Interaction between Surface Water and Groundwater in Experimental Site Close to Damietta Branch, Egypt.

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Abstract

The interaction between surface and groundwater is considered a continuous process. That study dealt with the interaction between the surface and groundwater in an experimental site close to the Damietta branch downstream of Delta barrage. Four groundwater wells with different depths (14m as shallow and 160m as deep) located inside and surrounding the experimental site. The distances of those wells from the riverbank ranged from 60 to 190m. Monthly water samples collected from the Nile River and wells during low and high river flow. Samples analyzed for chemical parameters, heavy metals, and bacteriology. The results showed that the river water salinity changed depending on the change in the river flow. While, the groundwater wells salinity values differed from winter to summer seasons with a high standard deviation. Analysis of variance indicated the significant relationships between the river and those of the studied wells. Manganese, Iron, Barium and Zinc concentrations were higher in groundwater than in the river. Fecal and total coliform appeared in surface water while disappearing in groundwater. The results showed during the Nile high flow discharge, the water levels of the observation well increased, and the opposite occurred during the low level of the Nile Damietta branch. The statistical relationship between water levels in the Damietta branch and the observation well was strong. The surface and groundwater were suitable for all purposes.

Keywords: Damietta branch; Egypt; Groundwater; Interaction; Surface Water.

1- Introduction

A significant component of the water cycle is the interaction between surface water with groundwater in a watershed. The equilibrium water and maintaining material exchange are the fundamental function of the surface and groundwater ecosystem, which affects water resources management and ecological system protection in arid areas (Sophocleous 2002, Lambs 2004, and Kalbus et al., 2006).

Interface and chemical exchange between surface and groundwater water are essential segments of the hydrological cycle. Surface water may recharge to the aquifer, where the groundwater may remain in storage for short or long periods. Finally, the groundwater discharged back into the stream.

In landscapes, surface water bodies like streams and rivers connected in three ways with groundwater: receive or gain groundwater, recharge groundwater or do both through the streambed, depending on stream location. Stream gain water if the groundwater table elevation is higher than the stream water surface.Stream loss water if the groundwater table below stream water surface elevation. If the groundwater table varies through the year, a part of the stream could receive groundwater for a time while other year times lose water to groundwater (Winter, 1999 and Stephen et al., 2002). In the wetland, surface and groundwater interactions controlled by the hydraulic head difference between groundwater and wetland (Haris Hasan Khan and Arina Khan 2019). The water movement between surface and groundwater leads to mixing of their qualities. High quantities of dissolved chemicals or nutrients can transfer to the associated groundwater (Kirk and James 2012).

Botta et al. (2014) mentioned that, there are four general flow scenarios at least associated with surface/groundwater interaction in a fluvial plain: gaining, losing, parallel flow and flow-through. Conversely, the streams that recharge the aquifer have water levels higher than hydraulic heads in the underlying sediment. In a flow-through scenario, hydraulic levels on one side of the stream bank are higher than on the other. This case usually occurs when the stream curves and becomes oriented perpendicular to the general direction of groundwater flow and the fluvial plain.

Che et al. (2021) studied relationship between surface and groundwater based on isotopic tracing methods in alluvial plain of the lower Yangtze River basin. The results demonstrated that in an alluvial plain, the river is recharged by groundwater, whereas in the urban area, the River recharged by groundwater. The groundwater recharge sources in alluvial plains are lake water and precipitation. In the mountainous area, groundwater recharged the River, but in the flat area, it recharged the River. Zhang et al., (2022) studied relationship between surface and groundwater in Wei River branches. Water samples collected, and hydrochemistry and isotopes analyzed. The results revealed that the hydraulic connectivity regarding the surface and groundwater relationships of Wei river was naturally weak bigger south than north of the river.

The study conducted in an experimental site close to the Damietta branch at Delta barrage inside the National Water Research Center camps (NWRC), Ministry of Water Resources and Irrigation (MWRI). This research aimed to study the interaction between surface and groundwater, considering water levels and quality.

2- Material and methods

To achieve the research objective the following activities conducted in the selected study area:

2-1 Study Area

The research area selected in the north direction of Delta barrage on the western side of the Damietta branch inside an experimental site related to National Water Research Center (NWRC) camps, ministry of water resources and irrigation (MWRI) figure (1). Damietta branch controls the River Nile water discharge to the east part of Nile delta from the Delta barrage. The experimental site is cultivated with some vegetables and wheat that irrigate from the surface and groundwater.

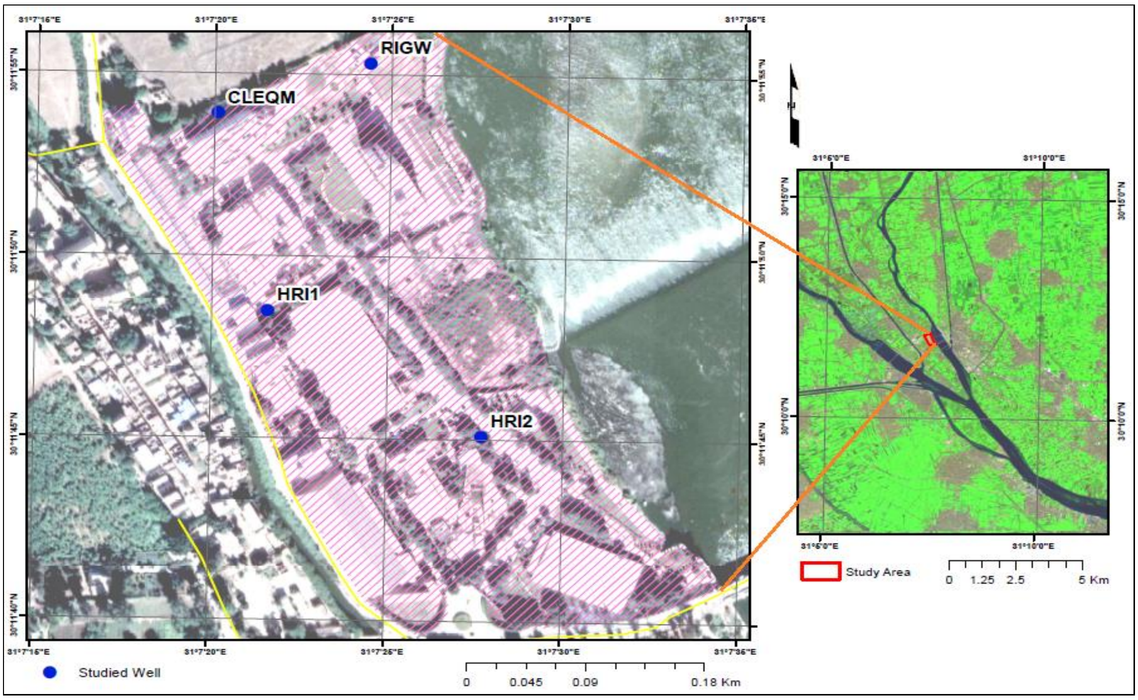

Figure (1). Location of National water research center camps (NWRC) and wells site.

Four groundwater wells considered in the study close to the River Nile at Damietta branch . Groundwater Research Institute for (RIGW) observation well with 14m depth. Production well related to Central Laboratory for Environmental Quality Monitoring (CLEQM) with a depth of 160m. In addition, two production wells (HRI1 and HRI2) related to the Hydraulic Research Institute with different depths of 70m and 55m. The distances of those wells from the riverbank ranged from 60 to 190 m (figure 1). Locations, descriptions of the research studied wells, and those distances from the riverbank demonstrated in the table (1).

Table (1). Locations and description of the studied wells.

Well	Coordinate		Well depth (m)	Distance from Nile (m)	Well type
RIGW	N 30 11 55.3	E 31 07 24.5	14	60	Observation
CLEQM	N 30 11 53.9	E 31 07 20.2	160	170	Production
HRI 2	N 30 11 45.1	E 31 07 27.8	55	75	Production
HRI 1	N 30 11 48.5	E 31 07 21.7	70	190	Production

The important aquifer in the studied area is the Nile delta aquifer. It consists of coarse sand and gravel with intercalation of clay lenses sometimes. The thickness of Quaternary aquifer increases in a northward direction and ranges between about 150 m in the south near Cairo and reaches about 500 m near Tanta, and increases to about 1000 m near the north coast. The aquifer thickness decreases towards the eastern and western fringes. The value of hydraulic conductivity "K" of the aquifer increases in the north and east direction, where its values vary from less than 50 m/day in the south to more than 100 m/day in the central portion then decreases again due to clay intercalation (RIGW/IWACO, 1992). It is a semi-confined aquifer due to the presence of a clay cap above the aquifer, which generally varies in its thickness from 20 m in the north and decreases until it disappears in Nile delta boundaries as shown in the regional cross section presented in Figure (2).

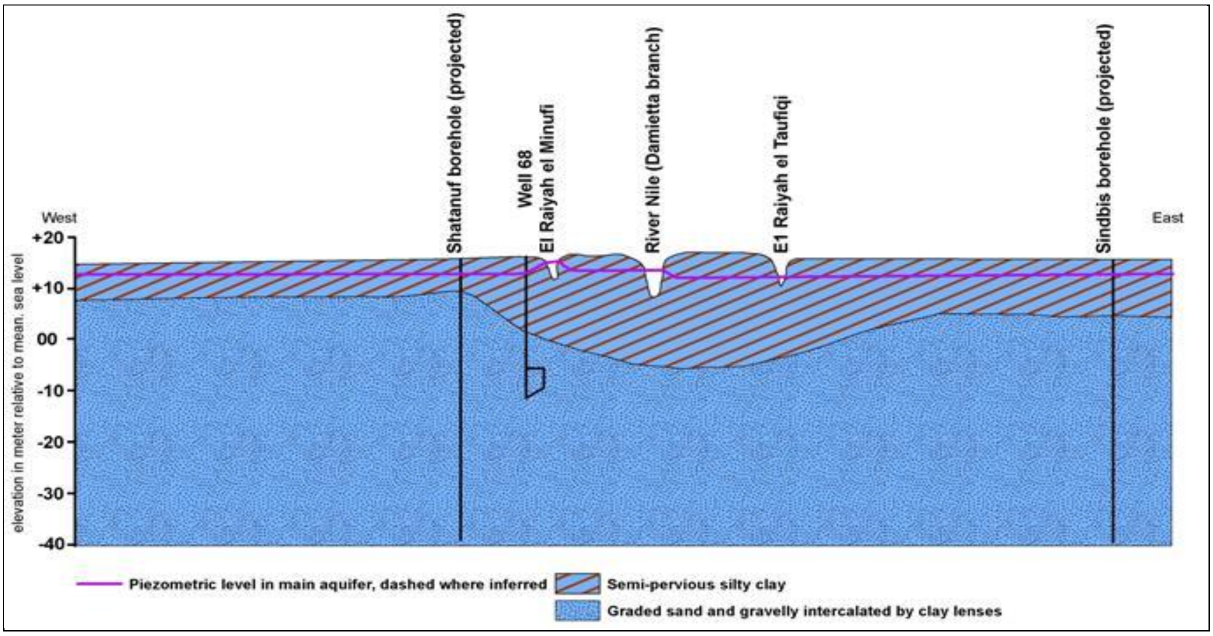

Figure (2). Regional hydrogeological cross section (RIGW/IWACO, 1992).

2-2 Water Quality

On a monthly base, surface water samples collected from the River Nile, the Damietta branch beside four different groundwater wells. Samples chemically analyzed in a central laboratory (CLEQM) related to NWRC. Samples were collected considering the quality control recommended by APHA, 2017 as follows:

- Samples collected in one-litre plastic bottles to determine the physio-chemical parameters (pH, EC, TDS), soluble anions and cations.
- Samples collected in plastic bottles acidified with two cm^3 of nitric acid to determine the concentrations of 16 heavy metals.
- For bacteriological analysis, samples collected in sterilized plastic bottles to determine total coliform and Fecal coliform.

2-3 Water Levels

Nile water levels are obtained from the Delta barrage irrigation office, which is usually measured through a reading scale fixed on the barrage. While the depth of the groundwater was measured during the water sampling process for the RIGW observation well using a light sound measuring tap.

Statistical analysis performed for the data of the different locations. The statistical analysis includes the following:

- Calculate the average, maximum, minimum, variance and standard deviation.

- Perform analysis of variance using the ANOVA test for total dissolved solids (TDS) between the Nile water and each well to examine the significance between each pair.
- Calculate the formula and correlation coefficient (R2) for the relation between the water level in the Nile River and the observation well.

3- Results and Discussion

The study deals with the interaction of surface and groundwater and its impact on some water quality parameters, in addition to the interaction between the water levels of surface and groundwater.

3-1 Water Quality

The study of the interaction includes statistical analysis of chemical analysis results for total dissolved salts (TDS). Soluble cations (Ca, Na, Mg, K) as well as soluble anions (CO_3, HCO_3, Cl, SO_4, NO_3, PO_4, NO_2, F), sodium adsorption ratio (SAR) and adjusted sodium adsorption ratio (Adj- SAR). Heavy metals as Mn, Fe, Al, Sb, As, Ba, Cd, Cr, Co, Cu, Pb, Ni, Se, Sn, V, and Zn. Bacteriological analysis for total and fecal coliform bacteria.

3-1-1 Total dissolved salts (TDS)

Table (2) presents the statistical analysis of TDS chemical analysis of the studied locations during low and high river flow seasons of the year and also presents the statistical analysis that includes the maximum, minimum, variance, average and standard deviation. The date clarifies the following points:

Table (2): Statistical analysis of the total dissolved solids (TDS).

Well	RIGW	CLEQM	HRI 2	HRI 1	Nile River
Parameter	**Low Nile River flow**				
Minimum (mg/l)	405	258	274	251	242
Maximum (mg/l)	659	300	343	342	313
Average (mg/l)	482.57	272.71	295.29	286.29	265.50
Variance	7572.95	242.57	501.57	907.57	625.10
Standard Deviation	87.02	15.57	22.40	30.13	25.00
High Nile River flow					
Minimum (mg/l)	452	267	268	282	203
Maximum (mg/l)	736	292	313	288	238
Average (mg/l)	532.20	278.80	293.40	285.60	218.80
Variance	13446.70	131.20	308.80	8.30	222.70
Standard Deviation	115.96	11.45	17.57	2.88	14.92

<u>Low Nile River flow</u>

- The average TDS values of the different studied points were 265.50, 286.29, 295.29, 272.71 and 482.57 mg/l for the locations Nile River, HRI1, HRI2, CLEQM and RIGW observation well, respectively.

- Maximum TDS occurred with the RIGW observation well compared with the other locations, which were 659 mg/l. Where TDS of the other studied wells and the Nile River range between 300 and 343 mg/l.
- Variance values of Nile River, HRI1, HRI2, CLEQM and RIGW were 625.10, 907.57, 501.57, 242.57 and 7572.95. The variance values of all locations were low except that of the RIGW observation well, followed by HRI1.
- The standard deviation values of Nile River, HRI1, HRI2, CLEQM and RIGW were 25.00, 30.13, 22.40, 15.57 and 87.02. The deviation of all locations was low except that of the RIGW observation well, followed by HRI1.

High Nile River flow

- The average TDS values of the different studied points were 218.80, 285.60, 293.40, 278.80 and 532.20 mg/l for the locations Nile River, HRI1, HRI2, CLEQM and RIGW observation well, respectively.
- Maximum TDS occurred with the RIGW observation well compared with the other locations, which were 736 mg/l. Where the TDS of the other studied wells and the Nile River range between 238 and 313 mg/l.
- Variance values of Nile River, HRI1, HRI2, CLEQM and RIGW were 222.70, 8.30, 308.80, 131.20 and 13446.70. The variance values of all locations were low except that of the RIGW observation well, followed by HRI2.
- The standard deviation values of Nile River, HRI1, HRI2, CLEQM and RIGW were 14.92, 2.88, 17.57, 11.45 and 115.96. The deviation of all locations was low except that of the RIGW observation well, followed by the Nile River.

The results clarify the following:

- The high variations in TDS values in the Nile River and RIGW observation well, while there were no significant variations between the values of other locations.
- The high standard deviation and variance values were in the Nile River and RIGW observation well, while there were no significant variations between the values of other locations.
- There is a significant relationship between the TDS data of the Nile River and that of the RIGW observation well. Pitz, 2016 approved the relationship between the levels of both locations shown in Figure (2).

3-1-2 Analysis of variance

Table (3) presents the F values resulting from the analysis of variance using the ANOVA test for total dissolved solids (TDS) of the Nile River water and each groundwater well to examine the relationship between each pair.

The data showed that the highest value of F was 69.461 between the Nile River and the RIGW well, while the other F values were 9.596, 21.383 and 13.588 between the Nile River and CLEQM, HRI2 and HRI1, respectively. ANOVA result showed that all the F values were significant where the values of calculated F were higher than the tabulated F (6.142).

Table (3): F values resulted from analysis of variance.

Pair	Calculated F value	Tabulated F	
		0.01	0.05
Nile River and RIGW	69.461	249	6.142
Nile River and CLEQM	9.596		
Nile River and HRI 2	21.383		
Nile River and HRI 1	13.588		

3-1-3 Soluble Cations and Anions

Table (4) presents the statistical analysis for the soluble cations that measured in the water samples of the studied groundwater wells and the Nile River Damietta branch. It is clear that the calcium was the dominant cations followed by sodium, while potassium cation was the lowest one.

Table (4): Statistical analysis of soluble cations (mg/l).

Well		Calcium (Ca)	Potassium (K)	Magnesium (Mg)	Sodium (Na)
RIGW	Min.	57.7	6.98	10.31	52.01
	Max.	104.85	10.97	30.22	100.03
	Avg.	69.35	8.35	19.57	70.89
	Var.	12.97	0.07	2.67	12.12
	SD.	16.11	1.59	5.66	16.7
CLEQM	Min.	38.73	2.99	6.43	21.01
	Max.	78.04	4.99	23.02	48.01
	Avg.	48.26	3.93	14.2	28.76
	Var.	8.31	0.02	1.93	3.00
	SD.	12.89	0.86	4.81	8.31
HRI 2	Min.	38.41	2.99	7.28	25.01
	Max.	56.31	5.98	15.35	44.01
	Avg.	44.19	4.3	12.62	29.38
	Var.	1.65	0.02	0.52	1.62
	SD.	5.75	0.96	2.5	6.09
HRI 1	Min.	33.61	1.99	7.28	25.01
	Max.	55.25	5.48	15.35	44.01
	Avg.	41.32	4.24	12.32	29.38
	Var.	2.18	0.04	0.48	1.66
	SD.	6.6	1.25	2.4	6.19
Nile River	Min.	30.01	2.99	5.37	15
	Max.	52.11	5.98	13.52	39.01
	Avg.	35.19	4.46	11.12	25.26
	Var.	2.49	0.03	0.60	2.37
	SD.	7.06	1.03	2.67	7.38

Min. minimum - Max. Maximum - Avg. Average - Var. Variance - SD. Standard Deviation.

The results reveal that the average values of the different soluble cations in the water of the observation well were (RIGW) higher than those of the other production wells. While the cations concentrations were lower in the River Nile compared with their concentrations in the other studied locations.

Table (5) presents the statistical analysis for soluble anions that measured in the studied groundwater locations and Rive Nile Damietta branch. From the result analysis, the following can be noticed:

- Bicarbonate (HCO_3) was the dominant anions in the water of the studied locations followed by chloride (Cl) then sulphate (SO_4). The minimum values for HCO_3 and Cl were 149.97, 12.36 mg/l for Nile River and 14.09 mg/l for SO_4 in CLEQM while their maximum values were 411.91, 127.69 and 62.66 mg/l all for RIGW.
- The soluble anions in groundwater observation well were higher than those of the other production wells.
- The soluble anions in surface water were lower than those of the groundwater.

Table (5): Statistical analysis of soluble anions (mg/l).

Well		Flouride (F)	Chloride (Cl)	Nitrite (NO2)	Nitrate (NO3)	Phoshate (PO4)	Sulfate (SO4)	Bicarbonate (HCO3)
RIGW	Min.	0.33	30.54	0.20	0.20	0.20	15.09	291.94
	Max.	0.33	127.69	0.20	12.60	0.90	62.66	411.91
	Avg.	0.33	61.11	0.20	3.12	0.29	46.23	330.56
	Var.	0.00	0.95	0.00	20.37	0.06	0.14	0.40
	SD.	0.00	34.57	0.00	4.51	0.25	18.12	38.48
CLEQM	Min.	0.05	20.93	0.20	0.20	0.20	14.09	178.96
	Max.	0.05	44.59	0.20	2.37	0.36	46.28	330.93
	Avg.	0.05	26.34	0.20	0.62	0.22	26.65	216.33
	Var.	0.00	1.64	0.00	0.63	0.00	3.14	51.04
	SD.	0.00	7.64	0.00	0.79	0.06	12.28	55.80
HRI 2	Min.	0.05	23.83	0.20	0.20	0.20	19.04	171.96
	Max.	0.05	45.47	0.20	6.07	0.42	43.95	218.95
	Avg.	0.05	29.72	0.20	1.11	0.23	28.44	196.08
	Var.	0.00	1.47	0.00	4.07	0.01	1.87	5.71
	SD.	0.00	7.22	0.00	2.02	0.08	9.47	18.66
HRI 1	Min.	0.31	16.59	0.20	0.20	0.20	19.68	154.97
	Max.	0.31	47.67	0.20	4.00	0.33	42.47	207.96
	Avg.	0.31	26.34	0.20	0.90	0.22	29.20	184.84
	Var.	0.00	2.39	0.00	1.67	0.00	1.48	4.18
	SD.	0.00	9.22	0.00	1.29	0.05	8.42	15.96
Nile River	Min.	0.35	12.36	0.20	0.20	0.20	18.89	149.97
	Max.	0.35	33.75	0.20	2.20	0.20	40.47	180.96
	Avg.	0.35	22.81	0.20	0.52	0.20	27.85	162.59
	Var.	0.00	1.54	0.00	0.47	0.00	1.06	1.76
	SD.	0.00	7.40	0.00	0.69	0.00	7.13	10.38

Min. minimum - Max. Maximum - Avg. Average - Var. Variance - SD. Standard Deviation.

3-1-3 Sodium adsorption ratio (SAR) and adjusted sodium adsorption ratio (Adj- SAR)

The values of sodium adsorption ratio (SAR) of different studied locations are calculated due to the equation (1). Table (6) presents the statistical analysis for the calculated SAR. Where the average values ranged between 0.93 and 1.93. The values were small for all the studied locations less than 7. It is clear that water are suitable for irrigation different crops. The values of standard deviation and variance were very low.

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}} \qquad (1)$$

Adjusted sodium adsorption ratio (Adj- SAR) consider the cations (CO_3 + HCO_3). Table (6) presents the calculated Adj- SAR using equation (2). The average values ranged between 1.71 and 4.63. The calculated Adj- SAR values for all the studied locations were very low less than 7. Therefore, water is allowable for irrigation different types of crops.

$$\text{Adj\_SAR} = \text{SAR}*[(8.4-\text{pHc})+1] \qquad (2)$$

Table (6): Sodium adsorption ratio (SAR) and adjusted (Adj- SAR) %.

Parameter	Well	RIGW	CLEQM	HRI 2	HRI 1	Nile River
SAR	Minimum	1.65	0.82	0.97	1.02	0.66
	Maximum	2.21	1.22	1.34	1.35	1.24
	Average	1.93	0.93	1.00	1.03	0.95
	Variance	0.08	0.04	0.04	0.04	0.08
	Standard Deviation	0.28	0.21	0.20	0.19	0.29
Adj_SAR	Minimum	3.64	1.48	1.70	1.65	1.00
	Maximum	5.39	2.86	2.74	2.75	2.43
	Average	4.63	1.86	1.94	2.07	1.71
	Variance	0.77	0.51	0.30	0.31	0.51
	Standard Deviation	0.88	0.72	0.54	0.55	0.71

3-1-4 Heavy Metals

The studied locations heavy metals concentration of the groundwater and the River Nile are presented in figure (3). The figure illustrates the following:

- The occurrence of Mn, Fe, Al, Ba, Cu, and Zn were in significant concentrations.
- The concentrations of Mn in the groundwater were higher than the other minerals followed by Fe then Zn and Al.
- The concentrations of those metals in the observation well (RIGW) were higher than other locations.
- The River Nile heavy metals concentrations were the lowest values followed order Fe, Al, Ba, Zn, and Mn.

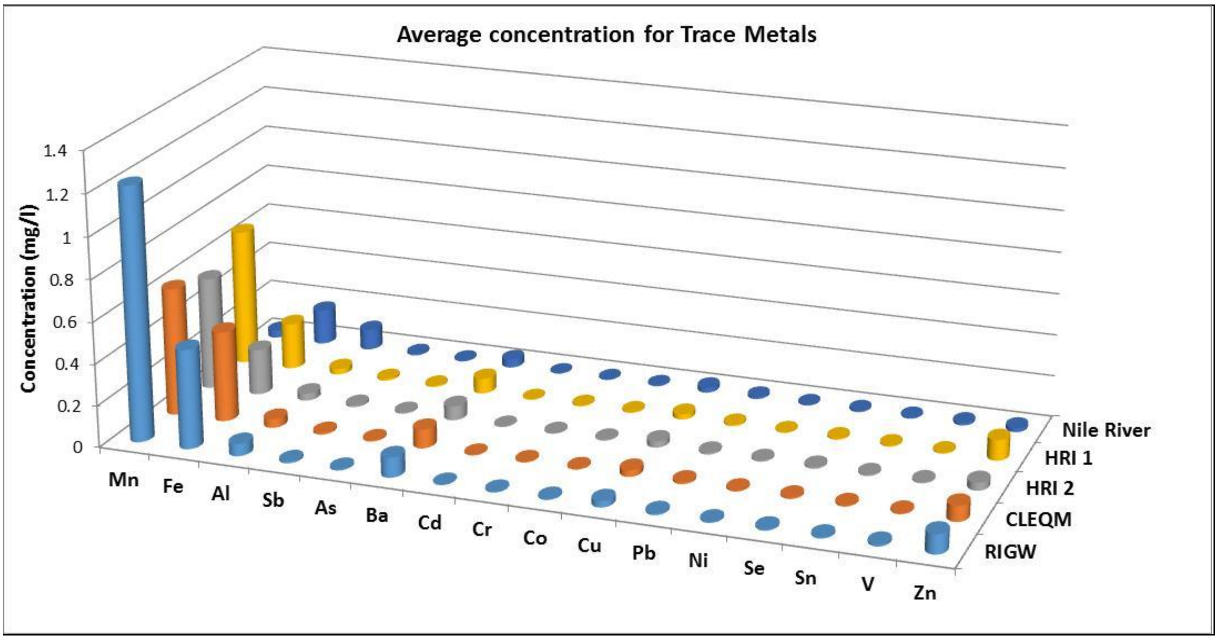

Figure (3). Average of heavy metals concentration of the studied locationds.

3-1-5 Bacteriological Analysis

Table (7) presents the counts of fecal and total coliform that measured in the water samples collected from the studied locations. The analysis result indicated the following:

Table (7): Total and Fecal coliform counts.

	Fecal coliform (CFU/100ml)					Total coliform (CFU/100ml)				
	Nile River	HRI 1	HRI 2	CLEQM	RIGW	Nile River	HRI 1	HRI 2	CLEQM	RIGW
	Low Nile River flow									
January	3.0E+2	ND	6.0E+0	ND	6.0E+0	7.0E+2	3.0E+0	1.54E+2	ND	1.43E+2
February	1.0E+2	ND	ND	ND	ND	1.8E+3	ND	ND	ND	ND
March	4.6E+1	ND	ND	ND	ND	8.9E+1	1.0E+0	ND	ND	ND
April	1.7E+2	1.0E+1	ND	ND	ND	2.8E+2	4.4E+1	ND	ND	ND
October	6.0E+2	ND	ND	ND	ND	5.3E+3	ND	ND	ND	5.0E+0
November	2.8E+2	ND	ND	ND	ND	4.5E+2	ND	1.0E+0	2.0E+0	ND
December	4.5E+2	ND	ND	1.0E+0	1.0E+0	9.0E+2	ND	ND	5.0E+0	7.0E+0
	High Nile River flow									
May	2.4E+3	ND	1.5E+2	ND	ND	1.54E+4	ND	2.6E+2	8.0E+0	ND
June	9.3E+1	ND	5.0E+0	ND	ND	1.76E+2	ND	2.0E+1	ND	ND
July	4.6E+2	4.5E+2	ND	ND	ND	1.9E+3	8.6E+2	ND	1.9E+1	ND
August	4.0E+2	2.0E+0	ND	ND	ND	1.8E+4	1.1E+1	ND	9.0E+0	ND
September	3.0E+2	ND	ND	ND	ND	3.5E+3	ND	ND	ND	ND

ND. Not Detected

Low Nile River flow

The fecal and total coliform, were existing in the surface water of Damietta branch site. The fecal coliform in the sampling site Damietta branch ranged between 4.6E+1 to 6.0E+2 CFU/100ml. The total coliform ranged between 8.9E+1 to 1.8E+3CFU/100ml. While they disappeared in the groundwater of the different locations during the study time.

High Nile River flow

The fecal and total coliform, were existing in the surface water of Damietta branch site. The fecal coliform in the sampling site Damietta branch ranged between 9.3E+1 to 2.4E+3 CFU/100ml. The total coliform ranged between 1.76E+2 to 1.54E+4CFU/100ml. While they disappeared in the groundwater of the different locations during the study time.

The fecal and total coliform, were existing in the surface water of Damietta branch site in low and high Nile River Flow times. While they disappeared in the groundwater of the different locations during the study time. The fecal coliform and total coliform higher in high Nile River Flow time than low Nile River Flow time.

3-2 Water Levels

Table (8) and figure (4) presents the statistical analysis of the water levels for the groundwater observation well and that of the Nile water. The statistical analysis indicated the following:

Low Nile River flow

The data in table (8) and figure (4) clear that the highest Nile water level was 13.51(m.amsl) and the lowest value was 13.18(m.amsl). Where the highest level of the groundwater of the observation well was 12.15(m.amsl) while the lowest values were 10.91(m.amsl) during the winter season during winter-closed period months.

Table (8). Statistical analysis for water levels in Nile and observation well.

	Depth to groundwater (m)	Water level (m. amsl)	
		Nile River	Groundwater
Low Nile River flow			
Minimum	4.64	13.18	10.91
Maximum	6.18	13.51	12.15
Average	5.40	13.33	11.69
Variance	0.26	0.01	0.26
Standard Deviation	0.51	0.12	0.51
High Nile River flow			
Minimum	3.63	13.95	12.45
Maximum	4.94	14.07	13.46
Average	4.26	13.81	12.83
Variance	0.33	0.07	0.33
Standard Deviation	0.58	0.26	0.58

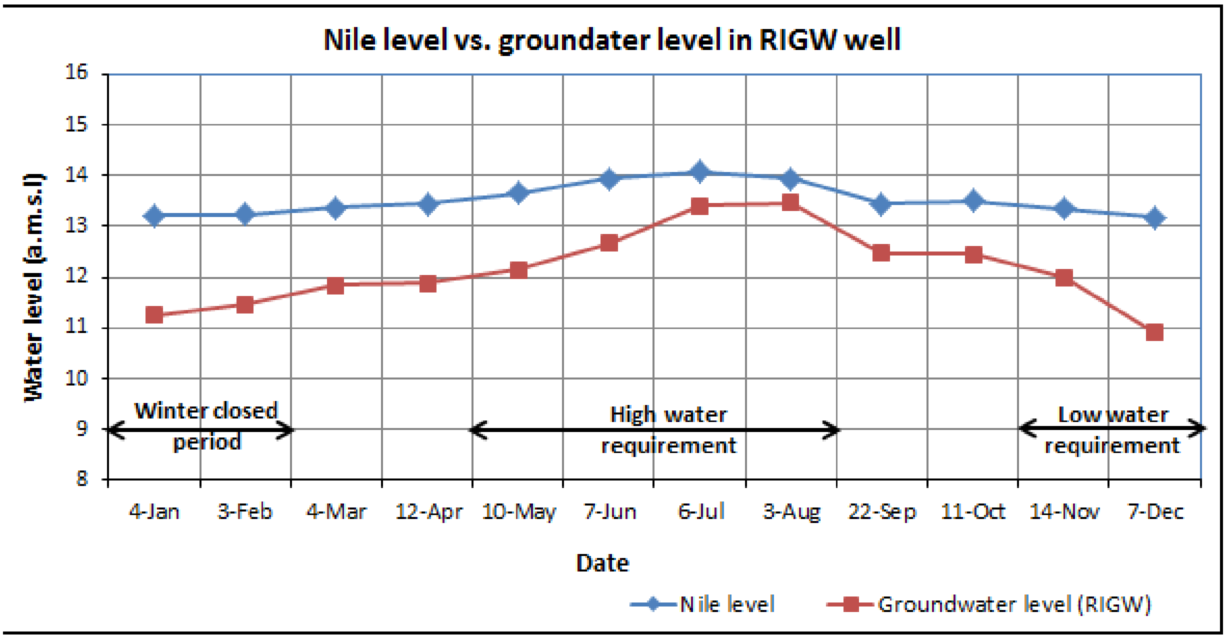

Figure (4): Nile water level vs. groundwater level in RIGW well.

<u>High Nile River flow</u>

The data in table (8) and figure (4) clear that the highest Nile water level was 14.07(m.amsl) and the lowest value was 13.95(m.amsl). Where the highest level of the groundwater of the observation well was 13.46(m.amsl), while the lowest values were 12.45(m.amsl). The highest level of the groundwater was occurred in July and August during the high water requirement for the summer crops.

The statistical analysis results clear that the highest level of the groundwater of the observation well was occurred during the high flow of the Nile. While the lowest values were occurred in the low flow of the Nile. While the Nile water discharge and its flow was very low and specially in the winter closer period where the low crop water requirements where the temperature degree is low. Which clear that the Nile water level followed the same trend of the observation well water level. Due to Winter, (1999), this means that the stream (Nile) lose water by outflow through the stream bed that closed to the well. While the water levels of the other wells did not affected by that phenomena because of the far distance of them from the bed of the Nile and their deep depths. Wroblicky et al (1998) approved the occurrence high Nile flow and discharge phenomena during the summer season where the needs of water are high due to the climate temperature.

Figure (5) demonstrate relation between Nile water level variable as x independent variable and the groundwater level as y dependent variable. The relation between them was expressed as a polynomial equation which is $y = -1.8443 x^2 + 52.582 x - 361.49$. The relation was strong due to the high value of R^2 which was 0.8618.

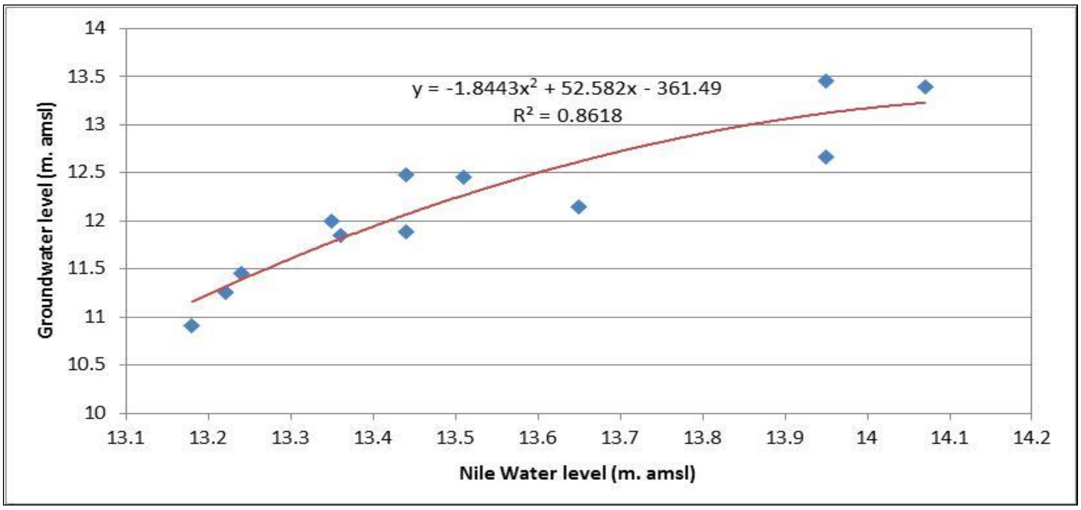

Figure (5): Relation between water levels in the Nile and observation well.

4- Conclusion

From the results, the following can be concluded:

- The statistical analysis of TDS values showed that the values of TDS of Nile River and the observation well were varied monthly from summer to winter seasons according to Nile River flow season.
- ANOVA test indicated the significant relationship for TDS of the Nile River water and each groundwater well as calculated F values higher than the tabulated F.
- The dominant cation was calcium followed by sodium in the most studied locations.
- The dominant anion was bicarbonate while the anion carbonate disappeared which coincide the pH values.
- Calculated SAR and Adj- SAR were small for all the studied locations less than 7, therefore water are suitable for irrigation all crops.
- Mn and Fe were the dominant heavy metals in the different studied locations. The concentrations of those metals in the shallow observation well were higher than other deep locations.
- Fecal and total coliform were presented in the surface water while they disappeared in the groundwater of the different locations during the study times.
- The Nile loses water by outflow through its bed that closed to the groundwater observation well in summer months during high Nile River flow. While the water levels of the other wells did not affect by that phenomena because of the far distance from the bed of the Nile and their deep depths. While during winter where the Nile flow was low, the flow occurred from groundwater to Nile River.
- There was a strong relation between Nile water levels and that of groundwater observation well with high significant correlation coefficient (R^2 = 0.8618) presented as $y = -1.8443 x^2 + 52.582 x - 361.49$.

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