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Evaluation of the Environmental Impacts of Water Disposal Associated With Crude Oil Production on El-Moghra Aquifer in Abu El-Gharadig Basin, South East Qattara Depression

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Abstract

Egypt entered the water poverty area where the water per capita amounted to700 m^3/year. This is due to the limited water resources compared with the water demands. The physical and chemical properties of the groundwater differ from surface water related to the environment in which it occurs. Groundwater is affected by surface activities, rainwater, seepage, irrigation water and drainage water and other effluents. Shortage of water sources in Egypt bring out the issue of using non-conventional water resources.Industrial activities represent the most hazardous source of ground water pollution and disposal lagoons for water associated with crude oil production represent the main source of pollution to Moghra aquifer in the study area. The large quantities of water drained daily to the un-lined disposal lagoons, facilitate the salt water intrusion to the aquifer layer. There are three main water disposal lagoons in the study area, the surface area of the main lagoons ranges from 0.08 to 2.08 Km^2 with a total surface area of about 3.28 Km^2 and the average quantity of water were drained to these lagoons equal 7,155 m^3/day, the water accompanied with the oil wells, disposed in open ponds, forms another source recharging the Moghra aquifer in the study area. The Moghra aquifer is steady at -50 m below disposal lagoons there will be a direct hydraulic connection with the aquifer.This fact indicated by the continuous rise of the water level of the Moghra aquifer around and in the vicinity of the disposal lakes. The Moghra aquifer is discharged through few wells inside the concerned area and through many wells outside the concerned area. and a rise in the Moghra aquifer's water salinity also was seen in the results of water analysis for water wells tapped to Moghra aquifer during time in the study area, Many water samples were collected between 2011 to 2021 from the study area, the TDS contents of groundwater samples collected in 2011 around 22,000 mg/l at wells No. 2, 3 & 5 and TDS start to increase with time to reach 35,000 mg/l in the same wells .Also the water samples were collected from the un-lined disposal lagoons, the TDS contents of these samples 42,000 mg/l. A proper interrelation between the surface water and groundwater systems in the study area is clearly recognized. The present work is a trail to evaluate the groundwater resources potentialities of El-Moghra aquifer in Abu El-Gharadig Basin, South east Qattara Depression to achieve a sustainable development of water in this area. In addition, investigation the possible environmental impacts of these disposal lakes on the groundwater regime of the area.

Keywords: Abu El-Gharadig Basin, disposal lagoons, Ground water, Moghra aquifer and South East Qattara Depression

Introduction

The study area is located in the proven and prolific Abu Gharadig Basin, North Western Desert of Egypt. It is geographically located in the middle portion of the Qattara depression **(Fig. 1)** .It is situated about 140 km south the Mediterranean Sea, 300 km to the west of Cairo and 200 km to the southwest of Alexandria. It's located between latitudes 29º40' 00" and 30º06' 00"N and longitudes 27º30' 00" and 28º06' 00"E, in the vicinity of several producing oil fields ranging from small and large size hydrocarbon accumulation. It covers an area of about 3600 Km^2 .The present work deals with the environmental impacts of the salt lakes on the hydrogeological setting of the study area which located south east Qattara depression The main purpose of this study is the evaluation of the groundwater potentiality of the present Moghra aquifer and clarifying the possible environmental impacts of the created lagoons on the quality and quantity of the groundwater in the area under concern. The scope of this study is the hydrochemistry، and related fields as hydrogeology, hydrology & geology.

Materials and Methods

Many field activities were carried out to collect a real and recent data of the different hydrogeological and hydrochemical aspects of the concerned area. Activities were carried out through many field trips. These field activities include the following:

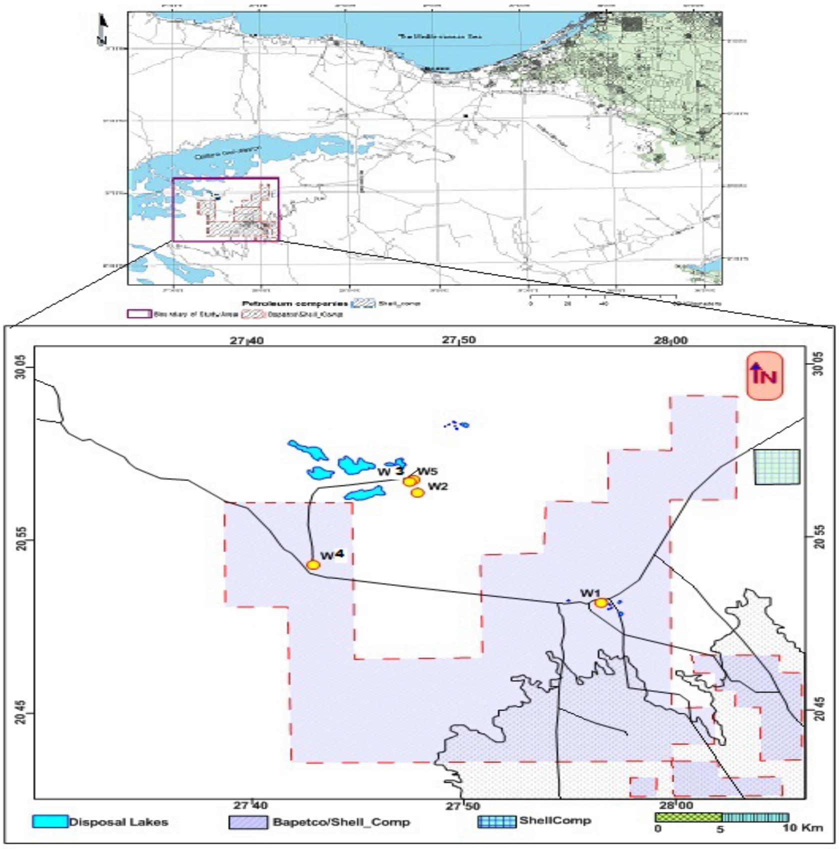


Fig. 1. Location map of the groundwater wells &disposal lagoons in the study area.

Reconnaissance of the various geophysical, geological and hydrogeological settings, inventories depths to water, water levels of the present water points, Collection of groundwater samples from production wells. Reviewing the geomorphological and geological units present in the concerned area. Performing pumping tests to determine the hydraulic parameters for the aquifer. Collecting the subsurface data including the geophysical and well logs with variable depths were obtained by personal communication, where they were operated by oil production companies in the study area and collecting twenty five different sample (groundwater samples from the productive wells & water disposal lagoons) for the purpose of hydrochemical investigation **(Fig. 2)**. Complete chemical analysis of 20 groundwater samples collected from the study area was done.

Groundwater analyses were carried according to ASTM methods. The analyses conducted both in the field and laboratory include total dissolved solids (TDS), measurement of pH, electrical conductivity (EC), concentrations of Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} as Cations, CO_3^{-2},HCO_3^{-} , SO_4^{-2} and Cl^{-} as anions, and determination of the trace

Fig. 2. Photographic photos for water disposal lagoons in the study area.

elements Fe^{3+},Mn^{2+}, Al^{+3} and Zn^{2+}). The water pH, temperature, electrical conductivity (EC), salinity and TDS were measured in the field.

Geological and hydrogeological setting

This topic explores the geology of the Qattara Depression, with a special reference to the geology of the Abu Gharadig Basin where the study area is located as a small part of the big Abu Gharadig basin. The geology of the study area was investigated through the previous literatures, geologic map of the Qattara Depression and the field observations. The geology of the northern part of the Western Desert and Qattara Depression were studied by many authors, of whom are; **Al-Sayyad (2018); Said (1962); Omara and Sanad (1975); Pickford et al. (2009); Albritton (2009); Hassan et al. (2012) and others**.

Accordingly, the surface of the study area is covered by a sedimentary rocks ranging in age from Lower Miocene to Quaternary (**Fig. 3**, geologic map). The oldest exposed rocks in the study area are the sandstone belongs to El Moghra Formation while the

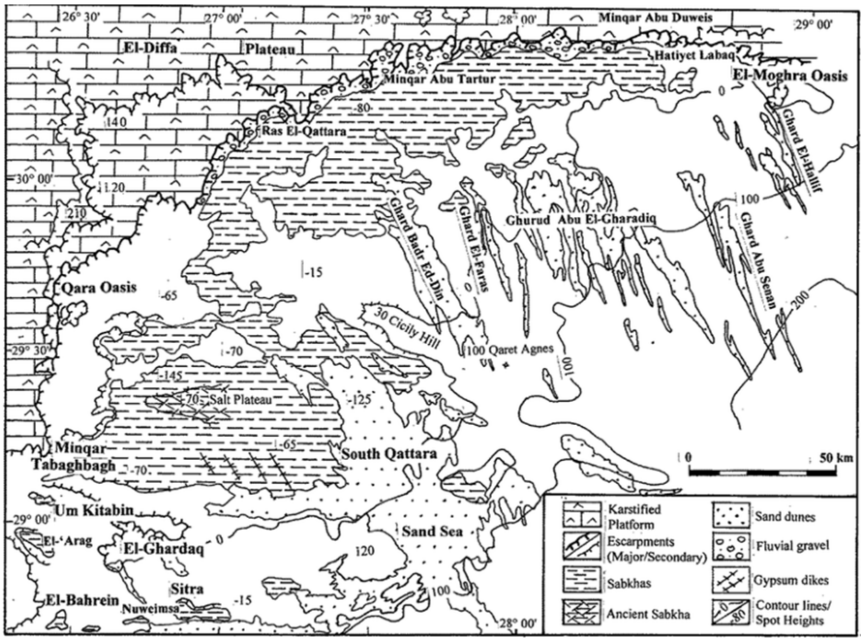


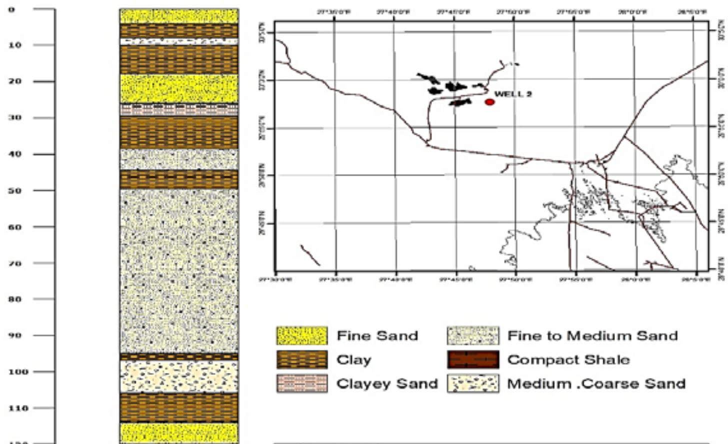
Fig. 3. Geomorphological map of Qattara Depression (**Embabi, 2013**).

youngest one is the friable sand dune accumulations and sabkhas belonging the recent time that prevailing vast areas of the study area.

Results and Disscussion

Groundwater is the only water source in Abu El Gharadig Basin. In addition to the fact that the Nile waters are very far from the region, the deep sandy soil and the scarcity of rain make dependence on surface water very difficult. Since the region is primarily an area of petroleum investments in which exploration, prospecting and oil production are carried out, the dependence on groundwater is limited to service activities, household and laundry services. As for drinking water, it is managed and brought to the region through bottled (mineral) water, which is provided by service companies associated with oil exploration, drilling and exploitation companies in the region. As, the area is mainly an industrial or semi-industrial area, groundwater is not used in agriculture except in a very narrow range, as the salinity of groundwater is mostly brackish to very saline, as it will be explained in detail in the this chapter. The data that will be processed in this chapter, are derived from previous studies that are abundant in the region and the data of deep drilling wells carried out by oil companies for the purpose of exploration and production of oil or shallow groundwater wells that were drilled for service and logistical purposes for the sites of various companies.

However, the vast previous studies of geology were predominantly based on surface data. Contrarily, the current study is based not only on surface data, but also on available subsurface data obtained from recent drillings water wells **(Fig. 4)**.



No.	Depth (m)		Description
	From	To	
1	0	4	Fine Sand
2	4	8	Clay
3	8	10	M.Coarse Sand
4	10	18	Clay
5	18	26	Fine Sand
6	26	29.5	Clayey Sand
7	29.5	38.5	Clay
8	38.5	44.5	Fine .Medium Sand
9	44.5	49.5	Clay
10	49.5	95	Fine to Medium Sand
11	95	97	Clay
12	97	106	Medium .Coarse Sand
13	106	114	Clay
14	114	120	Fine Sand
15	120	131	Compact Shale
16	131	169	Medium .Coarse Sand
17	169	171	Clay
18	171	179	Medium .Coarse Sand
19	179	181	Clay
20	181	187	Medium .Coarse Sand
21	187	188	Clay

Fig. 4. Stratigraphic column of water well (2) study area.

The hydrogeological evaluation of the groundwater occurrence in the study area is essentially based on the hydrologic inventory of almost all groundwater points and surface water systems. All the previous hydrogeological data collected together with the present field measurements were used to give a clear vision of the whole hydrogeological setting of the area of study. The hydrogeological setting of Abu El Gharadig Basin will be investigated under the following topics:

1. Surface system

The surface water system border the study area is consists of the water disposal lagoons for water associated with crude oil production and Moghra Lake. This system plays an important role in the hydrogeologic regime of the study area. It governs the inflow and outflow routes of the groundwater system. A proper interrelation between the surface water and groundwater systems in the study area is clearly recognized. In the following, a brief description of those elements and their probable effect upon the groundwater system.

2. Moghra Lake

Moghra Lake, is a natural lake, locates at the extreme north eastern end of the Qattara Depression outside the study area- The Lake has a perimeter of about 11.6 Km and around 4.9 km^2 surface area. It is surrounded by swamps and sand dunes (**Hughes and Hughes, 1992**). Moghra lake water salinity attains about 3000 ppm and has a surface level of about 38 meters b.s.l.

Most of the hydrogeological studies on Moghra Lake state that the water is derived from the intersection of the Moghra aquifer water table with the ground surface. From the GPR investigation (**Khan et al., 2014**). The author deduced that Moghra Lake is a remnant of a much larger lake that was fed by numerous channels flowing from the southeast during glacial and interglacial stages of post Miocene period. According, the lake basin was eventually filled with sediments, most of which were converted into fluvial plains as they were overrun by fluvial systems. Lake filling is commonly regarded as a regressive process. However, the gradual landward siliciclastic facies changed from lake-offshore mud to lake-margin sand and pebbles, which is good evidence of decreasing lake size during the Quaternary period. The final stage of lake filling commonly involves emigration of eolian sand dunes and sand sheets. The lake is considered a drainage pond to the groundwater flow from southeast to northwest (**Fig. 5**).

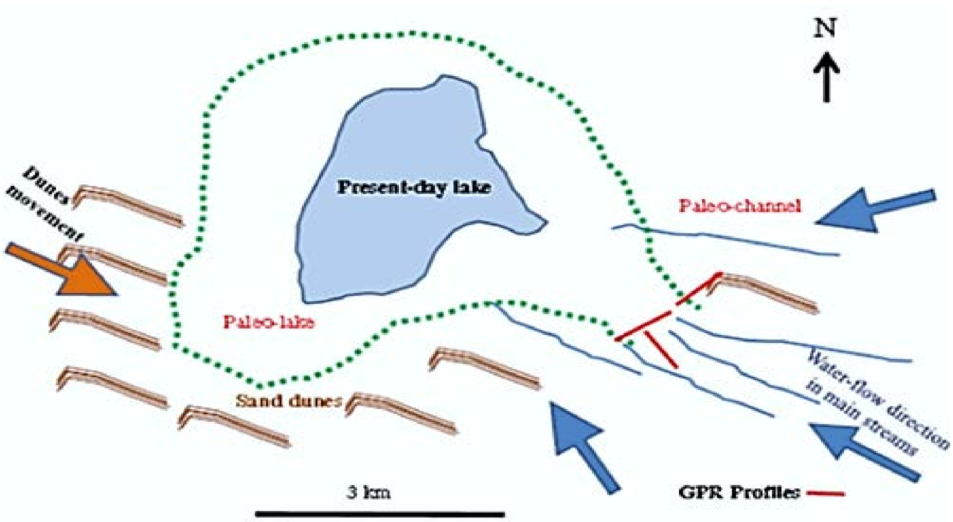


Fig. 5. Schematic map showing outline of the paleo-lake with braided discharge distributaries and present-day sand dune (**Khan et al., 2014**).

3- Disposal Lagoons

There are three main water disposal lagoons in the study (**Fig. 6**). Many other very small ones are present in separated areas. These ponds were excavated and deepened in sandy rocks which cover the ground surface of the area with depths ranges from 1m to 7 min some areas. The surface area of the main lagoons ranges from 0.08 to 2.08 Km^2 with a total surface area of about 3.28 Km^2 .The south western lagoon (pond 1) is the largest one where the north eastern is the smallest.

They are surrounded by swamps and sand sheets. These disposal lagoons are used to dispose the saline water associated with crude oil production of different oil fields of Abu El Gharadig oil fields. Large quantities of water drained daily to the un-lined disposal lagoons. The average quantity of water drained to these lagoons equal 7,155 m^3/day. As a result, a thin layer of oil floating on the surface of the ponds and mixes with the sandy soil of the pools and pond's walls. Mostly the oil layer is scraped from time to time, but considerable quantities dissolve in water and infiltrate downward. The disposal lagoons of the water associated with crude oil production represent a serious source of pollution to Moghra aquifer. The large quantities of water drained daily to the un-lined disposal lagoons, facilitate the salt water intrusion to the aquifer layer (**Table 1**).

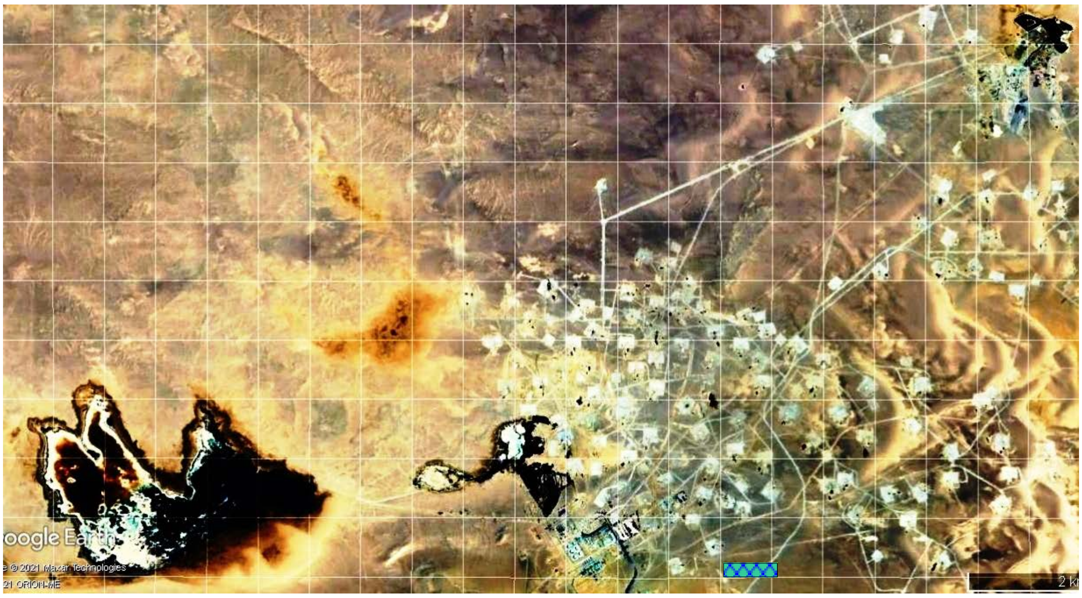


Fig. 6. Disposal Lagoons present in the study area.

Table 1. General characteristics of the disposal ponds.

Pond/Parameter	Perimeter (Km)	Area (Km2)	Salinity (ppm)
Pond 1	8.97	2.08	47000
Pond 2	5.3	0.40	42800
Pond 3	1.16	0.08	36000
Total	15.25	3.28	Aver. 42000

Efficiency for wells (2) tapped to Moghra aquifer Study area

Step draw down test was carried out at three discharge rates 48, 60& 66 m3/hrs. Respectively. Each step continued for 180 minutes and water level inside the well casing was recorded with the time (**Table 2**).

Table 2. Estimation of Formation loss, Well loss and well efficiency in Well No.2, Moghra aquifer.

Stage NO.	Discharge Rate (m3/hr)	Total Drawdown (m)	Specific drawdown S/Q) (hr/m^2)	B	C	Formation Loss (BQ)	Well Loss (CQ^2)	Total Loss (m)	Well Efficiency %
1	48	10.65	0.222	0.2077	0.0003	9.9696	0.692	10.661	93.52
2	60	13.5	0.225			12.4620	1.082	13.542	92.02
3	66	15	0.2273			13.7082	1.31	15.015	91.30

Among those results, the value of the formation loss (BQ) equals 12.5 m and the well loss equals 1.08 m for the pumping by a rate of 60 m3/hr. Where: **B**: Formation loss coefficient and **C**: well loss coefficient.

Groundwater Depths

The groundwater depths constitute great importance in the development and reclamation of desert lands, as they affect the cost of extracting groundwater by wells. ***The deeper the groundwater***, the higher the pumping economic cost, and vice versa.

The depth to water of Moghra aquifer varies from 0 m at Moghra spring to 141.24 m at Samaket Gaballa. (**Al-Sayyad, 2018**). The depth to water of Moghra aquifer 80 m for wells No. 2, 3, 5 & Elwany & 70 m for wells WG Study area (**Table 3**).

Table 3. Groundwater level measurements of Moghra aquifer in the study area (2011-2020).

Observation Well	Elevation (m)	Depth To Water (m)			Groundwater Level (m)		
		2011	2015	2020	2011	2015	2020
W2	-54	9.8	9.6	8.95	-63.8	-63.6	-62.95
W3	-50	14.85	14.5	14.1	-64.85	-64.5	-64.1
W4	-52		9.4	9.4		-61.4	-61.4
W5	-50	15.77	15.2	14.7	-65.77	-65.2	-64.7
WG1	-28	14.43	14.2	14.1	-42.43	-42.2	-42.1
WM1	-38	3.23	3.45	3.5	-41.23	-41.45	-41.5

A rise in the Moghra aquifer's water salinity in the study area was seen in the results of water analysis for water wells 2, 3&5 tapped to Moghra aquifer during time (**Table 4**).

Table 4. Salinity measurements for water wells tapped to Moghra aquifer in the study area (2011-2020)

Well Name	location		Total Depth (m)	Elevation m MSL	S.W.L m 2011	S.W.L m 2015	S.W.L m 2020	Salinity (ppm) 2011	Salinity (ppm) 2020
	latitude	Longitude							
W2	**29°57'38.9"**	**27°47'57.4"**	**188**	**-54**	**9.80**	**9.60**	**8.95**	**24700**	**30000**
W3	**29°58'23.2"**	**27°47'48.7"**	**168**	**-50**	**14.85**	**14.50**	**14.10**	**22100**	**33730**
W5	**29°58'20"**	**27°47'46"**	**180**	**-50**	**15.77**	**15.20**	**14.70**	**24100**	**35000**
W4 Elwany	**29°53'34"**	**27°42'54"**	**100**	**-52**	**-----**	**9.40**	**9.40**	**-----**	**16000**

Conclusion

The groundwater recharge and geochemical evolution in the study area and associated aquifers of the region are complex. Using hydro geochemistry and geological knowledge, a rise in the Moghra aquifer's water salinity in the study area was seen in the results of water analysis for water wells 2, 3 & 5 tapped to Moghra aquifer during time. Thes analysis results reflect the effect of salty lagoons for water associated with crude oil production in the Moghra aquifer in the study area. The large quantities of water drained daily to the un-lined disposal lagoons, facilitate the salt water intrusion to the aquifer layer.

So to eliminate this effect special recommendation must take on consideration.

- Drained water salty lagoons must be lined with P.V.C.
- Drained water can be re inject to depleted layers as storage layers for water taking on consideration underground injection rules by using underground injection control.
- Water associated with crude oil production can be re inject to oil production reservoir under oil layer for the purpose of enhanced oil recovery from the reservoir.

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