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Groundwater Potentiality and Suitability for Drinking and Irrigation in the New Valley, Western Desert, Egypt

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Abstract:

Egypt is facing increasing water demand by the rapidly growing population, increased urbanizations, higher standards of living and the agricultural policy which emphasizes expanding crop production in order to feed the growing population. The Western Desert of Egypt is considered as important area for expansion depending on the groundwater resources. The groundwater needs more studies regarding its quantity, quality and sustainability for irrigation and drinking purposes. The Nubian sandstone aquifer system (NSAS) is considered as one of the most significant and potable groundwater basins in the world; it is the only water resource for most of the areas sharing its valuable reserve. It extends over a vast area in Egypt, Libya, Sudan and Chad. The area occupied by the aquifer extends between lat 15° and 25° N and long 20° and 35 ° E. The area of the Nubian aquifer system of Eastern Sahara is about 2.35 millions km^2. It encompasses some 850000 km^2 in Egypt (670000 km^2 in Western Desert, including the area known as Wadi Elgidid (New Valley) CEDARE (2000) and Sefelnasr (2007). The current study aims to evaluate the groundwater potentiality and suitability for drinking and irrigation in the New Valley, Western Desert, Egypt. This evaluation includes analysis for the cations: Na^+, K^+, Ca^{++} and Mg^{++} and the anions: Cl^-, HCO_3^- and SO_4^{2-}, soluble heavy metals (Fe and Mn). Values of pH, TDS and EC of the groundwater samples in El Kharga and El Dakhla Oases were determined. The results were compared with the standards such as: Egyptian standard (2007), WHO (2006) and FAO standard (1980). Result concluded that soluble iron is the major problem for drinking water, since only 2.4% of the studied samples were in the safe limits for drinking. 42.8% of the studied samples are in the safe limits for the modern irrigation systems. Dealing with manganese, 89.8% of the studied wells were in the safe limits for drinking and there is no problem in irrigation. The soluble salts in the groundwater were at the safe level for drinking and irrigation.

Keywords: *Potentiality, Suitability, Evaluation, Groundwater, New Valley, Western Desert, Hydrochemical analysis, Anions, Cations, Heavy metals, Iron, Manganese, Total dissolved solids (TDS).*

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Introduction:

Egypt is facing increasing water demand by the rapidly growing population, increased urbanizations, higher standards of living and the agricultural policy which emphasizes expanding crop production in order to feed the growing population. The Western Desert of Egypt is considered as important area for expansion depending on the groundwater resources. The groundwater needs more studies regarding its quantity, quality and sustainability for irrigation and drinking purposes. The Nubian sandstone aquifer system (NSAS) is considered as one of the most significant and potable groundwater basins in the world; it is the only water resource for most of the areas sharing its valuable reserve. It extends over a vast area in Egypt, Libya, Sudan and Chad. The area occupied by the aquifer extends between lat 15° and 25° N and long 20° and 35 ° E. The area of the Nubian aquifer system of Eastern Sahara is about 2.35 millions km^2. It encompasses some 850000 km^2 in Egypt (670000 km^2 in Western Desert, including the area known as Wadi Elgidid (New Valley).

Location of study area:

The New Valley is bounded by Lat. 24° 32' 44", to 25º 37' N and Long. 27º 10' 24" to 29º, 00' 00" E, located on the south western part of Egypt (Figure 1), shares the international borders with Libya to the west and Sudan to the south. It is divided into 5 counties (markazs) which comprise 5 cities, 37 local units and 164 villages. The area of the New Valley is about 440,098 km^2, equivalent to 44% of the total area of Egypt and about 66% of the area of Western Sahara. It includes El Kharga, Baris, El Dakhla, Gharb Elmohoub, Abo Monqar and El Farafra Oasis.

The results of the census in 1996 that the population had reached 141,774 people, and the rate of population growth was 2.3%. In 2010, the population density on the total area is 0.5 per one km^2 and on the inhabited area of 166 inhabitants per 1 km^2. The present study deals mainly with the El Kharga and El Dakhla Oases which are considered the major Oases in the New Valley governorate (Figure 2). El Kharga Oasis is located about 230 km South-West of Assiut occupying about 86223 km^2 with the population reached 80173 persons (2010). El Dakhla Oasis is located about 190 km west of El Kharga Oasis. The area of El Dakhla is about 120438 km^2 with population number of 81981 persons. El Dakhla Oasis was subdivided recently to El Dakhla and Balaat.

Objectives:

The main objective of present study is:

1- Evaluation the groundwater potentiality and suitability for drinking and irrigation in the New Valley, Western Desert, Egypt. The evaluation includes groundwater wells (Figures 3 and 4) in El Kharga (37 studied wells) and El Dakhla Oases (154 studied wells).

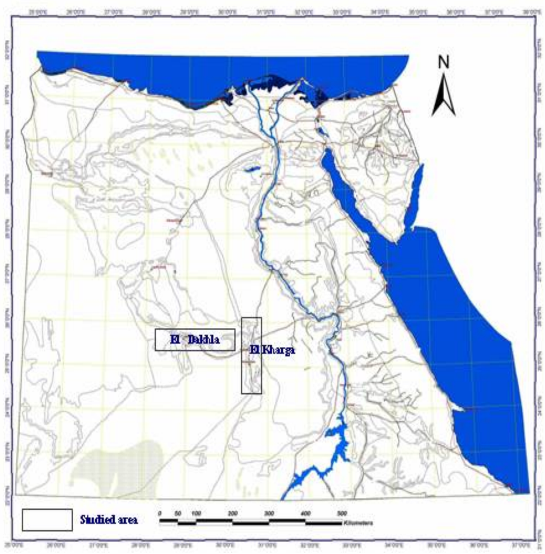
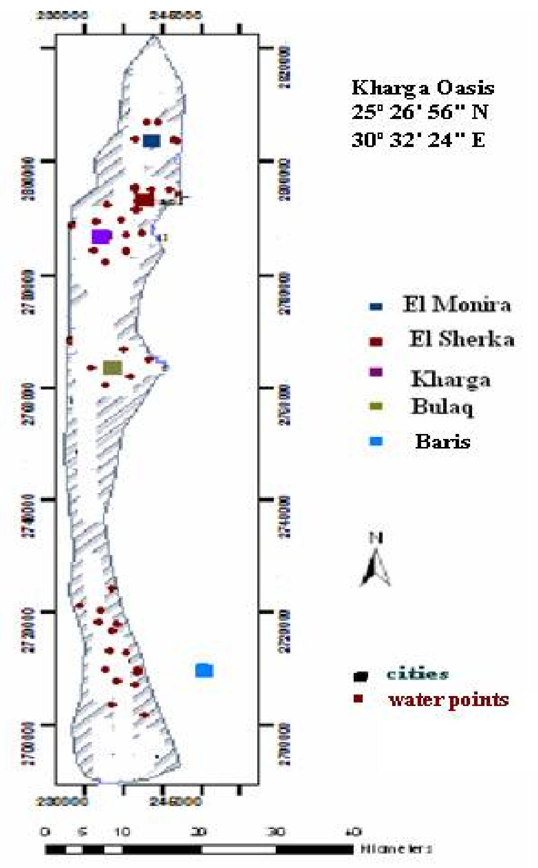


Fig. (1): Map of Egypt showing the location of the studied areas

Fig. (2): Satellite image of the New Valley Governorate



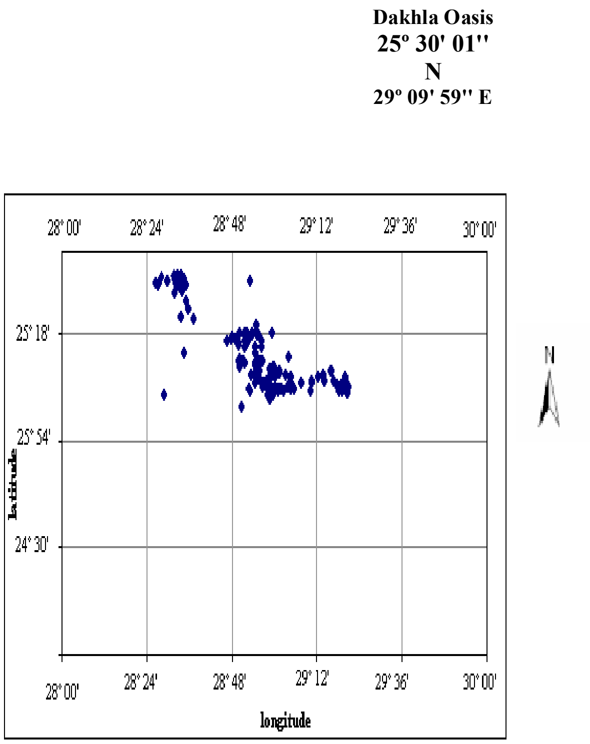


Fig. (3): Studied wells in El Kharga Oasis

Fig. (4): Studied wells in El Dakhla Oasis

Materials and Methods:

The work is subdivided into:

1. Collecting groundwater data in El Dakhla and El Kharga Oases from the Ministry of Irrigation.
2. Analyzing the data to evaluate the groundwater potentiality and suitability for drinking and irrigation in the New Valley. This evaluation includes analysis for cations: Na^+, K^+, Ca^{++} and Mg^{++} and anions: Cl^-, HCO_3^- and $SO4^2$ and soluble heavy metals (Fe and Mn) and related factors (pH, TDS and EC) of the groundwater samples in El Kharga and El Dakhla Oases.
3. Producing graphical presentation maps for major cations, anions, soluble heavy metals and related of the groundwater samples in El Kharga and El Dakhla Oases by using SURFER 9 software.
4. Comparing the results with the standards such as: Egyptian standard (2007), WHO (2006) and FAO standard (1980).

Results and Discussion:

1. Iron in the studied groundwater wells:

The studied groundwater samples from the El Dakhla and El Kharga are characterized by high soluble iron concentration. The frequency of iron concentrations in 379 groundwater samples is presented in Table (1). Considering suitability of the groundwater for drinking according to WHO (2006) and Egyptian limit (2007), it was found that only 2.4 % of the groundwater wells are in the permissible limit and only 17.2 % of the wells are suitable according to the Egyptian limit (1995) (< 0.3 - 1 ppm) and 82.8% are over the acceptable limit. Therefore, groundwater treatment for drinking is a vital issue. Also, utilizing this groundwater for sprinkler or trickle or drip irrigation methods is questionable, since more than 3 ppm soluble iron in the groundwater is harmful for the systems (Gameh, 2001). Only 42.8 % of the groundwater wells are at the safe limit, while 23.5% are in medium hazardous range, 28.2 % are highly hazardous and 5.5 % are very highly hazardous. Using this groundwater for irrigation needs especial treatment before being pumped in the irrigation system.

Table (1): Frequency of iron concentration in the investigated groundwater wells

Iron (ppm)	0.3	1	2	3	4	5	6	7	8	9	10	11	13	16	26	total
Number of wells	9	56	51	46	26	33	30	52	45	10	4	7	8	1	1	379
% Frequency of wells	2.4	14.8	13.5	12.1	6.9	8.7	7.9	13.7	11.9	2.6	1.1	1.8	2.1	0.4	0.4	100
Suitability for Drinking% (1995)	17.2		82.8													100
Suitability for Drinking% (2007)	2.4	97.6														100
***Suitability for Irrigation%**	42.8 Safe				23.5 Medium hazard			28.2 Highly hazard		5.5 Very highly hazard						100

*(Gameh, 2001)

The obtained kriged contour maps of iron and depth distribution show that iron concentration of the 154 studied groundwater wells in El Dakhla was higher than the iron concentration of 34 groundwater wells in El Kharga Oasis (Figures 5-8). The iron in El Kharga contour map varied between 0.4 to 7.5 ppm in Monerai, El Agouz and Baris 24/56 at the same respect of 0.5 ppm with surface distance. However, in Dakhla Oasis the iron varied between 1 and 13.2 ppm in El Khasar, El Elstawady and Balaat 44/5 with 1 ppm surface distance.

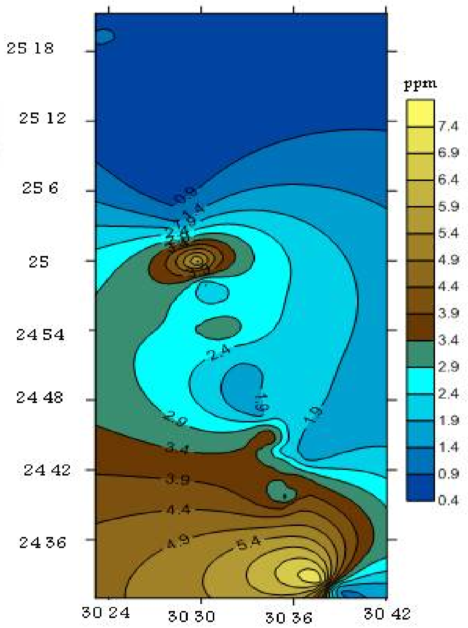


Fig. (5): A kriged contour map showing the iron concentrations of the groundwater in El Kharga Oasis

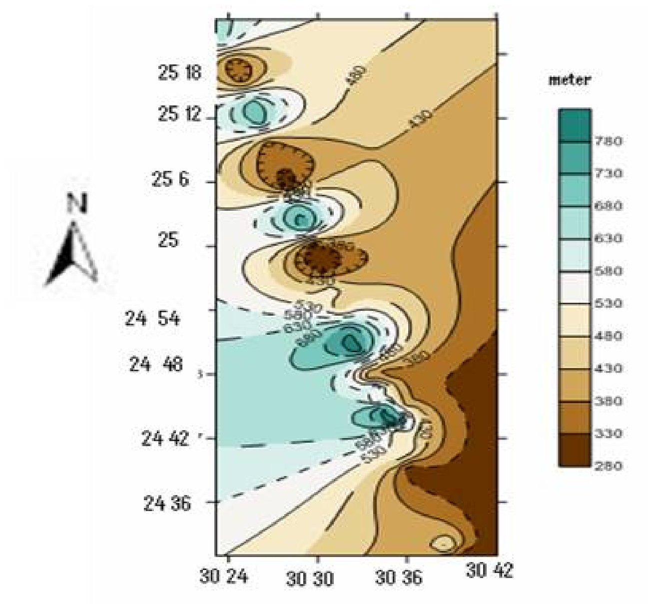


Fig. (6): A kriged contour map showing the depth of the groundwater in El Kharga Oasis

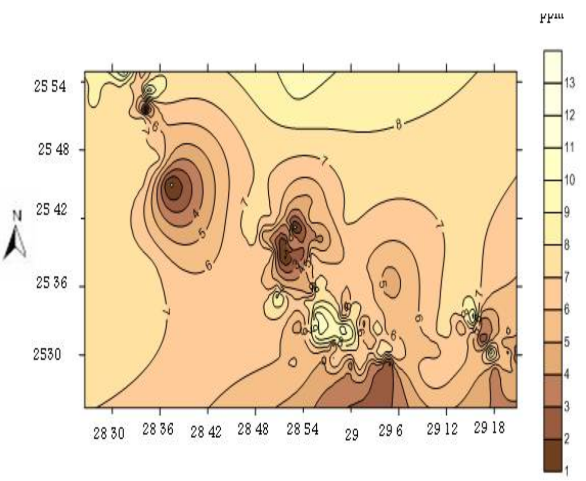


Fig. (7): A kriged contour map showing the iron concentrations of the groundwater in El Dakhla Oasis.

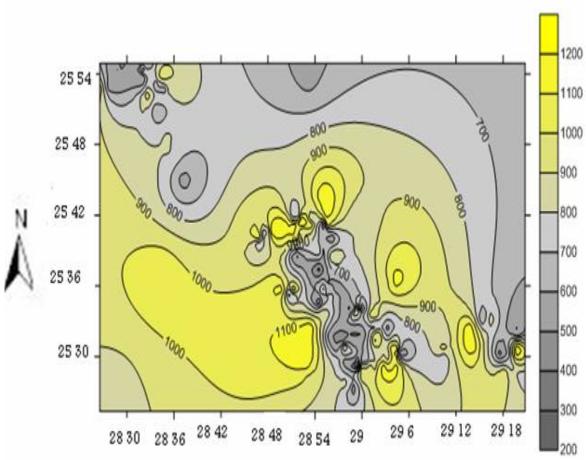


Fig. (8): A kriged contour map showing the depth of the groundwater in El Dakhla Oasis

2. pH of the studied groundwater wells:

The pH of the groundwater in the New Valley is characterized by a wide range of 5.4 – 8.8. The frequency of pH in 394 groundwater samples is presented in Table 2. Conceding suitability of the groundwater for drinking, there are 70.1 % of the groundwater wells in the permitted range (7- 8.5) according to the Egyptian limits, 1995 and 29.9% of wells are in maximum permitted range (6.5 – 9.2). However, the Egyptian permitted range is very wide therefore the pH of the groundwater is not a problem for drinking, but the pH affects the solubility of iron since they are negatively correlated (R= - 0.76). Utilizing this groundwater of low pH with high soluble iron in sprinkler irrigation systems cause corrosion for the metallic pipes **(**O'Connor, 1971, Hem, 1989, Chapelle, 1993, Davis, 1997 and Gameh, 2001).

Table: (2) Frequency of pH values in the groundwater of the New Valley

p H	5.4	5.8	6	6.2	6.4	6.6	6.8	7	7.2	7.4	7.6	7.8	8	8.5	8.8	total
No of wells	3	6	3	7	16	37	40	44	43	61	55	45	8	20	6	394
%	0.76	1.5	0.76	1.8	4.1	9.4	10.2	11.2	10.9	15.5	14	11.4	2	5.1	1.5	100
Suitability for drinking %	28.4							70.1							1.5	100
Suitability for irrigation%	2.3		96.2												1.5	100

The kriged contour maps of the pH values distribution show that the studied groundwater wells in Dakhla is more basic than the groundwater wells in Kharga Oasis (Figures 9 and 10). The pH in Kharga surface map varies between 6.2 to 7.8 in Kharga 41 and Elsherka 18/R6 at the same respect with 0.2 surface distances. However in Dakhla Oasis, the pH varies between 6.4 to 8.8 ppm in El Kaser 2 and Gharb El Maohoub with 0.2 surface distances.

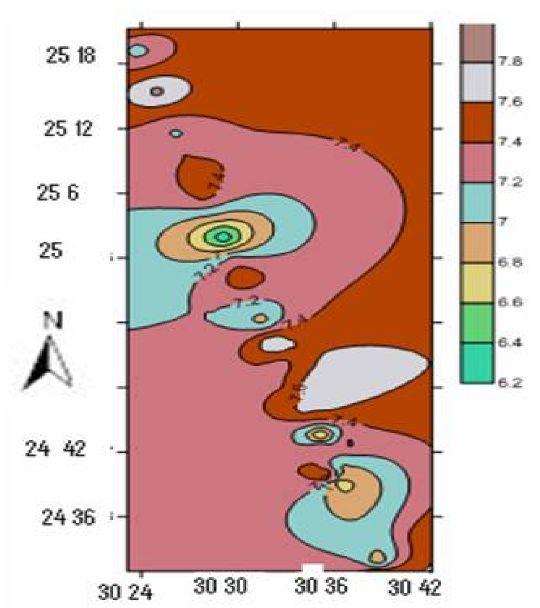


Fig. (9): A kriged contour map showing the pH values of the groundwater in El Kharga Oasis

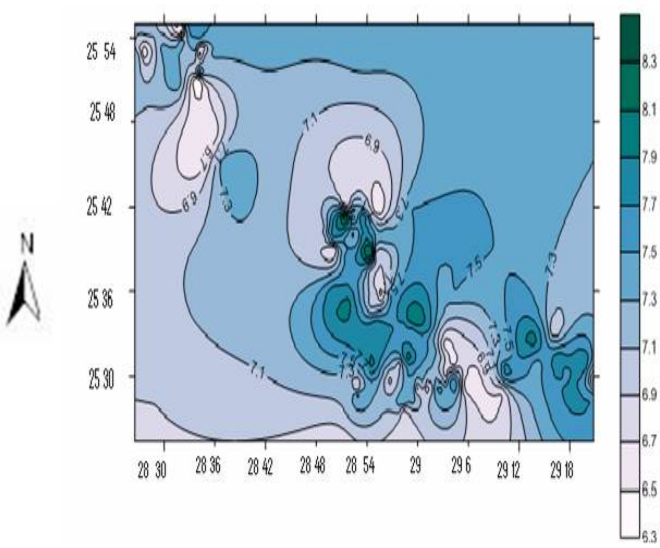


Fig. (10): A kriged contour map showing the pH values of the groundwater in Dakhla Oasis

3. TDS of the studied groundwater wells:

The TDS of the groundwater in the New Valley indicates by low total dissolved salts (TDS). The frequency of TDS in 252 groundwater samples is presented in Table 3. Considering suitability of the groundwater for drinking, 96.5 % of the groundwater wells are in the permitted range according to the USA, WHO and the minimum Egyptian limits, 1995 (500 ppm) and 3.5 % of the wells are in the maximum permitted range of 1000 ppm according to the Egyptian limits, 2007. However, the Egyptian permitted range is very wide therefore the TDS of the groundwater is not a problem for either drinking or irrigation. Almost 93% of the groundwater has no restriction for irrigation and only 6.7 % has slight to moderate restriction according to FAO.

Table (3): Frequency of average of TDS values in the groundwater of the New Valley

TDS ppm	50	100	150	200	300	400	450	500	550	600	650	1200	total
No of wells	1	3	92	60	29	37	13	8	4	3	2	none	252
%	0.4	1.2	36.5	23.8	11.5	14.7	5.2	3.2	1.6	1.2	0.79	0	100
[a] Suitability for drinking %	96.5[a]								3.5[b]				100
[c] Suitability for irrigation%	93.3 no restriction							6.7 slight to moderate restriction					100

[a] USA, WHO and Egyptian limits for drinking water 1995 and 2007, [b] Egyptian Maximum limit for drinking water, [c] FAO limits for irrigation water 1974.

The kriged contour maps of TDS distribution shows that the studied groundwater wells in Dakhla contain total dissolved solids more than the groundwater wells in Kharga Oasis (Figures 11 and 12). The TDS in Kharga surface map varied between 200 to 630 ppm in Genah 4/2 and Bulaq 25 at the same respect with 60 ppm surface distances. However, in Dakhla Oasis the TDS varied between 50 to 650 ppm in Moat 29 and Blaat 44/5 with 100 ppm surface distances.

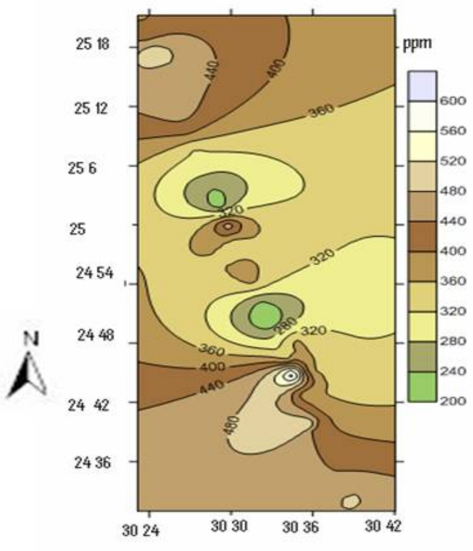


Fig. (11): A kriged contour map showing the TDS values in the groundwater of Kharga Oasis

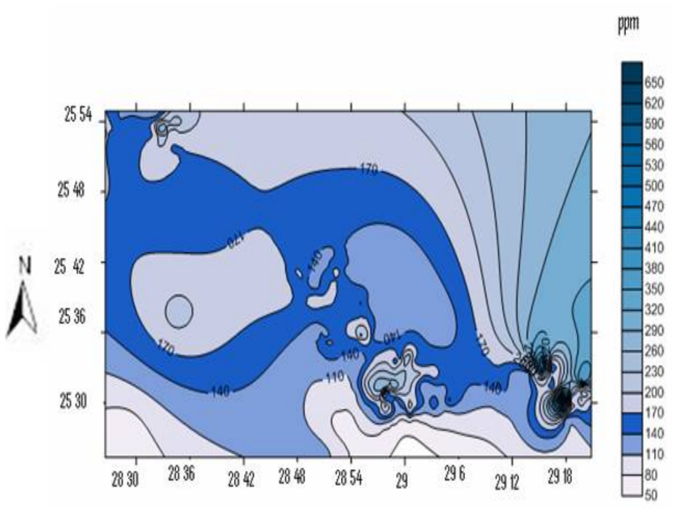


Fig. (12): A kriged contour map showing the TDS values in the groundwater of Dakhla Oasis

4. Manganese in the studied groundwater wells:

The Frequency of Mn concentrations in 197 wells of the New Valley (Kharga and Dakhla Oasis) are presented in Table (5). There are 79 groundwater wells with Mn concentration of 0.05 ppm. Those represent 40% of the wells, which are in the allowed values according to the WHO. The remained groundwater wells (60 %) have Mn concentration ranging from 0.1 to 2 ppm which is not accepted according to the WHO. According to the Egyptian limit, 1995 (0.1-1 ppm) there are 106 groundwater wells having Mn lower than 0.1 ppm with percentage of 53.7 %, these are accepted for drinking while there are 46.3 % of wells higher than the permitted range. But according to Egyptian limits, 2007, there are 89.8% in the permitted limits and 10.2 % higher than the Egyptian permitted limits. Considering the suitability of groundwater for irrigation according to the FAO limits (60 ppm), all the 197 groundwater wells are suitable for irrigation. However, the maximum Mn concentration in these groundwater wells was 2 ppm in El – Kaser 1 well at Dakhla.

Table (5): Frequency of the average Mn values in the groundwater of the New Valley.

Mn ppm	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1	2	total
No of wells	79	27	26	21	24	4	5	7	1	1	2	197
%	40	13.7	13.2	10.7	12.2	2	2.5	3.6	0.5	0.5	1	100
[b] Suitability for drinking Egypt (1995)	53.7		46.3									100
Suitability for drinking Egypt (2007)	89.8					10.2						100
[a] WHO	40	60										100
[c] Suitability for Irrigation	100											100

[a] USA, WHO 1975 , [b] Egyptian limit for drinking water, 1995 and 2007 [c] FAO limits for irrigation water 1974.

The kriged contour maps of the manganese distribution show that the Mn contents in the studied groundwater wells in Dakhla are higher than those in Kharga Oasis (Figures 13 and14). From the surface map in Kharga, the Mn content varies between 0.1 to 0.8 ppm in El Sherka 20 R2 and Kharga 26 at the same respect with 0.1 ppm surface distances. However, in Dakhla Oasis, the Mn content varies between 0.1 and 1.9 ppm in well Moat (29) and 5% of the studied samples in Dakhla have 0.1 ppm such as well El Maohoub (12/2) and 4.5% has 0.8 ppm such as Moat 14 with 0.2 ppm surface distances.

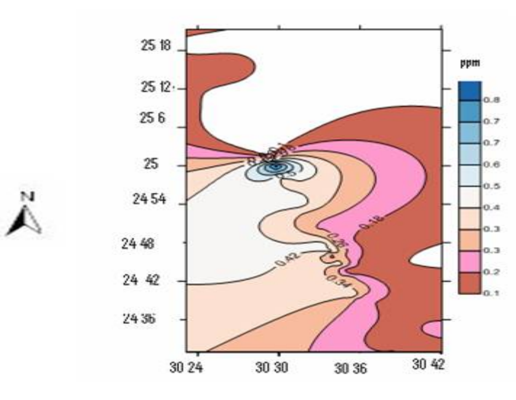


Fig. (13): Manganese distribution kriged contour map of Kharga Oasis

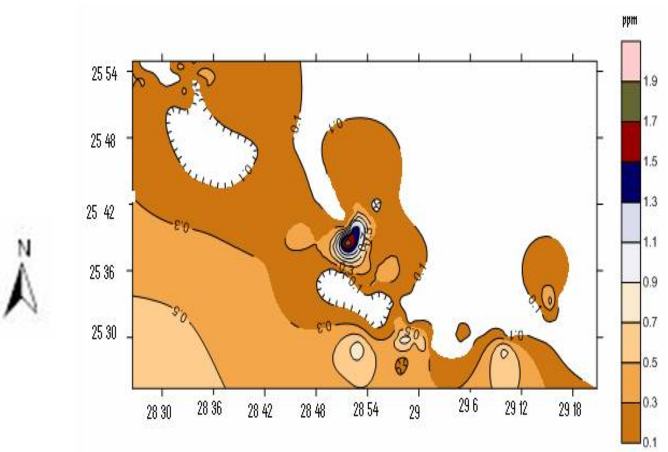


Fig. (14): Manganese distribution kriged contour map of Dakhla Oasis

5. Sulphate in the studied groundwater wells:

The sulphate concentration in the groundwater of the New Valley is generally low. The frequency of SO_4^{-2} in 329 groundwater samples is presented in Table (6). Considering the suitability of the groundwater for drinking, all the sampled wells are lower than the permitted range according to the USA, WHO and Egyptian limits, 2007 (250 ppm), the Egyptian limits (200 - 400 ppm), 1995 also according to FAO limits (0 – 980 ppm) for irrigation. Therefore the SO_4^{-2} of the groundwater is not a problem for either drinking or irrigation.

Table (6): Frequency of average of SO_4^{--} values in the groundwater of the New Valley

SO_4^{-2} ppm	20	40	60	80	100	120	140	160	200	total
No of wells	85	120	60	30	14	7	8	3	1	329
%	26	36.5	18.2	9.1	4.3	2.1	2.4	0.91	0.3	100
Suitability for drinking %	100									100
Suitability for Irrigation%	100									100

6. Chloride in the studied groundwater wells:

Generally, the total dissolved salts are low in the groundwater of the New Valley. Chloride is one the major components of these salts therefore chloride is low. The frequency of chloride in the 329 groundwater samples is presented in Table (7). Considering suitability of the groundwater for drinking, all the groundwater wells are in the permitted limits according to the USA, WHO and Egyptian limits, 2007 (250 ppm), the Egyptian limits (200 - 600 ppm), 1995 and FAO limits (0 – 1050 ppm). Therefore, the Cl^- concentration in the groundwater is not a problem for either drinking or irrigation.

Table (7): Frequency of average Cl^- values in the groundwater of the New Valley

Cl^- ppm	20	40	60	80	100	120	140	160	200	total
No of wells	85	120	60	30	14	7	8	3	1	329
%	26	36.5	18.2	9.1	4.3	2.1	2.4	0.91	0.3	100
Suitability for drinking %	100									100
Suitability for Irrigation%	100									100

7. Bicarbonate in the studied groundwater wells:

The bicarbonate in all the groundwater wells in the New Valley is low. The frequency of HCO^-_3 in 329 groundwater samples is presented in Table (8). Considering suitability of the groundwater for drinking, all the groundwater wells are in the permitted limits according to the USA, WHO (500 ppm), the Egyptian limit, 1995 (500 ppm) and FAO limits (0 – 610 ppm). Therefore the HCO^-_3 of the groundwater is not a problem for either drinking or irrigation.

Table (8): Frequency of average of HCO_3^- values in the groundwater of the New Valley

HCO^-_3 ppm	20	40	60	80	100	120	140	160	200	total
No of wells	5	89	136	17	44	16	8	1	13	329
%	1.5	26	41	5.2	13.4	4.9	2.4	0.3	4	100
Suitability for drinking %	100									100
Suitability for irrigation%	100									100

8. Electric conductivity in the studied groundwater wells:

The electric conductivity (EC) in the groundwater of the New Valley as alternative measurement of the TDS is presented in Table (9). The EC is usually used for agriculture irrigation suitability. Generally, the EC of the groundwater in the new valley is suitable for irrigation since 42.5 % of the groundwater wells have no restriction for irrigation, 50.6 % has slight to moderate restriction, and 6.9 % has severe restriction according to FAO limits.

Table (9): Frequency of EC values in the groundwater of the New Valley

EC µSm^{-1}	150	200	250	300	400	500	600	700	750	800	900	1000	total
Frequency	6	38	36	34	29	10	6	11	5	6	3	4	188
%	3.2	20.2	19.1	18.1	15.4	5.3	3.2	5.9	2.7	3.2	1.6	2.1	100
Sum%	42.5%			50.6%						6.9 %			100

9. Sodium adsorption ratio (SAR) in the studied groundwater wells:

The sodium adsorption ratio (SAR) is a measure of sodium hazard of the irrigation water on the irrigated land. It is calculated from the soluble sodium divided by the square root of half the concentrations of calcium and magnesium in water. The frequency of SAR in 188 groundwater samples is presented in Table (10). Considering suitability of the groundwater for irrigation, all the groundwater wells have no sodium hazard on the irrigated land according to FAO limits, and can be used for irrigation of all crops especially the sensitive to sodium such as Citrus.

Table (10): Frequency of SAR values in the groundwater of the New Valley

SAR epm	0.2	0.4	0.6	0.8	1	1.2	1.4	2	2.4	2.6	2.9	total
Frequency	7	18	17	44	24	23	13	4	3	3	1	188
%	3.7	9.6	9	23.4	12.8	12.2	6.9	2.1	1.6	1.6	0.53	100

10. Residual sodium carbonate (RSC) in the studied groundwater wells:

The Residual sodium carbonate (RSC) is used in irrigated agriculture as a measure for the expected residual carbonate in the irrigation water. It is calculated by subtraction of the soluble calcium and magnesium from the values of soluble carbonate and bicarbonate in me\l. Carbonate is not favored ions in irrigated land because it cause alkalinity hazard to the soil and the growing crops. The frequency of RSC in 190 groundwater samples is presented in Table (11). Considering suitability of the groundwater for irrigation, there are 72.2 % of the groundwater wells in class one (RSC < 1.25 me /l) that is considered as safe, which is good quality and suitable for using in irrigation for all types of soils. 22.1 % of the groundwater wells in class two (1.25 and 2.5

me/l) that it is considered as marginal, which may be used in well-drained soils, and 7 % of the groundwater wells in class three (< 1.25 me/l) that considered as not suitable especially in soil that is poor in calcium and drainage according to FAO limits.

Table (11): Frequency of RSC values in the groundwater of the New Valley

RSC me/l	low	medium	high	total
Frequency	141	42	7	190
%	72.2	22.1	3.7	100
Criteria	< 1.25	1.25-2.5	> 2.5	----

Conclusion:

The evaluation of the studied groundwater wells in the New valley, Egypt, concluded that the soluble iron is the major problem for drinking water, since only 2.4% of the studied samples were in the safe limits for drinking, and 42.8% are in safe for the modern irrigation systems. Dealing with manganese, 89.8% of the studied wells were in the safe limits for drinking and there is no problem in the irrigation system. The soluble salts in the groundwater were at the safe level for drinking and irrigation.

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تقييم امكانيات المياه الجوفية وقياس مدى صلاحيتها للشرب والري في الوادي الجديد، الصحراء الغربية، مصر

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[٢]قسم الجيولوجيا - كلية العلوم جامعة أسيوط

الملخص:

تواجه مصر زيادة الطلب علي المياه بسبب النمو السكاني السريع، وارتفاع مستويات المعيشة والسياسات الزراعية الأمر الذي أدي إلي التوسع في البحث عن المياه الجوفيه واستحداث انماطا حديثه للزراعه لكي تغطي احتياجات النمو السكاني، وتعد الصحراء الغربية من أهم المناطق المصرية في التوسع الزراعي معتمده علي المياه الجوفية وتحتاج المياه الجوفية لمزيد من الدراسات التي تخص الكمية والجودة والاستدامة لأغراض الري والشرب . يعد خزان الحجر الرملي النوبي أحد أهم خزانات المياه الجوفيه الصالحه للشرب في العالم ، فهو يمتد عبر مصر وليبيا والسودان وتشاد، بين خطوط الطول ١٥ درجة و ٢٥ درجة شمالا ودوائر العرض ٢٠ و ٣٥ شرقاً ويشغل مساحة ٢,٣٥ مليون كليومتر مربع منها ٨٥٠٠٠٠ كليومتر مربع في مصر(٦٧٠٠٠٠ كليومتر مربع في الصحراء الغربية مشتملة علي محافظة الوادي الجديد).

تهدف هذه الدراسة إلي دراسة الموارد المائية في الوادي الجديد وتقييم مدي صلاحيتها للشرب والري وذلك طبقاً للمعايير الدولية والمحلية وهذا التقييم للكاتيونات (الصوديوم، البوتاسيوم والماغنسيوم) والانيونات (الكلوريدات، البيكربونات والكبريتات) والمعادن الثقيلة القابلة للذوبان (الحديد والمنجنيز) والعوامل ذات الصلة مثل (الرقم الهيدروجيني، المواد الكلية الذائبه، التوصيل الكهربي للمياه، احتمالية ادمصاص الصوديوم و كربونات الصوديوم المتبقية).

خلصت نتائج الدراسه التي تم أجراؤها علي ابار المياه الجوفيه المتواجدة في الوادي الجديد أن مشكلة المياه الجوفيه تتلخص في تواجد الحديد والمنجنيز بها ، فبالنسبة لتواجد عنصر الحديد بآبار الوادي الجديد فقد تبين أنه لا يوجد سوي ٢,٤% من الأبار المدروسة (عددها ٣٩٤ بئر) وقعت في الحد الآمن للشرب وأن ٤٢,٨% من الآبار المدروسة وقعت في الحد الآمن لاستخدامها في طرق الري الحديثة. أما بالنسبة لتواجد عنصر المنجنيز بآبار المياه الجوفيه فقد اتضح أن ٨٩,٨% من الآبار المدروسة في الحدود الآمنه للشرب ولا يوجد مشكلة منجنيز بالنسبة لمياه الري، أما بالنسبة للعناصر الآخري الذائبة فلا يوجد بها مشكلة فكلها تقع في الحدود المسموح بها بالنسبه للشرب والري.