First time delimitation of the saltwater-freshwater interface shape applying geophysical methods and groundwater conductivity logs in Motril-Salobreña Aquifer (South Spain)

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ABSTRACT

Motril-Salobreña coastal aquifer is located in the South of Spain where the climate is classified as semi-arid. For this reason, it is usual in this area the construction of infrastructures as weirs and dams for water resources regulation. Nevertheless, associated with the anthropic modifications for improving the water supply to the population, the inflows to the aquifer have been reduced. As a main consequence of this, saltwater intrusion risk is growing and monitoring the saline wedge position is essential for preventing undesirable changes in the aquifer water quality. Several geophysical surveys have been carried out for detecting the saline wedge but there are uncertainties about the exact position and shape. In 2009 a 250 meter depth borehole was drilled near the coastline in Motril-Salobreña aquifer. Electrical water conductivity logs showed a brackishwater-freshwater change that is considered as the beginning of the saltwater-freshwater interface. The information obtained with the logs and the geophysical methods has been combined and an approximation to the upper limit of the saltwater-freshwater interface shape is presented for the first time in this aquifer.

INTRODUCTION

Saltwater intrusion is very common in coastal aquifers where humans pump groundwater for developing their activity. Monitoring the saline wedge position is a complicated task due to saltwater intrusion occurs most of the times at important depths. The direct detection with groundwater resistivity logs has the disadvantage that it is necessary to drill expensive boreholes for only research objectives. For this reason geophysical methods have been applied for locating low resistivity areas in the aquifers that can be associated with saltwater intrusion. However, geophysical results only show the resistivity as physical property and the low values can be confused with lithological changes.

In Motril-Salobreña aquifer, previous geophysical studies and the recent drilling in the area near the coastline can be applied for a precise study of saltwater intrusion situation. In this aquifer, anthropic actions as the construction of a dam in the Guadalfeo River or changes in the cropping irrigation techniques (the main inflows to the aquifer) are reducing the aquifer recharge. The changes in the hydrogeological system increase the saltwater intrusion risk. The study has been carried out in the Guadalfeo river mouth sector where previous studies considered that in the most sensible area to saltwater intrusion (Calvache et al., 2009). The saltwater-freshwater interface is characterized by a mixing zone, where the water is brackish. In Motril-Salobreña aquifer has been possible to detect the upper limit where freshwater and brackishwater are in contact. This point can be considered as the beginning of the saline wedge. The position of the
limit can be monitored for detecting saltwater intrusion processes and applied for plotting the interface shape.

**HYDROGEOLOGICAL SETTING**

Motril-Salobreña coastal aquifer has a 12 km length contact in its south border with Mediterranean Sea (Fig.1). It is composed of detrital sediments and the mean hydraulic conductivity estimated is 50 m/d (Duque, 2009), but it changes considerably along the aquifer from 200 m/d to less than 5 m/d., therefore the groundwater flow in the aquifer can be considered as relatively fast. The advance of saltwater intrusion is considered in a short term period associated with the inflows reduction.

![Map of Motril-Salobreña Aquifer location and study area.](image)

Figure 1. Motril-Salobreña Aquifer location and study area.

**METHODS AND RESULTS**

Several studies have been carried out for detecting saltwater intrusion. In 2006 a time domain electromagnetic soundings survey allowed to detect the depth of the freshwater-saltwater interface in two points of the study area (Duque et al, 2008). The TDEM sounding A is located very near of the coastline. A change in the resistivity is detected at 130 meters depth from 80 Ω.m to less than 8 Ω.m (Fig.2). The TDEM sounding B is 300 meters away from the coast. A similar abrupt change in the resistivity values is observed but at greater depth, about 180 meters (Fig.2).

In 2009 an electric tomography in a perpendicular profile to the coastline was carried out parallel to the river track. With this geophysical technique is possible to obtain continuous information about the electrical properties of the aquifer in a 2D section. In the nearest sector to the sea very low values of resistivity were detected (1 Ω.m). This can be considered as the beginning of the freshwater-saltwater interface. Nevertheless the depth reached was 40 meters (Fig. 2) and only in this point the resistivity indicates the presence of saltwater.
In 2009 a borehole was drilled in the study area looking for the direct detention of the freshwater-saltwater interface. The depth reached was 250 meters that it was considered enough with the previous geophysical studies. From October of 2009, groundwater conductivity logs have been monitored periodically. The results show a sharp change between 130 and 170 meters depth where the water conductivity increased from less than 1000 µS/cm to higher than 24 000 µS/cm. The conductivity varies from freshwater to brackishwater properties (the conductivity of the Mediterranean Sea water in this area is higher than 50000 µS/cm). That is the reason because in the TDEM soundings the measured resistivity does not reach very low values.

**DISCUSSION AND CONCLUSIONS**

The results obtained with different methodologies can be combined for obtaining a complete overview of the marine intrusion in the area near the Guadalfeo mouth. The TDEM sounding results have been tested with the water conductivity logs in the borehole and therefore, they are directly related with the saltwater intrusion (the lithological changes can be depreciated). Also the electric tomography is coherent with the other results because the resistivity associated with the presence of sea water is only detected in the areas near the coastline.
Data congruence makes possible to plot the saline wedge shape (Fig.3). The freshwater-saltwater interface has an abrupt drop from the coastline until 50 meters inland where is located at 130 meters depth. After this drop, the freshwater-saltwater contact slope decreases and in the following 250 meters only goes down 50 meters more. This is the first time that the saline wedge is characterized spatially in this aquifer that represents the starting point to a saltwater intrusion alert system for mitigating anthropic impact in the aquifer.

REFERENCES


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