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Origin of the groundwater salinization in La Aldea coastal aquifer (Gran Canaria, Canary Islands)

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ABSTRACT

Groundwater chemistry in La Aldea aquifer (Gran Canaria, Canary Islands) shows high contents of chloride and nitrate ions. The salinization process has been modelled using the geochemical data, taking into account the results of a previous flow model. The results allow to identify the salinity of the recharge from the rainfall under aridity conditions and the irrigation returns like the main causes of the groundwater salinization.

INTRODUCTION

La Aldea ravine, located on the western side of Gran Canaria (Canary Islands, Spain), presents a flat bottom surrounded by high mountains (with heights varying from sea level to 1,415 m). The climate is dry subtropical with high temperatures throughout the year. Intensive greenhouse horticulture (mainly tomatoes and cucumbers) is practiced with a cultivation surface of 645 ha and irrigation water is mainly supplied by three dams situated upstream, although more than 370 large-diameter wells also provide crop water requirements in the dry seasons, diminishing the quality of groundwater.

The geology of the area shows a sedimentary unit, heterogeneous, composed of alluvial and screes deposits (consisting of detritical material with phonolites-trachytes, ignimbrites and basalts boulders) and a volcanic unit, also heterogeneous, consisting of Miocene basalts located beneath the sedimentary unit and occupies the entire surface with a lower permeability than the alluvial deposits (Figure 1). There is a residual relief located east of the study area between Furel and La Aldea ravines (Las Tabladas) with a complex geology, where slid hydrothermal deposits (Azulejos) crops out.

Groundwater flows mainly through alluvial materials from east to west along the La aldea alluvial, that represents a discharge area from the aquifer to the sea. There is also an important flow from mountainous areas located north and south towards the La Aldea alluvial. Water balance has been done for the hydrological years 1991-1999 (Cruz, 2008) and shows that the recharge is a result of irrigation returns (60%) and rainfall (20%).

The hydrogeochemistry of the area has been studied since 1992 during several research projects in order to qualitatively characterize La Aldea aquifer (Muñoz *et al.*, 1996; Muñoz, 2005; Cruz; 2008). The hydrogeochemical conceptual model was established and suggests that a water flow from basalts to the alluvial exists, and therefore the extracted water represent a mixing of water from both units.

Groundwater in the area presents high salinity ratios (Cl contents up to 7000 mg·L^{-1} and N contents up to 700 mg·L^{-1}) in some places, and the origin of salinity is the aim of the present communication.

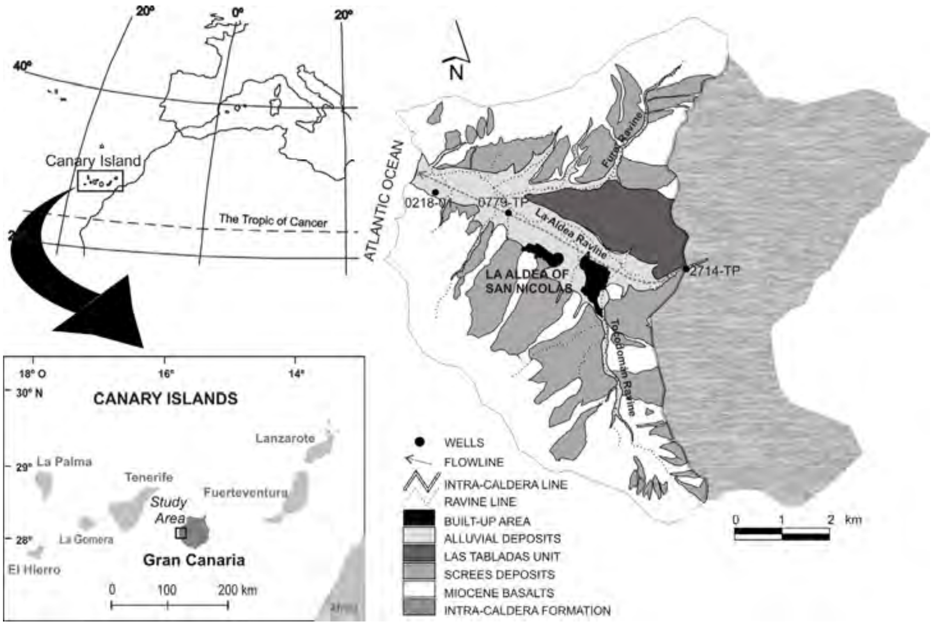

Figure 1. Localization of La Aldea aquifer in Gran Canaria (Canary Island, Spain) and geologic map showing the main geological units.

METHODS

In this work, the spatial and temporal distribution of chloride and nitrate ions and chemical characteristics of the different sources of recharge have been studied to quantify the influence of the different sources of salinity (mainly salinity of rainfall due to aridity and irrigation returns). The aquifer salinity has been modeled along a flow line (with three representative wells) in the aquifer (Figure 1) using PHREEQC. The model has simulated mixing processes between recharge water (rain and irrigation returns) and groundwater and chemical reactions that occur in soil and rocks in different areas of the aquifer.

RESULTS

Figure 2 shows the spatial and temporal evolution of chloride for the years 1992 and 1999. The highest concentrations are observed in Las Tabladas foot and results from the leaching of the Azulejos. The lower concentrations were found in the Miocene basalts in the highest levels. In general, there is coincidence between the direction of groundwater flow and the increase in chloride concentration. Comparing both years, an increase in chloride concentrations is observed. The average concentration of chloride in the study area is 711 mg·L^{-1} for 1992 and 1110 mg·L^{-1} for 1999.

The average concentration of nitrates is 88 mg·L^{-1} for 1992 and 175 mg·L^{-1} for 1999 which represents a substantial increase in the concentration for this time period, reaching maximum values of 484 mg·L^{-1} for 1992 and 708 mg·L^{-1} 1999. Figure 2 shows the spatial and temporal evolution of nitrate ion showing that maximum values are located at the mouth of the

Tocodomán ravine and the southern of La Aldea ravine in 1992 and in 1999 high values of nitrates occupy most of the alluvial located that is where most crops are located.

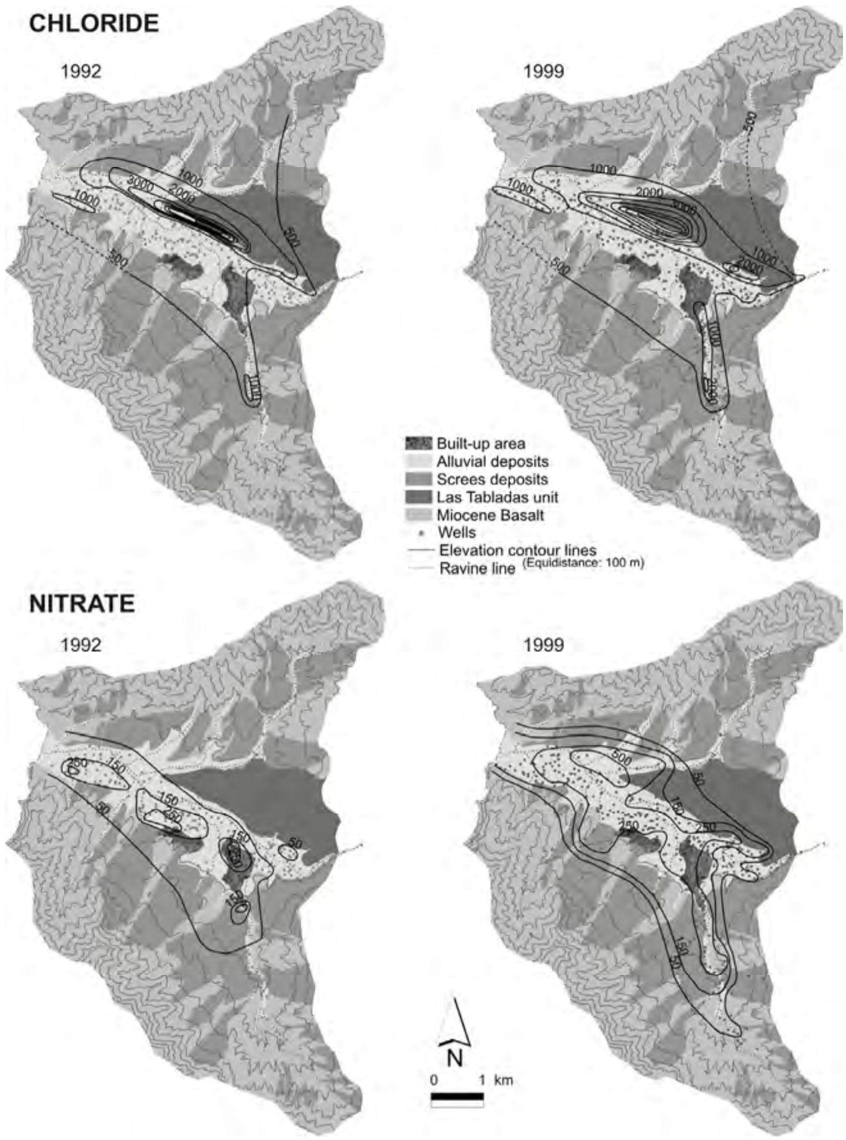

Figure 2. Isoconcentration of chloride and nitrate for 1992 and 1999.

DISCUSSION AND CONCLUSIONS

Different hydrogeochemical processes that control groundwater geochemistry have been identified and quantified. Rainwater represents the 20% of recharge that joins the aquifer with extra salinization due to salinity of the recharge from the rainfall under aridity conditions (Custodio, 1993). Irrigation returns represents 60% of the recharge and causes increased salinity due to the high evapotranspiration rates. Finally, other geological input of high salinity waters is located at Las Tabladas has been attributed to leaching of the deposits known as Azulejos.

Chloride concentration in rainwater ranges from 30 mg·L^{-1} and 450 mg·L^{-1} in areas farther and nearer the sea respectively (Munoz, 2005; Alcala, 2005, Cruz 2008). Rainwater evaporation has been calculated between 60% and 70% (Cruz, 2008) producing an increase in the salinity of the recharge. Irrigation returns waters have a nitrate concentration of more than 650 mg·L^{-1} (Cruz, 2008) The Azulejos influence has been studied from the chemistry of some oozes located in Las Tabladas with waters that have chloride concentrations of more than 8000 mg·L^{-1} and nitrate concentration above 500 mg·L^{-1}.

The modeling has been carried out reproducing the chloride and nitrate concentration in two wells located in the middle and low part of La Aldea ravine (0779-TP and 0218-O1, respectively) from the well water 2714-TP located at header (Figure 1) assuming that all nitrate comes from irrigation returns and chloride recharge by rainfall. The study of the chemical evolution of groundwater in the flow line (2714-TP to 0779-TP and 2714-TP to 0218-O1) shows that the well 0779-TP presents 2% of marine water respect to 2714-TP and the well 0218-O1 presents 4% of marine influence respect to 2714-TP. This means a marine contribution of 0.5% per km in the flow line for 0779-TP, ranging to 0.7% for 0218-O1. This increase in the rate of marine spray contribution of 0.2% in 0218-TP shaft with respect to the well 0779-TP implies an increase in the contribution as we approached the coast, which also confirm rainfall chemical data.

Attending to the model results, the groundwater receives 51% of irrigation returns in the well 0779-TP and 89% in the well 0218-O1. This demonstrates the importance of irrigation returns water as input to the system and as a source of contamination of groundwater and confirms that groundwater presents more influence of irrigation returns as moving in the direction of flow.

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