Environmental Impacts of Over Exploitation on the Groundwater Quality in El Kharga Oasis, Western desert, Egypt

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Abstract

The Nubian Sandstone Aquifer (NSSA) has provided the majority of the water for Egypt's western desert. The excessive groundwater withdrawal from this aquifer causes a decline in groundwater levels and quality degradation for the groundwater. In order to provide preliminary data for the management of the NSSA in the investigated area, the groundwater quality were evaluated utilizing a variety of techniques and geochemical mechanisms. Sixty-five groundwater wells were gathered for this, and 12 physicochemical parameters were examined using conventional analytical techniques. According to data on groundwater quality, NaHCO3, NaSO4, and NaCl were the three most prevalent water types. Additionally, abnormal iron element concentrations were found in some groundwater samples, which produced brown slime that accumulates on well screens, and relatively high salinity contents were also noted.

Keywords: Environmental impacts, El-Kharga Oasis, Groundwater, NSSA

Introduction

The integration of water-saving innovations with the limnological qualities of groundwater, both in terms of quantity and quality, have arisen as a result of rising water consumption and global water shortage challenges. Because freshwater resources are so restricted in El-Kharga Oasis, Egypt, there is a substantial need for using trimming and innovative water quality management innovations in crop yields. The farming uses more than 90 percent of all water utilized in the research region and more of around 86.8 percent of all water used across Egypt

(FAO, 2005). As stated by **Jahin and Gaber (2011)**, El-Kharga is a portion of the Saharan Nubian aquifer, which is extend in warm and dry region. In order to evaluate the sustainability of groundwater use in the NSSA, a number of groundwater management plans have been created **(Giordano, 2009)**. Moreover, In order to achieve these stated objectives, it is critical to evaluate the hydrogeochemical properties of the NSSA under the semi-arid to arid conditions that prevail in the province **(Mohamed and Hua 2010; Mossad *et al*., 2014; Switzman *et al*., 2015)**. Therefore, it is crucial to progress evaluation hydrogeological and hydrogeochemical data for the area to assist in improving groundwater management practises.

Additionally, to evaluate groundwater chemical composition varies over time at different distances from a recharge area, diagrammatical methods and hydrogeochemical methodologies may be employed (Rummel 1970; Judd 1980; Johnson and Wichern 1992; Berry 1995). For instance, El Kashouty and El Sayed (2008) demonstrated qualitatively that groundwater hydrogeological and hydrochemical evaluations frequently combine maps and graphical approaches. Some of these techniques were created for determining the source of groundwater and researching how groundwater interacts with the aquifer composite over vast distances and aeons of time. Numerous variables, such as rainfall type, water bearing formation, recharge rates and hydraulic parameters, have an impact on the chemical makeup of groundwater. A number of hydrochemical processes have an impact on groundwater's hydrochemistry in order to keep interrelations between rock and water and the mixing of different fluids in balance. Research on hydrochemistry describes the elements of groundwater and how they communicate. There are dissolved ions in all types of groundwater, so it is never completely pure. Numerous variables, such as the lithology, flow rate of groundwater, geochemical mechanisms, salt dissolution rate, and human induced have an impact on the total dissolved salts in groundwater (Bhatt and Saklani, 1996; Karanth, 1987). The primary goals of this study are to: (i) investigate the groundwater facies; (ii) determine hydroulic parameters and groundwater levels; and (iii) assess the quality of the groundwater and the geochemical mechanisms that regulate it.

Material and Methods

Study area

The region under examination is El-Kharga Oasis's northernmost region. It is located between latitudes 25° and 26° north and longitudes 30° and 31° east **Fig. 1**. The region under research is approximately 33,000 km^2 of the Dakhla depression. Gebel Abu Tartur and the Abu

Tartur Plateau encircle El Kharga Oasis' northern boundary. The Tebes Plateau and the Kharga plain border the El Kharga Oasis to the east and west, respectively. The depression was elevated anywhere between close to 0 m and 120 m. In the Kharga plain, the surface elevation rises gradually from the depression to over 400 m above mean sea level.

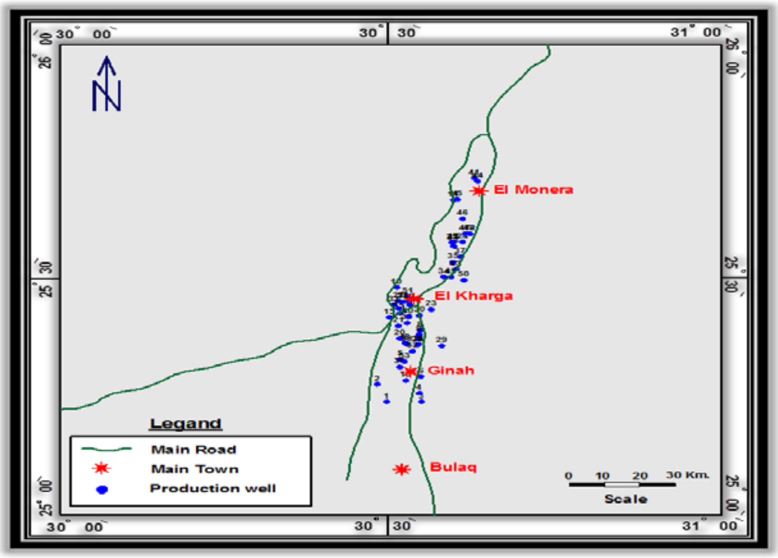

Fig. 1. Groundwater wells location map

Sampling and analyses

Sixty-five groundwater samples were analyzed in accordance with **ASTM standards, 2002**. Temperature (T ^{o}C), TDS, pH, EC, concentrations of ions, and trace element (Fe, Mn) were measured according to standard analytical methods. In order to determine Fe and Mn using a HACH (DR/2040) metre and examine Ca^{2+}, Mg^{2+}, Cl^{-}, and HCO_3^{2-} using argentometric and titration techniques **(ASTM, 2002)**, respectively. While Na^{+} and K^{+} were determined using flame photometer instrument (ELEX 6361, Hamburg, Germany).

Results and discussion

Physicochemical properties

Salinity contents

The groundwater samples in the studied region was fresh water facies, with salinity levels ranging from 200 to 400 mg/l **Fig. 2**. Salinity levels in some samples ranged between 400 to 600 mg/l. Aquifer materials containing intercalated shale were leached and dissolved, which resulted in relatively high salinity.

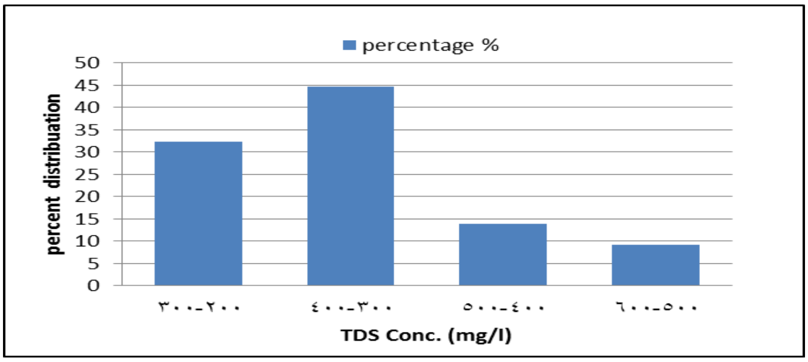

Fig. 2. Distribution of salinity content

The most prevalent cation in water samples was Na^{+}, which was followed by Ca^{2+} and Mg^{2+} ions. The contents of Na^{+}, Ca^{2+}, and Mg^{2+} ions varied from 7 to 23 mg/l, 30 to 145 mg/l, and from 30 to 145 mg/l, respectively. The HCO_3^{2-} was the most common anion, followed by SO_4^{2-} and Cl^{-} ions, which were present in concentrations of 20 to 380, 6 to 164, and 15 to 115 mg/l, respectively. The main physicochemical properties for the collected samples had valiable values that did not have an impact on the quality of the groundwater. The Fe contents ranged from 2 mg/l to 10 mg/l and were distinguished by abnormally high concentrations. The distribution of iron content increased gradually toward the southwest of the investigated region **Fig. 3**. High Fe content revealed iron-bearing deposits rich in aquifer materials dissolving.

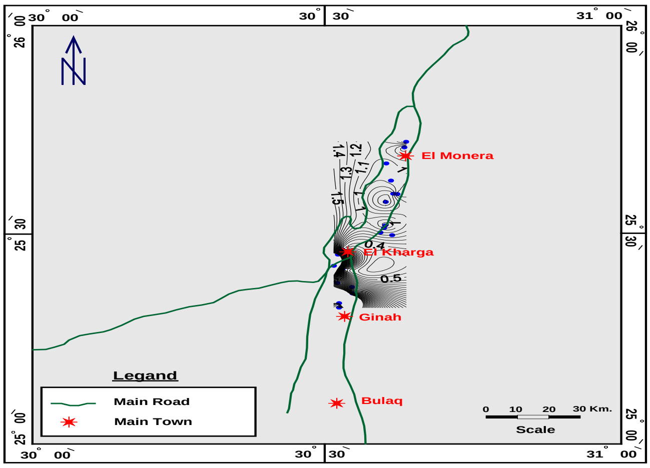

Fig. 3. Spatial distribution map of Fe contents

The chemical analyses of water points (**Table 1**), revealed that the ion sequences were ($Na^{+} > Ca^{2+} > Mg^{2+}$), ($HCO_3^{-} > Cl^{-} > SO_4^{2-}$), ($Na^{+} > Mg^{2+} > Ca^{2+}$), ($Cl^{-} > HCO_3^{-} > SO_4^{2-}$), ($Na^{+} > Mg^{2+} > Ca^{2+}$), and ($SO_4^{2-} > Cl^{-} > HCO_3^{-}$). The physicochemical parameters for the obtained water wells of samples revealed $Na^{+} > Ca^{2+} > Mg^{2+}$ and $HCO_3^{-} > SO_4^{2-} > Cl^{-}$, which indicating $NaHCO_3$ followed by $NaSO_4$ and NaCl water types. These findings demonstrated the active

Table 1. Ionic sequences in the Nubian sandstone aquifer**.**

Wells	**Ionic sequence**	**Water type**	**(%)**
1-2-3-5-6-8-9-10-11-12-13-14-15-16-17-25-43-44-45-46-47-48-49-50-51-52-53-54-56-58-59-61-64	$Na^{+} > Mg^{2+} > Ca^{2+}$ $HCO_3^{-} > Cl^{-} > SO_4^{2-}$	Na^{+} - HCO_3^{-}	**54.01 %**
1-4-7-18-19-23-24	$Na^{+} > Ca^{+2} > Mg^{2+}$ $HCO_3^{-} > Cl^{-} > SO_4^{2-}$	Na^{+} - HCO_3^{-}	**11.47 %**
21-26-27-28-29-30-31-32-33-34-38-39-41-42	$Na^{+} > Mg^{2+} > Ca^{2+} >$ $SO_4^{2-} > Cl^{-} > HCO_3^{-}$	Na^{+} - SO_4^{2-}	**23 %**
20-55-57-22-35-37-40	$Na^{+} > Mg^{2+} > Ca^{2+}$ $Cl^{-} > HCO_3^{-} > SO_4^{2-}$	Na^{+} - Cl^{-}	**11.5 %**

leaching and dissolution of minerals bearing in formation matrix, including CO_3^{2-}, SO_4^{2-}, and Cl^{-}.

Piper's trilinear graph (**Piper, 1945**) for the groundwater points revealed that, the majority of water chemical components were positioned in subareas 8 (40 wells) and 7 (21 wells), where subarea 8 revealed Na-HCO_3 water type, and subarea 7 revealed $NaSO_4$ and NaCl water type **Fig.4**. The most common water type was $NaHCO_3$, followed by $NaSO_4$ and NaCl, which indicating active leaching and dissolution of carbonate, SO_4^{2-}, and Cl^{-} minerals in formation matrix. The Na-HCO_3 water type reflected the influnce of carbonate rock dissolution in the aquifer.

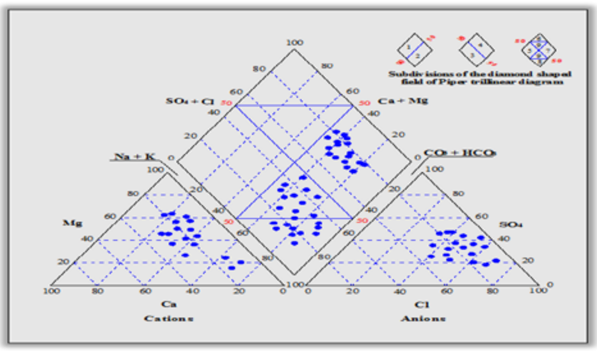

Fig 4. Groundwater types for the NSSA

The hydrochemical correlations provided a useful evidence of the geochemical process that occurs in groundwater. The hydrochemical relations (rK/rCl), (rNa/rCl), (rMg/rCl), (rCa/rCl), (rSO_4/rCl), ($rCl/rHCO_3+rCO_3$), ($rHCO_3$/rCl) and (rNa/rK) were estimated, which revealed fresh water.

According to hypothetical salt of the NSSA in the investigated region, the collected water points revealed assemblages I, II, and III as showed in **Table 2**.

Table 2. Hypothetical salt fot the groundwater samples in the NSSA**.**

Assemblage	Hypothetical salt	Percentage (%)
I	KCl, NaCl, Na_2SO_4, Na HCO_3, Mg $(HCO_3)_2$, Ca $(HCO_3)_2$	(60.32 %)
II	KCl, NaCl, Na_2SO_4, $MgSO_4$, Mg $(HCO_3)_2$, Ca $(HCO_3)_2$	(23.82 %)
III	KCl, NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, Ca $(HCO_3)_2$	(15.87 %)

The majority of the groundwater points from the NSSA in the investigated region were distinguished by salt mixture aggregations, such as Assemblages I, II and III. The first assemblage depicted an initial phase of chemical advancement than assemblage three (60.32%). The influences of recent recharge as well as natural rainwater on groundwater were revealed by assemblages one (three HCO_3 salts) and assemblage two (two HCO_3 salts). The impacts of leaching and dissolution of evaporated deposits and an intermediate phase of chemical advancement were shown by assemblage three (three sulphate salts). The occurrence of clay intercalated with the NSSA in the investigated region may have contributed to cation exchange mechanisms. In addition, assemblage three revealed mature stage of chemical progress and salt assemblage revealed the impact of marine salt contamination.

Groundwater flow

Using the Surfer® 11.0, the groundwater table of the current monitoring stations were estimated, and a piezometric heads contour map was created (2012). The groundwater levels varied from +35 m to -25 m. Some areas showed a significant drop in groundwater heads, which was a result of overpumping and quick drawdown. Numerous depleted closed regions, disrupting the main trend of water flow in several directions **Fig. 5**.

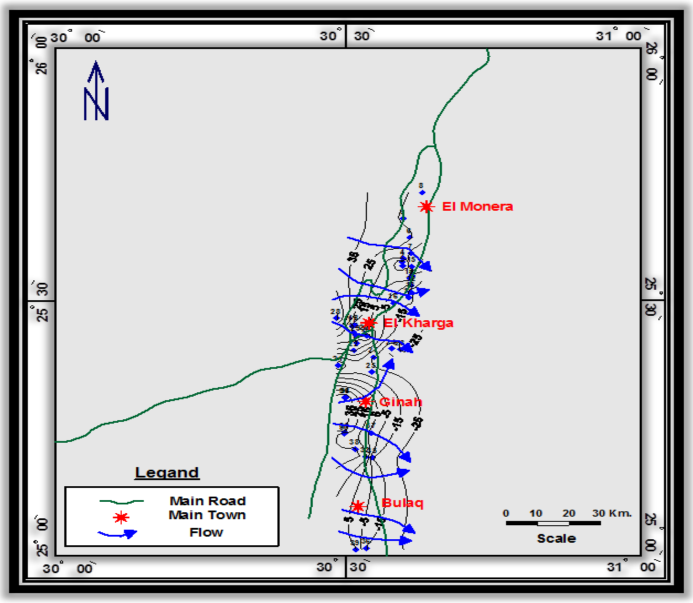

Fig. 5. Flow direction of the groundwater in the investigated area

Effect of high iron concentration

As far as we know, hemochromatose patients who absorb large amounts of iron end up storing it in their pancreas, liver, spleen, and heart, endangering these essential organs. The Fe contents less than 0.3 mg/L, usually has no effects on healthy people. Iron itself is a relatively harmless element, but iron compounds may be more harmful to health. Binary iron compounds that are water soluble, including $FeCl_2$ and $FeSO_4$, can be toxic at doses greater than 200 mg and can be fatal to adults at doses between 10 and 50 g. Iron dust may also contribute to lung disease.

This implies that the plant is unable to draw in vital elements like phosphate or nitrogen, which are required for its proper operation but which it is unable to produce on its own. The plant's internal systems malfunction, resulting from severe decay of the stem and leaves' vital tissues and, ultimately, the plant's demise. When there isn't enough Fe nearby, many plants can produce an enzyme "chelate reductase" that makes Fe easier to absorb. If iron levels are adequate or too high, plants may also decrease the production of this enzyme. While some plants can change quickly due to their skill in manipulating this mechanism, others have a much slower response time. Iron bacteria have dramatic effects on water, showing up as dark slimy masses on lakes and stream bottoms. An extra significant issues develop in well systems, when germs build up. Iron bacteria in wells can decrease well output via clogging screens and pipelines even if it may not be harmful to human health **Fig. 6**.

Fig. 6. Brownish masses on the underside of streams

Conclusions and recommendation

The NSSA serves as the primary source of groundwater for the Western Desert's development activities. The sustainability of the new planned territory west of the investigated region and its surroundings, should be the focus of groundwater extraction. Because more groundwater was put back into the aquifer, groundwater exploitation was restricted. The high concentration of salts levels for some collected water wells were observed, in addition anomalous Fe concentrations were demonstrated, producing brown slime that accumulates on well screens and pipes. Therefore, flood irrigation system should be changed with more sophisticated drip and sprinkle irrigation techniques because they conserve water, reduce operational costs, and enhance benefits.

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