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Extended Abstracts

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title: **Hydrogeochemistry modelling in La Aldea Aquifer (Gran Canaria, Canary Islands, Spain)**

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INTRODUCTION

La Aldea Valley is located on the western side of Gran Canaria (Canary Islands, Spain) and covers an area of 44 km². In the lower part of the La Aldea-Tejeda basin, shown in Figure 1, the valley presents a flat bottom surrounded to the north and south by high mountains (with heights varying from sea level to 1415 m). It is bounded to the east by the Atlantic Ocean and to the west by the impermeable materials of the inner part of the island. The climate is dry sub-tropical. Rainfall and temperature mean values are 160 mm/year and 21°C respectively. The main economic activity in the area is intensive greenhouse horticulture. Irrigation water comes mainly from three dams located upstream of the study area, but more than 370 large-diameter wells are exploited in times of drought. The intensive agriculture has an important impact on the aquifer, degrading groundwater quality and, during droughts, causing the drawdown of groundwater levels.

This article deals with the hydrogeochemical model that has been developed in La Aldea aquifer (Gran Canaria, Canary Islands). This model allows the interpretation of major ions taking into account the entire process that takes place in the aquifer.

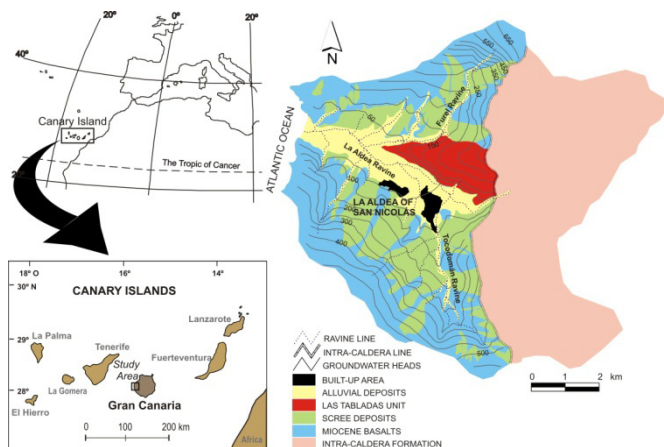


Figure 1. Location of La Aldea aquifer, showing the defined geological units.

HYDROGEOLOGICAL CHARACTERIZATION

A flow conceptual model of the aquifer has been established within the framework of the insular aquifer. It has been conceptualized as a single, stratified, heterogeneous groundwater body where recharge takes place mainly at the top of the island, with groundwater flowing towards the coast (SPA 15, 1974; Custodio, 2007). Within this framework, La Aldea Valley represents a discharge area from the aquifer to the sea.

Based on the geology, four hydrogeologic domains have been defined in the study area: Alluvial formation, scree deposits, Las Tabladas unit and Miocene basalts (Fig. 1), of which the alluvial formation and Miocene basalts are the most significant. The aquifer is unconfined and the alluvial deposits and the basalt rocks can be considered to be a single aquifer with two sub-layers: the upper alluvial deposits layer and the lower basalt layer. The flow has a main east to west direction in the La Aldea ravine, a south-north direction in the Tocodomán ravine and north-south

direction in the Furel ravine (Fig. 1). Recharge is a result of rainfall, irrigation returns, supply network leaks and inflow from the intra-caldera zone. Rainfall and irrigation returns are the main sources of groundwater recharge. Discharge takes place by pumping wells and seaward outflow. The maximum permeability values are located in the La Aldea alluvial area, 17–106 m/d. In the Tocomodán and Furel alluvial areas it is 5.5–22 m/d. The permeability for Miocene basalts is 0.0009–0.005 m/d and for scree deposits and secondary tributary alluvial areas permeabilities are 0.25–1.2 m/d and 6 m/d, respectively (Muñoz, 2005; Cruz, 2008; Cruz et al., 2008).

HYDROCHEMICAL CHARACTERIZATION

Groundwater flows mainly through the alluvial materials to the sea and these materials are fed by the basalts in the upper parts and through the bottom of the alluvial unit. Thus, the exploited groundwater is a mix of groundwater from these two units and shows hydrochemical characteristics of both units in different proportions, with all the inputs from different origins (Muñoz et al., 1996).

The electrical conductivity of groundwater ranges from 837 $\mu\text{S}/\text{cm}$ in $\text{HCO}_3^- - \text{Na}^+$ type water to 11370 $\mu\text{S}/\text{cm}$ in $\text{Cl}^- - \text{Na}^+$ type water. The resulting spatial distribution of groundwater types is shown in Figure 2. The hydrogeochemical inputs that have been considered in the model are: rain water (considering the influence of marine aerosol at the coast and the Saharan dust deposition), dams and runoff water, irrigation returns (increase in concentrations of nitrate and sulphate) and the geologic prints. The geologic inputs identified are two: groundwater from basalts (increase in the concentrations of magnesium and calcium) and trachyte-rhyolitic ignimbrites that form the scree deposits (increase in the concentration of sodium) and saline waters located in the Las Tabladas area that have been attributed to hydrothermally altered materials (locally called “Azulejos”).

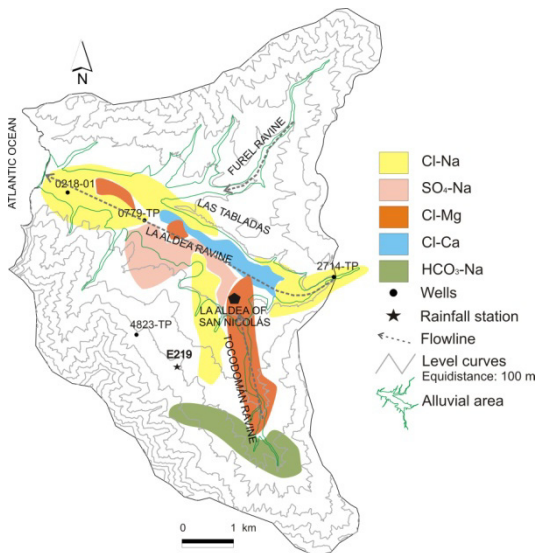


Figure 2. Location of observation wells and rainwater collector. Spatial distribution of groundwater types at La Aldea aquifer.

In general, chloride increases towards the sea, although there are some deviations in samples from wells near to the Las Tabladas area. In this area, a significant increase is observed in the concentrations of chloride, sodium and sulphate (reaching 8100, 3900 and 1800 mg·L⁻¹ respectively), localized around the Las Tabladas area.

HYDROCHEMICAL MODELLING

Two chemical models have been made using PHREEQC: one simulates the chemical reactions taking place under the natural flow regime in the unsaturated zone (Fig. 3), and the other considers the anthropic inputs along a flow line in the aquifer (Cruz, 2008).

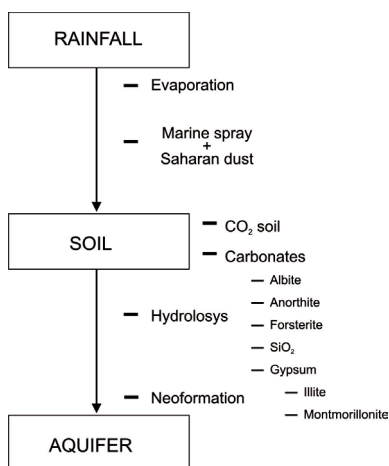


Figure 3. Conceptual model of the groundwater mineralization under a natural flow regime in unsaturated zone.

The quantification of these chemical reactions is in agreement with the groundwater chemical composition, that is controlled by the influence of dry deposition of marine spray and Saharan dust; soil CO₂ input, a significant evapotranspiration rate, silicate hydrolysis, irrigation returns inputs (of anthropic origin) and the saline waters from Las Tabladas input.

RESULTS AND DISCUSSION

Table 1 shows the results of hydrogeochemical modelling for obtaining groundwater from rainwater (Station E219 to well 4823-TP, Fig. 2) and mixtures in low line (well 2714-TP to well 0779-TP and well 2714-TP to well 0218-01, Fig. 2) by simulating chemical reactions with PHREEQC. The result of modelling in flow line 2714-TP to 0218-01 allows evaluation of the mixtures produced during the groundwater flow through the main alluvial deposit, from headwaters to the mouth, while the study of flow between well samples 2714-TP and 0779-TP allows its spatial distribution to be obtained, describing the chemistry evolution in the middle of the alluvial aquifer.

Table 1 Summary of results of hydrochemical modelling in natural conditions (from rainwater to groundwater) and anthropogenic conditions (flow line within the alluvial aquifer). Units:mmol/l.

Process	Rain → Groundwater	2714-TP → 0779-TP	2714-TP → 0218-01
	E219 → 4823-TP		
Evaporation	72.40%		
Mixture with marine aerosol		2%	4%
Mixture with irrigation water return		51%	89%
SiO ₂	-0.9	33.1	172.33
Gypsum	-0.126	6.3	7
Calcite	-5.9	1.98	4
Forsterite		6.9	10.3
Albite	3.9		4.5
Anorthite	1.28		
Illite	-3.14	-4	-6.98
Montmorillonite	-0.32	-25.5	-43

The hydrogeochemical simulation for groundwater not influenced by anthropogenic inputs was carried out in the south of the aquifer: rain station 219 and well sample 4823-TP (Fig. 2), both located in the same area and not influenced by the irrigation return flows (nitrates= 0 mg·L⁻¹). Equilibrium between rainwater and CO₂ soil was simulated. The evaporation process was introduced by removing 72.4% water (40.22 mol H₂O) to obtain a chloride content similar to that of well sample 4823-TP. The mineralogy of basalts and trachyte-rhyolitic ignimbrites has conditioned the considered minerals: SiO₂ (amorphous), Gypsum, Calcite, Forsterite, Albite, Anorthite, Illite and Montmorillonite. The simulation obtained a good fit between the calculated and observed chemical concentrations for well sample 4823-TP from rain station 219.

Another simulation was carried out according to the east-west flow line and taking into account lithology and system hydrological functioning. Thus, the chemical composition of wells 0779-TP and 0218-01 from well 2714-TP located in the header of the ravine is reproduced (Fig. 2). The simulated water from well 0779-TP has been obtained from the composition of well 2714-TP mixed with 51% of irrigation water returns and the resulting water is mixed with 2% sea water to reach the concentrations of sodium and chloride existing in groundwater that represent the airborne salinity. The simulated water from well 0218-01 is obtained by mixing groundwater from well 2714-TP with 89% of irrigation water return and 4% of airborne salinity. The final groundwater composition implies the hydrolysis and dissolution (positive values) or neoformation (negative values) of the considered minerals (Table 1).

CONCLUSIONS

Hydrochemical modelling has been used to establish mixing processes and chemical reactions evolution that take place in the aquifer, shown to be a useful tool to identify and quantify the processes that are occurring. Consistency is increased if the flow model previously developed allows the characterization of hydrodynamic behaviour of the aquifer and its corresponding flow pattern, identifying main flow lines that are represented in the hydrogeochemical model. Hydrochemical modelling will help in developing a transport model that reproduces the spatial distribution of chloride concentrations in the study area.

If no anthropogenic effects are present, the chloride content (conservative ion) found in groundwater points to an evaporation process which removes 72.4% of rainwater volume, according to the evapotranspiration rates (69%) calculated in water balance from a previous flow model developed in the aquifer (Cruz, 2008; Cruz et al., 2008). Another important source of salinity exists in the area, spatially defined at the base of Las Tabladas area, which has not been taken into account in this study. It is produced by the leaching of hydrothermal *Azulejos* deposits, that affects the wells located near the plume but not the selected wells used in the simulation.

The existence of irrigation return flows in the flow direction has been confirmed and reaches 51% and 89% of the water exploited in the middle part of the aquifer (well 0779-TP) and the coastal area (well 0218-01). The geological print of basalts has been identified in Tocodomán ravine. These data are also consistent with the previous water budget of the aquifer.

Modelling has confirmed that groundwater chemistry in the study area is the product of mixing water with different chemical characteristics in different proportions depending on the area of the aquifer. Groundwater is mainly of the sodium-chloride type, pointing to the importance of marine aerosol in this area. Where the influence of marine aerosol is low (highest parts of the study area and furthest from the sea), groundwater is of the sodium-bicarbonate-chloride type.

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