DJS Vol. 44 (1) (2022) pp.99—112 ISSN: 1012-5965

Delta Journal of Science

Available online at **https://djs.journals.ekb.eg/**

Research Article **GEOLOGY**

Hydrochemical Evaluation of Groundwater for Irrigation in the Arid Regions, Bahariya Oasis Outskirts, Western Desert, Egypt

Samar Abd El Kereem[1]*, Mohamed M. El-Horiny[1], Mahmoud Ashmawy[1]

1Geology Department, Faculty of Science, Tanta University, Tanta, 31527, Egypt.

*Corresponding author: Samar Abd El Kereem e-mail: samar.abdelkereem@science.tanta.edu.eg

Received: 15/1/2022 Accepted: 31/1/2022

KEY WORDS

Hydrochemistry, Nubian Sandstone Aquifer, irrigation groundwater, physio-chemical parameters.

ABSTRACT

Recently, the demand for groundwater has been increasing with population growth and irrigation practices. Owing to this growth, Egypt's per capita freshwater will severely decrease. The Nubian Sandstone Aquifer System (NSAS) is the great aquifer that extends through several countries and considered the promising potential aquifer in the area. Bahariya Oasis, located in a hypo-arid climate, is mainly dependent on groundwater extracted from the Nubian aquifer, which is considered the source for agricultural and development projects in the oasis. The main aim of the present study is to help the decision-makers in planning the new reclamation land in Bahariya depression. To achieve this objective, 52 samples from different aquifers were collected and analyzed to document the processes controlling the chemistry of the groundwater in the (NSAS) and evaluate its quality for irrigation use. Physio-chemical parameters of the collected samples were assessed to estimate the processes that impacted the quality of groundwater. Major ion concentrations of Na^+, K^+, Mg^{+2}, Ca^{+2}, SO_4^{-2}, HCO_3^-, Cl^-, and NO_3^- were calculated. A combination of irrigation groundwater indexes such as sodium percentage (Na%), chloride content (Cl^-), total soluble salts (TDS), and sodium adsorption ratio (SAR) provides guidance to estimate the suitability of irrigation groundwater in Bahariya Oasis. Except in some shallow aquifer locations, the obtained result was referred to as the suitability of groundwater for irrigation.

1. Introduction

Agricultural activity is considered one of the main sectors of the economy in Egypt, which is dependent on the water of the Nile River. But with the increase of the population, the reclamation of more lands has become an urgent matter for the government to face this increase. Therefore, it is necessary to evaluate and monitor the quantity and quality of the groundwater to obtain the required results (Singh *et al.*, 2011; Adimalla and Li, 2019). The government paid a lot of attention to the desert, looking for alternative sources of water.

Unmanagement of groundwater in the studied area causes a lowering of water level, which accelerates the reduction of groundwater quality and soil degradation as a result of soil salinization (El Hossary, 2013; Masoud and El Osta 2016; Sharaky and Abdoun, 2020).

The soil in Bahariya Oasis is considered one of the most promising lands in the Western Desert due to its location and groundwater resources. The origin of the soil in the depression is lithological and anthropogenic. Soil quality degradation in the depression is due to many factors (by humans or even naturally) that accelerate soil problems such as groundwater flow, evaporation of near-surface saline groundwater, and phosphatic fertilizers in the soil. These soil contaminations are more effective than those of iron ore erosion (Baghdady *et al.*, 2018), as well as their fragility and sensitivity to desertification, the agricultural production improvement of these new lands is sluggish and takes a long time (Elwan and Khalil, 2018).

Bahariya Oasis is located in the central part of the Western desert, including the great groundwater supply represented by the Nubian Sandstone Aquifer (NSAS). The concentration of groundwater ions in arid and semi-arid regions is controlled by different factors such as rock water interaction, weathering, structural setting, dissolution, ion exchange, chemical fertilizers, and largely anthropogenic activities (Singh *et al.*, 2011; Adimalla and Venkatayogi, 2017, 2018, Adimilla *et al.*, 2018). Therefore, it is essential to evaluate the groundwater in Bahariya oasis aquifer to detect the different factors that can degrade the irrigation water quality.

In the present study, GIS and remote sensing techniques (RS) were used to estimate the zones of water quality and polluted zones by generating distribution maps (Jasrotia *et al.*, 2018, 2019; Adimalla and Taloor, 2020). Moreover, the study provides information on the hydrochemistry of the groundwater in the area to help the decision maker in planning the new reclamation land.

2. Study area

Bahariya Oasis is located in the center of the Western Desert, between longitudes of 28° 35' and 29° 10' E and latitudes of 27° 48' and 28° 30' N. The oasis covers about 2100 km^2 of the total area of the Western Desert, with a slope from the south to the north and has an elevation range from 73 m to 360 m above sea level. It is located in an extremely arid to semi-arid environment, characterized by low annual rainfall with high evaporation (Fig .1). The climatic conditions in Bahariya Oasis are characterized by temperatures of up to 37 C^o during the summer and at least 10 C^o.

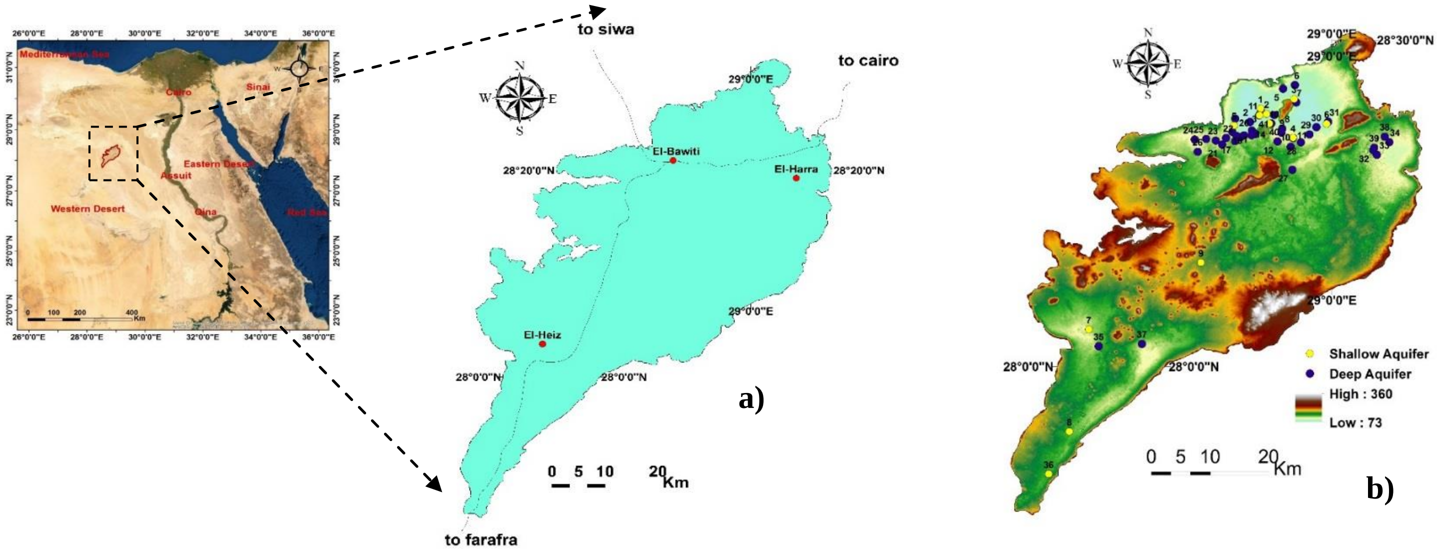

Fig.1: a) location map of Bahariya Oasis b) Topography of the area as shaded elevation derived from SRTM with sampling sites of groundwater.

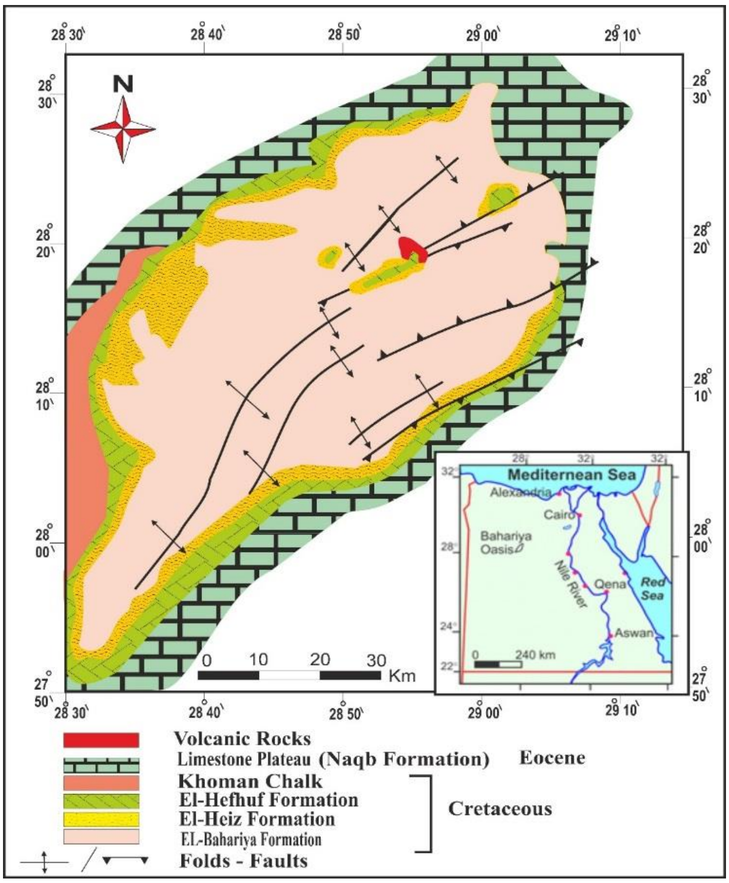

Fig. 2. Geological map of Bahariya Oasis illustrating the main rock distribution, Compiled from field work and correlations with the geological map of (**El-Akkad and Issawi, 1963; Moustafa *et al.*, 2003; Hamdan and Sawires, 2013**).

during the winter with a relative humidity increase of 59% during the summer, which contributes to further saturation of water vapor and a decrease to 37% in the winter (Boghdadi, 2012; Anber, 2015). Because of the arid climate, the rain is gating scaring, with an annual rate of 4.1 mm.

The soil ranges from sub mature to mature sand and muddy sand. These soils were inherited by physical weathering from the sedimentary succession and basaltic rocks that formed the depression's scarps. The relative importance of these sources differed according to soil type (Baghdady and Gad, 2013). The soil sediments consist mainly of sand granules, silt, clay, a low amount of carbonate and very low content of organic matter with clay loam and sandy texture. Due to the dominance of sodium cation and chloride anion, the soil represents an increase in salinity. Bahariya soil is classified as good, fair, or poor based on its land capability, fertility, and water index (El-Naggar, 2017).

3. Geology and Hydrology

The exposed exposures sediments in the studied area are mostly upper cretaceous to Oligocene in age. The Cretaceous sediments range between (sandstone and intercalation of clay and siltstone) and the types of carbonate sediments (limestone, dolomite, and chalk). The cretaceous succession is capped by basalt flows, dolerite sells, and dikes of Miocene age, as indicated by the geological distribution map of the Bahariya Oasis (Fig. 2). On the depression's floor, the quaternary sediments are represented by sand dunes, sabkha, and Hummocks. The studied area form NE-trending anticline fold related to the Syrian Arc System, which is dissected by the Bahariya mid dextral strike slip fault striking ENE-WSW and several NE-SW and NW-SE normal and reverse faults. Three phases of structural deformation affected the exposed Cretaceous and Eocene rocks in the Bahariya region and led to the rejuvenation of the deep-seated faults. These are (i) Late Cretaceous to pre-Early Eocene deformation, post-Middle Eocene deformation, and Middle Miocene deformation (Moustafa, *et al*., 2003).

The hydrological investigation indicated that the closed, non-renewable Nubian Sandstone Aquifer System (NSAS) is the only groundwater source in Bahariya Oasis. The aquifer covers a vast area, where it covers about 2.2 million km^2. They have a presence in four countries, each with a different area. In Egypt, 828.000 Km2 (38%), 376.000 Km^2 (17%) in Sudan, Libya, 760.000 (34%), and about 235.000 Km^2 (11%) in Chad. In the oasis, it has an average thickness exceeding 1880m with an average transmissivity of 8.8×10^{-3} m^2/s and 4.5×10^{-5} m/s of hydraulic conductivity (Hesse *et al*., 1987; Sefelnasr, 2002), which makes it a promising potential aquifer in the studied area. It is classified into two lithological units (i) pre-Cenomanian with high porosity and permeability sandstone and alteration of clay and shale. It has a high level of fresh groundwater and low salinity of 267 ppm (Salem, 2002; Hamdan and Sawires, 2013; Anbar, 2015). (ii) two layers of sandstone separated by an impermeable clay layer of the lower Cenomanian with a thickness of 240-410 m. There is another water bearing strata in Bahariya Oasis known as the Cambrian water bearing with a thickness of 460 m that is fresher than other horizons with salinity of about 120-200 ppm and composed of clastic sediments and carbonate complexes (marly and dolomite) (Himida, 1964; Diab, 1972; Hamdan and Sawires, 2013). This paper focuses on assessing the characteristics of groundwater extracted from the Nubian aquifer to assess their suitability for irrigation purposes, using 52 samples and measured physio-chemical parameters in Bahariya Oasis.

4. Materials and Methods

In April 2019, a random distribution of groundwater samples was collected for parameter measurements and evaluations of groundwater for various purposes, as well as to estimate the direction of flow and head pattern of water. 40 groundwater samples from a deep aquifer were collected at indicated depths of 760–1170 m, while 12 shallow aquifer samples were collected at a depth range of 250–498 m. To avoid contamination, the well was pumped for a few minutes, and the samples were talked about using a 1-L polyethylene bottle. The samples were transported for chemical laboratory analysis.

Immediate measurements of some parameters were done in the field using a hand-held collection device to avoid any change in groundwater properties such as electrical conductivity (Ec), total dissolved solids (TDS), temperature (T), and pH. Using a Hach Direct Reading /2000 Spectrophotometer, iron concentration (Fe^{+2}) was estimated in the field. The standard analytical methods were followed for groundwater analysis to determine the concentration of major cations (Na^{+}, K^{+}, Ca^{+2}, and Mg^{+2}) and major anions (Cl^{-}, HCO_3^{-}, and SO_4^{-2}). As well as Mn^{+2} and NO_3^{-} were measured. The field measurements were checked in the lab and charge balance errors for ion concentration were calculated for quality assurance (Table 1). The ArcGIS 10.5 was used to extract and visualize distribution maps for the investigated groundwater quality parameters in the study area.

4.1. Determining of sodium adsorption ratio (SAR)

The SAR was estimated using the following equation

$$\text{SAR}= \frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}}$$

(concentration of cations in milliequivalent per liter)

4.2 Determination of Sodium Percent (Na%)

Sodium is considered one of the most important cations that should be taken into consideration in the classification of groundwater for irrigation and agricultural activities. A classification proposed by (Wilcox, 1955) is based on sodium percentage which can calculate using the following equation:

$$Na\% = \frac{Na + K}{Ca + Mg + Na + K} \times 100$$

All concentrations in meq/l

The obtained result of Na% values represented in (Table 2).

Table 1: Summary of statistics of the hydrochemical parameters of the shallow and deep aquifers, Units of the ion concentrations in mg/l: Min= Minimum, Max=Maximum, St.dev=Standard deviation.

Shallow aquifer					Deep Aquifers				
Variables	***Min***	***Max***	***Mean***	***St. dev***	***Variables***	***Min***	***Max***	***Mean***	***St.dev.***
TDS	147.9	1740	455.32	434.015	***TDS***	133	354	189.35	50.58
EC (µS/cm)	296	3530	916.16	881.28	***EC (µS/cm)***	267	708	379.97	98.91
T C	26.1	32	28.48	1.487	***T C***	29	47.4	37.43	5.88
pH	5.74	6.76	6.225	0.329	***PH***	5.61	6.97	6.24	0.325
Ca	7.67	128.7	34.62	33.898	***Ca***	6.07	22.24	10.5	3.377
Mg	9.84	196.1	39.11	51.59	***Mg***	6.73	26.21	12.2	4.001
Na	20.08	334.69	71.57	84.804	***Na***	11.56	57.2	31.76	9.72
K	11.47	158.29	39.6	40.58	***K***	6.93	26.17	15.43	5.281
HOC_3	28	56	37	8.31	***HOC_3***	6	98	46.93	21.661
SO_4	29	825	182.42	236.611	***SO_4***	9	81	30.2	18.14
Cl	49	728	146.83	188.13	***Cl***	27	126	61.33	20.951
NO_3	0	5.72	2.05	2.19	***NO3***	0	9.24	4.43	2.24
Fe	0.19	21.5	5.63	6.804	***Fe***	0.1	7.2	2.65	1.67
Mn	0.37	49.01	7.26	14.31	***Mn***	0.12	2.93	1.15	0.604

Table 2: Water classification based on sodium percentage (Na%).

Value Range (Wilcox, 1955)	*classification*	*deep samples*	*Percentage %*	*Shallow samples*	*Percentage %*
< 20	*Excellent*	*-*	*-*	***1***	***8.33***
20 – 40	*Good*	*1*	*2.5*	*1*	*8.33*
40 – 60	*Permissible*	*30*	*75*	*9*	*75*
60 -80	*Doubtful*	*9*	*22.5*	*1*	*8.33*
> 80	*Unsuitable*	*-*	*-*	*-*	*-*
	Total	*40*	*100*	*12*	*100*

Table 3: suitability of groundwater in Bahariya Oasis according to total dissolved solids according to **Ayers (1975**)

TDS	*Quality*	*Shallow aquifer*	*Deep aquifer*
< 480	*No problems*	*All samples except 51, 50, 45 (75%)*	*All samples (100%)*
480 – 1920	*The problems increase*	*Samples 51, 50, 45 (25%)*	*No samples*
> 1920	*Problems become severs*	*No samples*	*No samples*

5. Results and Discussion

5.1. Irrigation groundwater quality

5.1.1. Total concentration of soluble salts (TDS)

The activation of weathering and leaching processes in the soil and hosted aquifer rocks lead to an increase in ion concentration in groundwater (Singh *et al*., 2013; Rawat *et al*., 2018). In the arid climate of Bahariya Oasis, the increasing rate of evaporation accelerates the accumulation of salts in the root zone, influencing osmatic pressure (Modi, 2000; Rawat *et al*., 2018). Therefore, the salinity in irrigation groundwater should not exceed 2000 mg/l (FAO, 2006; Rawat *et al*., 2018).

According to (Ayer's, 1976) classification and distribution map of the studied area (Table 3), (Fig. 3). The majority of shallow aquifers (75%) have no problems, and about (25%) of shallow groundwater samples suffer from problems with salinity, while all samples from the deep aquifer are suitable for irrigation where salinity values are below 480 mg/l.

5.1. 2. Chloride content

The sensitivity of crops to chloride content varies from plant to plant. Some factors accelerate the toxicity of chloride, such as sprinkler irrigation systems, where the chloride accumulates in the leaves of plants, which damage their tissues and make them dry. It also effects the infiltration of soil, where it increases total salinity in soil. The chloride ion does not occur naturally as well as the most soluble anion in water. The main source of chloride ions in groundwater in Bahariya depression is from the leaching and dissolution processes of sedimentary rocks in the aquifer.

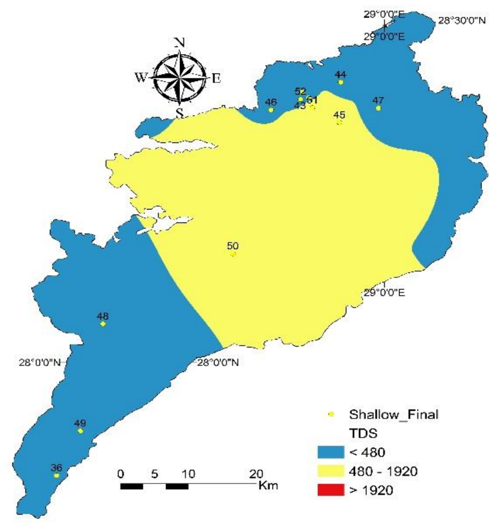

Fig.3: Zoning map for TDS for shallow aquifer

According to the distribution map of groundwater samples (Table 4), (Fig. 4a.b) most shallow and deep aquifer samples (41.66% and 67.5%, respectively) can be used without any problems, while the rest of the deep and shallow groundwater reflect moderate injury (50% and 32.5%, respectively). Only one sample showed a high concentration of chloride, which led to severe problems.

5.1.3. Sodium percentage (Na%)

The suitability of groundwater for irrigation can judged based on sodium content Na%. Sodium is considered one of the most important cations that should be taken into the classification of groundwater for irrigation and agricultural activities. sodium accumulated affects the permeability of the soil and the crop yield (Batarseh, 2017). According to Wilcox classification the groundwater can classified to $0 \leq \%Na \leq 20\%$ excellent water, $20 < \%Na \leq 40\%$ good water, $40 < \%Na \leq 60\%$ permissible, $60 < \%Na \leq 80\%$ doubtful, and $80 < \%Na \leq 100$ unsuitable (Table 2). Moreover, the Wilcox diagram shows the relationship between

Table 4: Classification of irrigation water according to chloride content (**Cf. Ludwick *et al.*, 1990; Bauder *et al.*, 2011**)

Quality	*Effect on crops*	*Deep aquifer samples*	*Shallow aquifer samples*
< 70	*Generally safe for all plants*	*3,6,7,9,11,12,13,14,15,17 ,18,19,21,22,24,26,27,29 ,31,33,34,35,36,37,38,39,40*	*43,48,49,52,36*
70-140	*Sensitive plants usually show slight to moderate injury*	*1,2,4,5,8,10,16,20 ,23,25,28,30,32*	*42.44.47.50*
141-350	*Moderate tolerant plants usually show slight to substantial injury*	*No samples*	*45,46*
> 350	*Can cause severe problems*	*No samples*	*51*

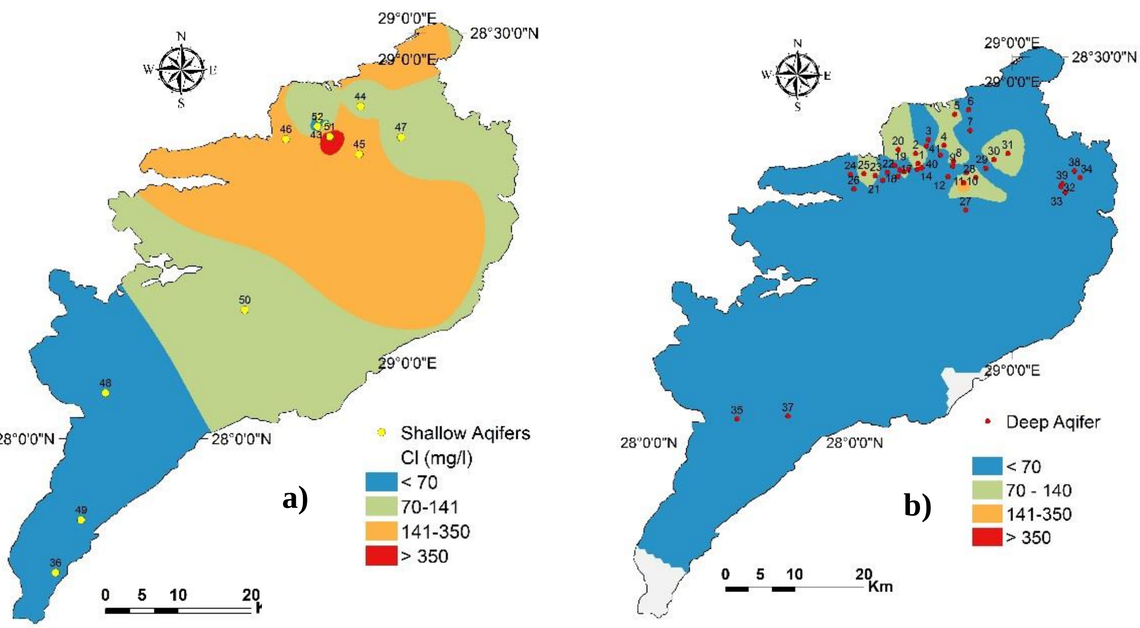

Fig.4: Zoning map of chloride content a) shallow aquifer and b) deep aquifer

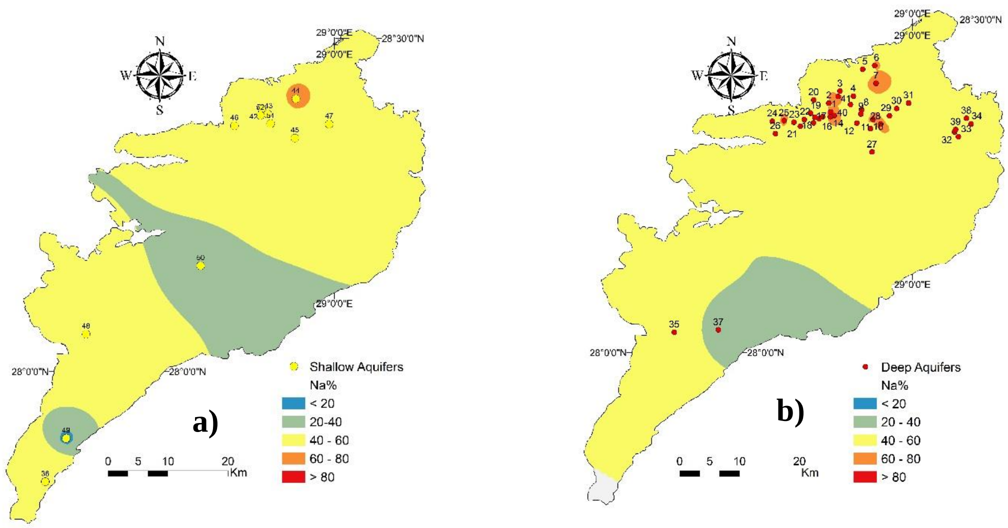

Fig.5: Zoning map of sodium percentage a) shallow aquifer and, b) deep aquifers.

salinity hazard (expressed via the EC value in mS/cm) and sodium content in water (expressed as Sodium Ratio, Na%) (Salifu *et al*., 2017).

The diagram characterizes the suitability of water for irrigation in several grades, namely excellent to good (I), good to permissible (II), permissible to doubtful (III), doubtful to unsuitable (IV), and unsuitable (V) (Adimalla *et al*., 2020). The result obtained from the studied area revealed that (58.33%) of shallow aquifers and all deep groundwater samples (100%) belong to excellent to good irrigation water, while the rest of the shallow groundwater samples belong to good to permissible water, except for the sample unsuitable for irrigation and agricultural activity (Fig. 5a.b) (Fig.6a and b). according these obtained results the groundwater in Bahariya Oasis suitable for irrigation water especially from deep wells.

5.1.4. Sodium adsorption ratio (SAR)

Soil structure is affected by increasing the concentration of some cations in irrigation water. One of these effects is reduced permeability and infiltration of soil. This phenomenon occurs in some soils that have sodium imbalances in irrigation water relative to the concentration of calcium and magnesium ions, where sodium can replace both ions as the following:

$$\mathbf{Na^{+} + Ca^{+2}\ (Clay) \ldots\ldots\ldots\ldots\ Na^{+}\ (Clay)\ Na^{+} + Ca^{+2}}$$
$$\mathbf{Na^{+} + Mg^{+2}\ (Clay) \ldots\ldots\ldots\ldots\ Na^{+}\ (Clay)\ Na^{+} + Ca^{+2}}$$

The most common quality factor used to measure the concentration and replacement of sodium relative to calcium and magnesium is the sodium adsorption ratio (SAR).

SAR is a more reliable parameter used for determining the effect of all cation concentrations on sodium which has accumulated in the soil, as well as measuring alkali/sodium hazard to crops as well as the extent to which soil adsorbs it, so one can easily evaluate the quality of the groundwater for agricultural activity.

The classification of irrigation water represented in the graph has salinity hazard on the X-axis and sodium hazard on the Y-axis depending on electrical conductivity and SAR, respectively. The majority of shallow groundwater samples (58.3%) and all samples from deep aquifers (100%) belong to class (C2 – S1), which means that water is suitable for irrigation with low salinity and medium SAR. Class (C3- S1) has (33.3%) shallow aquifer samples, which refer to high salinity and cannot be used in Bahariya Oasis, where it does not have a drainage system but is suitable for sodium hazard. Only one sample from the shallow aquifer in the north part of the oasis is suitable for irrigation, and that is because it has a high salinity of > 2250 and a medium sodium hazard (Fig.7a and b).As seen from the comprehensive chemical parameters and zoning maps of irrigation quality index, majority of the groundwater are suitable for agricultural activity. Only some samples from the shallow aquifer in the northern part of the oasis classified as un suitable. Good quality water is mainly `distributed at the southern part where the high transmissivity and hydraulic potential of aquifer and low salinity.

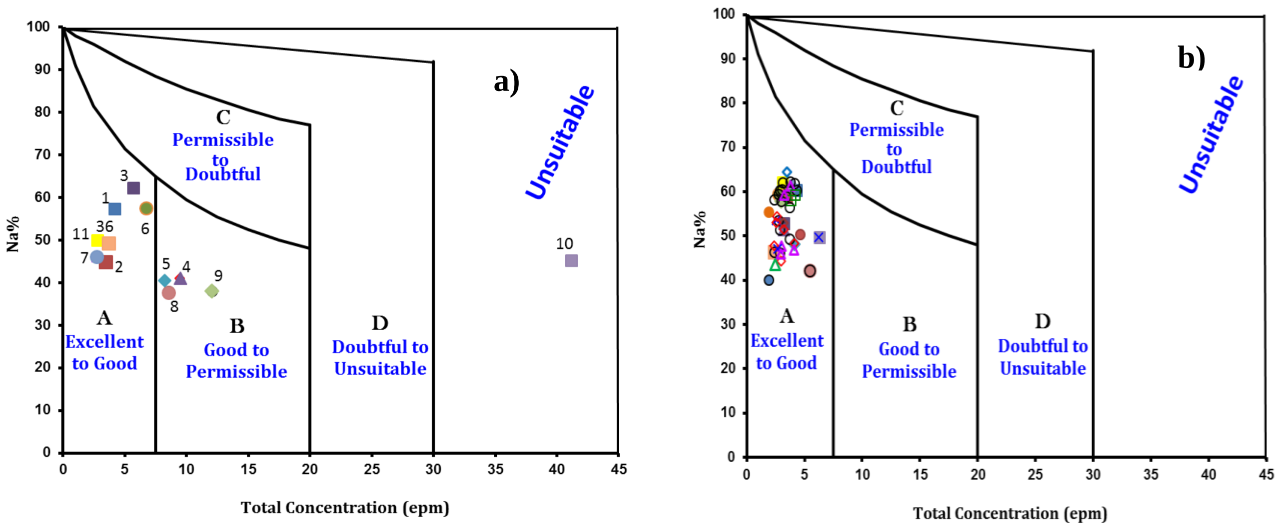

Fig.6: Wilcox classification for irrigation water a) shallow aquifer's samples and b) deep aquifer samples.

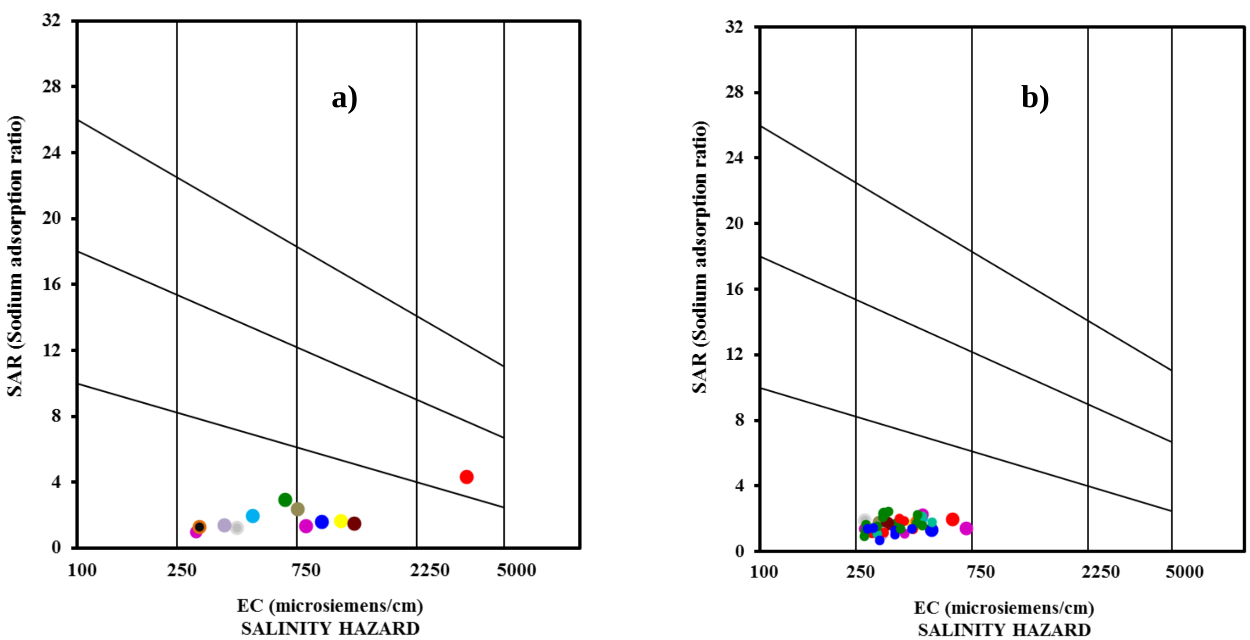

Fig.7: U.S. Salinity Laboratory Stuff Diagram for classification of irrigation water of a) shallow aquifers and b) deep aquifer samples.

5. Conclusion

The hydrochemical analysis carried out on the collected groundwater samples in the arid and semi-arid environments of Bahariya Oasis in the Western Desert is to be compared with the world standard limit inferring to water quality for irrigation purposes. Groundwater in the studied area is suffering from an increase in trace elements such as iron Fe^{+2} and manganese Mn^{+2}. The leaching process and interaction of groundwater with hosted aquifer sediments play a role in increasing the concentration of ions in water. Most groundwater samples in the area are suitable for irrigation purposes, except for a few locations. The US Salinity Laboratory diagram revealed that the majority of shallow groundwater samples (58.3%) and all samples from deep aquifers (100%) belong to class (C2 – S1). Class (C3-S1) has (33.3%) shallow aquifer samples, which refer to high salinity, which requires a good drainage system. Other irrigation indexes such as sodium percentage, chloride content, and total salinity of groundwater show no problems, except for some shallow wells. It is recommended to develop a strategy for groundwater management in Bahariya Oasis, especially since it has a promising potential aquifer represented by the Nubian sandstone aquifer (NSAS).

Reference

Adimalla, N. and Li, P. (2019): Occurrence, health risks, and geochemical mechanisms of fluoride and nitrate in groundwater of the rock-dominant semi-arid region, Telangana State, India. Human and Ecological Risk Assessment: An International Journal, 25(1-2), p.81-103.

Adimalla, N. and Venkatayogi, S. (2017): Mechanism of fluoride enrichment in groundwater of hard rock aquifers in Medak, Telangana state, South India. Environ Earth Sci 76:45. https://doi.org/10.1007/s12665-016-6362-2

Adimalla, N. and Venkatayogi, S. (2018): Geochemical characterization and evaluation of groundwater suitability for domestic and agricultural utility in semi-arid region of Basara, Telangana state, South India. Appl Water Sci 8:44. https://doi.org/10.1007/s13201-018-0682-1

Adimalla, N., Dhakate, R., Kasarla, A. and Taloor, A.K., (2020). Appraisal of groundwater quality for drinking and irrigation purposes in Central Telangana, India. *Groundw. Sustain. Dev*. 10, p. 100334. https://doi.org/10.1016/j.gsd.2020.100334.

Adimalla, N., Li, P. and Venkatayogi, S. (2018). Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index studies. *Environmental Processes*, *5*(2), p. 363-383.

Adimalla, N.and Taloor, A.K. (2020): Hydrogeochemical investigation of groundwater quality in the hard rock terrain of South India using Geographic Information System (GIS) and groundwater quality index (GWQI) techniques. *Groundw. Sustain. Dev.* 10, p.100288. https://doi.org/10.1016/j.gsd.2019.100288.

Anber, M, A. (2015): The Climatological and Environmental Hazards in Bahariya Oases Depression A Study Using Remote Sensing Techniques and Geographical Information Systems Applications. Ph.D. Thesis, Fac. Art., *Cairo Univ*., p. 356. (In Arabic).

Ayers, R. S. (1976): Water quality for agriculture. Irrigation and drainage paper, *Food and Agricultural Organization*, V.29, p. 174.

Baghdady, A. R. and Gad, A. (2013): Textural and mineral attributes and sedimentary history of the various Quaternary soil types in the Bahariya Oasis, Western Desert, Egypt. *Sedimentology of Egypt*, *21*, p.105-117.

Baghdady, A., Awad, S. and Gad, A. (2018): Assessment of metal contamination and natural radiation hazards in different soil types near iron ore mines, Bahariya Oasis, Egypt. Arab. *J. Geosci*., 11(17). https://doi:10.1007/s12517-018-3814-x.

Batarseh, M. (2017): Sustainable Management of Calcareous Saline-Sodic Soil in Arid Environments: The Leaching Process in the Jordan Valley. *Appl. Environ. Soil Sci*. 2017, p.109-2838. https://doi.org/10.1155/2017/1092838.

Bauder, T. A., Waskom, R. M., Sutherland, P. L., and Davis, J. G. (2011): Irrigation water quality criteria, Doctoral dissertation, *Colorado State University*. Fact sheet no 0.506. p.4.

Boghdadi, M.D. (2012). Application of GIS and remote sensing in geoenvironmental assessment for support of sustainable development of Bahariya Oasis Depression. Ph.D Thesis, Geography, Fac. Arts, *Mansoura Univ*., 218p. (In Arabic).

Diab, M. S. (1972): Hydrogeological and Hydrochemical studies of the Nubian Sandstone water-bearing complex in some localities in United Arab. Republic PhD thesis, Assiut University, Egypt, p.241.

El Hossary, M.F. (2013:) Ensuring sustainable development via groundwater management (case study: El Bahariya Oasis). J Am Sci 9(6), p.6–13.

El -Naggar, A. A. (2017): Development of land capability and suitability maps for Bahariya Oasis, Egypt. Egyptian *Journal of Soil Science*, 57(4), p.489-503.

El-Akkad, S. and B. Issawi. (1963): Geology and iron ore deposits of the Bahariya oasis: Geological Survey and Mineral Research Department, Egypt, Paper 18, p.301.

Elwan, A. and Khalil, M. (2018): Quantitative Assessments of Desertification in Bahariya Oasis Environment, Western Desert, Egypt. *Journal of Productivity and Development*, *23*(3), p.505-533.

FAO (Food and Agriculture Organization) (2006): Prospects for food, nutrition, agriculture, and major commodity groups. World agriculture: toward 2030–2050, Interim report. Global Perspective Studies Unit. FAO, Rome.

Hamdan, A. M. and Sawires, R. F. (2013): Hydrogeological studies on the Nubian sandstone aquifer in Bahariya Oasis, Western Desert, Egypt. Arabian Journal of Geosciences, 6(5), p.1333-1347.

Hesse, K., Hissne, A., Kheir, O., Schnaecker, E., Schneider, M. and Thorweihe, U. (1987): Hydrogeological investigations in the Nubian Sandstone Aquifer System, Eastern Sahara. Research in Egypt and Sudan. Verlag Von Dietrich Reimer, Berlin, (A) 75(2), p.397–464.

Himida, I. H. (1964): Artesian water of the oases of Libyan Desert in UAR PhD. Thesis, MGRU, Moscow (Russian Language).

Jasrotia, A.S., Kumar, R., Taloor, A.K.and Saraf, A.K. (2019). Artificial recharge to groundwater using geospatial and groundwater modelling techniques in North Western Himalaya, India. Arab. J. Geosci. 12, p. 774. https://doi.org/10.1007/s12517-019-4855-5

Ludwick, A.E., Campbell, K.B., Johnson, R.D., McClain, L.J., Millaway, R.M., Purcell, S.L., Phillips, I.L., Rush, D.W. and Waters, J.A. (1990): Water and plant growth. In: Western Fertilizer Handbook – horticulture Edition, Interstate Publishers Inc, Illinois, p. 15–43.

Jasrotia, A.S., Taloor, A.K., Andotra, U.and Bhagat, B.D. (2018): Geoinformatics based groundwater quality assessment for domestic and irrigation uses of the Western Doon valley, Uttarakhand, India. Groundw. Sustain. Dev.6, p.200–212. https://doi.org/10.1016/j.gsd.2018.01.003

Masoud, M. H. and El Osta, M. M. (2016): Evaluation of groundwater vulnerability in El-Bahariya Oasis, Western Desert, Egypt, using modelling and GIS techniques: A case study. *Journal of Earth System Science*, *125*(6), p.1139-1155.

Modi, P.N. (2000): Water engineering and water power engineering. New Delhi Press, New Delhi, p. 339–360.

Moustafa, A.R., Saoudi, A., Moubasher, A., Ibrahim, I.M., Molokhia, H. and Schwartz, B. (2003): Structural setting and tectonic evolution of the Bahariya Depression, Western Desert, Egypt. *Geo Arabia* 8(1), p.91-124.

Rawat, K.S., Singh, S.K. and Gautam, S.K. (2018). Assessment of groundwater quality for irrigation use: a peninsular case study. Appl. Water Sci, p.8. https://doi.org/10.1007/s13201-018-0866-8

Salem, A.A. (2002): Hydrogeological studies on the Nubian Sandstone Aquifer in Bahariya and Farafra Depression, Western desert, Egypt, unpub, Ph.D thesis, Fac. Sci., Ain shams Univ.

Salifu, M., Aidoo, F., Hayford, M.S., Adomako, D. and Asare, E. (2017): Evaluating the suitability of groundwater for irrigational purposes in some selected districts of the Upper West region of Ghana. Appl. Water Sci. 7, p.653–662. https://doi.org/10.1007/s13201-015-0277-z.

Sefelnasr, A. (2002): Hydrogeological studies on some areas on the new Valley governorate, Western Desert, Egypt, MSc thesis, Assiut Universit.

Sharaky, A. M. and Abdoun, S. H. (2020): Assessment of groundwater quality in Bahariya Oasis, Western Desert, Egypt. *Environmental Earth Sciences*, *79*(6), p.1-14.

Singh, C. K., Rina, K., Singh, R. P., Shashtri, S., Kamal, V. and Mukherjee, S. (2011). Geochemical modeling of high fluoride concentration in groundwater of Pokhran area of Rajasthan, India. *Bulletin of environmental contamination and toxicology*, *86*(2), p. 152-158.

Singh, S.K., Srivastava, P. K, Pandey, A.C. and Gautam, S.K. (2013) Integrated assessment of groundwater influenced by a confluence river system: concurrence with remote sensing and geochemical modelling. Water Resour Manag 27(12), p.4291–4313.

https://doi.org/10.1007/s11269-013-0408-y.

Wilcox L.V. (1955): Classification and use of irrigation waters. USDA, Washington, DC Circular 969.

التقييم الهيدروكيميائي للمياه الجوفية لأغراض الري في المناطق االجافة، الواحات البحرية، الصحراء الغربية، مصر

سمر عبدالكريم[١] ، محمد ماهر الهورينى[١] ، محمود العشماوى[١]

[١]قسم الجيولوجيا ، كلية العلوم، جامعة طنطا، طنطا، ٣١٥٢٧ مصر.

في الآونة الأخيرة ، ازداد الطلب على المياه الجوفية جنبًا إلى جنب مع النمو السكاني وممارسات الري. وبسبب هذا النمو ، أنخفض نصيب الفرد من المياه العذبة في مصر انخفاضًا حادًا. يعتبر نظام خزان الحجر الرملي النوبي (NSAS) الخزان الجوفي الكبير الذي يمتد عبر العديد من البلدان والذى يعتبر مصدرًا للمشاريع الزراعية والتنموية في الواحة. تعاني المياه الجوفية في منطقة الدراسة من زيادة في العناصر مثل الحديد Fe^{+2} والمنجنيز Mn^{+2}. تلعب عملية الترشيح وتفاعل المياه الجوفية مع رواسب الخزان الجوفي دورًا في زيادة تركيز الأيونات في الماء. معظم عينات المياه الجوفية في المنطقة مناسبة لأغراض الري ، باستثناء مواقع قليلة. أظهر الرسم البياني لمختبر الملوحة بالولايات المتحدة " U.S. Salinity Laboratory Stuff Diagram" أن غالبية عينات المياه الجوفية الضحلة (٥٨.٣٪) وجميع العينات المأخوذة من طبقات المياه الجوفية العميقة (١٠٠٪) تنتمي إلى الفئة (C2 - S1). الفئة (C3-S1) تحتوي على (٣٣.٣٪) عينات من طبقات المياه الجوفية الضحلة ، والتي تشير إلى ارتفاع الملوحة ، الأمر الذي يتطلب نظام تصريف جيد. أشيرت العوامل الاخرى لمعرفة مدى جودة المياه للرى، مثل نسبة الصوديوم ومحتوى الكلوريد والملوحة الكلية للمياه الجوفية أنه لا توجد أي مشاكل ، باستثناء بعض الآبار الضحلة. توصى الدراسة الى تطوير إستراتيجية لإدارة المياه الجوفية في الواحات البحرية خاصة أنها تحتوي على خزان جوفي واحد يمثله خزان الحجر الرملي النوبي (NSAS).