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Factors controlling groundwater hydrogeochemistry in the area west of Tahta, Sohag, Upper Egypt

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ABSTRACT

Groundwater quality suffers from various degradation mechanisms such as extensive urbanization, agricultural and industrial activities in many developing countries. This study was carried out to identify the factors responsible for the change in the hydrogeochemistry of groundwater in the area west of Tahta, Sohag, Upper Egypt. The Piper diagrams show the predominance of Na–Cl (75%) with minor Ca–Na–HCO_3 and Ca–Cl water-types. The equiline diagrams and ionic ratios show the dominance of $Ca^{2+} + Mg^{2+}$ over $Na^+ + K^+$ and $HCO_3^- + SO_4^{2-}$ over Cl^- suggesting silicate minerals dissolution and reverse ion exchange reactions Results of Gibb's diagram revealed that the chemical budget of the groundwater in this area is mainly derived from water–rock interaction and evaporation-crystallization dominances. The R-mode factor analysis applied to quantify the chemical characteristics of groundwater and the anthropogenic impacts that affect groundwater quality, revealed that the Pliocene clays are the major sources of Cl^- and Na^+ in the groundwater due to silicate minerals dissolution and ion exchange reactions and, Ca^{2+} and Mg^{2+} are mainly from dissolution of carbonates and silicate minerals abundant in the Pleistocene Qena Formation lithologies. Higher concentration of SO_4^{2-} at the newly reclaimed lands may be due to the effect of rainfall, addition of potassium sulfates fertilizers to the agricultural soils and gypsum-anhydrite dissolution. The results of this study suggest that the R-mode factor analysis combined with the geological–hydrogeological analyses of the aquifer is useful in recognizing the geochemical trends and identifying the anthropogenic sources affecting the groundwater quality.

1. Introduction

Water scarcity is one of the main problems that many societies face due to the unequal distribution of resources, in addition to man-induced pollution (agricultural and urbanization activities), and unsustainable or improper management of the water resources. Groundwater is the main source of fresh water supply in many countries and it makes up about ninety percent of the world's readily available freshwater resource (Boswinkel, 2000). Therefore, assessment of its occurrence, distribution, potentiality and quality is of a great concern to public and local authorities. In Egypt, the increasing population, agricultural expansion, and urbanization in the newly reclaimed areas have opened the way for the search of new groundwater resources with good quality for various purposes in this arid zone.

Generally, there are many factors affecting groundwater quality that include natural processes (aquifer lithology, groundwater recharge source, and water–sediment interaction), anthropogenic activities (urbanization, agriculture, industry), and/or atmospheric inputs (Helena et al., 2000). Many dissolved inorganics containing a wide variety of chemical constituents in various concentrations are found in groundwater depended on the time of interaction between water and the water bearing sediments. Other constituents in groundwater are biochemicals associated with urban, industrial, and agricultural activities (Daniele et al., 2013). Therefore, the understanding of the different processes that control the quality of groundwater is a prerequisite to achieving water quality controlThe Sohag Governorate is one of the Upper Egypt provinces located midway between the cities of Cairo and Aswan. The study area is in Tahta city located to the west of the Nile north of Sohag (Fig. 1). Most of the urban growth and agricultural activities on new reclaimed areas have taken place on the west of the Nile Valley due to its distinct geomorphological features. The study area is bound on the west by the limestone plateau dissected by many drainage basin systems trending mainly to the W–E direction giving way to

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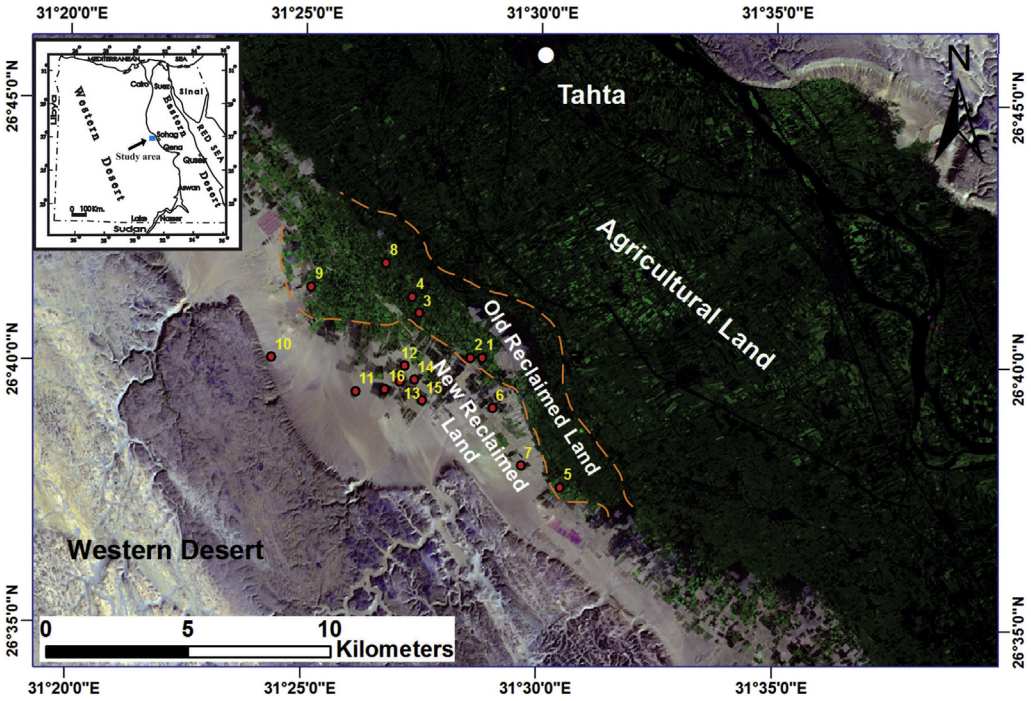

Fig. 1. Location map of the area west of Tahta city.

low-lying desert land areas and finally to the agricultural areas adjacent to the River Nile. Recently, the development activities in Sohag have expanded dramatically towards the desert zones where new industrial zones, urban centres on reclaimed land, including new villages have been established. Uncontrolled urbanization has been taken place creating pressure on the groundwater aquifer systems as they are the main sources for water. Few authors have investigated the groundwater potentiality in the study area and its surroundings and have not dealt with the factors influencing hydrogeochemistry of the groundwater (Dawoud, 1997; Ahmed, 2009; Esam et al., 2012). The principal aim of this study is to determine the factors influencing the groundwater geochemistry using hydrogeochemical signatures of the major ions employing the factor analysis (FA) method.

2. Geology

The area under consideration represents a part from the Nile Valley zone in Egypt underlain by sedimentary rocks that range in age from Lower Eocene to Recent (Fig. 2a and b). The following is a brief description of these sedimentary units:

a) Thebes Formation (Lower Eocene) (Said, 1960): It consists of massive to laminated limestone with flint bands and/or nodules and marl rich with *Nummulites sp.* and planktonic foraminifera.
b) Muneiha Formation (Early Pliocene) (Issawi et al., 1978): It consists of a thick succession of estuarine and fluvial sediments that are composed principally of grains of quartz and clay beds (mainly montmorillonite and kaolinite). It formed in the Early Pliocene due to the invasion of the sea to the Nile valley forming a long estuary from Cairo to Aswan (Said, 1975). These sediments form the lower parts of the water bearing formations in the Nile Valley (Fig. 2). The Muneiha Formation (Early Pliocene) also crops out near the eastern and western Eocene limestone plateaus and in the dissected wadis. The Pliocene clay is frequently dissected by irregular shrinkage cracks of various thicknesses that are filled by secondary gypsum and anhydrite (Omer and Abdel Moneim, 2001).
c) Qena Formation (Early Pleistocene) (Said, 1981): These sedimentary rocks were first described and named by Said (1981) are composed mainly of quartzitic sand and gravel deposited in braided and low-moderate sinuos streams. The deposits of the Qena Formation lack basement fragments and are rich in heavy minerals of metamorphic origin thought to come from the Sudanese Red Sea hills (Omer, 1996). During Early Pleistocene, the river system was mostly draining from the east to west directions, deriving its water from within Egypt and also from the Red Sea hills in Sudan (Omer, 1996). The main sources of the sediments deposited during this stage are the sedimentary rocks covering the Basement Complex in the central and southern Eastern Egyptian Desert. The Qena Formation represents the main water bearing formation in the study area.
d) Kom Ombo Formation (Early Pleistocene–Middle Pleistocene) (Issawi and Hinnawi, 1980): It overlies the Qena Formation and is composed of sands and gravels of igneous and metamorphic origins. The Kom Ombo Formation sediments are characterized by alluvial and fluvial facies. In the Sohag area, the Kom Ombo Formation is represented by very coarse cross-bedded sands together with gravel intercalations (Omer, 1996).
e) Ghawanim Formation (Middle Pleistocene) (Omer, 1996): It is composed of cross-bedded fluvial sand and gravels together with inter-bedded bands and lenses of conglomerate and quartzitic sandstone. During the Middle Pleistocene, the Eastern Egyptian Desert continued to supply sediments through its active wadis. Simultaneously, Ethiopian water reached Egypt for the first time and a mixture of Egyptian and Ethiopian sediments was deposited giving rise