

**EVALUATION OF ENVIRONMENTAL POLLUTION USING  
HYDROCHEMICAL AND ISOTOPIC STUDIES ALONG  
ISMAILIA CANAL**

W.M. SALEM\*, A.M.KHOUDARY\*\*, M.M.K.FOUAD\*\*\*, A.N. MAHDY\*\*\*

\*National Centre for Nuclear Safety and Radiation Control

\*\*\* Cairo University, Faculty of Eng., Chemical Eng. Dept.

**ABSTRACT**

The aim of the present work is to achieve better understanding of the water resources in the Ismailia Canal area. The area of study which is located on the eastern side of the River Nile bounded by latitudes 31°0'38" and 31°19'00" East and 30°23'00" and 30°12'42" North, is considered one of the most promising areas for new communities and land reclamation projects. A hydrochemical study was performed for the water resources in the study area which involved collection and analysis of water samples from both surface and groundwater. Electrical conductivity and TDS were measured and major ions and trace elements were analyzed for all samples. Results indicated some impact of industrial effluents on surface water. Based on the hydrochemistry, the types of the ground water samples were determined, the majority of which were found to be mixed water characterized by salt composition of NaCl, KCl, Na<sub>2</sub>SO<sub>4</sub>, NaHCO<sub>3</sub>, Mg(HCO<sub>3</sub>)<sub>2</sub>, Ca(HCO<sub>3</sub>)<sub>2</sub>. In addition the suitability of ground water for drinking, domestic, irrigation and industrial purposes was studied. The analysis of total dissolved solids, sodium adsorption ratio and %Na was performed for all samples. Results indicated low TDS implying suitability of most samples for drinking and domestic uses except for a few which were found to be contaminated with heavy metals due to industrial activities. The stable isotopic content (Deuterium and Oxygen-18) was determined for groundwater samples as a monitor of its origin and its interrelation with surface water in the study area. Results indicated that groundwater was affected by both the River Nile and irrigation water.

**KEYWORDS:** Ismailia Canal area, hydrochemical study, water pollution, industrial impact, groundwater.

## 1. INTRODUCTION

The Ismailia Canal area, located in the Eastern side of the River Nile is considered extremely promising for new communities and land reclamation projects. Such development depends mainly on the optimum exploitation of all existing water resources.

The Ismailia Canal, running through the study area, is one of the most important water streams in Egypt. Its water is used in irrigation, drinking , navigation and industrial purposes [1]. The second main source of available fresh water in the area is groundwater.

In the present work the suitability of both ground and surface water for use in different purposes, is studied. Samples were analyzed for the major chemical composition , trace elements, TDS, Na adsorption ratio and %Na. In addition the stable isotopic content (D and  $^{18}\text{O}$ ) were identified and used as a monitor for the origin of water and interrelation between surface and groundwater

## 2. EXPERIMENTAL WORK

Water samples were collected from sampling points shown on Fig. 1. The chemical analysis of the collected samples were carried out at the National Center for Nuclear Safety and Radiation Control laboratories according to the following scheme:

- Electrical Conductivity (EC) was determined using an electrical conductivity meter.
- ( $\text{Ca}^{++} + \text{Mg}^{++}$ ) was determined by titration against ethylene di-amine tetra-acetic acid (EDTA) using eriochrome black T as indicator.
- $\text{Na}^+$  and  $\text{K}^+$  were measured by using Flame Photometer.
- $\text{HCO}_3^-$  was determined by titration against sulfuric acid.
- $\text{Ca}^+$  was determined by titration against versinate solution using ammonium perpetrate as indicator.

- $\text{Cl}^-$  was determined volumetrically by titration against a standard solution of  $\text{AgNO}_3$  using potassium chromate as indicator.
- $\text{SO}_4^{2-}$  was determined by the turbidity method using a spectrophotometer.
- Trace elements were measured using Inductivity Coupled Plasma Mass Spectrometer (ICP-MS).
- TDS was determined using the evaporation method
- Stable isotope content (D and  $^{18}\text{O}$ ) was determined using Delta-S-Mass Spectrometer.

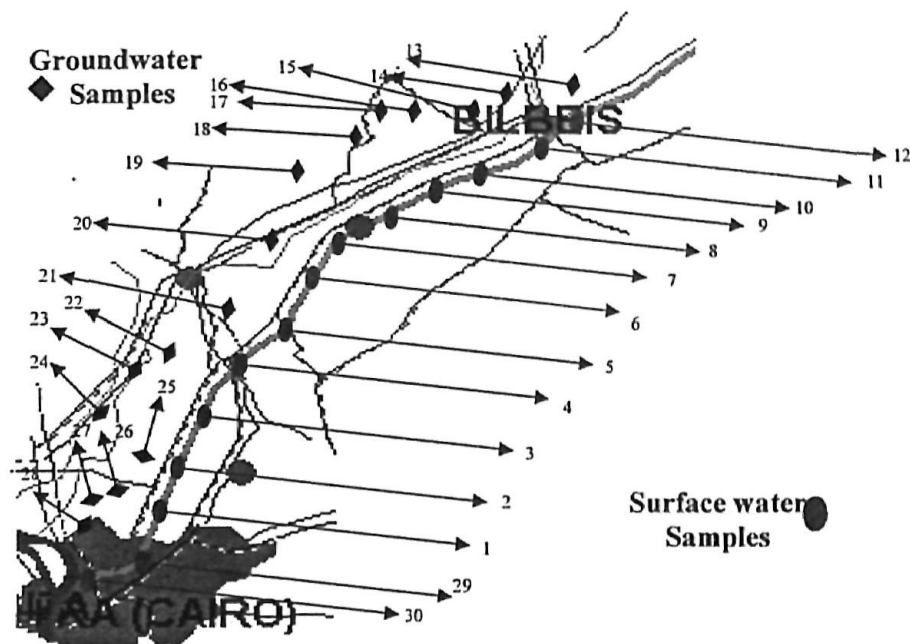


Fig 1: Sampling points in the study area

### 3. RESULTS AND DISCUSSION

#### 3.1. Hydrochemical Analysis

The chemical analysis results for surface and groundwater samples are shown in tables 1 and 2 respectively.

Results show TDS of all surface and groundwater samples falling in the low and medium salinity ranges indicating the intrusion of the River Nile and Ismailia Canal water.

Table 1: Hydrochemical analysis for the surface water in the study area

#	Temp. °C	pH	EC $\mu\text{S/C}$ m	TDS ppm	Unit	Major Cation					Major Anion					Water types
						Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	
1	25	7.2	0.39	249.6	ppm	38	6.052	14.02	34.05	23.66	219.4	28.8	Magnesium - Bicarbonate			
					epm	1.65	0.15	0.70	2.83	0.666	3.596	0.6				
					%	30.96	2.81	13.13	53.1	13.70	73.99	13.34				
2	25	7.3	0.36	230.4	ppm	28	5	20.04	24.32	21.13	176	26.7	Magnesium - Bicarbonate			
					epm	1.217	0.128	1.002	2.02	0.595	2.884	0.556				
					%	27.87	2.93	22.94	46.25	13.63	71.47	13.78				
3	25	7.2	0.37	236.8	ppm	36	5.263	24.04	19.45	23.6	192.8	24	Magnesium - Bicarbonate			
					epm	1.565	0.135	1.292	1.623	0.666	3.16	0.5				
					%	34.62	2.98	26.59	35.91	15.40	73.04	11.56				
4	25	7.3	0.37	236.8	ppm	28	5.263	40.08	2.432	23.66	168.3	22	Calcium - Bicarbonate			
					epm	1.217	0.134	2.004	0.202	0.666	2.759	0.458				
					%	34.21	3.76	56.34	5.68	17.15	71.05	11.80				
5	25	7.3	0.37	236.8	ppm	28	4.21	40.06	6.08	22.82	191.3	22	Calcium - Bicarbonate			
					epm	1.22	0.11	2.003	0.51	0.642	3.13	0.458				
					%	31.77	2.86	52.16	13.28	15.17	73.99	10.82				
6	25	7.4	0.37	236.8	ppm	26	5	28.05	6.08	23.66	171.4	28.1	Calcium - Bicarbonate			
					epm	1.13	0.128	1.40	0.31	0.666	2.809	0.556				
					%	35.76	4.05	44.30	16.14	16.37	69.87	13.83				
7	25	7.2	0.42	268.8	ppm	34	5.263	24.04	13.37	21.13	191.3	20	Sodium - Bicarbonate			
					epm	1.478	0.135	1.20	1.11	0.595	3.135	0.416				
					%	37.68	3.44	30.60	28.30	14.37	75.72	10.05				
8	25	7.1	0.38	243.2	ppm	28	5.263	36.07	7.296	25.36	171.1	20.0	Calcium - Bicarbonate			
					epm	1.217	0.135	1.803	0.608	0.714	2.805	0.416				
					%	32.34	3.58	47.91	16.15	18.16	71.37	10.58				
9	25	7.3	0.40	256	ppm	38	6.315	30.06	13.37	21.13	185.1	25.0	Sodium - Bicarbonate			
					epm	1.652	0.162	1.503	1.114	0.595	3.03	0.521				
					%	37.29	3.65	33.92	25.14	14.37	73.19	12.58				
10	25	7.2	0.37	236.8	ppm	26	5	30.04	8.512	21.97	162.2	20.0	Calcium - Bicarbonate			
					epm	1.13	0.128	1.502	0.709	0.618	2.658	0.416				
					%	32.57	3.69	43.30	20.44	16.74	71.99	11.26				
11	25	7.3	0.38	243.2	ppm	26	5.265	30.6	8.512	25.36	168.3	20	Calcium - Bicarbonate			
					epm	1.130	0.135	1.53	0.709	0.714	2.759	0.416				
					%	32.28	3.85	43.72	20.25	18.36	70.94	10.70				
12	25	7.3	0.38	243.2	ppm	26	5	20.04	17.02	25.36	176	27	Magnesium - Bicarbonate			
					epm	1.130	0.128	1.418	1.418	0.714	2.884	0.56				
					%	30.27	3.48	27.24	38.55	17.17	69.36	13.46				
29	25	7.2	0.37	236.8	ppm	26	5.789	30.04	12.04	25.35	160.2	20.5	Calcium - Bicarbonate			
					epm	1.130	0.148	1.502	1.07	0.714	2.88	0.55				
					%	29.35	3.84	39.01	27.80	19.66	69.70	11.33				
30	25	7.2	0.38	243.2	ppm	24	5.526	35.05	14.19	25.36	176.0	26.5	Calcium - Bicarbonate			
					epm	1.04	0.142	1.75	1.182	0.714	2.88	0.55				
					%	25.30	3.45	42.58	28.76	17.24	69.56	13.28				

Table 2: Hydrochemistry analysis for the Groundwater in the Study area

#	Temp. °C	pH	EC µS/cm	TDS ppm	Unit	Major Cation						Major Anion				Water types
						Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>				
13	25	7.2	0.84	537.6	ppm	98	3.42	30.06	12.16	43.95	283.1	28.8	Sodium - Bicarbonate			
					ppm	4.261	0.087	1.303	1.013	1.238	4.64	0.6				
					%	62.11	1.27	21.91	14.76	19.13	71.17	9.27				
14	25	7.2	0.81	518.4	ppm	90	3.68	40.08	10.94	63.39	300.2	20	Sodium - Bicarbonate			
					ppm	3.913	0.094	2.004	0.912	1.78	4.92	0.416				
					%	56.54	1.36	28.96	13.18	25.03	69.20	14.06				
15	25	7.3	0.58	371.2	ppm	36	5	38.07	18.24	38.04	237.2	29.1	Calcium - Bicarbonate			
					ppm	1.56	0.128	1.903	1.52	1.07	3.887	0.606				
					%	30.62	2.50	37.24	29.74	19.26	69.91	10.90				
16	25	7.5	1.08	691.2	ppm	120	3.421	36.07	15.81	93.82	405.5	28.7	Sodium - Bicarbonate			
					ppm	5.217	0.087	1.803	1.317	1.12	6.646	0.597				
					%	61.96	1.03	21.41	15.64	13.39	79.47	7.14				
17	25	7.1	0.79	505.6	ppm	50	5.789	44.08	21.88	50.71	283.1	27.4	Calcium - Bicarbonate			
					ppm	2.173	0.148	2.204	1.824	1.428	4.640	0.57				
					%	34.22	2.33	34.71	28.72	21.51	69.90	8.59				
18	25	7.4	0.93	595.2	ppm	60	10.53	70.14	17.02	78.60	300.2	26.55	Calcium - Bicarbonate			
					ppm	2.608	0.269	3.507	1.418	2.214	4.92	0.532				
					%	33.43	3.45	44.95	18.17	28.80	64.01	7.18				
19	25	7.4	0.87	556.8	ppm	76	25.52	36.07	15.81	34.09	328.9	26.5	Sodium - Bicarbonate			
					ppm	3.304	0.654	1.803	1.317	1.523	5.392	0.532				
					%	46.73	9.25	25.50	18.63	20.41	72.28	7.40				
20	25	7.1	0.80	512	ppm	56	5.263	34.07	21.88	27.05	316.7	22	Sodium - Bicarbonate			
					ppm	2.434	0.135	1.70	1.824	0.762	5.192	0.458				
					%	39.97	2.21	27.91	29.95	11.88	80.99	7.15				
21	25	7.5	1.28	819.2	ppm	80	11.84	80.64	15.81	59.16	415.5	28.8	Calcium - Bicarbonate			
					ppm	3.48	0.303	4.032	1.317	1.66	6.81	0.6				
					%	38.09	3.32	44.16	14.42	18.35	75.03	6.61				
22	25	7.6	0.64	400.6	ppm	48	7.105	60.15	14.60	43.95	278.5	27.1	Calcium - Bicarbonate			
					ppm	2.087	0.182	3.00	1.216	1.238	4.56	0.56				
					%	32.20	2.81	46.30	18.76	19.47	71.72	8.81				
23	25	7.6	0.55	352	ppm	82	5	16.03	4.864	23.80	236.7	28.4	Sodium - Bicarbonate			
					ppm	3.565	0.128	0.802	0.405	0.670	3.88	0.591				
					%	72.77	2.61	16.36	8.26	13.03	75.48	11.50				
24	25	7.5	0.61	390.4	ppm	44	4.756	60.15	18.24	28.74	300.2	28.5	Calcium - Bicarbonate			
					ppm	1.913	0.122	3.00	1.52	0.809	4.92	0.593				
					%	29.20	1.853	45.80	23.20	12.81	77.85	9.38				
25	25	7.3	0.83	531.2	ppm	46	5.789	60.12	30.4	76.92	305.8	27.7	Calcium - Bicarbonate			
					ppm	2	0.148	3.006	2.53	2.166	5.01	0.577				
					%	26.06	1.92	39.14	32.94	27.95	64.64	7.44				
26	25	7.4	0.37	236.8	ppm	24	5.576	30.06	4.864	25.36	136.7	20	Calcium - Bicarbonate			
					ppm	1.043	0.142	1.503	0.405	0.714	2.24	0.416				
					%	33.72	4.59	48.60	13.09	21.18	66.47	12.34				
27	25	7.5	1.03	640.6	ppm	96	1.315	34.06	36.48	43.95	442.7	28.9	Sodium - Bicarbonate			
					ppm	4.174	0.033	1.703	3.04	1.238	7.258	0.60				
					%	46.63	0.37	19.03	33.97	13.61	79.79	6.60				
28	25	7.5	0.86	550.4	ppm	54	5.0	60.12	21.88	24.51	380.2	28.7	Calcium - Bicarbonate			
					ppm	2.347	0.128	3.006	1.824	0.69	6.23	0.597				
					%	32.13	1.75	41.15	24.97	9.18	82.88	7.94				

As for the water type; 50% of groundwater samples were found to be of the Bicarbonate-Sodium type and the other 50% of the Bicarbonate Calcium type.

57% of collected surface water samples were of Bicarbonate-Calcium type, 14% of Bicarbonate-Magnesium type and 29% of Bicarbonate-Sodium type.

Regarding the hypothetical salt assemblages, the majority of surface and ground water samples were classified as meteoric water of  $\text{NaHCO}_3$  type with hypothetical salt combination of:-



Two of the samples (no. 18 and no. 25) were found to have the combination



It is clear that the majority of the samples include bicarbonate salts in their composition and thus could be considered of meteoric origin.

### 3.2. Graphical Representation

#### a- Grid system [2]

Using the grid system method the sequence of the ion dominance are recognized in analyzed water samples. This method is based on the percentage reacting values of the major anions and cations. In this method all the possible cationic-anionic combinations are recorded. It is used to reflect the processes affecting mineralization which involve cationic changes e.g. leaching, adsorption and cationic exchanges. Fig. 2 shows the grid system representing the study area which clarifies the main water types. 53.33% are of the  $\text{Ca}(\text{HCO}_3)_2$  type, 40% of the  $\text{NaHCO}_3$  while only two samples of the  $\text{Mg}(\text{HCO}_3)_2$ .

This indicates that the study area is mainly recharging from fresh water following the same ion sequence of the Nile water.

#### b- Piper Diagram [3]

The chemical data was plotted using the Piper Diagram as seen in Fig. 3. The left triangle is used for plotting the cations and the right for the anions. The rhombic part is composed of two equal triangular fields. Water appearing in the lower triangular field is considered of primary alkalinity where carbonates and bicarbonates exceed the calcium and Magnesium. On the other hand water appearing in the upper triangle is

of secondary salinity properties where sulfates and chlorides exceed sodium and potassium.

Fig. 3 shows that the ground water samples in the study area fall on the left hand side of the lower triangular field of the rhombic shape indicating low salinity properties.

Ca	Mg-Na	Chloride	Sulfate	Bi-carbonate	(25)	
	Na-Mg					Calcium
Mg	Ca-Na	Chloride	Sulfate	Bi-carbonate	(1)	
	Na-Ca					Magnesium
Na	Ca-Mg	Chloride	Sulfate	Bi-carbonate	(13)(14)(16)(17)(9)	
	Mg-Ca					Sodium
Grid system		SO <sub>4</sub> -HCO <sub>3</sub>	Cl-HCO <sub>3</sub>	HCO <sub>3</sub> -Cl	SO <sub>4</sub> -Cl	Cl-SO <sub>4</sub>
		Cl	SO <sub>4</sub>	HCO <sub>3</sub>		

Fig. 2. Grid system representing the study area

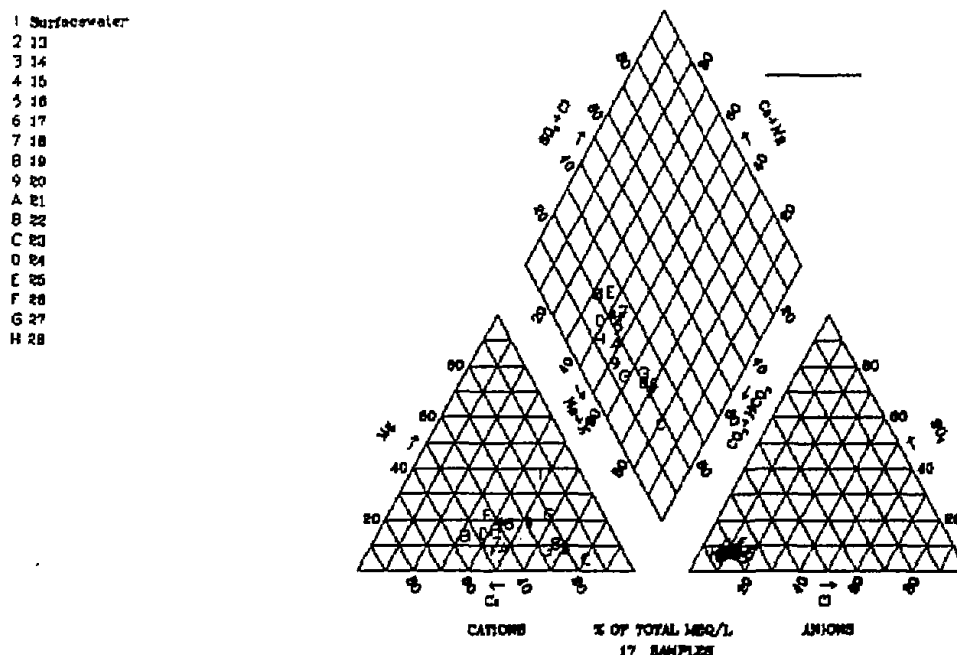


Fig. 3. The Piper Diagram for groundwater

c- Sulin diagram,[4]

Fig. 4 shows the distribution of the samples on the Sulin Diagram which consists of two equal quadrants. The upper represents water samples with the ratio  $(Na^+ + K^+)/Cl^- < 1$  indicating marine origin where  $CaCl_2$  and  $MgCl_2$  salts are formed. In the lower quadrant, where all studied samples are located, represents those with  $(Na^+ + K^+)/Cl^- > 1$  indicating meteoric origin where  $Na_2SO_4$  and  $NaHCO_3$  salts are formed.

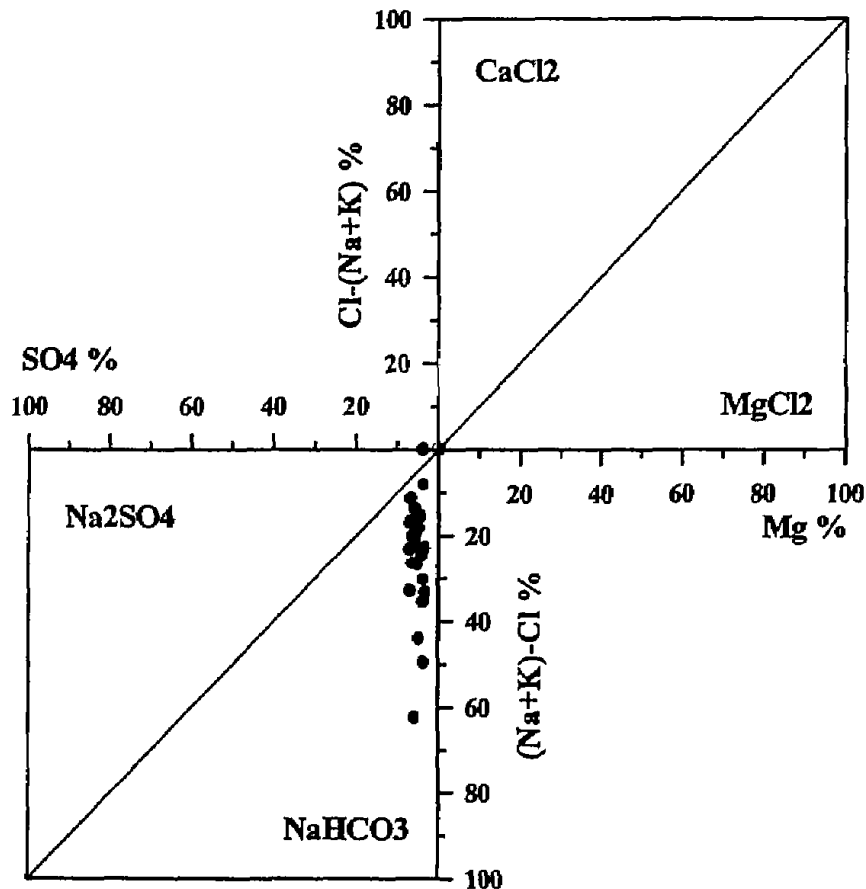


Fig. 4 Sullen diagram

### 3.4. Ionic Ratios

Table 3 shows the ratios between different ions in epm. Results show a great resemblance between the ionic ratios calculated in the groundwater and in the surface water samples. This could be attributed to the groundwater recharge from the Ismailia Canal water. Generally the ratios  $Na^+/Cl^-$ ,  $Ca^{++}/SO_4^{--}$  and



$Mg^{++}/SO_4^{-}$  are slightly higher in groundwater samples than in surface water due to the effect of the leaching process along the groundwater flow.

Table 3 : Ion Ratios in (epm) for both groundwater and surface water

Sample no.	HCO <sub>3</sub> <sup>-</sup> /Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup> /Ca <sup>++</sup>	HCO <sub>3</sub> <sup>-</sup> /Mg <sup>++</sup>	Na <sup>+</sup> /Cl <sup>-</sup>	Ca <sup>++</sup> /SO <sub>4</sub> <sup>-</sup>	Mg <sup>++</sup> /SO <sub>4</sub> <sup>-</sup>	Mg <sup>++</sup> /Cl <sup>-</sup>	Ca <sup>++</sup> /Cl <sup>-</sup>	SO <sub>4</sub> <sup>-</sup> /Cl <sup>-</sup>	Ca <sup>++</sup> /Mg <sup>++</sup>	Na <sup>+</sup> +K <sup>+</sup> /Ca <sup>++</sup>
1	5.399	5.137	1.271	2.477	1.167	4.717	4.249	1.051	0.901	0.247	2.571
2	4.847	2.878	1.428	2.045	1.802	3.633	3.395	1.684	0.935	0.496	1.342
3	4.745	2.629	1.947	2.350	2.404	3.246	2.437	1.804	0.758	0.740	1.414
4	4.143	1.377	13.658	1.827	4.376	0.441	0.303	3.009	0.687	9.920	0.674
5	4.875	1.563	6.137	1.900	4.373	1.114	0.794	3.119	0.714	3.927	0.664
6	4.218	2.006	5.508	1.697	2.518	0.917	0.766	2.102	0.834	2.745	0.898
7	5.269	2.613	2.824	2.484	2.885	2.668	1.866	2.016	0.699	1.081	1.344
8	3.929	1.556	4.613	1.704	4.334	1.462	0.852	2.525	0.582	2.965	0.749
9	5.092	2.016	2.720	2.776	2.885	2.138	1.872	2.526	0.875	1.349	1.206
10	4.301	1.770	3.749	1.828	3.611	1.704	1.147	2.430	0.673	2.118	0.837
11	3.864	1.803	3.891	1.583	3.678	1.704	0.993	2.142	0.582	2.158	0.826
12	4.039	2.034	2.034	1.583	2.532	2.532	1.986	1.986	0.784	1.000	0.887
13	3.748	3.087	4.580	3.442	2.505	1.688	0.818	1.214	0.484	1.483	2.892
14	2.764	2.455	5.395	2.198	4.817	2.192	0.512	1.125	0.233	2.197	1.999
15	3.633	2.043	2.557	1.458	3.140	2.508	1.421	1.778	0.566	1.252	0.887
16	5.934	3.686	5.046	4.658	3.020	2.206	1.176	1.609	0.533	1.369	2.941
17	3.249	2.105	2.544	1.522	3.867	3.200	1.277	1.543	0.399	1.208	1.053
18	2.222	1.403	3.470	1.178	6.353	2.569	0.640	1.584	0.249	2.473	0.820
19	3.540	2.991	4.094	2.169	3.266	2.386	0.865	1.183	0.362	1.369	2.195
20	6.814	3.054	2.846	3.194	3.712	3.983	2.394	2.231	0.601	0.932	1.511
21	4.102	1.689	5.171	2.096	6.720	2.195	0.793	2.428	0.361	3.061	0.938
22	3.683	1.520	3.750	1.686	5.357	2.171	0.982	2.423	0.452	2.467	0.756
23	5.791	4.838	9.580	5.321	1.357	0.685	0.604	1.197	0.882	1.980	4.604
24	6.082	1.640	3.237	2.365	5.059	2.563	1.879	3.708	0.733	1.973	0.678
25	2.313	1.667	1.980	0.923	5.210	4.385	1.168	1.387	0.266	1.188	0.714
26	3.137	1.490	5.531	1.461	3.613	0.974	0.567	2.105	0.582	3.711	0.788
27	5.863	4.262	2.388	3.372	2.838	5.067	2.456	1.375	0.484	0.560	2.470
28	9.029	2.073	3.416	3.401	5.035	3.055	2.643	4.356	0.865	1.648	0.823
29	4.034	1.917	2.692	1.583	2.731	1.945	1.499	2.103	0.770	1.403	0.850
30	4.034	1.646	2.437	1.457	3.182	2.149	1.655	2.451	0.770	1.480	0.675
Ismailia Canal (avg.)	4.4849	2.2103	3.9221	1.949	3.034	2.169	1.701	2.211	0.754	2.259	1.0674
Ground water (avg.)	4.4940	2.5001	4.0991	2.527	4.117	2.614	1.262	1.953	0.503	1.8046	1.6297

### 3.5. Water Quality

The purpose of the water quality study is to evaluate whether the water of a certain composition is satisfactory for proposed different uses. Accordingly the standards and tolerances for water to be used for various purposes must be taken into consideration[9,10]. According to Schoeller [5], the analysis of both ground and surface water samples in the study area were found to be suitable for drinking purposes. TDS of samples fall in the range 236-819 ppm which could be considered as good on the scale of suitability for permanent supply. The quality of water for laundry and cleaning purposes depends on its hardness

i.e. the sum of  $Mg^{++}$  and  $Ca^{++}$  concentrations expressed terms of mg/lit of  $CaCO_3$  which could be calculated using equation 1.

$$\text{Hardness} = 2.5 \times Ca^{++} (\text{mg/l}) + 4.1 \times Mg^{++} (\text{mg/l}) \quad (1)$$

3.33% of total groundwater samples were found soft (0-75 mg/l  $CaCO_3$ ), 53.33% moderate (75-150 mg/l  $CaCO_3$ ) and 43.34% hard (150-300 mg/l  $CaCO_3$ ).

The increase of TDS in irrigation water affects the soil efficiency, growth and crops' yields. For long term irrigation under average conditions TDS should not exceed 2000 mg/l. As clear from table 1, for all samples TDS falls in the range 240-880 ppm indicating suitability for agricultural use.

The SAR of water is defined according to Richards [6] by equation 2 where ions concentrations are expressed in epm.

$$\frac{Na^+}{((Ca^{++} + Mg^{++})/2)^{0.5}} \quad (2)$$

It is clear from Fig. 5 that the groundwater samples in the study area could be classified as having low-medium sodium hazard which indicates good water quality for irrigation purposes.

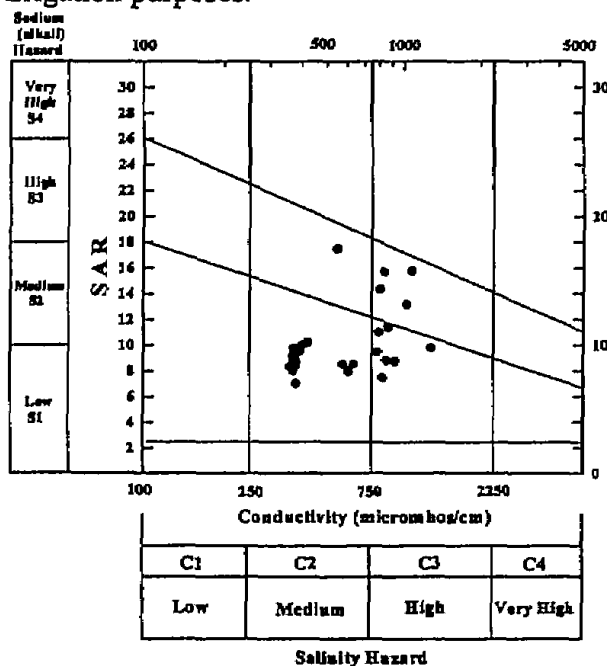


Fig.5: Classification of irrigation water

### 3.6. Environmental Stable Isotopes

The stable isotopes (D and  $^{18}\text{O}$ ) are considered the main monitors for groundwater origin.

The relative difference in the ratio of the heavy isotope to the more abundant light isotope of the sample w.r.t. a reference is defined by equation 3 where R in the case of water is  $^{18}\text{O}/^{16}\text{O}$ .

$$\delta = ((R_{\text{sample}} - R_{\text{reference}}) / R_{\text{reference}}) \times 1000 \quad (3)$$

Table 4 shows the results of the stable isotopic analysis of the tested samples.  $^{18}\text{O}$  and D content of surface water samples were found to be non homogeneous and fall in the ranges 3.1538‰-6.679‰ and 20.415‰-48.761‰ respectively. This reflects the Canal water modification due to different degrees of evaporation along the flow path in addition to the effect of the return water irrigation on some points.

Compared to surface water samples groundwater ones were found to have a wider range of variation where  $^{18}\text{O}$  and D were found to fall in the ranges 0.199‰ - 5.1785‰ and 5.156‰-39.219‰ respectively. This reflects the presence of different recharge sources to the Ismailia Canal which are more enriched in the isotopic content e.g. return water irrigation.

The stable isotopic contents of all water samples are plotted on the conventional diagram shown in Fig. 6 as a relation between  $\delta^{18}\text{O}$  and  $\delta\text{D}$ . The water sources in the study area show a wide range of isotopic composition reflecting a multitude of origins. Most of the samples lie between the meteoric water line and the local Mediterranean Sea meteoric water line [7].

The local meteoric water line is calculated from the weighted mean monthly concentration of D and  $^{18}\text{O}$  in a precipitation period of 22 years in Alexandria station, [8].

Table 4: Result of analysis  $\delta^{18}\text{O}$ ,  $\delta\text{D}$  for surface and groundwater samples

Surface water Samples				Groundwater Samples			
S. #	$\text{O}^{18}$	$\delta\text{D}$	d excess	S. #	$\text{O}^{18}$	$\delta\text{D}$	d excess
1	4.25567	43.122	9.07664	13	1.958	20.396	5.296
2	4.017218	38.933	6.795256	14	4.43355	29.576	-5.898
3	3.91659	30.72	-0.61272	15	4.85024	34.913	-33.88
4	4.005	31.7919	-0.2481	16	5.1785	39.216	-2.212
5	3.1538	35.8465	10.6161	17	4.23515	26.06	-7.82
6	4.2664	46.44	12.3088	18	4.3757	28.347	-6.65
7	3.873	28.071	-2.913	19	4.14586	26.83	-6.336
8	4.0522	36.06	3.6424	20	5.4735	36.24	-15.548
9	4.793	41.03	2.686	21	4.72884	35.28	-2.55
10	4.03646	31.473	-0.81868	22	3.7757	20.03	-10.175
11	5.6733	48.761	3.3746	23	5.02526	35.139	-35.063
12	3.61655	20.415	-8.5174	24	0.199	5.156	3.56
29	6.679	48.545	-4.887	25	1.9964	24.3311	8.358
30	4.24055	41.839	7.9146	26	4.420718	33.1312	-2.235
				27	5.16727	36.944	-4.394
				28	4.0875	24.862	-7.83
<b>Return Irrigation Water (RIW)</b>					5.13	39.1	-1.94
<b>Old Nile</b>					-0.6	4.3	9.1
<b>Recent Nile ( Domietta Branch)</b>					3.18	28.3	2.86
<b>Precipitation point (Rain water)</b>					-2.6	11.2	32

The groundwater samples could be divided into two groups. The first group, in which most of the samples fall, are characterized with  $^{18}\text{O}$  and D content similar to that of Ismailia Canal water.

The second group, on the other hand, reflects the Old Nile water which is more depleted than the Donizetti branch. This enrichment is due to evaporation beyond the High Dam.

The distribution of D around the Ismailia Canal is shown in Fig. 7. It illustrates that the D content decreases with a frame of the canal border.

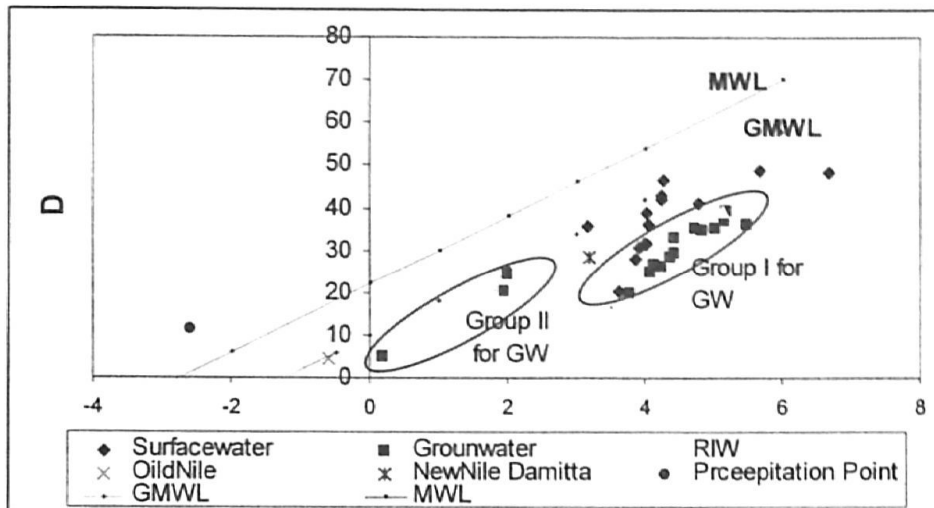


Fig. 6: Relation between  $\delta^{18}\text{O}$  and  $\delta\text{D}$  in groundwater samples

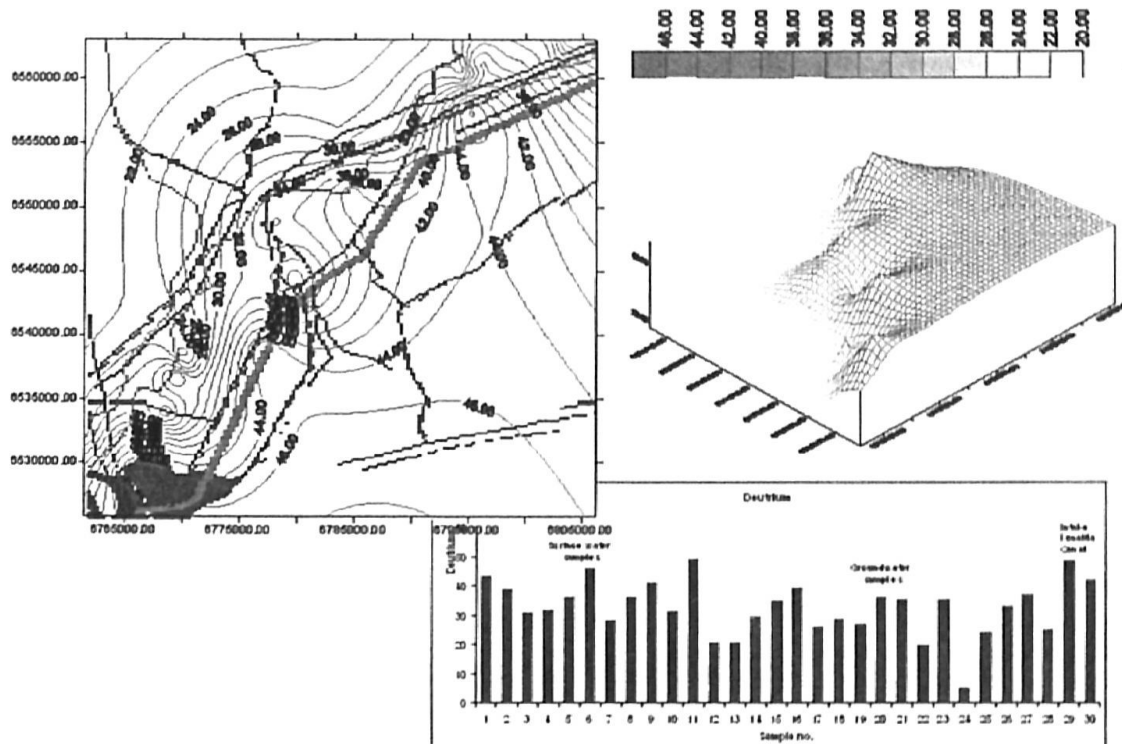
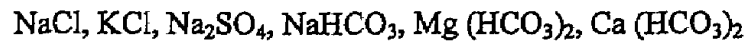


Fig. 7: Deuterium distribution around Ismailia Canal

#### 4. Conclusion

Since Egypt's development projects and its needing towards the 21<sup>st</sup> century depend on the expansion towards the desert, the present research was directed towards the eastern part of the River Nile, around the Ismailia Canal. Based on the hydrochemistry, the majority of the groundwater and surface water samples were found to be mixed water characterized by salt composition of:



Such a sequence indicates high bicarbonate content, which could be explained by the intrusion of the River Nile and Ismailia Canal on groundwater. Such intrusion was also indicated by the low and medium values of TDS of all samples.

50% of groundwater samples were found to be of the Bicarbonate-Sodium type and the rest of the Bicarbonate-Calcium type. However for surface water, 57% of collected samples were of the Bicarbonate-Calcium type, 14% of Bicarbonate-Magnesium type and 29% of Bicarbonate-Sodium type.

Most collected groundwater samples proved to be suitable for drinking and domestic uses except for only two samples which were found to be contaminated with heavy metals due to industrial activities.

Environmental isotope technique illustrated that the charging of ground water is not only from the Ismailia Canal and the River Nile but also from the Old Nile and irrigation water.

#### References

- 1- Ministry of Irrigation, " Some Information About Ismailia Canal, Technical Report", 1977.
- 2- Attia, F.A.R., "Economic Evaluation of Groundwater Development Plans in Upper Egypt", Water Science Special Issue, vol. 10 pp.71-83, 1991.

- 3- Wafaa, M.M., " Application of isotopic and Hydrochemical Techniques to Study Groundwater in Eastern Nile Delta and Assessment of Pollution – Lake Manzala", PhD thesis, Faculty of Engineering, Cairo University, 1996.
- 4- Nada, A.A. and El Gamal, S.A., "Environmental Isotopes and Hydrochemical Characteristics of El Saff Groundwater, Southern Cairo, Egypt", Isotope and Rad. Res. Egypt, 1995.
- 5- Awad, M.A.A., " Chemical and Isotopic Properties of Groundwater along the Coastal Plain of Aqaba Gulf Egypt", Arab Journal of Nuclear Sciences and Application, vol. 32, pp. 323-334, 1999.
- 6- Richards, L.A., " Diagnosis of Improvement of Saline and Alkali Soils", United States Salinity Lab., Agriculture Handbook no. 60, US Government Printing Office, Washington D.C., 1989.
- 7- Clark, I. and Fritz, P, " Environmental Isotopes in Hydrogeology", 2<sup>nd</sup> edition, Lweis Publishers, Baco Roton, 1997.
- 8- International Atomic Energy Agency, IAEA , " Statistical Treatment of Data on Environmental Isotopes in Precipitation", Technical Reports Series no. 331, Vienna, 1992.
- 9- Boers, H.P. and Rosmeijer, J., " Groundwater Quality Trend Detection at the Regional Scale", Groundwater quality 2004, 4<sup>th</sup> International Conference, Ontorio Canada, July, 2004.
- 10- McCall, G.J.H. and Nash, H. , " Groundwater Quality", Springer, 1<sup>st</sup> edition, 2003.