites used within the area of study.

Once the analytic data was obtained, the geoaccumulation index (I_{geo}) was computed according to Müller (1979):

$$I_{geo} = \log_2 (C_m / 1.5 B_n)$$

where: C_m = experimentally measured mean concentration; B_n = background superficial sediments, using the baseline value previously established by Ahumada (2006) for this central fjord region, *i.e.*, Ba = 649.7 µg g⁻¹; Cu = 18.0 µg g⁻¹; Pb = 27.6 µg g⁻¹; Sr = 155.8 µg g⁻¹; and Zn = 102.5 µg g⁻¹.

The enrichment factor was calculated according to Chester (2003):

$$FE = (C_{Exp m} / C_{Exp n}) / (C_{Bn m} / C_{Bn n})$$

where: C_{Exp m} = experimentally measured concentration; C_{Exp n} = experimentally measured concentration of the standardization element; C_{Bn m} = base line (background) concentration of the metal; and C_{Bn n} = background concentration of the standardization element.

The geoaccumulation index (Table 1) and enrichment factor (Table 2) were conceptually defined for the sake of interpretation.

The relation between metals and sample sites was analyzed through bilateral Pearson correlations ($P < 0.0001$). A dendrogram was used for the exploratory analysis of characteristic patterns of distribution, and a multivariate analysis was applied to group the sampling sites considering their metal concentrations and spatial dispersion.

Table 3 lists the characteristics of the collected sediments, and it is possible to observe that five of the sampling site had a depth of more than 300 m.