Groundwater characterization in the semi-arid Punata alluvial fan (Bolivia)

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ABSTRACT

To plan a sustainable management of groundwater resources is necessary to understand the aquifer system geometry and some hydrogeological process. Alluvial fans are generally located in arid and semi-arid regions, and they use to have permeable layers where groundwater is stored. In the Punata alluvial fan the monitoring of groundwater level shows a decreasing trend of the water table, and probably the main reason for this decline is due to the fact that groundwater extraction has equaled or exceeded the natural recharge during the last few years. In this region the main socio-economic activity is the extensive agriculture, thus a shortage in groundwater supply might lead to conflicts between local water supply companies serving urbanized areas and agricultural interests. In order to plan a sustainable management of groundwater, the aim of this study is to use hydrochemical and geophysical methods for providing information and propose a hydrogeological model in terms of groundwater recharge, flow patterns, chemical evolution, and aquifer system geometry. A specific objective of this project is to train Bolivian and Scandinavian students on PhD, MSc and BSc level. A further objective is to transfer knowledge of integrated geophysical aquifer mapping to local authorities within the groundwater and environmental sector.

Electrical Resistivity Tomography (ERT), Induced Polarization (IP), and Time Domain Electromagnetics (TDEM) were the geophysical methods used for refining the geological conceptual model of the aquifer system. A total of 30 Km of ERT and IP were collected, and 130 TDEM soundings were performed. The results show a complex structure in the apex region of the fan dominated by fluvial and colluvium deposits, while in the distal area the stratification is smoother and is dominated by lacustrine deposits. ERT surveys showed that the top layers are composed of coarse material, and the confining bottom layer is mainly composed of clay and silt. IP was useful during the ERT interpretation for solving ambiguities. TDEM provided hints about the existence of a very thin brackish layer located just below of the coarse material.

The used hydrochemical analysis were: 1) major ion chemistry and chemical weathering process, 2) Stable isotopes (deuterium and oxygem-18), and 3) statistical analysis (Hierarchical Cluster Analysis and Principal Component Analysis). A total of 45 water samples were taken, and come from groundwater and surface water. The samples from groundwater are located within the Punata alluvial fan, while the latter are distributed along water bodies in the neighboring basins. The samples were spatially distributed in order to take into consideration all the possible recharge sources. The analysis of $\delta^{18}O$ and $\delta^{2}H$ concentrations in water samples assisted in identifying that groundwater in the Punata alluvial fan is mainly recharged by heavy flash floods, rather than precipitation or rivers base flow. The multivariate statistical and hydrochemical analysis indicated that weathering of carbonated rocks contributed to the increase of Ca^{2+} concentration, and that there is an increase of Cl^{-} and TDS concentration in the middle and distal part of the fan. These changes in the ion concentrations leads to established that groundwater flow is from the East to the West and Northwest of the fan.

The results obtained from the geophysical surveys provide valuable information for building a geological conceptual model of the aquifer system in the Punata alluvial fan. While the hydrochemical results have implications for the knowledge of hydrogeological processes in alluvial fans in general in that it shows that the integration of hydrochemistry, stable isotopes and multivariate statistical can be useful tools for characterizing flow patterns, recharge mechanisms and groundwater mineralization processes. The integration of the results might contribute in the making of policies for sustainable groundwater management in the Punata alluvial fan.