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Hydrogeochemical and nitrate isotopic indicators of vulnerability in the Katari-Lago Menor basin-aquifer, Lake Titicaca-Bolivia

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In the semi-arid Bolivian Altiplano, the Katari and Lago Menor Basin, ranging between 6000 and 3800 m a.s.l. in altitude, hosts a major aquifer in Quaternary sediments of fluvioglacial and paleolacustrine origin. This basin supports a population of over 1.2 million of inhabitants and the largest city in the Altiplano, El Alto, one of the Latin America's fastest growing cities in the 1980s. This rapid urban growth was accompanied by minimal land planning, and lack of basic infrastructure and environmental policies. In addition, the region is greatly affected by climate change, causing the glaciers to shrink. A multi-tracer approach was used to understand the main hydrogeochemical processes taking place along the groundwater flow, and to evaluate the impact of anthropogenic activities on groundwater quality and nitrate concentrations. In the upper part of the aquifer (above 4000m), in the Piedmont subsystem, siliciclastic and evaporitic rocks host groundwater of high quality. Here, groundwater chemistry is dominated by silicate weathering leading to a Ca(Mg)-HCO₃ facies, low nitrate concentrations (<3.2 mgL⁻¹), and low mineralization. At lower altitude, the anthropogenic impact is revealed by the increase in NO₃⁻ concentrations, reaching up to 35.6 mg L⁻¹. Nitrate stable isotopes allowed discriminating three main nitrate contributions: leaching from areas influenced by manure piles, use of synthetic N fertilizers, and leakage from sewage collection pipes. Natural attenuation of nitrate occurs when fresh groundwater mixes with brackish groundwater of evaporitic origin. On the other hand, in the lacustrine plain (~3860 to 3810 m a.s.l.), the groundwater geochemistry is dominated by evaporite dissolution and calcite precipitation, while nitrate originates from nitrification of synthetic fertilizers. This first hydrogeochemical study of one of the major groundwater systems in the Northern Altiplano is an important step towards a better management of this crucial water resource for the sustainable development of this region.

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