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Arsenic and other trace elements in groundwater and its impact on drinking water supplies in the Lower Katari Basin, Bolivian Altiplano

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Hydrochemical investigations were performed in order to better understand the spatial distribution of arsenic (As), major ions and trace elements (TEs). They were a part of the study of geochemistry of the shallow groundwater and surface water with the objective to evaluate the sources of dissolved species and elucidate the processes that govern the evolution of natural water in the Lower Katari Basin on the Bolivian Altiplano. The area of study is in the Southeastern part of the Titicaca Lake near Cohana Bay, the aquatic pollution is caused mainly by urban and industrial wastes upstream of the basin, by agricultural activities and by natural geological conditions. The pollutants are transported by the Seque and Seco rivers (both located at upstream of the basin) and the Pallina river that is connected to the Cohana Bay through the Katari River. The aquatic pollution in the last decade and in recent years have been extensively studied, taking into account hydrological, physicochemical, chemical and bacterial data, but the dynamics and sources of As and TEs in the shallow and deep groundwater of the Lower Katari Basin were not studied. Due to the geographical location of the Lower Katari Basin, it could be the recipient of all the pollutant load upstream of the basin.

A total of 37 water samples were collected during wet season (2015), 31 groundwater samples including drinking water wells and 6 surface water samples. The hierarchical cluster analysis and principal component analysis were simultaneously applied to groundwater and surface water hydrochemical data. The principal component analysis was more useful and provided more information about processes controlling the hydrochemistry using Kaiser criterion; three factors (59% of the total variance) were used. Results show high salinity in groundwater related to the evaporation enrichment of the salt deposit of the paleo-lakes causing serious problems to the groundwater quality and rendering it unsuitable for drinking. The groundwater is very diverse, there are: Na-SO_4-Cl type, Na-Ca-Mg-HCO_3 type and Ca-Na-HCO_3-Cl type, each one is 10%, with neutral to slightly alkaline pH and moderately oxidizing character. Dissolved As concentration ranges from 0.75 to 89.7 μg/L; more than 48% of the samples exceeded the WHO guideline (10 μg/L) value for As and more than 22% for NO_3^-. The distribution of the other TEs (Cu, Fe, Mn, Pb, Cd and Zn) shows low concentrations. Speciation of As indicates that the predominant oxidation state is As (V). The geochemical modelling with the calculation of the mineral saturation indices indicate that As could be associated with iron oxides and hydroxides which are probably the most important mineral phases for the As adsorption. The villages that are close to the Katari River (64% of the wells sampled), especially at the east side of the river, suffer of severe drinking water scarcity, and the water resources in the area are impacted by the presence of high As, NO_3^-, and high salinity levels. The spatial distribution of dissolved As concentrations in groundwater raises a significant concern about drinking water quality.