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Application of A Geochemical Model For Assessing Groundwater Quality of The Quaternary Aquifer in El-Marashda Area, Qena, Egypt

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ABSTRACT

Management of water supplies requires the planning, production, delivery and efficient management of water resources. Actually, not only the amount but also the quality of groundwater is diminishing due to growing population and industrial activity, overuse of fertilizers in agricultural products and intensive cultivation. This study aims to groundwater quality assessment based on the hydrogeochemical properties, and a geochemical model (NETPATH). The physico-chemical parameters indicated that the total dissolved salts (TDS) value of the 37 groundwater samples varies between 176.56 to 2096 ppm. The water type is dominance of Na- K- Cl-SO4, while only six samples represented in Ca-Mg-Cl-SO4 water type. The saturation indices (SIs) of the water with regard to mineral phases were determined using NETPATH to detect the possible chemical reactions in the groundwater. The state of mineral saturation helps to define the evolution of hydrochemistry and isolate the geochemical reactions that regulate water chemistry along the water flow path. With regard to dissolved minerals, the SI quantitatively defines the divergence of water from equilibrium.

Key words : Physicochemical parameters, Geochemical model, Quaternary aquifer, El-Marashda area, Egypt

الملخص

تتطلب إدارة إمدادات المياه التخطيط والإنتاج والإدارة الفعالة لموارد المياه. في الواقع ، لا تتضاءل كمية المياه الجوفية فحسب ، بل نوعيتها أيضًا بسبب تزايد عدد السكان والنشاط الصناعي ، والإفراط في استخدام الأسمدة في المنتجات الزراعية والزراعة المكثفة. تهدف هذه الدراسة إلى تقييم جودة المياه الجوفية بناءً على الخصائص الهيدروجيوكيميائية ، وتطبيق نموذج جيوكيميائي (NETPATH). أشارت العوامل الفيزيائية والكيميائية إلى أن قيمة المواد الصلبة الذائبة لعينات المياه الجوفية تتراوح بين ١٧٦,٥٦ ملغم / لتر و ٢٠٩٦ جزء في المليون. نوع الماء المسيط فى منطقة الدراسة هو Na- K- Cl-SO4 ، بينما ستة عينات فقط ممثلة في نوع Ca-Mg-Cl-SO4 المائي. تم تحديد مؤشرات التشبع (SIs) للمياه فيما يتعلق بالمراحل المعدنية باستخدام

نمــوذج NETPATH لتحديــد التفــاعلات الكيميائيـــة المحتملـــة فـــي الميـــاه الجوفيـــة. تســـاعد حالـــة التشـــبع فـــي تحديــد تطور الكيمياء المائية وعزل التفاعلات الجيوكيميائية التي تنظم كيمياء المياه على طول مسار تدفق المياه.
الكلمـــات الدالـــة : الخصـــائص الفيزيائيـــة والكيميائيـــة – نمـــوذج جيوكيميـــائى – الخـــزان الربـــاعى – منطقـــة المارشـــدة - مصر

1. INTRODUCTION

Water is the basic resource for any life to exist in this world. Prehistoric man was leading a nomadic life on the banks of rivers. With natural threats such as floods, earthquakes etc., it was disturbed and up rooted from its dwelling place. With the advent of civilization, the human life became more stable. The supply of freshwater from surface water and groundwater supplies has become important because a variety of pollutants are exposed to just 1% of the available freshwater for consumption, agricultural and domestic uses (Karthika and Dheenadayalan 2015). Groundwater ions are typically predominantly impacted by the features of the catchment area, including dissolution-precipitation, geological composition and structure, aquifer rock-forming mineral chemistry, oxidation-reduction, Organic matter conversion, aquifer geological techniques and anthropogenic behaviors (Yang et al. 2016; Pazand et al. 2018). The shortage of fresh surface water adds to the misuse of groundwater to satisfy the demands of various regions. The consistency of groundwater is as important as its quantity is due to the appropriateness of water for the multiple goals. The physical, chemical and biological causes that are greatly influenced by aquifer geology and human activity are a part of spatial variations in groundwater quality in some regions (Subramaniam et al., 2005).

Hydrochemical parameter-based groundwater chemistry includes preliminary knowledge on water types, water characterization for specific applications, and the study of various chemical processes (Saxena et al., 2003; Jalali 2007; Sarwade et al. 2007; Mondal and Singh 2011; Mondal et al., 2011). Changes in groundwater quality attributable to geogenic interaction or some form of anthropogenic impact (Kelley 1940; Wilcox 1948). The chemical composition of groundwater in the shallow alluvial aquifers is regulated by various hydrogeochemical processes such as dissolution, precipitation, ion-exchange processes, etc (Apodaca et al., 2002).

The software package NETPATH for windows is employed to detect the geochemical processes of the subsurface mineral concentrations and provide an indication for the system's reaction potential (El-Kadi et al., 2011). The NETPATH software perform simulating chemical reactions in nature soil or contaminated water and transport systems. The software is targeted on aqueous solution equilibrium chemistry concerning with minerals, gases, solid solutions, as well as exchangers and surfaces of sorption (Sohallel and Gomaa, 2017).

The (SI) indicates when water appears to dissolve or precipitate a mineral with negative values that mean mineral dissolution, positive values that indicate mineral precipitation, and zero values indicate that water and mineral are in equilibrium (Yan et al.2016). The (SIs) of the water with regard to mineral phases were determined using NETPATH to estimate the possible chemical reactions in the groundwater. The state of saturation helps to define the evolution of hydrochemistry and isolate the geochemical reactions that regulate water chemistry along the water flow path (Abboud 2018). With regard to dissolved minerals, the SI quantitatively defines the divergence of water from equilibrium.

2. MATERAILS AND METHODS

2.1. Study area

The study area is located on the west of Qena City, Egypt. It occupies the area between 25° 53′ 30 ″ to 26° 06′ 38 ″ N and 32° 17′ 00 ″ to 32° 31′ 30″ E The Quaternary deposits represent the main groundwater aquifer in the study area. The present work aims to study the hydrochemical characteristics and quality assessment of the quaternary aquifer groundwater. (Figure 1).

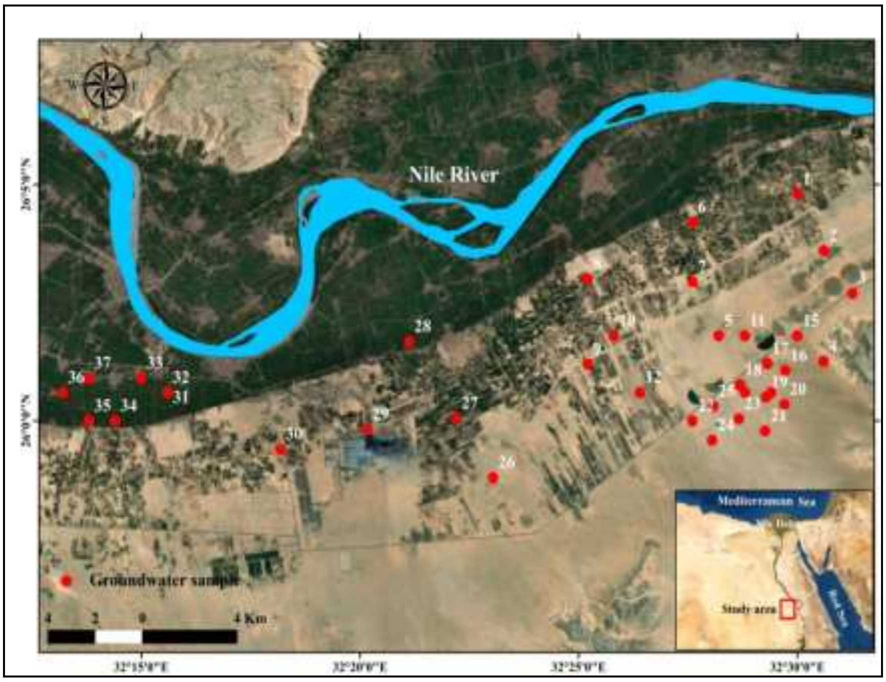

Figure 2: Location of the study and measuring points.

2.2. Geological and hydrogeological settings

The regional geology of the study area ranges from tertiary rocks to Quaternary deposits. According to the surface geological map after the Quaternary deposits cover the area between the Nile River and the calcareous plateau (whole of the study area) while the Tertiary rocks appeared in the east and south side of the calcareous plateau, the aerial distribution of the geologic units of the area mapped in figure 2.

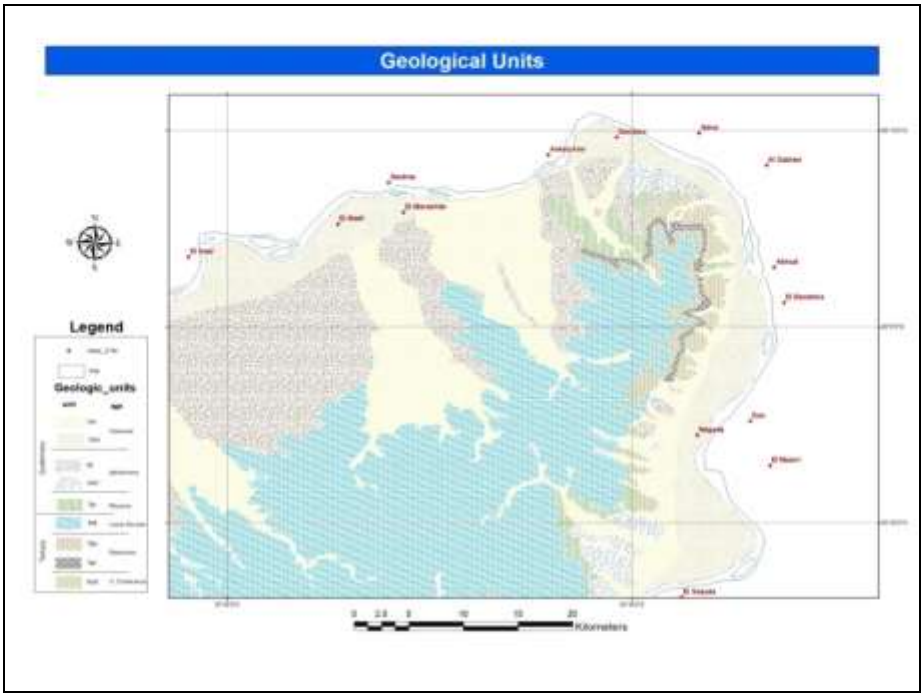

Figure 2: Geological units in the study area after Conoco 1989

The previous hydrogeological studies the Quaternary aquifer characteristics in West El- Marashda area are estimated based on the information collected from 36 ground water wells in addition to the pumping test data (step drawdown and continuous) for 12 selected wells (engineering authority of the army forces) were conducted, The step-drawdown test was conceptually formulated and analyzed by Jacob (1947) and later modified by Rorabaugh (1953). These studies assume a homogenous and isotropic confined aquifer of infinite areal extent and a pumping well that fully penetrates the aquifer. For water table aquifers with small drawdown compared to the aquifer thickness, the solution presented by Jacob (1947) and Rorabaugh (1953) is also applicable (Driscoll, 1986).

2.3. Methodology

2.3.2. Sampling and analyses

In water quality evaluations, physiochemical parameters play a decisive role and are considered a valuable guide for understanding the essence of water chemistry. Physicochemical parameters such as, PH, TDS, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^- have been measured to assess and detect the hydrogeochemical characteristics within the study region. To achieve that, 37 groundwater samples were collected and analyzed. The collected 37 samples were measured using a measured multi-parameter professional plus handheld instrument such as, TDS, EC and PH. The collected water samples were filtered for analysis of Na^+ and K^+ by flame spectrometry, Ca^{2+} and Mg^{2+} by EDTA titration, HCO_3^- and CO_3^{2-} by acid titration, Cl^- by $AgNO_3$ titration, and SO_4^{2-} by $BaCl_2$ titration. The basic physical and chemical properties of the water samples, including pH were measured by a portable multi-parameter water quality analyzer (HQ40d, Hach Corporation, USA). The analytical precision of the measurement of ions was determined by calculating the ion balance error, which was within 5% which was accepted for the purpose of this study.

2.4. Geochemical model (NETPATH)

Geochemical modeling (NETPATH) is an effective tool for assessing the quality of groundwater and understanding the key geochemical characteristics that affect the quality of groundwater. The relationship between rock and water impacting the aquifer structures are assumed from the geochemical model findings obtained (NETPATH). Geochemical reactions, including rock-water interactions, dissolution reactions, salt solubility, precipitation, evapotranspiration, ion exchange, and anthropogenic activities, are expressed in the mineral saturation index (SI), which relies on the physicochemical properties of the groundwater and the aquifer matrix (Bozdag and Goçmez 2013; Gad and Saad 2017; Khan et al., 2017; Gad et al., 2018; Li et al., 2019a). For environmental simulation based on the physicochemical parameters of the obtained groundwater samples, a geochemical model, NETPATH software package v. 2.0 (Plummer et al., 1991), was implemented to interpret the hydrochemistry of the groundwater supplies depending on the balance between mineral phases and water and is represented by SI (Garrels and Christ 1965). In a groundwater environment, to predict the net geochemical mass balance transfer and reactions of potential minerals and gases, the inverse approach can be used according to a geochemical model. This model helps to measure the quantities of chemical constituents produced by the dissolution or precipitation of the main mineral phases in groundwater (El Osta et al., 2020). With regard to dissolved minerals, the SI quantitatively defines the divergence of water from equilibrium. The SI of a particular mineral is calculated based on the Equation:

$$SI = \log (IAP/Ksp) \qquad (1)$$

Where IAP is the ion activity product and Ksp is the mineral solubility product.

3. RESULTS AND DISCUSSION

3.1 Groundwater type

The results showed in Piper diagram (Fig. 3), based on the chemical content (piper 1994), the water type of thirty one samples lies on type (III) which refers to the dominance of Na, K, Cl, SO_4, while only six samples represented in type (IV) Ca, Mg, Cl, SO_4. The Chadha diagram (Fig. 4) reveals that on the number three filed, thirty-one samples reveal that the alkali metals exceed alkaline earths and strong acid anions exceed weak acid anions. This category consists of relatively high freshwater salinity.

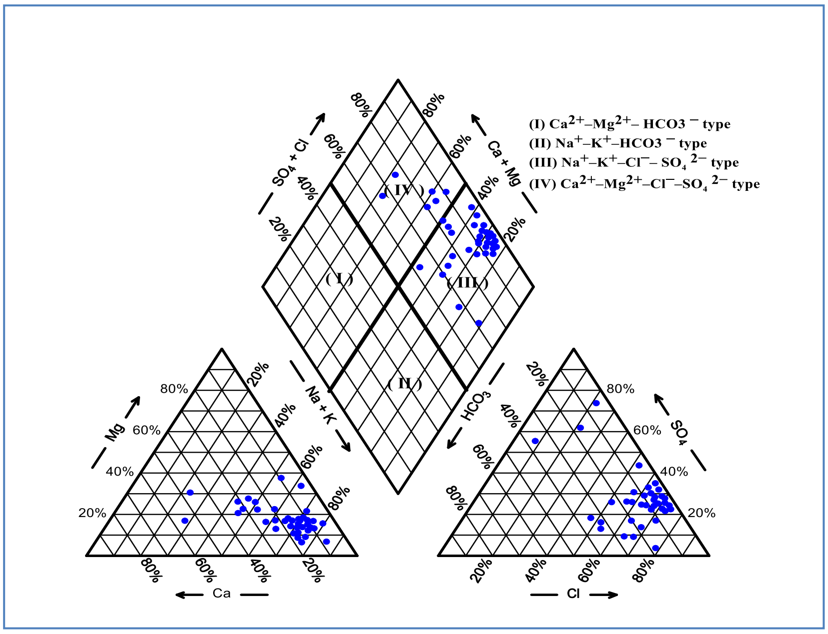

Figure 3: Groundwater types according to Piper 1994

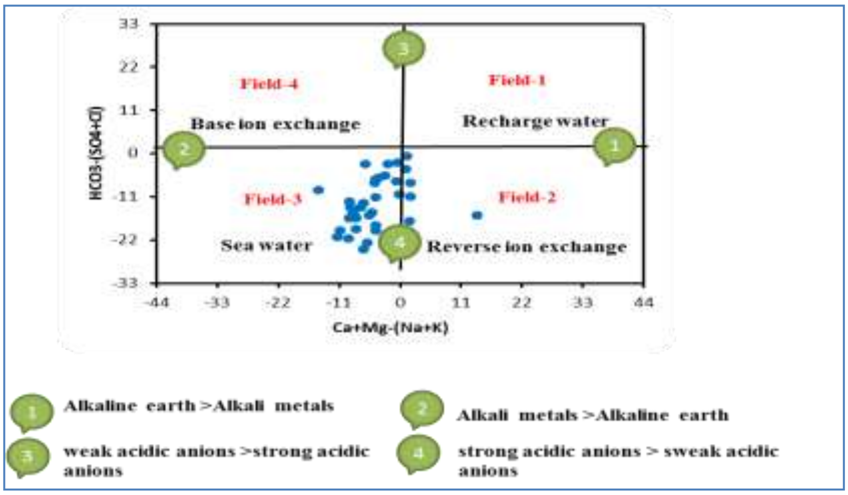

Figure 4: **G**eochemical controlling mechanisms according to Chadha diagram 1999

3.2. Mineralization processes

Owing to both the evaporation of recharge water and the results of reactions with groundwater and natural formations such as dissolution, drainage, leaching and cation exchange, the mineralization of groundwater will be likely to result from ionic concentrations increasing. The NETPATH model results in silicate, quartz, chalcedony, and phosphate mineral phases not being saturated in general, and dolomite, calcite, and aragonite are around saturated, but anhydrite and gypsum tilt to be saturated in the study area.

Relevant location showed that the increase in fertilizer usage induces positive phosphate carbon dioxide concentration vales, this location is situated on the old cultivated land near the Nile River, leaching of carbonate rocks from the calcareous plateau on the south side of the study region indicates the growth of gypsum and anhydrite minerals.

The ground water samples selected with respect to the flow direction from east and south – east towards west and north east direction, path through well numbers 1,2,3,5,8,10,11,12,15,21,23,25,29,30,31. The statistical analysis of the measurements of the saturations of nine minerals was presented in Table 1.

Table 1: Statistical analysis of the irrigation water quality indices

Mineral Saturation	Calcite	Aragonite	Dolomite	Gypsum	Anhydrite	Silicon	Chalcedony	Quartzite	Phosphoric Carbon Dioxide
Min.	-2.393	-2.536	-4.551	-2.548	-2.768	-5.066	-4.227	-3.798	-2.766
Max.	0.585	0.441	1.104	-1.149	-1.369	-0.782	0.058	0.487	-1.77
Avg.	-1.275	-1.418	-2.500	-1.754	-1.974	-4.503	-3.664	-3.235	-2.422
Stander Dev.	0.801	0.801	1.571	0.471	0.471	1.051	1.051	1.051	0.293

The calculated values of the mineral saturations 21, 22, 23, 24, 25, 26, and 27) indicated that the majority of the minerals didn’t reach the saturation state while the values are negative and /or nearby zero.

4. CONCLUSION

The groundwater in the study area has beenevaluated for its chemical composition and suitability for drinkingl purposes. The physico-chemical parameter refers to that the TDS value of groundwater samples varies between 176.56 mg/L and 2096 ppm. The water type is dominance of $Na\text{-}K\text{-}Cl\text{-}SO^4$, while only six samples represented in $Ca\text{-}Mg\text{-}Cl\text{-}SO_4$ water type. Thirty one samples lies on the filed number three which shows that the alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. This group consists of relatively high salinity groundwater such water generally creates salinity problems drinking uses while six samples lies in the filed number two which shows that the strong acidic anions exceed weak acidic anions. The in general, and dolomite, calcite, and aragonite are around saturated, but anhydrite and gypsum tilt to be saturated in the study area.

Relevant location showed that the increase in fertilizer usage induces positive phosphate carbon dioxide concentration vales, this location is situated on the old cultivated land near the Nile River, leaching of carbonate rocks from the calcareous plateau on the south side of the study region indicates the growth of gypsum and

anhydrite minerals. The geochemical facies and controlling mechanisms results suggested that rock – evaporation dominance interaction is the main process of controlling the water chemistry in the studied area.

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