3D mapping, hydrodynamics and modelling of the freshwater-brine mixing zone in salt flats similar to the Salar de Atacama (Chile)

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ABSTRACT
Salt flat brines are a major source of minerals and especially lithium. Moreover, valuable wetlands with delicate ecologies are also commonly present at the margins of salt flats. Therefore, the efficient and sustainable exploitation of the brines they contain requires detailed knowledge about the hydrogeology of the system. A critical issue is the freshwater-brine mixing zone, which develops as a result of the mass balance between the recharged freshwater and the evaporating brine.

The complex processes occurring in salt flats require a three-dimensional (3D) approach to assess the mixing zone geometry. In this study, a 3D map of the mixing zone in a salt flat is presented, using the Salar de Atacama as an example. This mapping procedure is proposed as the basis of computationally efficient three-dimensional numerical models, provided that the hydraulic heads of freshwater and mixed waters are corrected based on their density variations to convert them into brine heads. After this correction, the locations of lagoons and wetlands that are characteristic of the marginal zones of the salt flats coincide with the regional minimum water (brine) heads.

The different morphologies of the mixing zone resulting from this 3D mapping have been interpreted using a two-dimensional (2D) flow and transport numerical model of an idealized cross-section of the mixing zone. The result of the model shows a slope of the mixing zone that is lower than expected, similar to that obtained by 3D mapping. Additionally, the 2D model was used to evaluate the effects of heterogeneity in the mixing zone geometry. The higher the permeability of the upper aquifer is, the lower the slope and the shallower the mixing zone become. This occurs because most of the freshwater lateral recharge flows through the upper aquifer due to its much higher transmissivity, thus reducing the freshwater head. Similarly, aquitards further hinder the flow of groundwater to deeper layers and force it to flow through the upper aquifer.

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