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Extended Abstracts

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title: **Hydrochemical and isotope analysis of deep groundwater from the Nubian Aquifer system in the Egyptian Oases**

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INTRODUCTION

The groundwater of the Nubian Aquifer System is the vital source for the water supply of the Egyptian oases in the Eastern Sahara (Western Desert of Egypt). It has been the subject to various studies in more than 100 years. Most recently groundwater flow and transport models were developed by numerical modelling approaches e.g. of Heini & Brinkmann (1989), Gossel et al. (2004), Sefelnasr (2007), Gossel et al. (2008) and Gossel et al. (2010). The drinking water and irrigation water in the oases was taken in former times from the uppermost aquifer, today it is mostly extracted from deep wells with a depth of 500 – 1200 meters to ensure high quality and safe yield. The potentiometric surfaces of the confined aquifers reach about 2 – 50 meters below ground, in some cases the wells are free flowing. Due to the great depth the groundwater temperatures range from about 40°C to 60°C and thus the hydrochemistry is influenced by dissolved minerals. Therefore the recent study focuses the main component analysis, the analysis of metals and the isotopic measurements of hydrogen and oxygen. For these analyses samples were taken at the locations in Fig. 1. The ages of the groundwater of some of the wells and other deep wells in these Egyptian oases were published by Du et al. (2006) and range from 200 to 1000 kyr. The isotopes of hydrogen and oxygen were also subject to diverse studies in the last decades but led to an indifferent picture of the climatic conditions during the recharge times. The numerical groundwater flow model, the hydrochemical and isotope analyses were expected to give a consistent picture of the paleoclimatic recharge conditions of this very old groundwater, the hydrochemical conditions of this part of the aquifer and the fate of dissolved minerals during pumping and use.

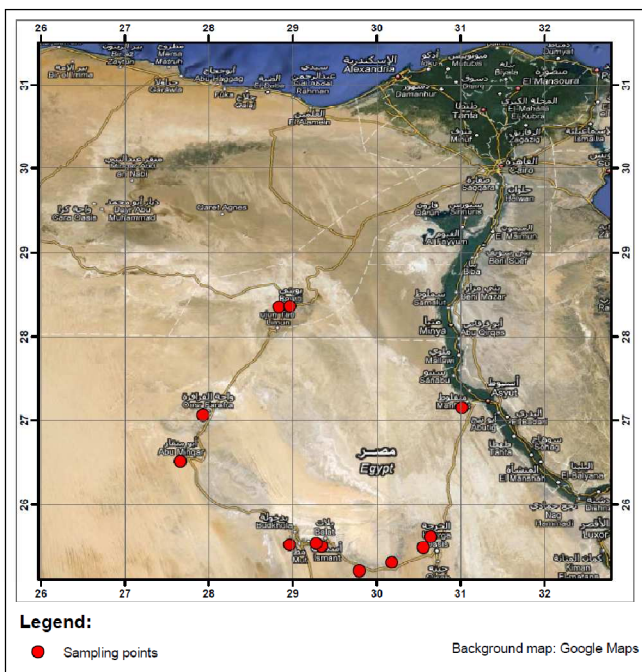


Figure 1. Sampling locations of the Egyptian oases and Assiut.

METHODS

The groundwater samples were taken at the locations outlined in Fig. 1. The main components were analysed by ion chromatography, the metals by ICP-MS and ICP-OES and the isotopes were analysed with an equilibration device-IRMS system. The results of the hydrochemical analyses were used for a statistical analysis and further modelled by using the geochemical code PhreeqC to obtain a consistent picture of the redox conditions in the aquifer and the rock – water interaction. The threedimensional numerical model based on the model described in Sefelnasr (2007) in detail and in Gossel et al. (2010) in an enlarged area. Based on the flow model the pathlines and retention times of the groundwater were calculated.

RESULTS

The hydrochemical analyses and model results showed that the groundwater is in most cases under reductive conditions. This leads to high contents of iron, manganese but only in rare cases of other metals. A factor- and cluster analysis showed a differentiation between groundwater from the edge of the Nile Valley near Assiut, the North of Kharga Oasis and the locations in the other oases. The factors can be gathered into 4 groups (components): In the first group sodium chloride dominates with factor loadings > 0.9, in the second group calcium, magnesium and iron have the highest loadings. The third group is dominated by sulphate and strontium and the fourth group is marked by copper and barium. The cluster analysis was carried out based on all parameters. A classification into four clusters gives the most reasonable results. As expected the sample from the edge of the Nile Valley and from the North of Kharga Oasis could be obviously distinguished from the other samples into a unique group whereas the other samples divide into two quite similar groups.

The interpretation of the measurements of the iron and manganese species as well as the sulphur species with inverse modelling in PhreeqC showed that the groundwater is under reductive conditions. Medium range iron and manganese contents that fall out when pumped and flowing under oxidative conditions can not be explained by high temperatures of the water and subsequent cooling. The contents of other trace metals are very low although they play an important role in the factor and cluster analysis. The sulphate content marks also a special group and can be explained completely by an oxidation of sulphide.

A comparison of the ages of the groundwater reported by Du et al. (2006) with the results of the groundwater models showed a good accordance. In Fig. 2 the backward pathlines with isochrone markers are shown. They indicate that the groundwater is flowing from South to North and that the retention time is in the frame of several 100,000 years. In this time the hydrologic conditions (precipitation, evapotranspiration and vegetation) have changed several times significantly in the recharge areas and thus the mixture of water from different times is evident.

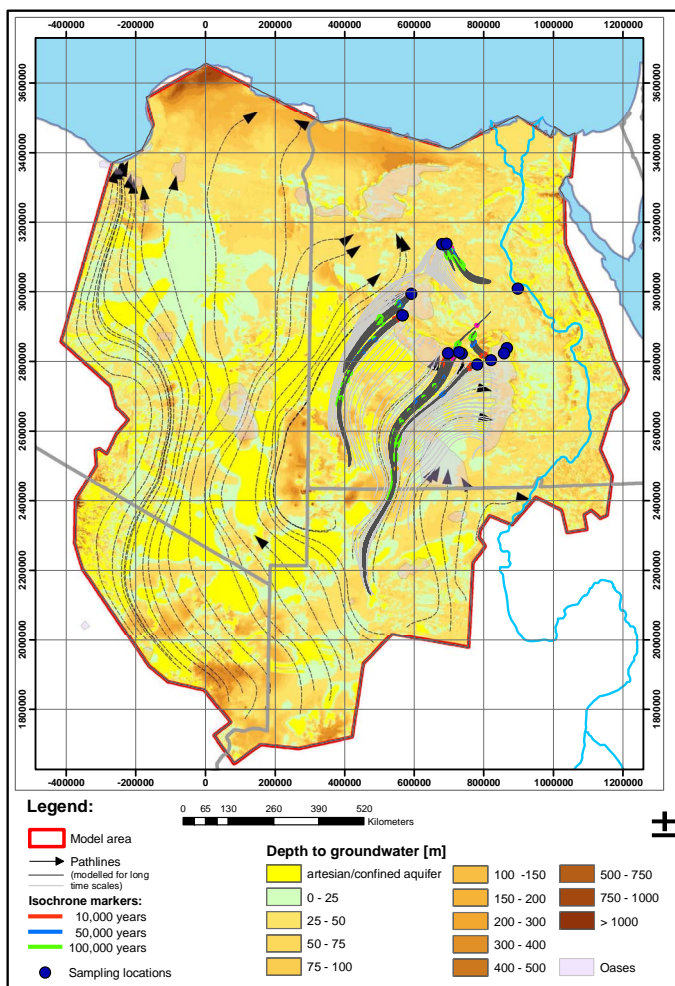


Figure 2. Pathlines calculated by the numerical groundwater model for a time horizon of 10000 b.p. are shown on the background of the depth to groundwater. The isochrone markers show the long retention time between infiltration and discharge in the Oases.

The results of the isotope analyses (Fig. 3) are also consistent with the former investigations but maybe have to be interpreted completely new. The highly negative excess of both the hydrogen and oxygen isotopes is not explained sufficiently by the former reports. In combination with the ages the question of the climatic conditions during the recharge of the groundwater has to be focussed again. About 300 to 1000 ky ago the infiltrating water from precipitation must have undergone a long history of evaporation and condensation processes.

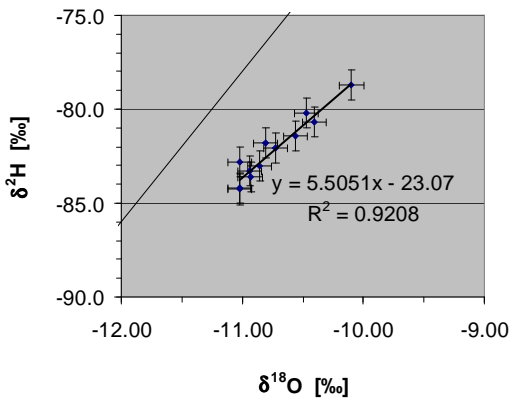


Figure 3. Results of the isotope analysis $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of the water of the Egyptian Oases. The sample from the edge of the Nile Valley is not plotted.

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