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Hydrogeochemical assessment of the Carbonate rocks of the Eocene aquifer in the eastern Nile valley, Egypt

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Abstract

The goal of the ongoing research is to better understand the physical-chemical mechanisms that regulate the physical and chemical characteristics of groundwater resources in the studied region. The water samples were obtained at different depths varied from 120 m to 230 m. The physicochemical properties of fourty groundwater points were obtained through the fractured limestone aquifer, such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, K^+, and CO_3^{2-}. The salinity of the groundwater varied from 1000 mg/L to 3300 mg/L, with the central region and the area close to the River Nile having the highest salinity and decreasing in the north, south, and east. The most of water points from the investigated region revealed that the water needed proper drainage and treatment for irrigation purposes.

Keywords: Groundwater, Geochemical, Eocene aquifer, Egypt.

Introduction

In order to address the issue of overcrowding, the Egyptian government now gives the construction of new settlements and land reclamation initiatives a lot of attention. In desert regions, groundwater is regarded as the primary source of freshwater and is a valuable natural resource. Through the existing studies, extensive hydrogeological and hydrogeochemical studies were conducted in The Eocene aquifer. Additionally, enormous amounts of data were gathered from numerous boreholes dug for groundwater explorations, to interpret the characteristics of the groundwater resources in the investigated region **(Desoky, 2010)**.

The region is a part of the Eocene Eastern Plateau. Its altitude varies from 40 to 130 metres (AMSL). The El-Abiad Mountain's northern extension, which borders the El-Hadid Mountain to its southeast, is represented by the highland remnants. Middle Eocene limestone deposits make up these mountains. The entire investigated region is situated on this plateau, which highlights the flatness of the terrain and the absence of any declines or high-rises **(Salem, 2015)**. The Wadi Deposits (also known as sediments), which represent the Quaternary deposits and have a thickness 15 m, cover the eastern plateau and dry valleys of the investigated region **(Sultan et al., 2000; Shabana 2014; El Abd et al. 2015).** Wadi El-Faqira has a dendritic drainage system. A thin layer of sediment valleys, primarily composed of limestone, covers the surface of the valleys where streams and their tributaries flow.

Many studies were conducted to evaluate the mixing and evaporation processes using a suitable geochemical code. In response, **El Ammawy et al. (2020)** examined and outlined the routes of recharge to the Eocene aquifer using the NETPATH code. Therefore, the main goal of this study is to evaluate the dominant geochemical controlling mechanisms that influence the composition of Eocene groundwater in the area east of El Minia and in nearby settings that are similar to those around the Nile.

Methodology

Study area

The study area extends from 100 kilometres south of Cairo to 10 kilometres east of Beni Suef City. Between the latitudes of 28° 47' 25" and 28° 52' 12" North and the longitudes of 30° 56' 50" and 31° 04' 12," the study area stretches from Beni Suef and El Minya of about 75 km long and 16 km wide, which covering an area of about 1200 km^2 (Fig. 1). The Eastern Desert's high plateau and the Nile River's valley form the region's eastern and western boundaries, respectively.

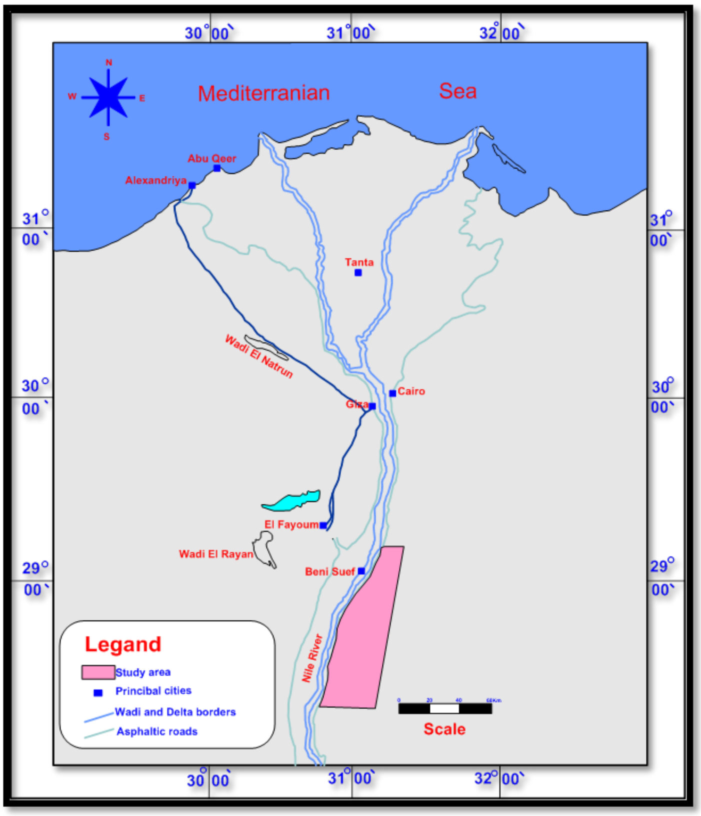


Figure 1. Location map of the investigated region

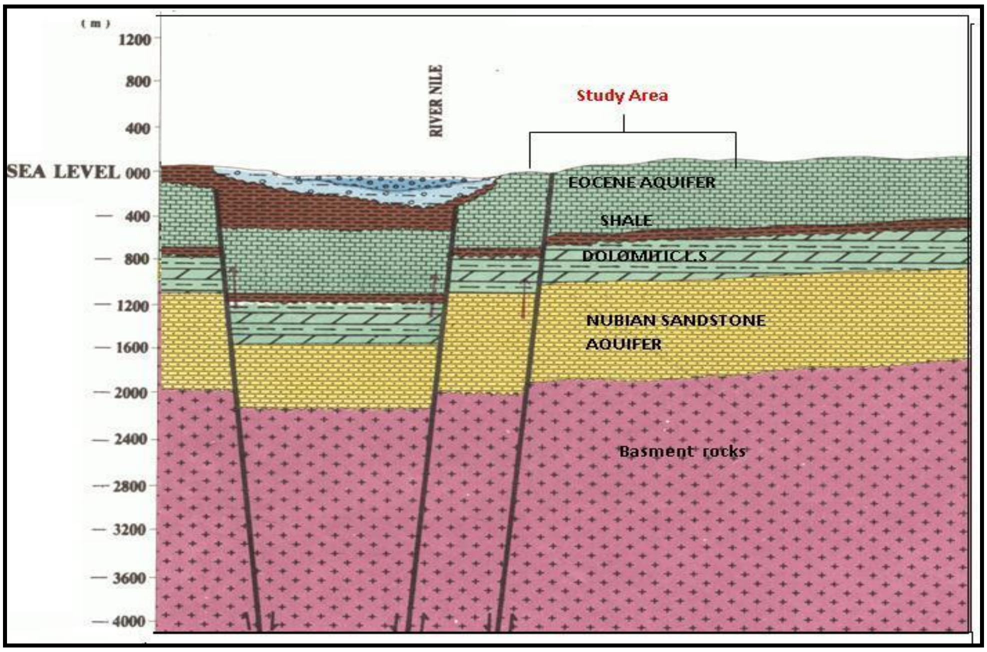
Sampling and analyses

The groundwater samples were analyzed in accordance with ASTM standards (2002). Temperature (T °C), TDS, pH, EC, and the concentrations of ions such as, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and HCO_3^{2-} were measured according to standard analytical methods. The examine Ca^{2+}, Mg^{2+}, Cl^-, and HCO_3^{2-} using argentometric and titration techniques (ASTM 2002). While Na^+ and K^+ were determined using flame photometer instrument (ELEX 6361, Hamburg, Germany).

Results and discussion

Geochemical settings

The investigated region was predominantly consisted of Middle Eocene stratigraphic successions that was covered by a thin layer of Quaternary Wadi deposits (Fig. 2). This sequence is clearly visible near the study area on Al-Abiad and Hadid Mountains **(Zaki et al., 2015; El Gamal and Ibrahim 2017).** With some exchanges of yellow marl, the lower portion was composed of thin stratifications of white limestone rocks, especially Numolites and other fossils. Exchanges of limestone clay with gypsum veins protect the limestone from erosion. In the southeast of the investigated region, El-Hadid Mountain was consisted of limestone and Marl. The NSSA was actually the preliminary source of groundwater rising via fractures, cracks, and faults (Fig. 2).



Figur 2. Hydrogeologic cross section (W-E)

The following can be summarised in light of the chemical data that was obtained. The Eocene aquifer's groundwater samples' pH values ranged from 7.11 in well number 3 to 7.80 in well number 26. All of the studied areas' pH values showed neutral to extremely alkaline water conditions. The majority of the Eocene aquifer's groundwater is relatively fresh, with salinity levels ranging from 7,000 to 1,500 mg/L (Fig. 3). The low salinity levels indicated that the water came from a meteor.

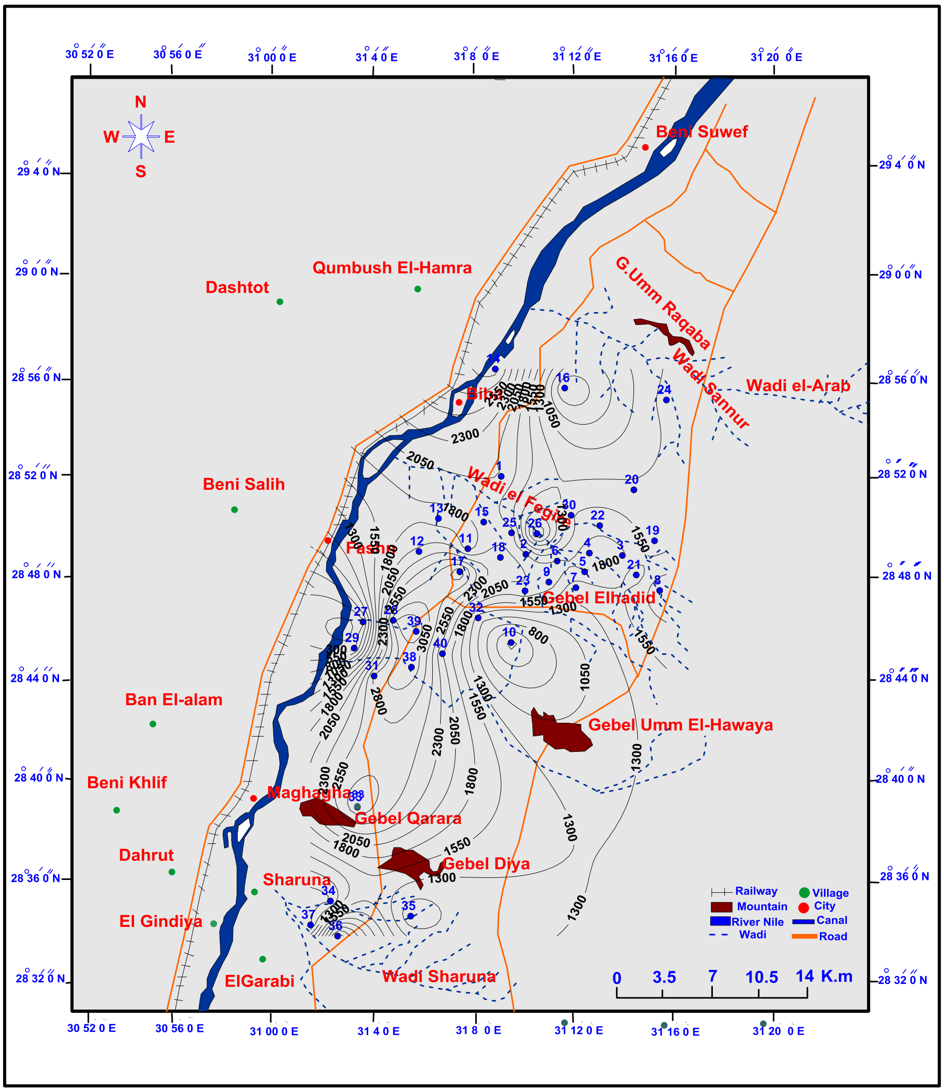


Figure 3. Salinity distribution map of the groundwater aquifer

Tha calcium content was the most common principle cation, which varied between 3.9 mg/L and 19.5 mg/L. The most prevalent calcium-containing minerals in sedimentary rocks were calcite ($CaCO_3$), aragonite ($CaMg(CO_3)_2$), and fluorite (CaF_2). The leaching of highly soluble carbonate minerals like calcite, dolomite, and gypsum from the water-bearing formation revealed high content of calcium ions for the groundwater in the investigated region. These processes have a significant impact on the geochemistry of the groundwater in its flow path. The existence of MgCl salts showed the influence and leaching of marine deposits, which may be responsible for the high magnesium content. The magnesium ion concentrations varied from 6 mg/L (Well No. 10) to 24.32 mg/L (Well No. 37).

In the study area, Na^+ was the predominant cation, which varied from 440 mg/L (Well no. 22) to 1020 mg/L (Well no. 14). In the area under investigation, K^+ displayed the lowest dominant cation varied between 3.9 mg/L in well number 7 and 37.8 mg/L in well number 1. The high contents K^+ ions in the groundwater samples revealed that clay minerals were present in the aquifer materials (Wedepohl, 1974).

According to general consensus, the main source of chlorides was thought to be marine sediments, specifically evaporates and chloride shales. Chloride concentrations ranged from 335 mg/L (Well No. 22) to 674 mg/L (Well No. 17). The high content of Cl^- ion in the Eocene aquifer of the investigated region revealed leaching of chloride minerals from the aquifer matrix. The SO_4^{2-} contents in groundwater samples varied from 323 mg/L (Well No. 19) to 1478 mg/L (Well No. 38). The highly soluble of SO_4 minerals revealed a significant impact on the chemical composition of the groundwater in the investigated region. The organic detritus found in the aquifer matrix are considered the primary sources of carbon dioxide. The bicarbonate concentrations varied from 62 mg/L to 124 mg/L, which revealed leaching processes of soluble carbonate minerals.

The hypothetical salt of the collected water points reflected the presence of different salts, such as Na_2SO_4, NaCl, $Ca(HCO_3)^2$, $MgSO_4$, $CaSO_4$, and KCl, respectively (Fig. 4).

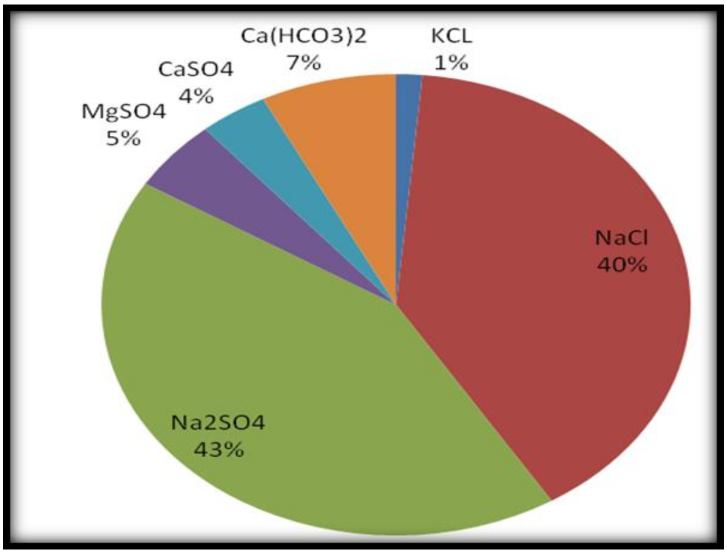


Figure 4. The distribution of hypothetical salt in the collected groundwater samples

The spatial distribution of the groundwater chemistry:

Three hydrochemical cross sections were constructed with the groundwater flow directions as shown in Figure 5.

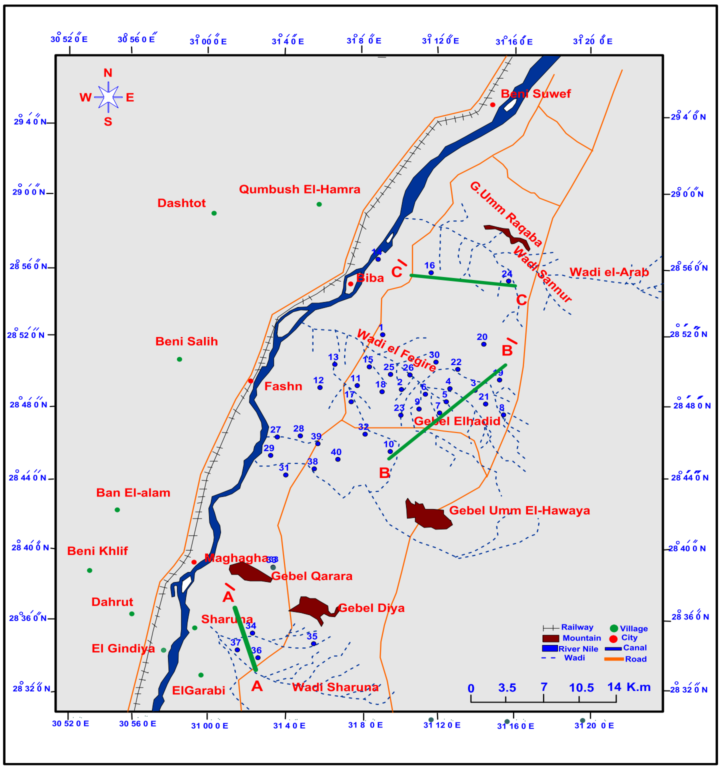


Figure 5. Hydrochemical cross sections along the groundwater flow directions

Cross section A – A

The TDS content was increased gradually from the N-W to southern parts, which revealed the assemblages of Na_2SO_4, NaCl, $Ca(HCO_3)^2$, $MgSO_4$,$CaSO_4$ (Well No. 34) and Na_2SO_4, NaCl, $CaSO_4$, $Ca(HCO_3)^2$, $MgSO_4$ (Well No. 36) as shown in Figure 6.

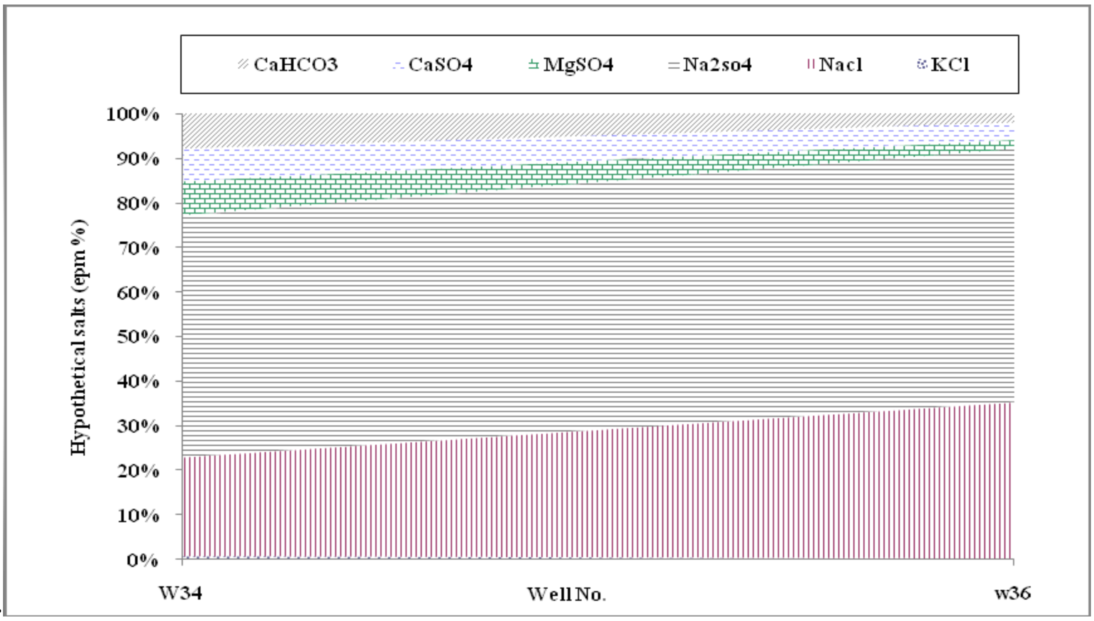


Figure 6. Hydrochemical cross section A - A'

Cross section B – B

The TDS content was increased gradually from the N-E direction to middle part of investigated region, which revealed the assemblages of $Ca(HCO_3)_2$, NaCl, $MgSO_4$,Na_2SO_4 (Wells No. 10) and NaCl, Na_2SO_4, $Ca(HCO_3)_2$, $MgSO_4$, $CaSO_4$ (Wells No. 7, 3 and 19) as shown in Figure 7.

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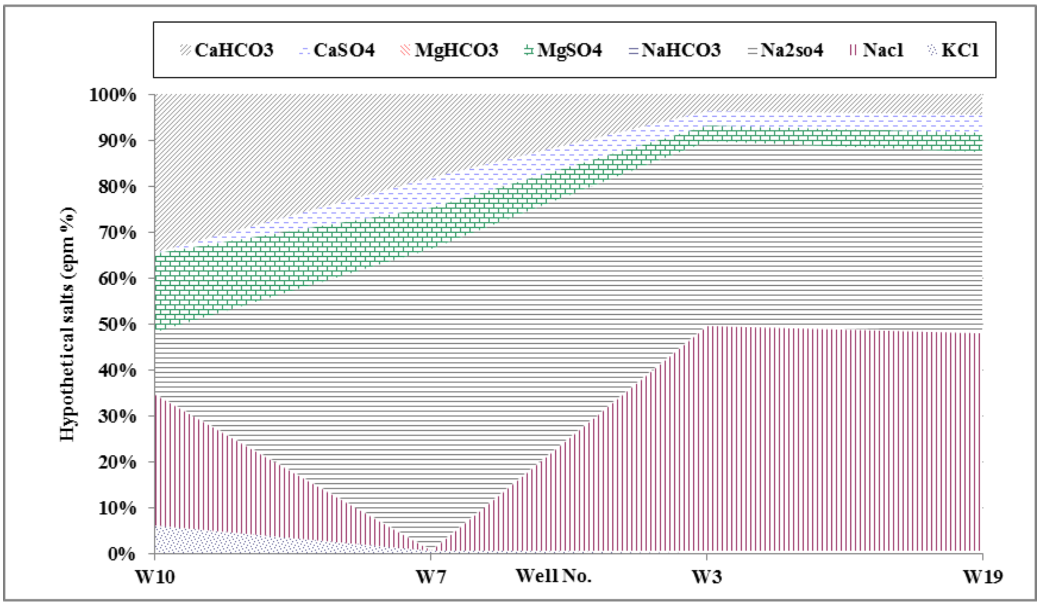

Figure 7. Hydrochemical cross section B - B'

Cross section C – C

The TDS content was decreased from the E-W t direction to the northern parts of investigated region, which revealed the assemblages of $CaSO_4$,$Ca(HCO_3)_2$, $MgSO_4$, NaCl, Na_2SO_4 (Well No. 16) and NaCl, Na_2SO_4, $Ca(HCO_3)_2$, $MgSO_4$, $Mg(HCO_3)_2$ (Well No. 24) as shown in Figure 8.

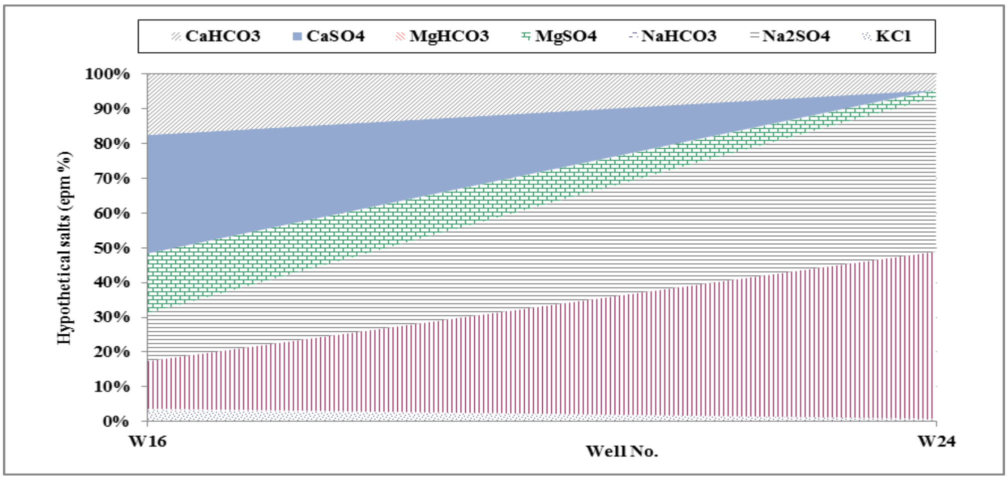

Figure 8. Hydrochemical cross section C - C'

The semi-logarithmic chart was created to allow for rapid visual evaluation of various water composition in the investigated area. Schoeller's graph (1962) was created by tracing the analyzed data from the groundwater points, which revealed two groups of water types, such as Na–Cl and Na–SO_4 water type (Figs. 9 and 10). The Na-Cl facies were showed about 47.5 % of the groundwater wells (Wells No. 1, 2, 3, 4, 6, 7, 9, 13, 15, 19, 23, 24, 25, 29, 31, 32, 35, 37, and 40), while the Na–SO_4 facies were showed about 52.5 % of the groundwater wells (Well No. 5, 8, 10, 11, 12, 14, 16, 17, 18, 20, 21, 22, 26, 27, 28, 30, 33, 34, 36, 38, and 39).

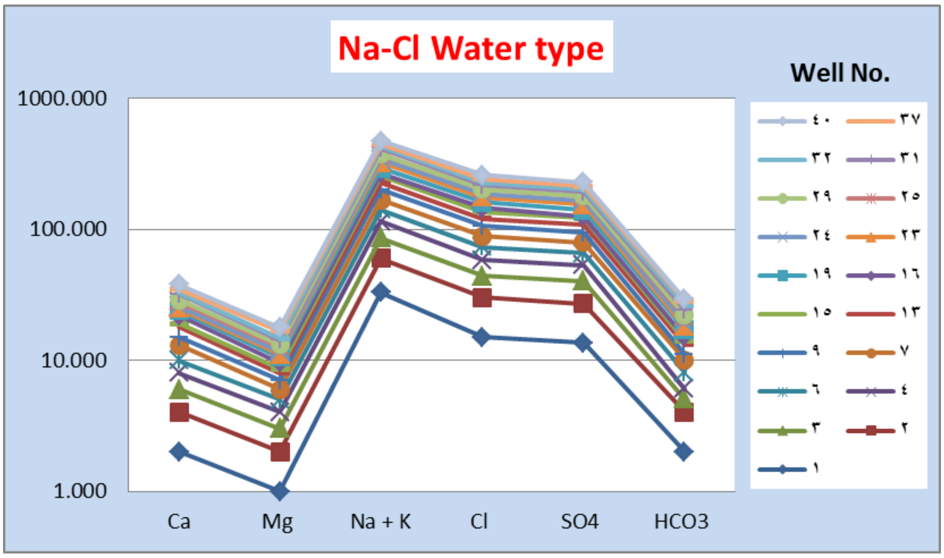

Figure 9. Na- Cl Facies

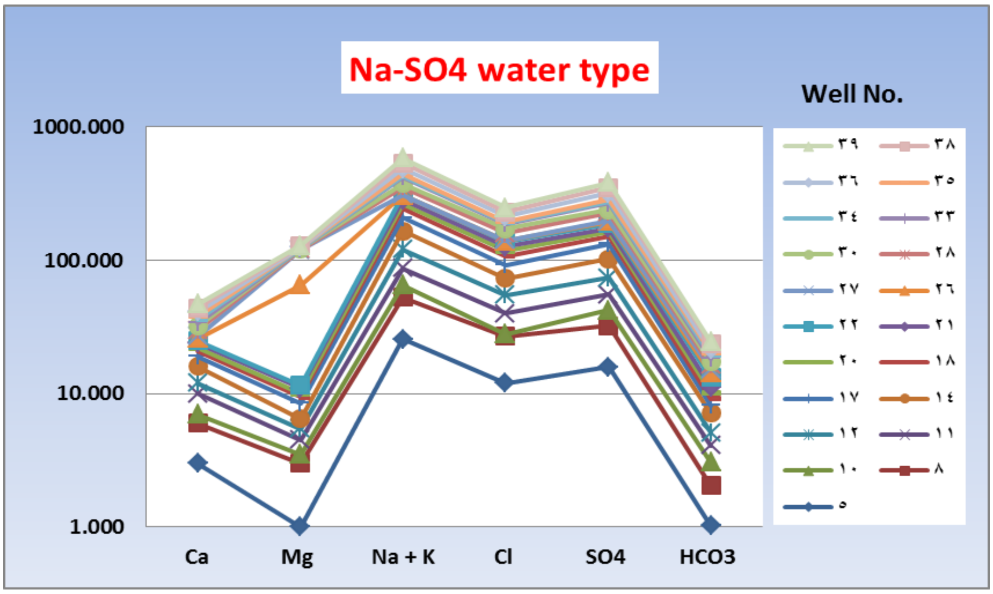

Figure 10. Na- SO_4 Facies

Piper trilinear 1953 for the collected groundwater points revealed primary alkaline properties, where CO_3+ HCO_3 more than Ca+Mg (Fig. 11).

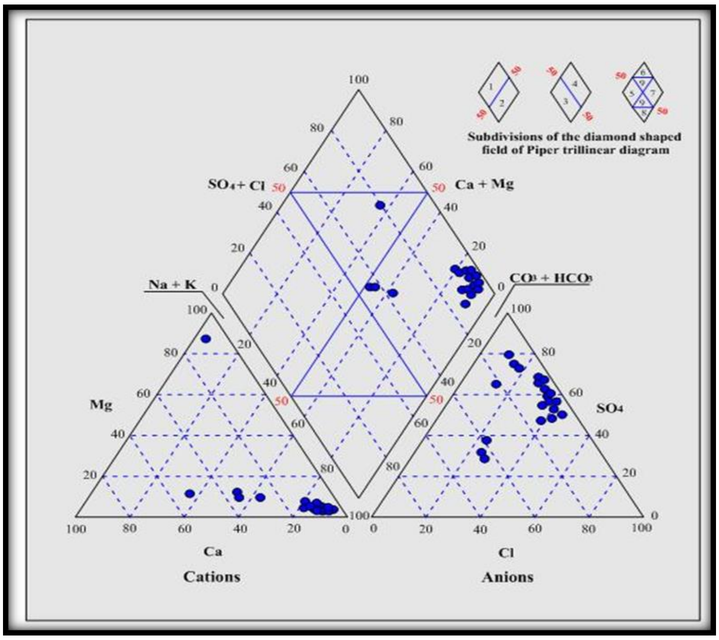

Figure 11. Piper trilinear diagram for the groundwater types

Evaluation of groundwater quality for irrigation:

Most of groundwater points in the investigated region were fall in the areas of C3s2, C3s3, C3s4, C4s1, C4s2, C4s3 and C4s4, based on the **U.S. Salinity Laboratory Staff 1954**, which revealed unsuitability for agricultural purposes without treatment and requires good drainage (Fig. 12).

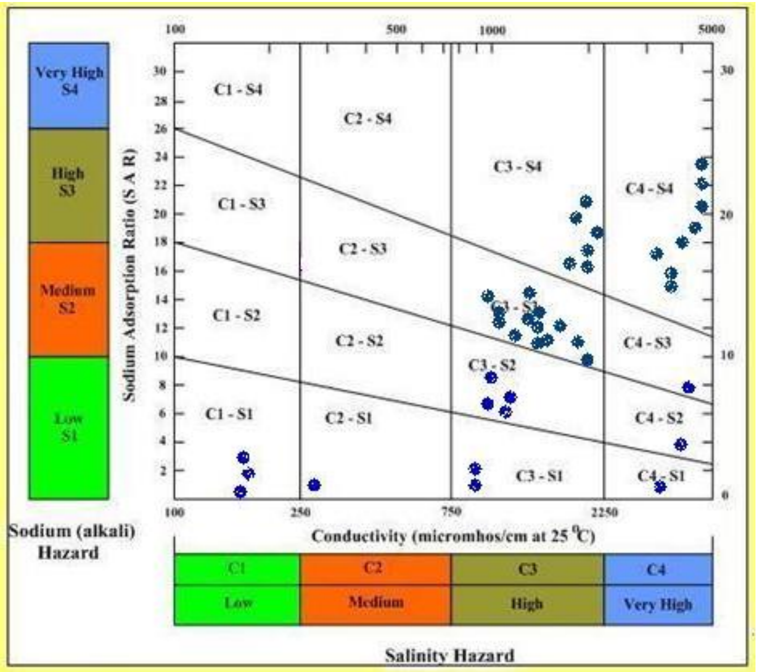

Figure 12. Groundwater valibility for agricultural purposes according to US Salinity Lab.

Conclusions

According to the results of physicochemical properties for the obtained groundwater points, the Ca^{2+} contents were varied from 3.9 mg/L to 19.5 mg/L, which revealed leaching of highly soluble carbonate minerals. The Mg^{2+} and Na^{+} ions contents were varied from 6 mg/L to 24.32 mg/L and from 440 mg/L to 1020 mg/L, respectively. While the K^{+} contents were varied from 3.9 mg/L to 37.8 mg/L. Most of the samples that were collected revealed that the SO_4^{2-} contents were varied from 323 mg/L to 1478 mg/L and the Cl^{-} contents were varied from 335 mg/L to 674 mg/L. In addition, the HCO_3^{2-} contents varied from 62 mg/L to 124 pm. The hypothetical salts of the obtained groundwater points were showed the presence of different salts, such as Na_2SO_4, NaCl, $Ca(HCO_3)_2$, $MgSO_4$, $CaSO_4$. Two types of groundwater facies were showed such as Na-Cl and the Na-SO_4 water type. Most of groundwater points from the Eocene aquifer in the investigated region revealed that the water needed proper drainage and treatment for irrigation purposes.

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