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Insights from stable isotopes and hydrochemistry to the Quaternary groundwater system, south of the Ismailia canal, Egypt

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SUMMARY

Stable isotopic ratios of water ($\delta^{18}O$ and $\delta^{2}H$) and major dissolved ions were analyzed from samples collected from the area south of the Ismailia canal, Egypt. This region has recently experienced rapid growth that has increased both surface and groundwater use. The data from the samples were used to identify recharge sources, and mixing and salinization processes in the groundwater system in this region. On the basis of the isotopic data and geochemical data, four end-members were defined representing, groundwater in a Quaternary aquifer, groundwater in a Miocene aquifer, water in the Ismailia canal, and wastewater from the 10th of Ramadan city. Several different mixing trends were recognized in the study area. As a consequence of mixing with groundwater in the Miocene aquifer, groundwater in the Quaternary aquifer was found to have depleted isotopic signatures and increased total dissolved ions (TDI) toward the south of the study area, near subsurface Miocene structural highs. Another mixing trend, consisting of, enriched isotopic ratios and lower TDI values toward the north in the Quaternary aquifer, indicated mixing with surface water, i.e., the Ismailia canal and freshwater ponds. A third trend of locally high TDI values together with depleted stable isotopic data, i.e., the Ramsis area and the vicinity of the well field, were interpreted to be due to excessive pumping for irrigation and reclamation activities, which in turn resulted in upconing of the deeper saline groundwater from the Miocene aquifer. Lastly, leakage from the wastewater ponds into the recharge process was suggested by considering chemical and isotopic signature of the Quaternary groundwater sample No. 31. These results strongly indicate the urgent need for monitoring, protection and remediation of the Quaternary aquifer in order to guarantee the sustainability of water resources in the study area. This work also illustrates the efficiency of using stable isotopes and major ion chemistry to improve our understanding of a flow system.

1. Introduction

An imbalance between available land in the Nile Valley and Delta and a growing population has become and will be one of the most critical problems facing Egypt. To address this issue, the Government of Egypt has created policies to reclaim areas which were originally deserts. Priorities were given to regions to the east and west of the Nile Delta with good quality aquifers, wide plains with sandy soil, and relatively good accessibility (El Sayed et al., 2012). For this study, we selected a reclaimed area, between latitudes 30°15′ and 30°27′ and longitudes 31°34′ and 31°56′, including an agricultural zone in the north and the Tenth of Ramadan city in the south (Fig. 1). The climate of the study area is arid to hyper-arid and it is hot and rainless in summer, whereas cold with occasional showers in winter. Mean monthly temperature ranges from about 7.8 °C in winter to 34 °C in summer and the average annual rainfall is 26 mm (Climate-Data.org, 2013). As shown in Fig. 2, reclamation activities are mainly represented by four agricultural projects, i.e. Adlia, Ramsis, El Mullak, and El Shabab, mostly in the lowlands nearby the Ismailia canal, and their elevation is about 30–60 m above mean sea level. The Tenth of Ramadan city is located in the southern highland with an elevation of about 100 m above mean sea level. Water resources in this area are the surface water from the Ismailia canal and groundwater from the aquifers of Quaternary and Miocene formations. No formal environmental impact assessment was conducted prior to the reclamation projects (El Arabi, 1997). As a result, unexpected

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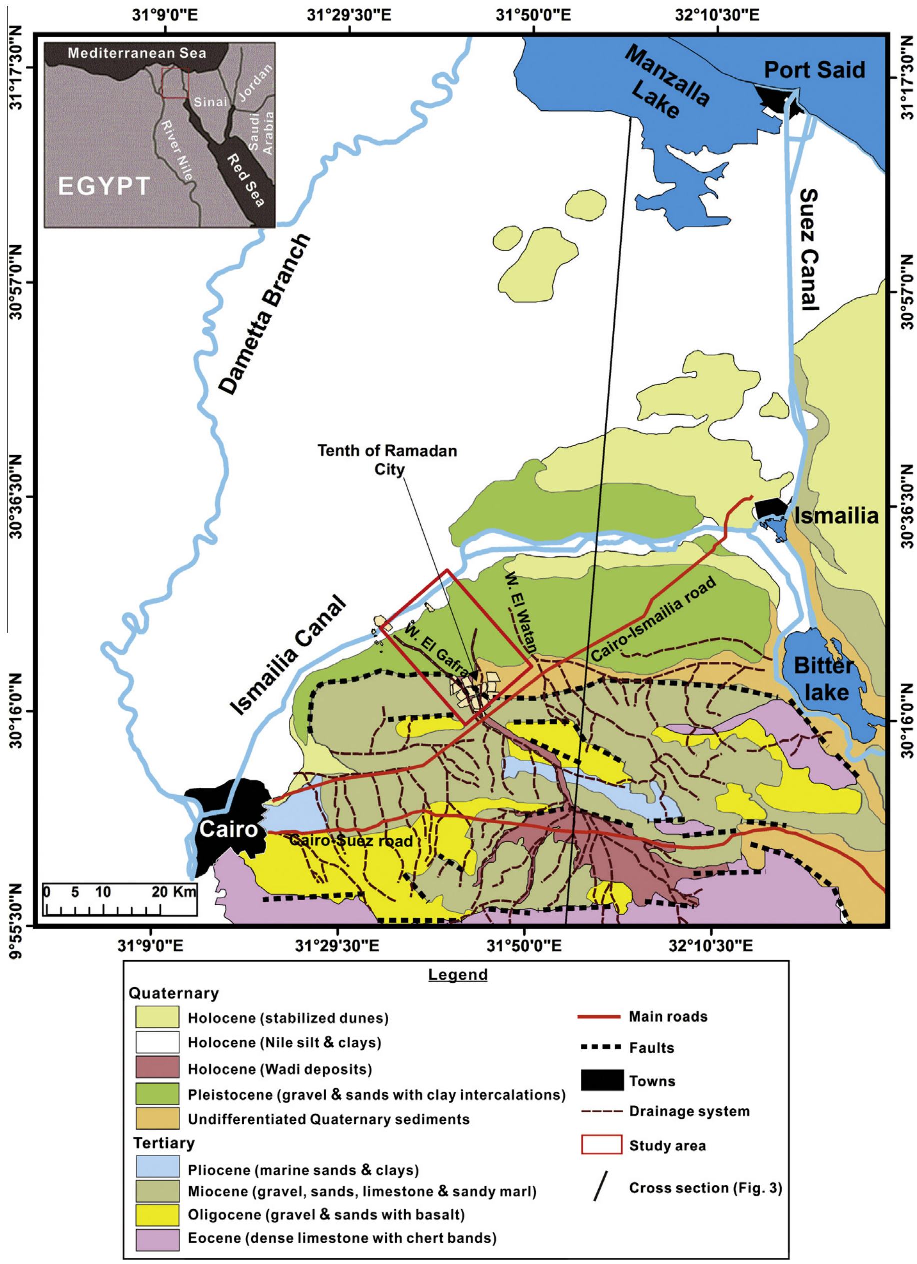

Fig. 1. Geologic map of the eastern Nile Delta (simplified and modified from CONOCO, 1987, and Research Institute of Groundwater, 1992).

negative hydrogeological impacts have started to appear. These include a decrease of water table elevations at Ramsis and an increase of water table elevations at El Mullak agricultural sites (Abou El-Magd, 2011), contamination from unlined wastewater ponds at the northeast of the Tenth of Ramadan city where all the domestic and industrial wastewaters are disposed (Abd El-Samie et al., 2002), water-logging and flooding of soils at the center and the eastern side of the Tenth of Ramadan city (Eleraki et al., 2010), and an increase of soil salinity (African Water Facility, 2007). For these reasons, it is important to evaluate these threats in terms of quality and quantity of the main aquifer in this area, the Quaternary aquifer. We choose to use groundwater chemistry and stable isotopes of water to evaluate these threats.

Water-chemistry patterns in aquifers can provide information on groundwater recharge paths when recharged water is chemically distinct from resident groundwater (Macpherson and Sophocleous, 2004). For example, because chloride is expected to behave conservatively, it is a good geochemical tracer for solute sources and transport processes (Fabryka-Martin et al., 1991). However, such approaches using major chemical components in groundwater are sometimes inconclusive and not sufficient because flow paths and recharge sources of aquifers are generally complex especially under the conditions that the aquifers have high sensitivity to anthropogenic pressures and environmental changes. The integration of geochemical and isotopic tracers can better resolve the origins of the different components in subsurface waters (e.g. Sheppard, 1986) and can improve the reliability of groundwater flow models (e.g. Carrera et al., 2005). Several studies have been conducted using this combined approach to understand the origin of variably mixed groundwater reservoirs (e.g. Gat and Gonfiantini, 1981; Clark and Fritz, 1997; Cook and Herczeg, 2000), to link groundwater recharge and salinization processes (e.g. Ma et al., 2005; Cartwright et al., 2007; Tweed et al., 2011), to relate groundwater recharge and salinity to geologic setting and structures (e.g. Morgan et al., 2006; Yuan et al., 2011), and to show degradation of groundwater with increasing urbanization