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Natural radioactivity and groundwater quality assessment in the northern area of the Western Desert of Egypt

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ABSTRACT

The chemical composition and natural radioactivity of the northern area of the western desert groundwater were determined to evaluate hydrogeochemical facies and assess groundwater quality for different uses. Many the groundwater samples belong to the Na^{+}- Cl^{-}, $Na_2SO_4^{-}$ type, followed by Ca^{2+}- Mg^{2+}- Cl^{-} type. Only a few samples are of the Na^{+}- HCO_3^{-} type. The spatial distributions of the major ions describe similar anomalies, with the highest concentrations found at the extreme northeastern margin of the oasis, as well as in its northern and northwestern parts. Fe is the most abundant toxic metal, followed by Cu and Mn. Anomalies of Cr, Ni and Zn are also detected. Rock/water interactions strongly affect the chemical composition of the groundwater. Dissolution and cation exchange are the main processes controlling the hydrogeochemistry. Most of the irrigation groundwater problems in the study area may be resolved using an effective drainage system. The estimated total annual dose due to ingestion of ^{238}U, ^{232}Th and ^{40}K in groundwater samples reveals that the groundwater is safe for human consumption. However, the toxic metal content of the Bahariya groundwater exceeds the permissible levels for both irrigation and consumption, and the water must be filtered through suitable membranes to exclude these toxic metals. Regular monitoring of the quality of this water for drinking is strictly required.

1. Introduction

The Western Desert covers about two-thirds of Egypt's land area. It spans from the Mediterranean Sea south to the Sudanese border and from the Nile River Valley west to the Libyan border. It is one of the driest areas of the Sahara. The irrigated oases and agricultural schemes are good breeding areas for grasshoppers. They are less suitable for the Desert Locust which generally prefers natural vegetation in the desert. Groundwater is the sole source of water supplying arid and semiarid regions such as the study area which known locally as Bahariya Oasis. Geochemical characteristics of groundwater, particularly the levels of potentially harmful metals and radionuclides, are significant factors in controlling groundwater usage and for health considerations (Baba and Tayfur 2011; Murad et al., 2014; Arslan and Turan 2015). The groundwater geochemistry and contamination levels are naturally influenced by the geological setting of the area (Edmunds and Shad 2008; Al-Katheeri et al., 2009; Banat and Howari 2003; Banat and Howari 2005; Banat et al., 2005) and the lithological composition of the aquifer (Yuce et al., 2009; Howari 2016; Howari et al., 2005; Howari and Banat 2001), in addition to anthropogenic factors, such as agricultural practices (Wongsasuluk et al., 2014), waste disposal (Dong et al., 2015), and industrial and mining activities (Dokou et al., 2015; Hao et al., 2016).

Assessment of the potentially harmful metals and the natural radioactivity levels in groundwater sources is important in

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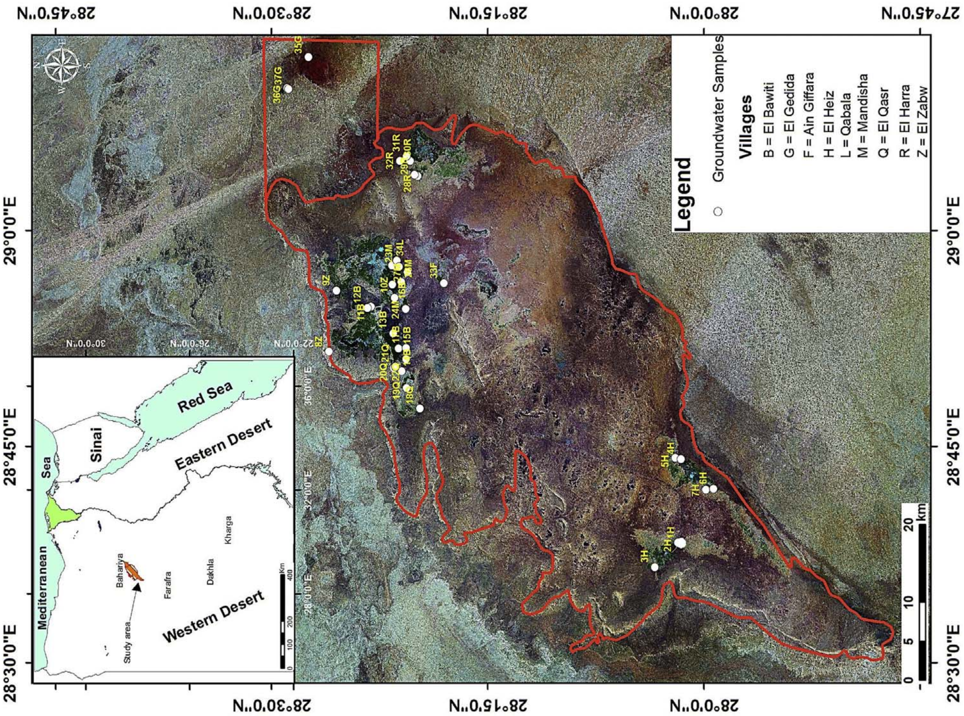

Fig. 1. Satellite image of the study area showing the groundwater sampling sites.

protecting the population against toxicity and high radiation dose due to ingestion (Yuce et al., 2009). The main sources of gamma radiation in natural waters are 238U, 232Th series and 40 K (ICRP, 2012). In the study area, groundwater represents the sole water source for irrigation and other human uses. Groundwater depletion and decline in water quality are the main concerns in this area. Consequently, many hydrogeochemical studies of the groundwater in the Bahariya Oasis have been published since the late 1980s (e.g. Eweida and Abdallah 1980; Shehata 1992; Kornay et al., 2002; Hamdan and Sawires 2013). However, few of these studies dealt with water contamination by toxic metals and radionuclides (Shahin et al., 1996; Khater 2003). The aim of the present work is three-fold: (1) contributing to the database on quality of groundwater in the northern part of the western desert; (2) assessing water pollution levels due to toxic metals and natural radioactivity; and (3) evaluating the suitability of this groundwater for irrigation, domestic and drinking needs.

2. Materials and methods

2.1. The study area

The study area in the northern part of the Western Desert of Egypt between longitudes 28° 35′ and 29° 10′ E and latitudes 27° 48′ and 28° 30′ N (Fig. 1). The approximate area of the depression is about 2000 km^2 (94 × 42 km). It has an elevation of 128 m above sea level and suffers from hyper-arid climate. Inhabitants of the area (population of 34,000) depend mainly on agriculture, with areas of cultivation at a few separate localities. The main Egyptian iron mines are also located in this oasis. Thus, the Bahariya Oasis is a prospective area for reclamation extension, geotourism and industrial activities.

2.2. Geology and hydrogeology

Several hills and high scarps (~175 m height) surround the Bahariya depression. They include mainly exposures of the Lower Cretaceous-Oligocene formations. This succession is overlain by Miocene volcanic rocks (typically basalt) and Quaternary surficial deposits (Said 1962; El Akkad and Issawi 1963; Catuneanu et al., 2006 and others). The Nubian Sandstone (1800 m thick) of pre-Cenomanian to Early Cenomanian age is the groundwater aquifer of the Bahariya Oasis (Korany 1984; Shehata 1992). This aquifer has been described as a multilayered artesian aquifer system that behaves as one hydrogeologic system (Youssef 1999; Hamdan and Sawires 2013). It consists of three successive water-bearing ferruginous and calcareous sandstone units separated by semi-permeable, regionally discontinuous clay and/or shale layers (Korany et al., 2002). The groundwater flow in the Bahariya Oasis has a (SW-NE) general pattern that is similar to that reported for the groundwater of the Nubian Sandstone Aquifer in the Western Desert of Egypt (Korany 1984; Shata 1982; Abdel Ati 2002; Hamdan and Sawires, 2013). The major part of the oasis floor is a flat or gently undulating ground of sandstone and layers of clay, strewn with fragments of rocks derived from the hills (Howari et al., 2016; Said,