5.2 Minor and trace metals from the surface sediments of the austral Chilean channels and fjords

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Knowledge about the metal contents in marine sediments has been poorly developed, especially for Chile's coastal fjord region. In fact, before 1995, only two articles had been published on this topic, both regarding the area around the Strait of Magellan (Lenardon, 1991; Mosca & Fontolan, 1991). The fjord ecosystems are highly fragile due to the region's estuarine characteristics, strong continental features (Pickard, 1967, 1971), deep basins of glacial origins, fine sediment contributions, and organic matter input from temperate-cold forests. On the other hand, the area has remained natural due to its low population density and scarce human activities. But the future will bring many changes as the region is subjected to new economic activities. Thus, knowledge about the abundance and distribution patterns of metals is fundamental for understanding the changes in natural systems, contributing to the development of different activities therein and helping to maintain and protect the aquatic systems.

Sediment samples for the analysis of Ba, Cd, Co, Cr, Cu, Ni, Pb, Sr, V, and Zn were obtained from three zones in the southern Chilean channel and fjord region: Puerto Montt to Laguna San Rafael (northern zone), Golfo de Penas to Strait of Magellan (central zone), and Strait of Magellan to Cape Horn (southern zone). A total of 180 samples were analyzed from 37 stations in the northern zone, as were 140 samples obtained at 23 stations in the central zone, and 96 samples taken from 20 stations in the southern zone (Fig. 1).

The sediment texture analysis in the deep basins and near the glaciers was silty-clay ($\leq 0.62$ mm) (Silva et al., 1998, 2001), whereas gravels and sands were detected in the areas more exposed to coastal waters. Organic matter was associated with the fine fraction of the sediments except in the fjords with glacial activity, where the silty-clay fraction was mainly inorganic in origin (Silva et al., 1998, 2001; Silva & Ortiz, 2003).

In order to study the metals contained in the sediments, samples were obtained with a box-corer and a gravity corer. Thus, the samples for the different depth strata at each of the stations could be fractionated. This technique favors the study of temporal variability in a given place and assumes that changes in the concentrations — because of their positions in the strata — are associated with a temporal pattern in the sedimentation process.

Chemical analyses were carried out by first performing an acid digestion of each sample and then analyzing the samples in an Atomic Emission Spectrophotometer with Inductively Coupled Plasma (AES–ICP). This was done using a multi-

<table>
<thead>
<tr>
<th>Metals</th>
<th>Northern Zone</th>
<th>Central Zone</th>
<th>Southern Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Ba</td>
<td>435.7</td>
<td>184.4</td>
<td>649.7</td>
</tr>
<tr>
<td>Cd</td>
<td>0.36</td>
<td>0.21</td>
<td>0.27</td>
</tr>
<tr>
<td>Co</td>
<td>14.7</td>
<td>3.2</td>
<td>12.3</td>
</tr>
<tr>
<td>Cr</td>
<td>50.1</td>
<td>24.5</td>
<td>67.5</td>
</tr>
<tr>
<td>Cu</td>
<td>24.5</td>
<td>10.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Ni</td>
<td>22.4</td>
<td>8.3</td>
<td>28.0</td>
</tr>
<tr>
<td>Pb</td>
<td>20.8</td>
<td>8.7</td>
<td>27.6</td>
</tr>
<tr>
<td>Sr</td>
<td>260.2</td>
<td>78.5</td>
<td>155.8</td>
</tr>
<tr>
<td>V</td>
<td>140.6</td>
<td>27.1</td>
<td>122.1</td>
</tr>
<tr>
<td>Zn</td>
<td>93.6</td>
<td>20.2</td>
<td>102.5</td>
</tr>
</tbody>
</table>

Figure 1: Geographic position of the sampling stations where surface sediments were collected to determine minor and trace metals.
Minor and trace metals from the surface sediments of the austral Chilean channels and fjords

Table II: Concentrations (µg·g⁻¹) of the metals in the upper part of the cores obtained in Bahía Inútil (this study), compared with the averages obtained in Canal Beagle and Bahía Windhond (from Pineda et al., 2002).

<table>
<thead>
<tr>
<th>Sites</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>Mg</th>
<th>Pb</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahía Inútil</td>
<td>17±4</td>
<td>62±6</td>
<td>22±4</td>
<td>17±1</td>
<td>507±30</td>
<td>20±4</td>
<td>117±10</td>
<td>90±7</td>
</tr>
<tr>
<td>Canal Beagle*</td>
<td>36</td>
<td>98</td>
<td>27</td>
<td>30</td>
<td>823</td>
<td>32</td>
<td>154</td>
<td>129</td>
</tr>
<tr>
<td>Bahía Windhond*</td>
<td>22</td>
<td>76</td>
<td>20</td>
<td>23</td>
<td>581</td>
<td>38</td>
<td>143</td>
<td>58</td>
</tr>
</tbody>
</table>

* surface sample

Table I gives the average concentrations for the metals present in the sediments of the different study areas. Because the variability of the system, expressed as the standard deviation, was high, it was necessary to separate the stations into smaller units.

These results show the average abundances for the different metals in the three studied zones, independent from the absolute concentration values. The abundance sequence of the different metals observed in the sediments was repeated in all three zones, with very few changes in the positions of the metals with similar concentrations, for example Ni, Pb, and Cu:

Ba > Sr > V > Zn > Cr > Cu > Ni > Pb > Co > Cd.

The analyses of the metal contents by site or smaller geographical units showed a notable decrease in the variability of the average values in relation to the general variability (Ahumada & Rudolph, 2004). Enriched amounts of Zn and Pb were only found in the area of Puerto Chacabuco in Aysén, although this was not observed in the general averages for Aysén (Ahumada, 1998).

In the southern zone, metal analyses were carried out on sediment samples obtained from similar sites at different stations (Pineda et al., 2002). These results are given in Table II. The presence of platinum (Pt), gold (Au), and silver (Ag) was also determined, albeit at concentrations lower than those of the analytical method's sensitivity. Thus, the existence of these metals was confirmed, but their concentrations were not determined.

Information on the concentration values is difficult to interpret without reference values, which are specific to each region. However, natural variations have certain limits that are determined by regional chemical, physical, and structural processes as well as rock composition. Due to this, and in order to make comparisons, Table III presents the values for similar processes or reference values for metal concentrations in the predominant rocks forming the Earth's crust. Moreover, the "non-polluted" concentration values found in the scientific literature were considered. These references clearly demonstrate that the austral fjords are still pristine, a condition that is absolutely necessary to preserve.

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In the first three years of the CIMAR Fiordo cruises, information was obtained about the metals present in the sediments of most of the austral channels and fjords from Puerto Montt to Cape Horn. This is the only systematic information available about metals in the Southern Hemisphere that involves such an extensive area, equivalent to the work carried out in Greenland.
Ahumada, R.

These results have allowed to determine the distribution and concentration of metals causing environmental risks. They have also provided an approach for establishing the baseline and "health status" of the austral channels. Due to its isolation and low anthropic load, the austral area has retained its pristine conditions, which must be preserved in order to protect this ecosystem. Nevertheless, the active development of aquaculture, forestry activities, fisheries, tourism, mining, and the service industry has transformed this sector into an environmentally risky area due to the assimilative capacity of the "nested", deep circulation systems.

References


