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Assessment of Irrigation Drainage Water for Sustaining Agriculture Activities in South Egypt

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Abstract: *Lack of water resources in arid/hyper-arid regions push the governments to search for non-convention water resources. In this article, the quality and suitability of irrigation drainage water were assessed to reuse in agricultural activities in southern Egypt. Thirty-five samples, collected from three agricultural drains, were analysed for estimating the major elements (Na, Ca, Mg,HCO_3, SO_4) along with physical parameters (EC and pH). The hydrochemical parameters such as SAR, RSC, and SSP were calculated to reveal the hydrochemical characteristics and suitability for irrigation. The results indicated that the irrigation drainage water belongs to bicarbonate-type water and the predominant hydrochemical facies are HCO3-Ca, HCO3-Na, and HCO3-Mg. In addition to, the hydrochemical investigation revealed that the predominant processes controlled the water quality is the rock weathering and/or evaporation. Based on comparing our finding with the FAO the irrigation drainage water can be reused for irrigation but are not suitable for fine texture soils and sensitive crops.*

Keyword: *Water Resources, Hydrochemistry, Agricultural Drainage Water, Egypt.*

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I. Introduction

In Egypt water resources can be classified to conventional and non-conventional groups. The first group in the study area are restricted to the Nile River, ground water, precipitation and flash floods. The main natural conventional resource that Egypt depends on is the Nile River that supplies Egypt with about 55.5 billion m^3/annually. The cultivated lands which cover about 6% of the total area of Egypt's land are mainly irrigated from the Nile River as the major source of fresh water (Abdalla et a., 2016; Abdelkareem et al., 2012a, b; Abdelkareem and E-Baz 2015;Saad et al 2015; Moubark and Abdelkareem 2018). In order to compensate the shortage of water resources, the Egyptian government proposed alternative resources such as groundwater and non-conventional water resources (e.g., drainage water and treated municipal wastewater, and desalinization,). For example, 9 billion m^3/annually of agriculture drainage water is suggested to be reused for irrigation process (Abdel Moneim 1988; Tanji and Kielen, 2002). Each resource has its limitations on use relate to cost, quantity, quality, location, and time of process(Amer et al., 2005).

The drainage water of agricultures in south Egypt back again directly to the Nile and mixed with the fresh water to be reused in different purposes. In 1995/96, the estimated amount of such indirect reuse is about 4.07 $X10^9$ m^3 /year. This drainage stream derives mainly from three supplies; seepage losses and tail end discharges; surface runoff from irrigated fields; and deep percolation related to irrigation process. Such process forms the official reuse approach that is conducted by using pumping stations of the Ministry of Water Resources and Irrigation (MWRI). Moreover, the unofficial reuse process that around 2.8 $X10^9$ m^3/y can be accomplished by the farmers, when they find shortage of canal water.

The aims of the present study are to (1) characterize the hydrochemical facies and processes that controlled the study irrigation drainage water, (2) estimate the suitability of irrigation drainage water for using in agricultural activities.

II. Study area

The area under investigation is located between latitudes 26^0 00´ and 26^0 14´ N and longitudes 32^0 00´ and 32^0 17´ E, west of the Nile River, in southern Egypt (Fig.1). The study area and its surroundings are essentially occupied by sedimentary rocks ranging in age from Quaternary to Early Eocene. Three main agricultural drains were selected for these studies (Fig. 1b). The first drain (from east to west) is Bakhaness drain, the second is Nagh Hammadi drain and the third is Salam drain.

Salam drain extends from south to north (in the western part of the area). There are many small drains which are nearly perpendicular to the main drain. Nagh Hammadi drain extends from south to north (in the middle part of the area). There are many subsurface drains which debouch their water and sediments into Nagh Hammadi drain, so that exist no surface drains on the location map.

Bakhaness drain starts beside Nagh Hammadi barrage and extends to west and after that to the north and finally debouches its water to the river Nile. Agricultural drainage system is influenced by intense agriculture including sugarcane, wheat, vegetables, groves and fruit plantations, which requires heavy fertilization. Several pumping stations take water from the drains for industrial use and irrigation. Untreated wastewater is discharged by industries, agriculture, cities and villages into drains, which has caused recent algal blooms.

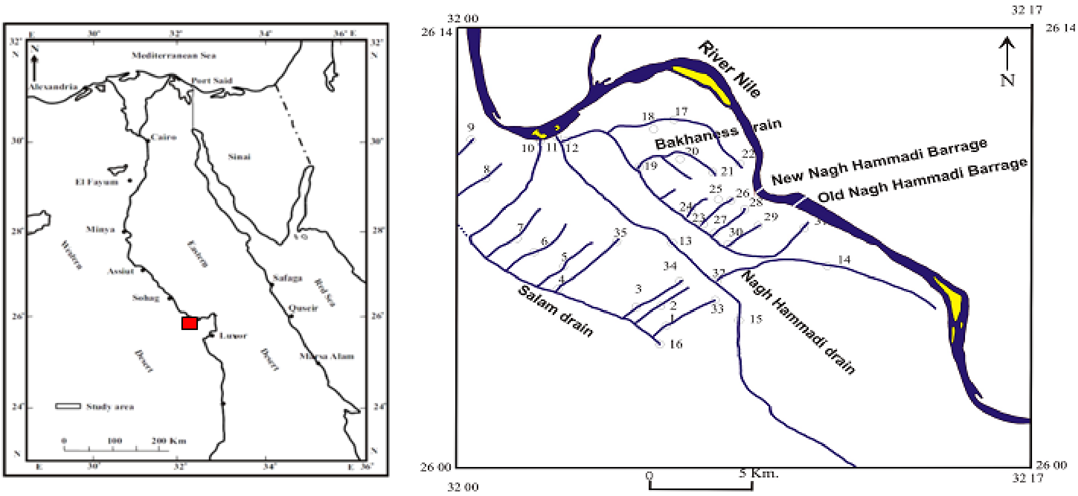

Fig. 1. Location map of the studied area (left); studied drains and water sample sites (right)

III. Materials and methods

Thirty five samples of the area (32samples from drain water and 3 samples 18, 20, 25 are from hand bumps representing the Quaternay aquifer) have been transferred to the laboratory in order to carry out hydrochemical analyses. Each sample was divided into two subsamples after filtration through (0.45 µm pore size membrane filters), the filtrate was then transferred to polyethylene bottles. One of them was prepared to measure the metals and Major Cations by using PERKIN ELMER 700 Atomic Absorption Spectrometer (AAS), the second subsample was prepared to measure Cl, and SO_4 by using a SHIMADZU HIC-6A Ion Chromatography (IC)., pH and total dissolved salts (TDS), were measured for each water sample in the field using Hach test kits during collection of samples at the studied localities. The Sodium Absorption Ratio (SAR), Residual Solid Carbonates (RSC), and Soluble Sodium Percentage (SSP) were calculated in the present study.

IV. Results

The results of the hydrochemical analyses of the 32 surface water samples of agricultural drains and 3 hand bump samples (representing the Quaternary aquifer) using the previously mentioned analytical approaches are reviewed in (Table1). Therefore, the sum of the equivalents of the cations and of the anions can be utilized to estimate the accuracy of the analysis. For estimation of the ion-balance error the usual method is the following (in Matthess 1982):

$$e = \frac{(r_c - r_a)}{(r_c + r_a)} x100$$

rc = sum of cation (epm), ra = sum of anion (epm)

Applying this equation to the present analysis, the value of "e" ranges from –0.7% to 5.4% in the area, indicating that the error percentage is in the permissible limit which is less than 5%. The pH-values of the analyzed surface water samples range from 7.4 to 8.1. This rather alkaline environment may be related to the high concentration of Na+. The guide lines for pH in drinking and irrigation water by 6.5-8.5 (WHO 1984 and FAO 1985).The increase in pH promotes the precipitation of metals or their adsorption on sediments, which subsequently are enriched in the drain sediments. Ultimately this results in reduced water column concentrations and perhaps increased concentrations of metals in sediments (Förstner and Wittmann 1983).

The estimated values of TDS range from 243 mg/l to 1290 mg/l. Water for domestic and industrial uses should have less than 1000 mg/l (World Health Organization Standard), and water used for most agricultural purposes should have less than 3000 mg/l TDS

The hydro-chemical data of groundwater were plotted on a Piper triangular diagram (Piper, 1953), which is perhaps the most commonly used method for identifying hydro chemical patterns of major ion composition (Alexakis et al., 2011).Regarding to cations, the majority of (Fig. 2). the plotted samples are lie on the lower-left triangle, signifying that some are Ca-rich type, and Na-rich-type water but the most samples are of a mixed types; regarding anions, most groundwater samples are plotted in zone E of the lower-right triangle (Fig. 2), showing that bicarbonate-type water is predominant. The predominant hydrochemical types are HCO3–Ca, HCO3–Na and mixed HCO3–Ca–Na–Mg types.

Table1: hydrochemical analyses and parameters of the studied water sample

sample	location	TDS	pH	Na+	K+	Ca2+	Mg2+	HCO3-	Cl^-	SO42-	e%	Na%	SAR
1	Salam drain	426.88	7.62	69.00	5.50	58.00	22.00	360.00	20.80	55.00	1.39	51.36	3.48
2		300.16	7.63	43.00	5.80	44.00	16.00	256.30	15.70	35.70	1.32	46.11	2.44
3		384.00	7.51	64.00	5.40	50.00	21.00	323.41	21.90	59.10	-0.02	51.59	3.36
4		465.28	7.62	81.00	5.10	59.00	25.00	366.12	26.20	72.30	0.90	52.75	3.90
5		563.20	7.35	100.0	5.20	68.00	30.00	421.04	39.10	84.10	1.39	54.10	4.46
6		639.36	7.60	120.0	5.50	66.00	33.00	427.14	51.40	105.60	2.29	58.60	5.37
7		724.48	7.45	144.0	5.90	80.00	38.00	488.16	63.90	138.40	2.52	58.41	5.86
8		416.00	7.57	56.00	4.10	60.00	29.00	366.12	18.10	43.90	2.51	41.03	2.55
9		1290.2	7.55	320.0	8.70	121.00	72.00	793.26	204.3	225.30	5.35	67.60	10.69
10		456.32	7.64	73.00	6.30	56.00	25.00	317.30	42.70	61.30	2.93	47.99	3.34
16		260.48	7.50	35.00	5.60	40.00	13.00	219.67	13.80	30.80	0.50	33.47	1.67
33		385.28	7.93	63.00	5.20	51.00	20.00	311.20	19.90	55.70	0.00	35.34	2.39
34		906.24	7.55	200.0	17.00	74.00	49.00	744.44	74.00	123.20	0.02	58.47	6.83
35		625.28	7.73	111.0	3.00	76.00	35.00	506.47	26.70	85.50	0.28	42.38	3.74
11	Nag hamadi	371.20	7.90	53.00	5.10	58.00	23.00	335.61	15.80	32.30	3.15	39.07	2.37
13		422.40	7.60	59.00	5.40	62.00	28.00	408.83	15.40	32.30	0.21	39.39	2.52
14		321.92	7.70	43.00	5.50	45.00	18.00	274.59	15.50	31.70	-0.02	37.19	2.03
15		321.28	7.66	47.00	5.40	48.00	19.00	305.10	15.10	31.00	-0.56	37.56	2.15
32		386.56	7.65	54.00	4.90	53.00	26.00	372.22	13.10	28.90	0.06	31.93	2.05
18	Bakhans Hand pump	387.84	7.60	68.00	2.50	45.00	30.00	408.83	12.80	27.10	0.71	44.79	3.07
21		449.28	7.95	55.00	4.10	69.00	34.00	457.65	10.90	25.60	0.69	32.58	2.10
25		547.20	7.35	56.00	2.50	52.00	68.00	482.06	17.70	44.60	0.94	34.97	2.26
12	Bakhans drain	300.80	7.50	35.00	7.80	50.00	18.00	286.79	15.10	21.30	0.09	33.10	1.63
17		291.84	7.40	35.00	4.90	50.00	18.00	299.00	11.80	19.90	-0.72	29.74	1.54
19		288.64	7.70	33.00	4.40	46.00	17.00	268.49	11.10	19.20	0.54	28.64	1.46
20		655.36	7.75	184.00	2.20	29.00	35.00	610.20	16.40	61.30	1.88	72.28	9.11
22		341.76	7.70	31.00	8.70	62.00	23.00	366.12	13.00	8.20	0.14	24.27	1.22
23		279.68	7.65	33.00	5.10	46.00	16.00	262.39	11.30	20.40	0.28	27.23	1.40
24		272.64	7.62	32.00	4.80	47.00	17.00	274.59	10.00	19.20	0.08	25.97	1.34
26		243.20	7.80	25.00	6.60	41.00	17.00	244.08	9.30	15.70	0.83	23.10	1.06
27		286.72	7.97	32.00	4.80	43.00	17.00	256.28	10.20	20.60	0.50	25.76	1.33
28		391.68	7.84	17.00	6.30	64.00	37.00	390.53	11.40	11.80	0.67	14.08	0.63
29		432.00	7.95	20.00	3.50	63.00	46.00	445.45	9.90	14.40	0.04	14.79	0.74
30		279.68	8.10	30.00	4.60	49.00	17.00	274.59	10.10	17.80	0.22	22.46	1.18
31		330.88	7.57	27.00	3.80	58.00	23.00	317.30	9.60	16.90	0.89	18.94	1.01

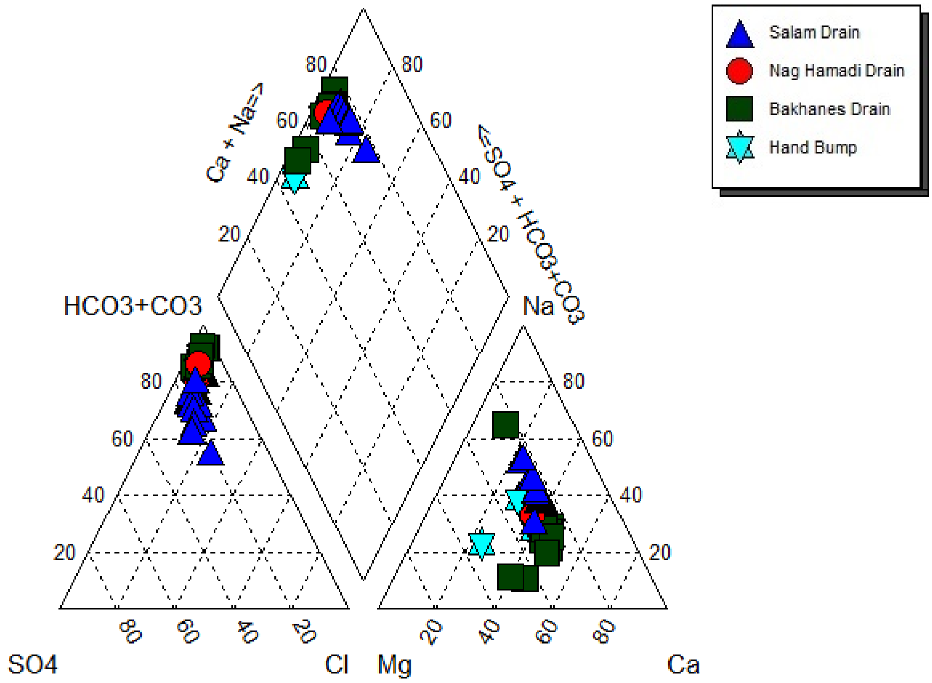

Fig. 2. Piper diagram of the studied agricultural drainage water samples

Gibbs (1972) recommended two diagrams to assess the main effects of rainfall, weathering process and rate of evaporation on the hydrochemistry of groundwater in semi-arid and arid regions. The diagram displays the precipitation power, rock dominance, and evaporation domination is included in the controlling mechanisms (Gibbs, 1970). The distributed characteristic of samples in Fig.3 shows that weathering process of a rock and evaporation–crystallization processes are dominant mechanism in the studied water samples

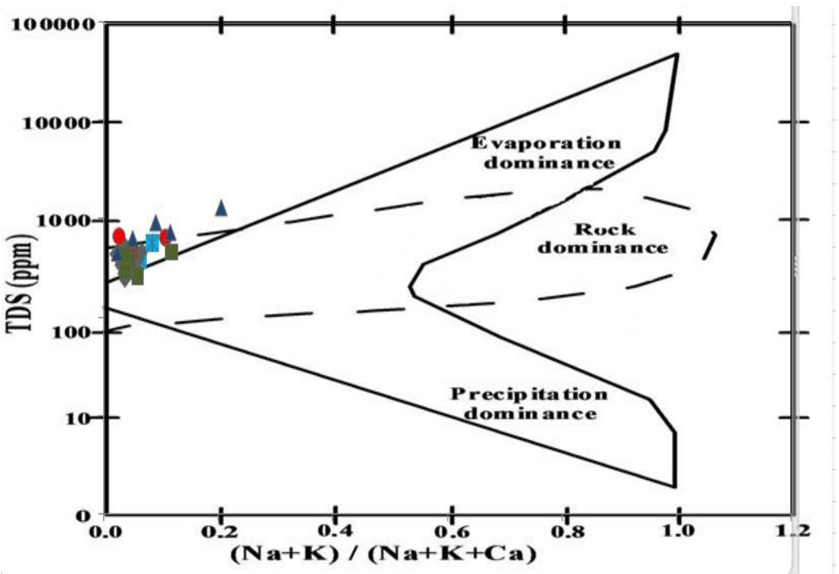

Fig. 3. Gipps diagram of the studied agricultural drainage samples

Sodium Adsorption Ratio (SAR)

The relation between Na and Ca + Mg ion content in waters affects to a wide extent in the physical characteristics of soils. The ability of water to expel Ca and Mg by Na can be estimated with the aid of the sodium adsorption ratio "SAR" (Richards 1954 in Matthess 1982). The value of Sodium Adsorption Ratio (SAR) is estimated by the following equation:

$$SAR = \frac{Na^{+1}}{\frac{1}{2}\sqrt{Ca^{+2} + Mg^{+2}}}$$

Where Na^{+}, Ca^{2+} and Mg^{2+} are expressed in equivalent per million (epm)

The computed values of SAR for the collected water samples are displayed in (Table 1). The distribution percentages of these classes in the area are illustrated in figure (4.26). It is clear that about 97% of the collected water samples extend in the range of excellent water (SAR<10) with no harmful effects from Na and 3% in the range of good water.).

Wilcox (1954) uses electrical conductivity, and SAR classifies groundwater as C_xS_x where, c_X is representing the salinity hazard and S_x is representing the sodium or alkalinity hazard .According to Wilcox diagram(fig4) the studied drain waters isC_2 S_1 with medium salinity hazard and low sodium hazard, however two samples from salam drain show a higher salinity and sodium hazard.

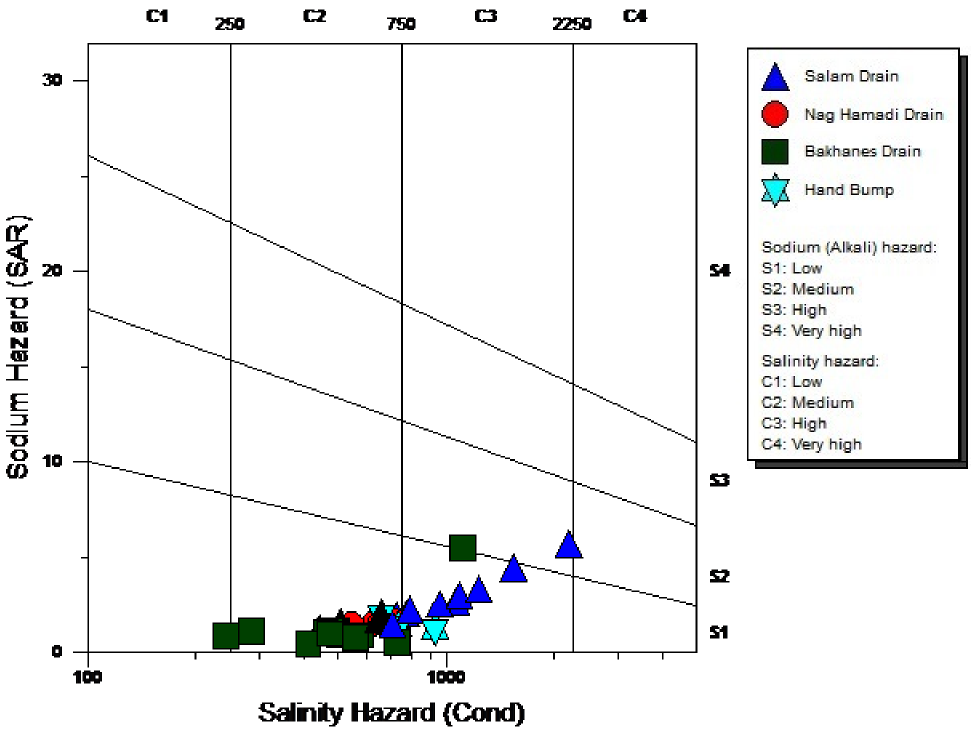

Fig. 4. Wilcox diagram of the studied agricultural drainage samples

Soluble sodium percentage (SSP)

The SSP is an estimation of the Na hazard of irrigation water, such as SAR, but it expresses the sodium % out of the entire cations and not as SAR correlating the Na with the Ca and Mg. SSP is computed by the following equation:

$$SSP = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} x100$$

Where the concentrations of ions are estimated in meq/l.

The irrigation water based on the SSP values are listed In Table (2) according to Todd classification (1980). Based on SSP values, 6% of samples belongs to "Excellent"
class, 60% of samples belongs to "Good", 30% samples belongs to Permissible "mostly belong to Salam Drian,0.3% samples belongs to " Doubtful".

Table (2): Classification of irrigation water based on SSP (Todd 1980) and the corresponding classes in the present study.

Water Class	SSP	EC µs/cm	Bakhaness drain	Nagh Hammadi drain	Salam drain	%
Excellent	< 20	> 250			28, 29	6%
Good	20-40	250-750	12, 17, 18 (HB), 19, 21, 22, 23, 24, 25 (HB), 26, 27, 30, 31,	11, 13, 14, 15, 32	2, 8, 16	60%
Permissible	40-60	750-2000			1, 3, 4, 5, 6, 7, 9, 10, 33, 34, 35	30%
Doubtful	60-80	2000-3000	20 (HB)			3%
Unsuitable	> 80	> 3000				

Residual sodium carbonate (RSC)

The RSC is the combination of the concentrations of HCO3 and CO3 minus the sum of the Ca^{+2} and Mg^{+2} ion concentrations, where the ions are expressed in meq/l. As RSC increases, most of the Ca^{+2} and some Mg^{+2} are precipitated when water is irrigating the soil; the increasing the Na^{+} percentages and the rate of sorption of Na^{+} on soil particles are increasing the potential for a Na^{+} hazard. The grade of Na^{+} hazard based on RSC is displayed in table (3).

The term RSC is estimated as follows:

$$RSC = \left(CO_3^{\ 2-} + HCO^{-}{}_3\right) - \left(Ca^{2+} + Mg^{2+}\right)$$

Table (3): Classification of irrigation water based on RSC values (College of Agricultural Sciences 2002) and the corresponding classes in the present study.

RSC	Hazard	Bakhaness drain	Nagh Hammadi drain	Salam drain	%
< 0	none.	25 (HB)		8, 9, 10	11.5%
0-1.25	low, with some elimination of Ca and Mg from irrigation water.	12, 17, 19, 22, 23, 24, 26, 27, 28, 29, 30, 31	11, 14,15	1, 2, 3, 4, 5, 6, 7, 16, 33	68.5%
1.25-2.50	medium, with substantial elimination of Ca and Mg from irrigation water.	21, 18 (HB)	13, 32	33	14.3%
> 2.50	high, with most Ca and Mg removed leaving Na to accumulate.	20 (HB)		34	5.7%

Based on RSC values, 68% of samples belongs to “Low soudium hzard l, with some elimination of Ca and Mg from irrigation water.”14.3% of water sample belongs to Medium hazard, 5.7% of water sample is high hazard most Ca and Mg removed leaving Na to accumulate. Some samples analyzed during this study showed RSC values less than zero indicating that sodium build-up is improbable since sufficient Ca and Mg are in excess of what can be precipitated as CO3 when the water is applied to the soil.

V. Conclusions

Lack of water resources and the increasing need for fresh water due to increasing water population in Egypt is pushing for discovering other water resources in arid/hyper-arid regions. The hydrochemical analyses were conducted on drainage water samples that collected from three drainages in southern Egypt. The major elements and physical parameters were estimated. Results showed that drainage water was corresponded mainly to HCO3-Ca, HCO3-Na, and HCO3-Mg type referring to fresh water facies. The results of SAR, RSC, and SSP assumed to be suitable for reuse purposes in the agricultural activities. Some of drain water(especially in salam drain) is of bad irrigation water quality as it has the permissible values of EC, SAR, RSC and SSP, so it is recommended to be utilized for irrigation but these waters are not suitable for fine-textured soils and with sensitive plants.

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