Some abiotic characteristics of shallow ponds included in an Andean peatland of the transitional desert of Chile

Algunas características abióticas de pozas superficiales interiores presentes en una vega altoandina del desierto transicional de Chile

J. Cepeda-Pizarro1*, Alfonso A. Armijo L.2, Sebastián O. Pérez B.2

ABSTRACT

The study ponds are part of a peatland located in the Elqui river basin of the Andes. They turned out to be heliotropic (homeothermic), mesotrophic and mesopoikilohaline microlimnotopes. The ponds showed high content of dissolved metals, mainly Ca (mean ~205 mg/l), Na (~60 mg/l), Mg (~60 mg/l) and K (~13 mg/l), and the inorganic non-metals sulfate (~976 mg/l), chloride (~34.2 mg/l), phosphate (~23 mg/l), bicarbonate (~11 mg/l) and nitrate (~3.3 mg/l). Excluding Hg, Se and nitrite, trace elements were represented by Al, As, Cd, CN, Cu, Cr, Fe, Ba, Be, Co, Zn, Mo, Ni, Pb, Li, Ag, and V. The cationic pattern of ponds was Ca > Na > Mg > K > Mn; whereas the anionic pattern was sulfate > chloride > phosphate > carbonate > Fl. Although we did not study, the hydrochemical characteristics of these water bodies seem to reflect the characteristics of the geological substrate of the mountains through which the water drains into the peatland.

Key words: Andean hydrochemistry, Andean wetlands, desert ponds, temporary ponds, saline ponds.

RESUMEN

Las pozas estudiadas forman parte de una vega ubicada en el piso altoandino de la hoya hidrográfica del río Elqui. Estas resultaron ser microlimnotopos heliotópicos (homeotérmicos), mesotróficos y mesopoikilohalinos. Las pozas mostraron niveles elevados de metales disueltos, principalmente Ca (promedio: ~205 mg/l), Na (~60 mg/l), Mg (~60 mg/l) y K (~13 mg/l), y los inorgánicos no metálicos sulfato (~976 mg/l), cloruro (~34,2 mg/l), fosfato (~23 mg/l), bicarbonato (~11 mg/l) y nitrato (~3,3 mg/l). Excluyendo Hg, Se y nitrito, las pozas presentaron niveles traza de Al, As, Cd, CN, Cu, Cr, Fe, Ba, Be, Co, Zn, Mo, Ni, Pb, Li, Ag y V. El patrón catiónico de las pozas fue Ca > Na > Mg > K > Mn; a su vez, el patrón aniónico fue sulfato > cloruro > fosfato > carbonato > Fl. Aunque no fue estudiado por nosotros, las características hidroquímicas de estos cuerpos de agua parecen reflejar las características del sustrato geológico de las montañas por medio del que el agua fluye hacia la vega.

Palabras clave: hidroquímica andina, humedales andinos, charcas desérticas, charcas temporales, charcas salinas.

Introduction

The geological and geomorphologic heterogeneity of the highlands of the transitional desert of Chile create a mosaic of environmental conditions in which habitats with highly contrasting features develop. For instance, peatlands originate in areas where water accumulates or emerges to the surface (Squeo et al., 2006). Contrasting with the arid surroundings, these landscape units provide good living conditions for animal and plant communities (Cepeda-Pizarro et al., 2006). Because of this, peatlands of the Andes transitional desert are considered spots of biodiversity. Nowadays, the possible effects of climate change and stress due to heavy water consumption by mining and the local human population have raised public concern about the well-being of these landscape units (Contreras, 2002; Souvignet et al., 2012).

A diverse array of environmental conditions of the highlands of the transitional desert are the main local factors shaping these peatlands as habitats.
(Squeo et al., 2006). Ponds, both permanent and temporary, are characteristic landscape components of these peatlands (Coronel et al., 2004). Given that they offer an array of microhabitats susceptible of being colonized and exploited by a diversity of small organisms, mainly insects in their larval stages (Cepeda-Pizarro & Pola, 2013), these aquatic habitats can contribute disproportionately to regional diversity (Williams, 1999). Nevertheless, water quality is a matter of adaptation and survival for this type of organism (Coronel et al., 2007). Although some information is available about the physical and chemical characteristics of ponds in the northern Andes (e.g., López et al., 1999; Risacher et al., 2002, 2003), little is known about the abiotic conditions of ponds located in the Andean transitional desert. Consequently, the aims of this study were to (1) describe the ponds in terms of their main physical and chemical attributes, and (2) compare their characteristics with those of ponds found in the Andes further north.

**Materials and Methods**

**Study site and ponds**

The present study was conducted in a peatland locally referred to as “vega Tambo-Puquíos” (VTP hereafter), located in the high-Andean section of the Elqui river basin (Figure 1). The VTP is located in a narrow valley, at 3850-4000 mamsl. It has an extension of ~6 km and a surface area of ~10 km². It derives its water from small arroyos and rivulets that flow down slope from the surrounding mountains, from its own snow cover formed during winter and from subterranean water. The VTP is flat in most sectors, with a micro-topographic pattern of vegetation formed by hassocks and hummocks. In other sectors, it is narrow and discontinuous. The aquatic habitats are a rivulet (the Tambo rivulet), water linked to its peat matrix and the underlying mineral soil, and a series of small and shallow ponds, most of them temporary (PQP henceforth).

**Physical and chemical analysis**

The study is based on the analysis of four PQPs (Figure 2). They had a surface area ranging from 50 to 1250 m² and a depth of 0.3 to 0.5 m (Figure 3). The physical parameters examined were total hardness, electrical conductivity, turbidity, alkalinity, total dissolved solids, total suspended solids and total solids. The chemical parameters were pH, dissolved metals, inorganic nonmetallic ions and the following trace-elements: Al, total As, Ba, Cu, B, Cd, Co, Cr, Fe, Pb, Li, Ni, Zn, and CN. Monitoring of these
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Parameters was done in accordance with Chilean environmental regulations (CONAMA, 2000). Water sampling was performed during three consecutive summers (January or February). The samples were taken from the surface (0.0-0.2 m). Both sampling and chemical analyses were conducted out by a specialized contractor (SITAC, 2001). The analytical chemical techniques were standard and are fully described in APHA et al. (1985). The comparisons with ponds found in the Andes further north were based on published data.

Results and Discussion

In general, the water of the PQPs was hard (mean \( \sim 834.0 \text{ mg/l CaCO}_3 \text{ equivalent} \)) and transparent (\( \sim 9.0 \text{ NTU} \)), with a rather small fraction of total suspended solids (7\%) and electrical conductivity of \( \sim 1678.0 \text{ µS/cm} \). On average the pond water was slightly alkaline (i.e., pH \( \sim 8.5 \); \( \sim 131.0 \text{ mg CaCO}_3/l \)), with a dissolved O\(_2\) content of \( \sim 10.0 \text{ mg/l} \) (Table 1). The dominant metal ions were Ca, Na, Mg, and K. The dominant inorganic non-metals ions were sulfate,
chloride, phosphate, and bicarbonate. The content of sulfate + Ca accounted for 96% of total dissolved solids. The surveillance detected the presence of Al, total As, Ba, Be, C, Co, total Cr, Fe, Pb, Li, total Mn, Mo, Ni, Ag, V, and Zn; but no Hg, Se or nitrite. The sequence of content of these trace-elements was B > Li > Al = Ba > As = Fe > Cr = Ni > Co > Pb > Cu > Cd = Zn > CN (Tables 2, 3).

Table 1. Mean (± se; n=4) of some physical and chemical parameters of shallow ponds of the Andes transitional desert of Chile.

<table>
<thead>
<tr>
<th>Parameter*</th>
<th>mean ± se</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical</td>
<td></td>
</tr>
<tr>
<td>EC (µS/cm at 25 ºC)</td>
<td>1678.0 ± 0.2</td>
</tr>
<tr>
<td>TH (mg/l CaCO₃)</td>
<td>834.3 ± 85.0</td>
</tr>
<tr>
<td>TDS (180 ºC)</td>
<td>1229.5 ± 0.0</td>
</tr>
<tr>
<td>TSS (105 ºC)</td>
<td>127.7 ± 23.1</td>
</tr>
<tr>
<td>TS (105 ºC)</td>
<td>1806.0 ± 134.0</td>
</tr>
<tr>
<td>TUR (ntu)</td>
<td>8.9 ± 4.2</td>
</tr>
<tr>
<td>2. Chemical</td>
<td></td>
</tr>
<tr>
<td>pH (at 22.5 ºC)</td>
<td>8.5 ± 0.5</td>
</tr>
<tr>
<td>Dissolved O₂</td>
<td>9.7 ± 0.0</td>
</tr>
</tbody>
</table>

*In this and following tables, numbers are expressed in mg/l except when indicated.

Table 2. Mean content (± se; n=4) of dissolved metals and trace elements in Andean shallow ponds of the transitional desert of Chile. Units as in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>mean ± se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>0.5 ± 0.0</td>
</tr>
<tr>
<td>Total As</td>
<td>0.3 ± 0.0</td>
</tr>
<tr>
<td>Ba</td>
<td>0.5 ± 0.0</td>
</tr>
<tr>
<td>Be</td>
<td>0.1 ± 0.0</td>
</tr>
<tr>
<td>B</td>
<td>1.9 ± 0.0</td>
</tr>
<tr>
<td>Cd</td>
<td>0.01 ± 0.0</td>
</tr>
<tr>
<td>Ca</td>
<td>204.8 ± 45.7</td>
</tr>
<tr>
<td>Co</td>
<td>0.04 ± 0.0</td>
</tr>
<tr>
<td>Total Cr</td>
<td>0.1 ± 0.0</td>
</tr>
<tr>
<td>Cu</td>
<td>0.02 ± 0.0</td>
</tr>
<tr>
<td>Fe</td>
<td>0.3 ± 0.0</td>
</tr>
<tr>
<td>Pb</td>
<td>0.03 ± 0.0</td>
</tr>
<tr>
<td>Li</td>
<td>0.8 ± 0.0</td>
</tr>
<tr>
<td>Mg</td>
<td>59.7 ± 0.0</td>
</tr>
<tr>
<td>Total Mn</td>
<td>2.4 ± 0.0</td>
</tr>
<tr>
<td>Hg</td>
<td>0.00 ± 0.0</td>
</tr>
<tr>
<td>Mo</td>
<td>0.01 ± 0.0</td>
</tr>
<tr>
<td>Ni</td>
<td>0.05 ± 0.0</td>
</tr>
<tr>
<td>K</td>
<td>12.8 ± 3.6</td>
</tr>
<tr>
<td>Se</td>
<td>0.00 ± 0.0</td>
</tr>
<tr>
<td>Ag</td>
<td>0.01 ± 0.0</td>
</tr>
<tr>
<td>Na</td>
<td>159.5 ± 0.0</td>
</tr>
<tr>
<td>Na (%)</td>
<td>47.5 ± 0.0</td>
</tr>
<tr>
<td>V</td>
<td>0.01±0.0</td>
</tr>
<tr>
<td>Zn</td>
<td>0.01±0.0</td>
</tr>
</tbody>
</table>

A remarkable renaissance in the study of pond ecology has taken place in the last decades (Cereghino et al., 2008); however, this assertion does not fully apply to mountain aquatic ecosystems. In the case of wetlands, the attention to conservation of large-scale systems has led to a general neglect of small-scale landscape elements such as pools and ponds, especially those of arid lands (Williams, 1999). From a typological viewpoint, the study ponds are heliotopic, mesotrophic, and mesopoikilohaline microlimnotopes. Their thermal stratification is monomictic, with few degrees of temperature difference between surface and bottom (Ringuelt, 1962). Water overturn is achieved by the frequent strong winds and convective currents that occur during nocturnal cooling (Cepeda-Pizarro & Novoa, 2006). The characteristics of their water are in between those of freshwater ponds and those truly saline. The water is hard and very close to the inferior limit for brackish water.

Compared to data reported in the literature for natural lentic freshwaters (e. g., Chapman, 1996), the study ponds are very high in phosphate, Ca and sulfate content, and high in fluoride, Fe, K, Mg, Cl, nitrate and total suspended solids, but lower in bicarbonate and CN content. Clearly, these chemical characteristics constrain the existence of biota as compared to water-bodies of better quality found in close basins (Ginocchio et al., 2008). Compared to data reported in the literature, the water of the study ponds is alkaline and higher in electrical conductivity, dissolved O₂ and sulfate content than the water of lentic habitats found in Chile further north; but lower in the content of dissolved metals, non-metals and trace-elements (Tables 4 through 7). In turn, salinity, as measured by TDS, is at the low margin of this range (Table 8). The greater
variability of the hydrochemical characteristics of the northern ponds compared to the ones studied in this work is clear in this table. This high intra-site variability seems to be frequent in water bodies of arid ecosystems, as previously reported from field work (e.g., López et al., 1999; Risacher et al., 2002, 2003; Coronel et al., 2004).

The cationic pattern of the study ponds is Ca>Na>Mg>K>Mn. This pattern is different than those recorded in highland meadows of central Chile (Ginocchio et al., 2008) and in ponds of the Gorbea salt flat (Risacher et al., 2002), Llamará (Garcés et al. 1998) and Ignorado (Risacher et al., 2002). The Mg/Ca index of the study ponds is ~0.29, a much lower value that the ones reported from more northern ponds (Garcés et al., 1999; López et al., 1999; Risacher et al., 2002; Demergasso et al., 2003). In turn, the (Mg+Ca)/(Na+K) index is close

Table 4. Mean content or range of some hydrochemical parameters of Andean ponds. Units as in former tables.

<table>
<thead>
<tr>
<th>Site or location</th>
<th>pH</th>
<th>EC</th>
<th>Alkalinity</th>
<th>dO₂</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>This site</td>
<td>8.2–8.9</td>
<td>1635.0</td>
<td>116.8–145.0</td>
<td>9.2–10.5</td>
<td>This study</td>
</tr>
<tr>
<td>High alpine meadows (Central-Chile)</td>
<td>5.6-7.6</td>
<td>380-700.0</td>
<td>–</td>
<td>–</td>
<td>Ginocchio et al. (2008)</td>
</tr>
<tr>
<td>Salar de Llamará (Atacama Desert)</td>
<td>7.5-8.2</td>
<td>20-5110.0</td>
<td>–</td>
<td>–</td>
<td>Demargasso et al. (2003)</td>
</tr>
<tr>
<td>Salar de Llamará (Atacama Desert)</td>
<td>7.1-8.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Garcés et al. (1998)</td>
</tr>
<tr>
<td>Salar de Llamará (Atacama Desert)</td>
<td>7.0-8.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>López et al. (1999)</td>
</tr>
<tr>
<td>Salar de Gorbea (Northern Andes of Chile)</td>
<td>1.3-7.2</td>
<td>–</td>
<td>–</td>
<td>0.32-5.8</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Salar de Ignorado (Northern Andes of Chile)</td>
<td>2.7-3.9</td>
<td>–</td>
<td>–</td>
<td>3.8-8.6</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Cordillera de Tunari (Bolivian Andes)</td>
<td>4.9-9.7</td>
<td>5.3-238.0</td>
<td>0-31.2</td>
<td>3.4-11.6</td>
<td>Coronel et al. (2004)</td>
</tr>
</tbody>
</table>

--: unavailable data.

Table 5. Range for dissolved metals in Andean ponds. Units as in former tables.

<table>
<thead>
<tr>
<th>Site or location</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>Na</th>
<th>Mn</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tambo-Puquíos site</td>
<td>162.7-253.3</td>
<td>58.3-61.1</td>
<td>10.2-17.0</td>
<td>147.5-171.5</td>
<td>1.5-6.0</td>
<td>This study</td>
</tr>
<tr>
<td>Salar de Llamará</td>
<td>741.1-1120.0</td>
<td>534-3063.0</td>
<td>534-3063</td>
<td>9919.7-74976.3</td>
<td>–</td>
<td>Demargasso et al. (2003)</td>
</tr>
<tr>
<td>Salar de Llamará</td>
<td>332.6-910.0</td>
<td>141-1799</td>
<td>222-4066</td>
<td>7471-113473.0</td>
<td>–</td>
<td>López et al. (1999)</td>
</tr>
<tr>
<td>Salar de Gorbea</td>
<td>200.3-1050.0</td>
<td>9.7-27956</td>
<td>43-5786</td>
<td>253-51035</td>
<td>3.3-489.0</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Salar de Ignorado</td>
<td>469-529</td>
<td>182-5761.0</td>
<td>86-4027</td>
<td>301.1-13126</td>
<td>2.2-93.4</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Cordillera de Tunari</td>
<td>0.5-9.6</td>
<td>0-6.3</td>
<td>0.1-1.5</td>
<td>0.1-5.3</td>
<td>–</td>
<td>Coronel et al. (2004)</td>
</tr>
</tbody>
</table>

--: unavailable data.

Table 6. Content of dissolved inorganic nonmetals in Andean ponds*. Units as in former tables.

<table>
<thead>
<tr>
<th>Site or location</th>
<th>Cl</th>
<th>SO₄</th>
<th>NO₃</th>
<th>PO₄</th>
<th>HCO₃</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>This site</td>
<td>27.7-40.7</td>
<td>940.2-1013.2</td>
<td>1.4-5.4</td>
<td>0.6-44.3</td>
<td>7.6-14.2</td>
<td>This study</td>
</tr>
<tr>
<td>Salar de Llamará</td>
<td>304-4021</td>
<td>61-603.4</td>
<td>–</td>
<td>–</td>
<td>1.8-4.7</td>
<td>López et al. (1999)</td>
</tr>
<tr>
<td>Salar de Gorbea</td>
<td>3.4-3490</td>
<td>5.2-893</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Salar de Ignorado</td>
<td>4-141</td>
<td>28.6-683</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Risacher et al. (2002)</td>
</tr>
<tr>
<td>Cordillera de Tunari</td>
<td>0.3-7.1</td>
<td>0.6-114.6</td>
<td>0-0.4</td>
<td>0.01-0.63</td>
<td>–</td>
<td>Coronel et al. (2004)</td>
</tr>
</tbody>
</table>

--: unavailable data.

Table 7. Mean or range for dissolved trace elements in Andean temporary ponds.

<table>
<thead>
<tr>
<th>Site or location</th>
<th>Al</th>
<th>As</th>
<th>Ba</th>
<th>Cu</th>
<th>B</th>
<th>Cd</th>
<th>Co</th>
<th>Cr</th>
<th>Fe</th>
<th>Pb</th>
<th>Li</th>
<th>Ni</th>
<th>Zn</th>
<th>CN</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>This site</td>
<td>0.5</td>
<td>0.3</td>
<td>0.5</td>
<td>0.02</td>
<td>1.8-2.0</td>
<td>0.01</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>Salar de Llamará</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>9.7-102.0</td>
<td>–</td>
<td>0.1</td>
<td>und</td>
<td>0.7-0.9</td>
<td>0.1</td>
<td>0.01</td>
<td>0.005</td>
<td>López et al. (1999).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salar de Gorbea</td>
<td>2.4-4560.0</td>
<td>0.4-10.5</td>
<td>–</td>
<td>–</td>
<td>5.4-1610</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.0-33.8</td>
<td>–</td>
<td>–</td>
<td>Risacher et al. (2002).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salar de Ignorado</td>
<td>18.9-2919.0</td>
<td>0.4</td>
<td>–</td>
<td>–</td>
<td>3.2-193.5</td>
<td>–</td>
<td>–</td>
<td>0.1-145.0</td>
<td>0.34-123.3</td>
<td>–</td>
<td>0.3-52.3</td>
<td>Risacher et al. (2002).</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: not reported; und: undetected.
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Table 8. TDS contents in some Andean ponds of northern Chile (range of altitude: 3000-3950 m asl). Units as in former tables.

<table>
<thead>
<tr>
<th>Site or location</th>
<th>Altitude (m asl)</th>
<th>TDS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This site (pond water)</td>
<td>3850</td>
<td>1229.5</td>
</tr>
<tr>
<td>This site (peat water)</td>
<td>3930</td>
<td>471-654</td>
</tr>
<tr>
<td>Gorbea salt flat (Northern Andes of Chile)</td>
<td>3950</td>
<td>2850-297000</td>
</tr>
<tr>
<td>del Huasco salt flat (Northern Andes of Chile)</td>
<td>3778</td>
<td>108-113093</td>
</tr>
<tr>
<td>Coposa salt flat (Northern Andes of Chile)</td>
<td>3730</td>
<td>119-330671</td>
</tr>
<tr>
<td>Carcote salt flat (Northern Andes of Chile)</td>
<td>3690</td>
<td>88-335536</td>
</tr>
<tr>
<td>Ascotán salt flat (Northern Andes of Chile)</td>
<td>3716</td>
<td>89-119853</td>
</tr>
<tr>
<td>Aguas Calientes 3 salt flat (Northern Andes of Chile)</td>
<td>3950</td>
<td>2491-25150</td>
</tr>
<tr>
<td>Capur salt flat (Northern Andes of Chile)</td>
<td>3950</td>
<td>6589-221804</td>
</tr>
<tr>
<td>Aguas Calientes 4 salt flat (Northern Andes of Chile)</td>
<td>3665</td>
<td>851-341759</td>
</tr>
<tr>
<td>Pajonales salt flat (Northern Andes of Chile)</td>
<td>3537</td>
<td>11728-246674</td>
</tr>
<tr>
<td>La Azufrera salt flat (Northern Andes of Chile)</td>
<td>3580</td>
<td>548-23473</td>
</tr>
<tr>
<td>Agua Amarg asalt flat (Northern Andes of Chile)</td>
<td>3558</td>
<td>7656-196672</td>
</tr>
<tr>
<td>Aguilar salt flat (Northern Andes of Chile)</td>
<td>3320</td>
<td>177044-343882</td>
</tr>
<tr>
<td>La Isla salt flat (Northern Andes of Chile)</td>
<td>3950</td>
<td>6229-329693</td>
</tr>
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<td>Las Parinas salt flat (Northern Andes of Chile)</td>
<td>3987</td>
<td>8907-333942</td>
</tr>
<tr>
<td>Grande salt flat (Northern Andes of Chile)</td>
<td>3950</td>
<td>8277-129707</td>
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<td>Infieles salt flat (Northern Andes of Chile)</td>
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<td>1677-318744</td>
</tr>
<tr>
<td>La Laguna saltflat (Northern Andes of Chile)</td>
<td>3494</td>
<td>3288-20430</td>
</tr>
<tr>
<td>Pedernales salt flat (Northern Andes of Chile)</td>
<td>3370</td>
<td>85-326745</td>
</tr>
<tr>
<td>Maricunga salt flat (Northern Andes of Chile)</td>
<td>3760</td>
<td>144-331453</td>
</tr>
</tbody>
</table>

*Sources: this study; Risacher et al. (2003); Echaniz et al. (2006).

Conclusions

The study ponds are somewhere in between freshwater and truly saline ponds. Their water quality is very close to the inferior limit for brackish water. Because of their alkaline condition, they are insensitive to acidification. The ponds show a clear transition from north to south compared to high alpine meadows of central Chile and with ponds from northern Chile. Compared to data reported in the literature for natural lentic freshwaters, the study ponds are very high in phosphate and sulfate content, high in fluoride, Na, Fe, K, Mg, chloride and nitrate content, and low in bicarbonate and CN. Compared to ponds from northern Chile, except for sulfate they are lower in the content of most dissolved metals, inorganic non-metals, and trace-elements. Apparently, the water chemistry of these ponds is related to the geological environment of the surrounding mountains.

Acknowledgments

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