Zagazig J. Agric. Res., Vol. 45 No. (6B) 2018 2417-2432

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

ASSESSMENT OF GROUNDWATER QUALITY FOR USE IN IRRIGATING SOME REGIONS OF SHARKIA GOVERNORATE, EGYPT

Akram H.M. Sakr*, A.S. Metwally, E.A.H. El-Naka and M.K. Abdel-Fattah

Soil Sci. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 17/10/2018 ; Accepted: 04/12/2018

ABSTRACT: Groundwater samples were collected monthly from different wells in Sharkia Governorate, Egypt, for 12 months, (from May 2015, to April 2016) to evaluate water quality for use in irrigation. Locations of samples (Longitude and latitude) were recorded by GPS device. Samples were analyzed for salinity. There were no severe problems of sodicity, alkalinity or toxicity for irrigation purposes, but there were some salinity hazards. The water can be used for supplementary agricultural irrigation provided proper management practices are taken.

Key words: Supplementary irrigation, groundwater, validity, quality, model, IWA-Mod.

INTRODUCTION

The Nile River is the main source of fresh water in Egypt, which has an annual shared 55.5 bilion m^3, 80% of which is consumed in agriculture, Egypt is facing water scarcity that requires utilizing every available source. The Major challenge facing Egypt is the strong need for development and management of the available limited resources of water, for the needs of increasing population and land reclamation (Table 1).

Groundwater is a vital source of water used for public and domestic, irrigation, industrial, commercial, mining and thermo-electric power production purposes. Groundwater serves as the only reliable source for drinking and irrigation. Unfortunately, this vital resource is vulnerable to contamination. These sources may be threatened by a vast array of pollutants from such diverse sources as sanitary landfills, soil treatment systems, septic tanks and subsurface disposal wells **(Ashour *et al.*, 2009)**.

Groundwater is a potential source of water for lands located at the end of irrigation canals **(Clawson *et al.*, 1971; Kashef, 1981)**.

Groundwater in conjunction with surface water can be used to overcome the deficiency of irrigation water, (**El-Arabi *et al.*, 2000; Morsy, 2009)**. They can recompense about 25% of irrigation requirement in some parts of the Eastern Nile Delta (**El-Fakharany, 2002; Samak, 2007)**.

Salinity of groundwaters and intrusion of saline water are prevalent pollutant in such water **(Todd and Mays, 2005)**. In Nile Delta, fresh Groundwater could push the saline Groundwater northwards **(Morsy, 2009; FAO, 2013)**.

Quality of Groundwater and surface water in the Nile Delta was studied by **Morsy (2009)**. Who noted that Fe and Mn were higher in the old cultivated lands and that Pb was detected in some industrial areas. **Hussien (2007)** recorded deterioration in groundwater quality for wells in and nearby the industrial areas.

Total area irrigated with groundwater in the Nile Delta is reported by **FAO (2013)** as 175 thousand ha (414000 faddan).

According to **Khodapanah *et al.* (2009)**, suitability of groundwater for irrigation depends on salinity which can be highly harmful. Salts can damage plant growth and their evaluation in groundwater is important (**Todd, 1980; Sheinberg and Oster, 1985**). Irrigation water

* **Corresponding author: Tel. :** +201123930047
E-mail address: akramsakr3000@gmail.com

quality criteria is evaluated based on, salinity, sodicity, alkalinity and specific ions: chloride, sulfate, boron, and nitrate as well as pH (**FAO, 1985)**. The main objectives of the current study were to assess the quality of groundwaters of some wells in Sharkia Governorate, which are used by famers.

MATERIALS AND METHODS

Study Area and Water Sampling

Sixteen water samples were collected monthly from different wells in El-Sharkia Governorate, Egypt (Maps 1 and 2) for a period which extended up to 12 months (May 2015 until April 2016) to evaluate water quality for irrigation. Position coordinates of wells (Longitudes and latitudes) were recorded by GPS device (Table 2). The area of study covers eight districts with 2 different wells for each, beginning from the South to the North. The Upper North of the governorate was excluded because of the groundwater wells rarely occurred. The size of water sample was about 1 L. Precautions were considered to avoid water contamination during sampling and handling.

Laboratory Analysis

Samples were subjected to analysis for salinity following standard methods (**APHA, 1995**). Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined using standard EDTA procedures, chloride (Cl^{-}) was determined by $AgNO_3$ titration, bicarbonate (HCO_3^{-}) was determined by titration with HCl, sodium (Na^{+}) and potassium (K^{+}) were determined by flame photometry and EC and pH were directly measured.

Criteria for Judging the Validity of Water

Standard water parameters for evaluating of water were calculated. They are soluble Sodium Percentage (SSP), Sodium Adsorption Ratio (SAR), estimated Exchangeable Sodium Percentage (ESP) expected in soil, Sodium to Calcium Activity Ratio (SCAR), Residual Sodium Carbonate (RSC), Residual Sodium Bicarbonate (RSBC), expected Permeability Index (PI) of soil, Potential Salinity (PS), Kelly Ratio (KR) and Magnesium Adsorption Ratio (MAR). Results were graphically presented using the IWA-Mod according to procedures of United States Salinity Laboratory (USSL), Wilcox Diagram, Piper Diagram and Doneen Plots.

Calculations were done using the Irrigation Water Assessment Model (IWA-Mod) Excel worksheet software developed by Mohamed K. Abdel-Fattah, Soil Science Department, Faculty of Agriculture, Zagazig University, Egypt, to help users evaluating irrigation water quality. IWA-Mod is an acronym for Irrigation Water Assessment Model. Fig. 1 shows the flowchart of IWA-Mod version 1-2013. The flow chart consists of three main parts as follows:

Main IWA-Mod interface

The main interface of IWA-Mod contains a quick introduction to the model, uses, and instructions with two main buttons for agree or disagree (Fig. 2).

Data file sheet

Data file Excel sheet appears when pressing on the agree button, found in the interface of IWA-Mod. Data file sheet contains cells to set the number of samples. The maximum number of samples is 100 (Table 3). The data file contains six main buttons as follows:

- Run button is used to move to window of results file (results sheet).
- About button is used to pop up window box contains the main information about designer of IWA-Mod (Fig. 3).
- Calculator button is used to recall calculator of Microsoft windows.
- Clear button is used to clear contents of data file.
- Inquiry button is used to send feedbacks about IWA-Mod to the creator *via* E-mail.
- Flowchart button is used to show the main flowchart sheet of IWA-Mod to help users for more understanding the model.

Results sheet

Results sheet appears upon pressing the Run button in data file. Results sheet contains most criteria for calculating water quality (Table 4). Results sheet contains dropdown menu of abbreviations for the used terms. Results sheet contains four sub buttons with different functions as follows:

- Go to data file button is used to move to data file directly.

Map 1. Groundwater samples locations on google earth

Map 2. Groundwater samples locations and position coordinates of wells by ArcMap

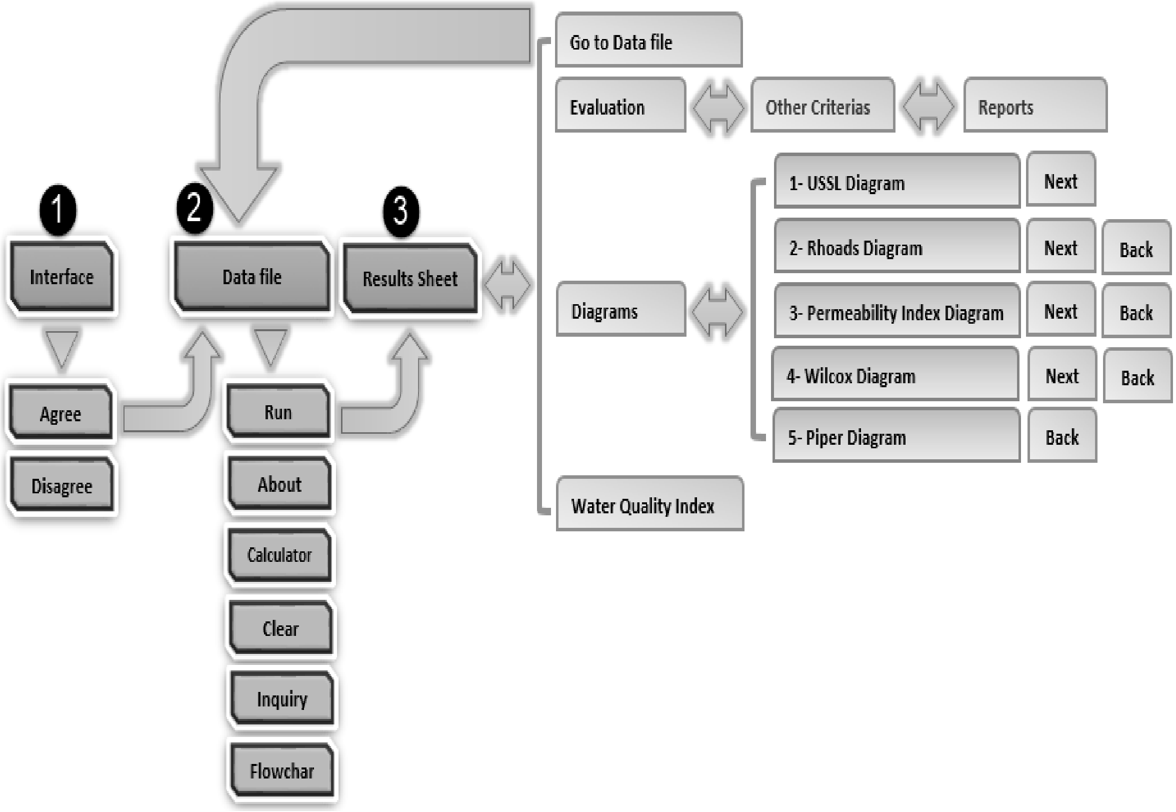

Fig. 1. Flowchart of IWA-Mod version 1.0-2013

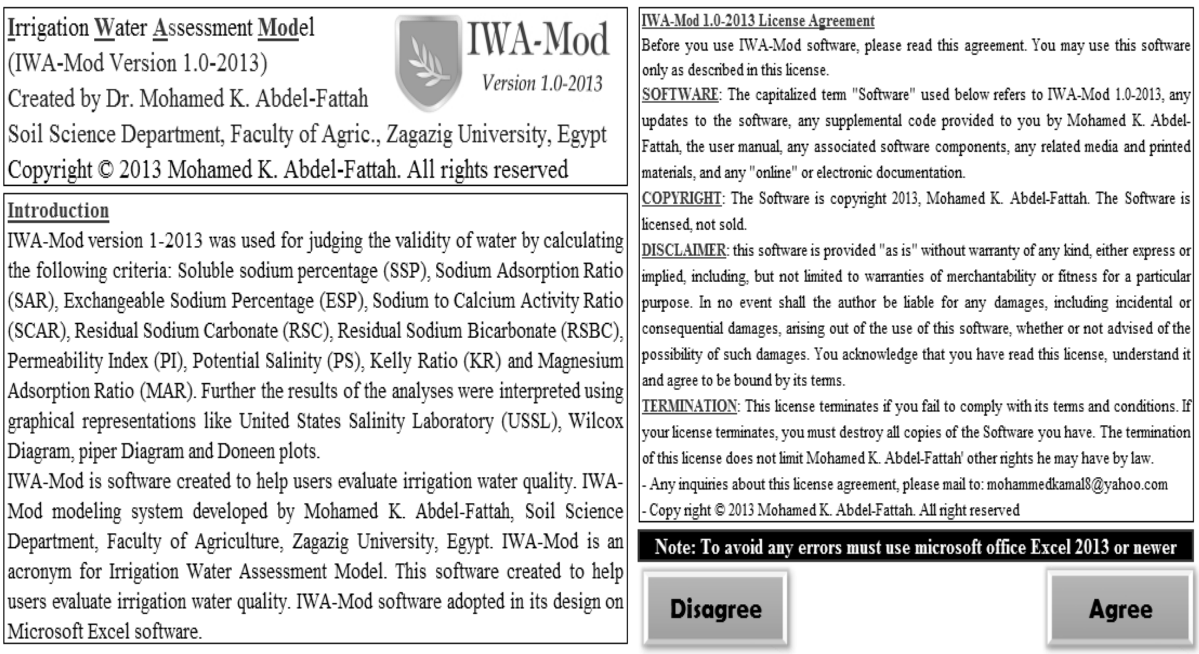

Fig. 2. The main interface of IWA-Mod version 1.0-213

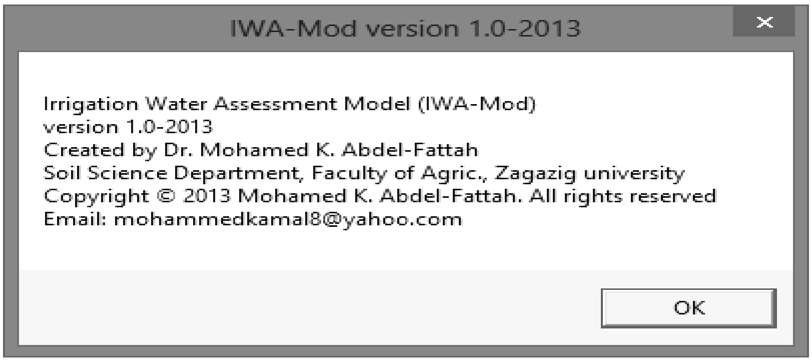

Fig. 3. Pop up window box contains the main information about designer of IWA-Mod

Table 1. The available water resources in Egypt (Allam and Allam, 2007)

Water resources (Billion $m^3 year^{-1}$)	Amount
Nile River	55.5
Groundwater (Delta and valley)	5.5
Deep ground water	0.8
Drainage water resources	
Canals in the Delta regions	4.5
Nile River and Bahr Youssef	5.0
Illegal uses	3.0
Waste water reuse	0.2
Rainfall and flash floods	0.5
Evaporation losses	(3)
Total	72.00

Table 2. Groundwater samples locations and position coordinates of wells (longitudes and latitudes)

Well No.	GPS Reading		Village name	District
	Latitude	Longitude		
1	30°23'55.268"N	31°23'21.231"E	As Sahafah	Mashtul as Suq
2	30°19'55.110"N	31°23'57.767"E	KafrIbrash	
3	30°23'23.182"N	31°31'05.155"E	Gheitah	Belbes
4	30°28'25.284"N	31°32'18.441"E	Kafr El-Shaikh Eissa	
5	30°27'28.265"N	31°18'14.218"E	As Sanafin Al Bahariyyah	Menya Al Qamh
6	30°32'05.244"N	31°18'09.288"E	Kardeidah	
7	30°37'30.966"N	31°42'46.502"E	Al Hilmiyya	AbouHammad
8	30°30'24.177"N	31°39'31.371"E	Al Isdiyyah	
9	30°30'32.952"N	31°31'47.158"E	Bardein	Zagazig
10	30°36'49.000"N	31°28'32.741"E	Al Qanayat	
11	30°39'12.825"N	31°36'57.206"E	Al Fawaqsah	Hihya
12	30°38'12.222"N	31°36'50.999"E	AZ Zarzamoun	
13	30°44'07.459"N	31°22'13.775"E	Hissat AR Ruhban	DyarbNegm
14	30°47'16.546"N	31°32'11.719"E	JimmayzitBani Amr	
15	30°41'23.260"N	31°38'28.324"E	Jazeera Al Abazia	Abukabir
16	30°44'21.280"N	31°42'18.570"E	Kafr Al Shobaki	

Table 3. Data file sheet forionic analysis of groundwater wells taken from different districts (average of six samples)

Insert Samples No. 16 | Run | About | Calculator | Clear | Inquiry | Flowchart

IWA-Mod Version 1.0-2013

Sample No.	pH	EC, dS/m	Cations, mmolc/L				Anions, mmolc/L				Boron, ppm	NO3, ppm
			Ca2+	Mg2+	Na+	K+	CO3=	HCO3-	Cl-	SO4=		
1	7.17	0.58	1.26	0.94	2.01	1.62	0.00	0.68	1.68	3.47	0.05	0.60
2	7.12	0.66	1.47	1.05	2.23	1.86	0.00	1.09	2.46	3.05	0.19	0.85
3	7.14	0.32	0.51	0.32	1.32	1.04	0.00	0.71	1.40	1.09	0.03	0.36
4	7.21	0.83	1.85	1.21	3.16	2.16	0.00	2.13	2.89	2.82	0.08	1.17
5	7.17	0.55	1.13	0.80	2.19	1.43	0.00	1.32	1.26	2.96	0.05	0.81
6	7.15	0.78	1.52	1.11	2.91	2.28	0.00	2.03	3.16	2.63	0.07	1.11
7	7.13	0.63	1.18	0.68	2.50	1.94	0.00	1.28	2.11	2.91	0.06	0.81
8	7.15	0.75	1.49	1.03	2.73	2.20	0.00	1.37	3.06	3.02	0.07	0.95
9	7.20	1.44	3.01	1.98	5.40	3.96	0.00	4.64	5.37	4.34	0.41	2.61
10	7.15	0.51	1.05	0.66	2.15	1.24	0.00	0.93	1.29	2.88	0.04	0.58
11	7.16	0.76	1.50	0.92	3.03	2.18	0.00	1.21	2.69	3.73	0.07	0.93
12	7.12	0.83	1.64	1.13	3.08	2.45	0.00	1.30	2.89	4.12	0.16	0.98
13	7.16	0.43	0.94	0.68	1.38	1.30	0.00	0.93	1.77	1.59	0.04	0.69
14	7.15	0.52	1.08	0.79	1.98	1.35	0.00	0.95	1.70	2.55	0.04	0.54
15	7.20	0.30	0.52	0.36	1.16	0.92	0.00	0.69	1.31	0.96	0.03	0.40
16	7.16	0.86	1.87	1.25	3.27	2.23	0.00	2.08	3.10	3.45	0.08	1.15

Table 4. Results sheet and criteria for judging the validity for groundwater in different districts and their Villages (average of six samples)

Meaning of abbreviations (select) ===> RSC
Residual Sodium Carbonate

Go to Data | Evaluation | Diagrams | Water Quality Index

IWA-Mod Version 1.0-2013

Sample No.	SSP	SAR	Adj.SAR	Adj.R Na	ESP	RSC	RSBC	SCAR	PI	PS	KR	MAR	Salinity Hazard	Sodicity Hazard	USSL Index	USSL Class
1	34.48	1.92	1.88	1.43	1.58	-1.52	-0.58	1.79	67.33	3.42	0.91	42.73	C2	S1	C2S1	Good
2	33.74	1.99	2.42	1.69	1.69	-1.43	-0.38	1.84	68.93	3.99	0.88	41.67	C2	S1	C2S1	Good
3	41.38	2.05	1.48	1.39	1.78	-0.12	0.20	1.85	100.59	1.95	1.59	38.55	C2	S1	C2S1	Good
4	37.71	2.55	3.96	2.55	2.53	-0.93	0.28	2.32	74.27	4.30	1.03	39.54	C3	S1	C3S1	Appropriate
5	39.46	2.23	2.73	1.93	2.05	-0.61	0.19	2.06	81.04	2.74	1.13	41.45	C2	S1	C2S1	Good
6	37.21	2.54	3.78	2.46	2.51	-0.60	0.51	2.36	78.25	4.48	1.11	42.21	C3	S1	C3S1	Appropriate
7	39.68	2.59	3.09	2.21	2.59	-0.58	0.10	2.30	83.29	3.57	1.34	36.56	C2	S1	C2S1	Good
8	36.64	2.43	3.18	2.17	2.35	-1.15	-0.12	2.24	74.29	4.57	1.08	40.87	C2	S1	C2S1	Good
9	37.63	3.42	6.86	4.02	3.82	-0.35	1.63	3.11	72.71	7.54	1.08	39.68	C3	S1	C3S1	Appropriate
10	42.16	2.33	2.41	1.82	2.19	-0.78	-0.12	2.10	80.68	2.73	1.26	38.60	C2	S1	C2S1	Good
11	39.71	2.75	3.41	2.37	2.83	-1.21	-0.29	2.47	75.78	4.56	1.25	38.02	C3	S1	C3S1	Appropriate
12	37.11	2.62	3.43	2.32	2.63	-1.47	-0.34	2.41	72.14	4.95	1.11	40.79	C3	S1	C3S1	Appropriate
13	32.09	1.53	1.59	1.21	1.01	-0.69	-0.01	1.42	78.15	2.57	0.85	41.98	C2	S1	C2S1	Good
14	38.08	2.05	2.21	1.64	1.78	-0.92	-0.13	1.91	76.74	2.98	1.06	42.25	C2	S1	C2S1	Good
15	39.19	1.75	1.29	1.19	1.33	-0.19	0.17	1.61	97.58	1.79	1.32	40.91	C2	S1	C2S1	Good
16	37.94	2.62	4.04	2.60	2.63	-1.04	0.21	2.39	73.74	4.83	1.05	40.06	C3	S1	C3S1	Appropriate

- Evaluation button is used to move to guideline used for irrigation water quality according to **FAO (1985)** (Fig. 4).
- Others criteria button, which leads to sheet, contains other measurements used for water validity for irrigation (Fig. 5). "Other criteria" sheet contains a button, called "Report" button used to give detailed report for the sample.
- Diagrams button is used to move to charts options used in classifying irrigation water according to its validity such as USSL diagram, Piper diagram, Doneen diagram, and Wilcox diagram. Next button is used to move to next diagram and Back button is used to move to previous one.
- Water Quality Index button is used to move to Water Quality Index (Fig. 6). A commonly-used water quality index (WQI) was developed according to **Brown *et al.* (1970)** to provide a standardized method for comparing the water quality of various bodies of water. Nine water quality parameters were selected to be included in the index. They are dissolved oxygen (DO), fecal coliform, pH, biochemical oxygen demand (BOD), temperature change, total phosphate, nitrate, turbidity and total solids.

Water Quality Parameters for Judging

Soluble sodium percentage (SSP)

High sodium in soil can impede drainage. SSP was calculated using the following equation (**USDA, 1958**):

$$SSP = \frac{Na^+}{Na^+ + Ca^{2+} + Mg^{2+} + K^+} \times 100$$

Where, concentrations of ions are expressed in mmolc L^{-1}. Water with SSP less than 60 is safe with little sodium accumulations that will cause a degradation of the soil physical properties (**Todd, 1980 and Fipps, 1998**).

Sodium adsorption ratio (SAR)

Sodium adsorption ratio is a measure of soil sodicity. The SAR was calculated using the following equation according to (**USDA, 1958**)

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

Where, concentrations of ions are expressed in mmolc L^{-1}. The SAR classes depend upon the salinity of water. They include, low, S1 (for SAR <10); medium, S2 (for SAR 10–18); high, S3 (for SAR 18–26); and very high, S4 (for SAR > 26).

SAR parameter may be used to predict sodicity hazard. Adjusted SAR takes into account other parameter and the equation is as follows (**Ayers and Wescot 1985**).

$$Adj.SAR = SAR\left(1 + (8.4 + pH_C)\right)$$

The adjusted SAR should be used in evaluating water with EC values higher than 1.5 and less than 3.0 dSm^{-1}. The adj R_{Na} (adjusted Sodium Adsorption Ratio) is presented in the following equation as an upgrade of the SAR. It can be used to predict more correctly potential infiltration problems due to relatively high sodium (or low calcium) in irrigation water supplies (**Suarez 1981; Rhoades 1982**). The equation is as follows:

$$Adj.R_{Na} = \frac{Na^+}{\sqrt{\frac{Ca^{2+}{}_x + Mg^{2+}}{2}}}$$

Sodium to calcium activity ratio (SCAR)

SCAR is the ratio of Na to Ca and calculated as follows (**Gupta 1990**).

$$SCAR = \frac{Na^+ \; mmolc \; L^{-1}}{\sqrt{Ca^{2+}} \; mmolc \; L^{-1}}$$

On basis of SAR/SCAR, the irrigation waters may be classified in six classes of sodicity, Non-sodic, S0 (<5); Normal, S1 (5-10); Low sodicity, S2 (10-20); Medium sodicity, S3 (20-30), High sodicity, S4 (30-40) and Very high sodicity, S5 (>40).

Residual sodium carbonate (RSC)

Excess carbonate and bicarbonate ions over calcium and magnesium ions in water lead to presence of sodium carbonate, therefore sodicity. The equation is as follows (**USDA 1958**).

$$RSC = (CO_3^{=} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Where, concentration of ions is expressed in mmolc L^{-1}. RSC hazard classes are none (<1.25), medium (1.25-2.5) and high (>2.5).

Back | Other Criteria | Water samples number: 4 | IWA-Mod Version 1.0-2013

	Water irrigation problem	Prameter	Value	Degree of Restriction on Use
1-	Salinity (affects crop water availability)	EC (dS/m) TDS (mg/l)	NDS NDS	NDS NDS
2-	Permeabilty (affects infiltration rate of water into the soil)	EC (dS/m) Adj.SAR	NDS NDS	NDS
3-	Specific ion toxicty (affects sensitive crops)	Sodium (Adj. SAR) Chlorid (meq/l) Boron	NDS NDS NDS	NDS NDS NDS
4-	Miscellaneous Effects (affects susceptible crops)	Nitrogen (NO3 - N)-ppm Bicarbonate (meq/l) pH	NDS NDS NDS	NDS NDS NDS

NDS: No Data Set

Fig. 4. Window of evaluation of irrigation water according to guideline for irrigation water quality established by FAO (1985)

Back | Report | IWA-Mod Version 1.0-2013 | Sample No. 4

	Criteria	Value	Degree of problem
1-	Salinity Hazard (dS/m)	NDS	NDS
2-	Sodium Hazard (SAR)	NDS	NDS
3-	Residual Sodium Carbonate (RSC)	NDS	NDS
4-	Soluble Aodium Percent (SSP)	NDS	NDS
5-	Permeability Index (PI)	NDS	NDS
6-	Kelly's Ratio (KR)	NDS	NDS
7-	Magnesium Absorption Ratio (MAR)	NDS	NDS
8-	Relative rate of water infiltration as affected by EC and SAR	NDS	
9-	New Classification of Waters Suggested for Arid And Semi-Arid Zones		
A-	Salinity (EC-dS/m)	NDS	NDS
B-	SAR/SCAR	NDS	NDS
C-	RSC/RSBC	NDS	NDS

NDS: No Data Set

Fig. 5. Window of evaluation of irrigation water by other criteria

National Sanitation Foundation Water Quality Index | Back | IWA-Mod Version 1.0-2013

Parameter (Test)	Result (Data) Required	Unit	Q-value	Weighting Factor	Subtotal
Dissolved Oxygen (DO)		% saturation	NDS	NDS	NDS
Fecal Coliforms		#/100 mL	NDS	NDS	NDS
pH		pH units	NDS	NDS	NDS
BOD		mg/L	NDS	NDS	NDS
Temperature Change		°C	NDS	NDS	NDS
Total Phosphorus		mg/L PO_4-P	NDS	NDS	NDS
Nitrate Nitrogen		mg/L NO_3-N	NDS	NDS	NDS
Turbidity		NTU	NDS	NDS	NDS
Total solids		mg/L	NDS	NDS	NDS

Water Quality Index (WQI)	NDS	
Water Quality Rating (WQR)	NDS	

Clear Contents | 0.00 | 0.00

More information about Water Quality Index

NDS: No Data Set

If you know the value of the Water Quality Index

Put Water Quality Index	
Water Quality Rating	NDS

Fig. 6. Window of water quality index calculation

Residual sodium bicarbonate (RSBC)

Since carbonate ions do not occur very frequently in appreciable concentrations and as bicarbonate ions do not precipitate magnesium ions, **Gupta (1990)** suggested RSBC as follows.

$$RSBC = HCO_3^- - Ca^{2+}$$

Based on RSC/ RSBC ratio, there are six hazard classes as follows: none, A0 (negative value); Normal, A1 (0); Low, A2 (2.5); Medium, A3 (2.5-5), High, A4 (5-10) and Very high, A5 (>10).

Permeability index (PI)

The PI is calculated by the following formula according to **USDA (1958) and Doneen (1964)**

$$PI = \frac{Na^+ + \sqrt{HCO_3^=}}{Na^+ + Ca^{2+} + Mg^{2+}} \times 100$$

Where, concentrations of all ions are in mmolc L^{-1}. The PI classes are as follows: Excellent (>75%), Good (25-75%) and Unsuitable (<25%) (**Al-Amry, 2008**).

Potential salinity (PS)

Potential salinity (PS) was defined as the chloride plus half of the sulphate ions, calculated as follows (**Doneen, 1962** and **Gupta, 1990**).

$$PS = Cl^{\mp 1} / _2 SO_4^=$$

The PS classes are as follows: permissible 5 to 20, 3 to 15 and 3 to 7, for soils of good, medium and low permeability, respectively.

Kelly's index (KI)

Kelly's index relates concentration of Na to the sum of Ca + Mg. A value exceeding 1 indicates an excess sodium (**Kelly, 1940; Sundaray *et al.*, 2009**). Equation is as follows:

$$KI = \frac{Na^+ mmolc\ L^{-1}}{Ca^{2+} + Mg^{2+} mmolc\ L^{-1}}$$

Magnesium ratio (Mg ratio)

MAR was suggested by (**USDA, 1958 Paliual, 1972; Hem, 1985**), and that high Mg^{2+} has adverse effects on soil (**Kumar *et al.*, 2007**). It is calculated as follows:

$$MAR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \times 100$$

Where ions concentrations are expressed in mmolc L^{-1}. Mg ratio classification is as follows: safe (<50) and having Mg^{2+} hazard (>50).

RESULTS AND DISCUSSION

Ionic Analysis for Groundwater Types

Obtained results evaluated by the IWA-Mod (Table 3). Results were plotted to produce a diagram to determine the Piper diagram (Fig. 7) which are given in two triangles (one for cations and one for anions) then a diamond-like field inference was drawn (**Piper, 1944**). The diagram indicates that the dominant types of water are "Sodium chloride type" and sodium and potassium type, while no specific anion was dominated.

Irrigation Water Quality Criteria

Table 4 shows the output results sheet of IWA-Mod that contains the calculated parameters used as criteria for evaluating irrigation water based on water pH, salinity hazard, sodicity hazard, alkalinity hazard and specific ions (chloride, sulfate, boron, and nitrate).

Water pH

The normal pH values should range from 6.5 to 8.4 for irrigation water (**Ayers and Wescot, 1985; Kundu, 2012**). The output results of IWA-Mod indicated that the pH ranged from 7.12 to 7.21 therefore, all samples fall in the acceptable range (Table 3).

Salinity hazard

Results in Table 3 indicate that the EC, ranged from 0.30 to 1.44 dSm^{-1}. According to **USDA (1954)**, ten samples are of a second class (C2 medium salinity, they are of wells 1, 2, 3, 5, 7, 8, 10, 13, 14 and 15 while six samples were of third class (C3 – high salinity): they are of wells 4, 6, 9, 11, 12 and 16. Medium salinity can be used for irrigation if a moderate leaching is performed. Plants with salt tolerance can be grown in most cases without special practices for salinity control. High salinity water cannot be used on soils with limited drainage system. With adequate drainage, this class can be used if special management practices for salinity control are taken, and plants with high salt tolerance are grown (**Abdel-Fattah and Helmy, 2015; Rouabhia *et al*, 2009**). According to the

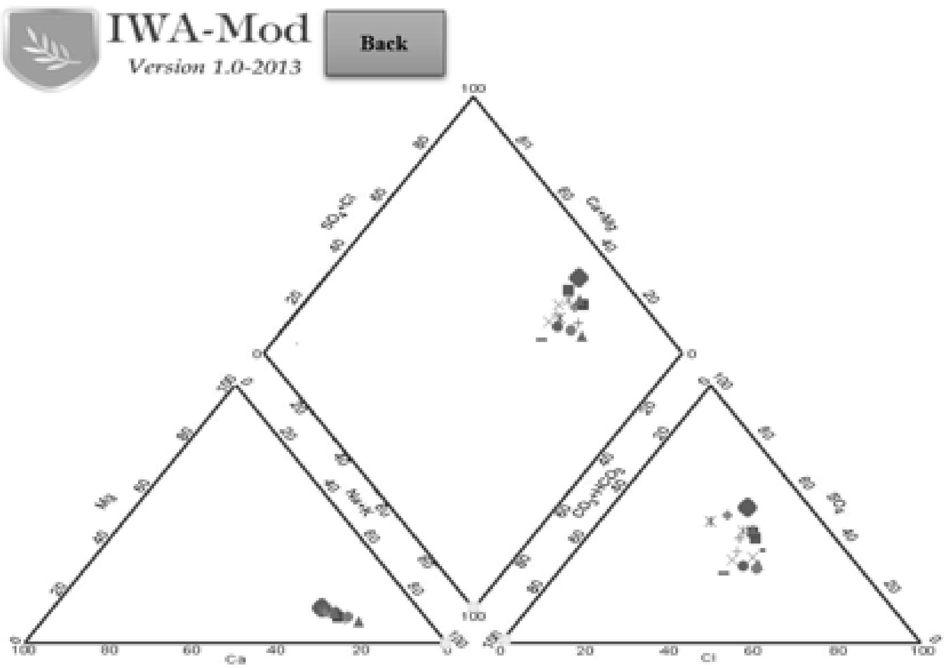

Fig. 7. Piper diagram for classification of groundwater samples abstracted from different wells

irrigation water classification system of **Gupta (1990) and Gupta *et al.* (1999)**, water of EC between 0.30 and 1.44 dSm^{-1} can be used for irrigation with most crops grown on most soils with little likelihood of soil salinity (**Gupta, 1990**).

Sodicity Hazard

Soluble sodium percentage (SSP)

Results of IWA-Mod indicate that SSP ranged from 32.09 to 42.16% (Table 4). Water with SSP > 60% is of sodium hazard and belongs to moderate class with mild restrictions. High SSP reduces soil permeability and eventually results in soil with poor conditions of drainage (**Perparim *et al.,* 2016**).The IWA-Mod shows a Wilcox diagram (Fig. 8) which determines the viability of water for irrigation purposes in the view of sodicity. Sodium was plotted as SSP on the Y-axis against EC on the X-axis (**Wilcox, 1955).** The water falls in the 'Excellent to Good' and 'Good to permissible' category for irrigation (**Abdel-Fattah and Helmy, 2015**).

Sodium adsorption ratio (SAR)

Results on the IWA-Mod show that the SAR ranged from 1.75 to 3.42 (Table 4). According to **FAO (1985)**, these waters are S1, low sodium hazard and can be used for irrigating of most soils with low sodium hazard. However, sodium-sensitive crops such as stone-fruit trees and avocados may not be suitable. Other outputs of IWA-Mod USSL diagram (Fig. 9) show a diagram correlated SAR with EC. Based on the USSL diagram (**USDA, 1954**), the water quality is C2-S1 (medium salinity, low sodicity) for wells 1, 3, 5, 7, 8, 10, 12, 14 and 15, while wells 4, 6, 9, 11, 12 and 16 are of C3-S1 (very high salinity low sodicity) .All samples are 'Good' and 'appropriate' irrigation (**Abdel-Fattah and Helmy, 2015**).

High salinity with high SAR cause infiltration problems. Results presented in Fig. 10 show relative rate of water infiltration as affected by salinity and sodicity **(Rhoades, 1977; Oster and Schroer, 1979)**. Fig. 10 shows that all samples are of slight to moderate infiltration hazards, except well 9, which falls in 'no problem **(Abdel-Fattah and Helmy, 2015)**.

Sodium calcium activity ratio (SCAR)

Results of IWA-Mod indicate that the SCAR ranged between 1.42 and 3.11 (Table 4). The sodicity classification **of Gupta (1990)** includes

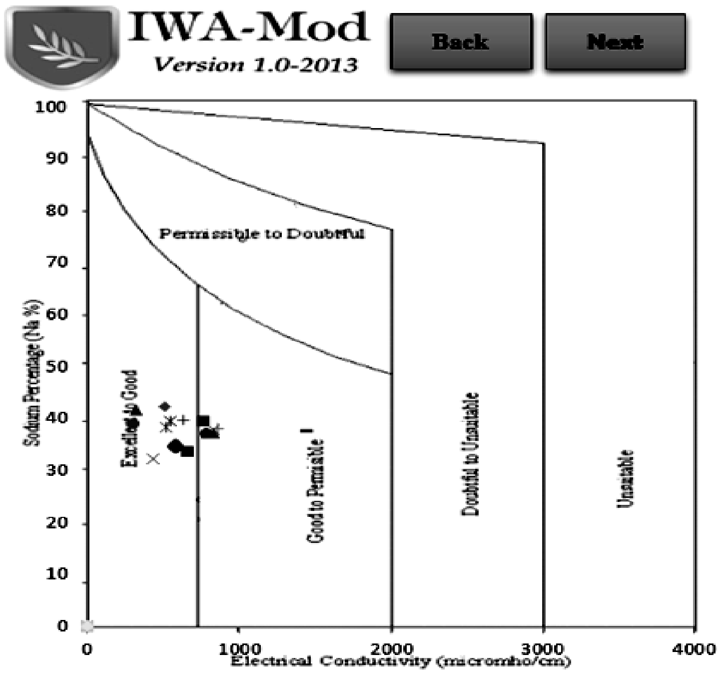

Fig. 8. Wilcox diagram for classification of groundwater samples abstracted from different wells

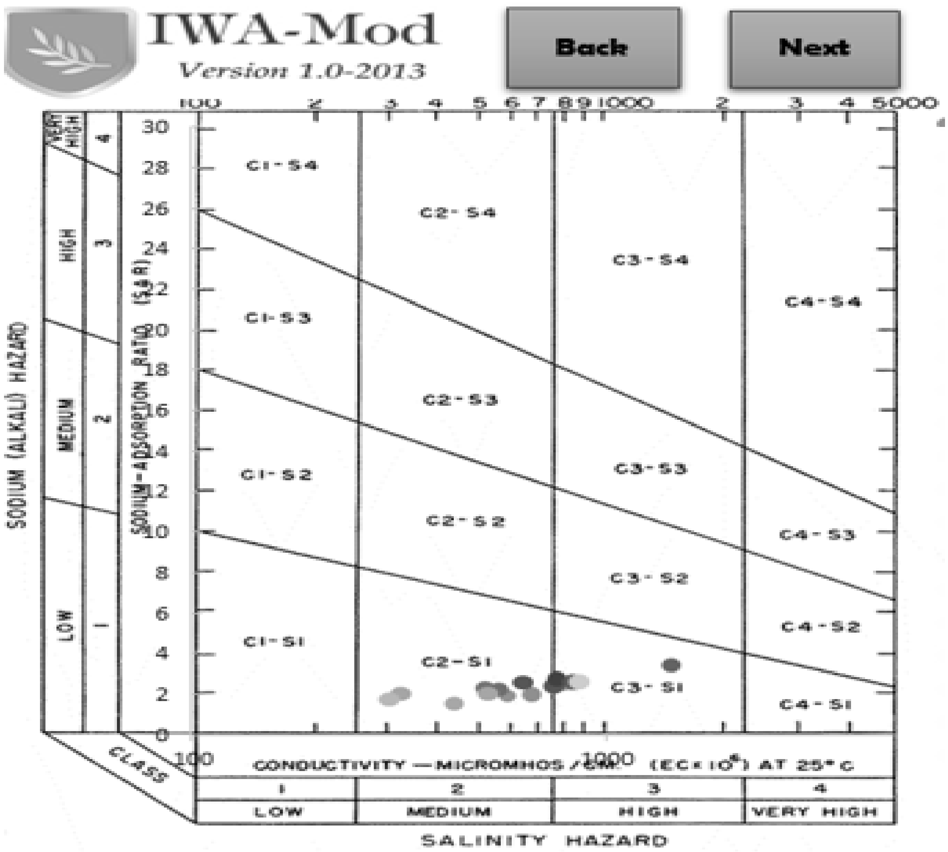

Fig. 9. USSL diagram for classification of groundwater samples abstracted from different wells

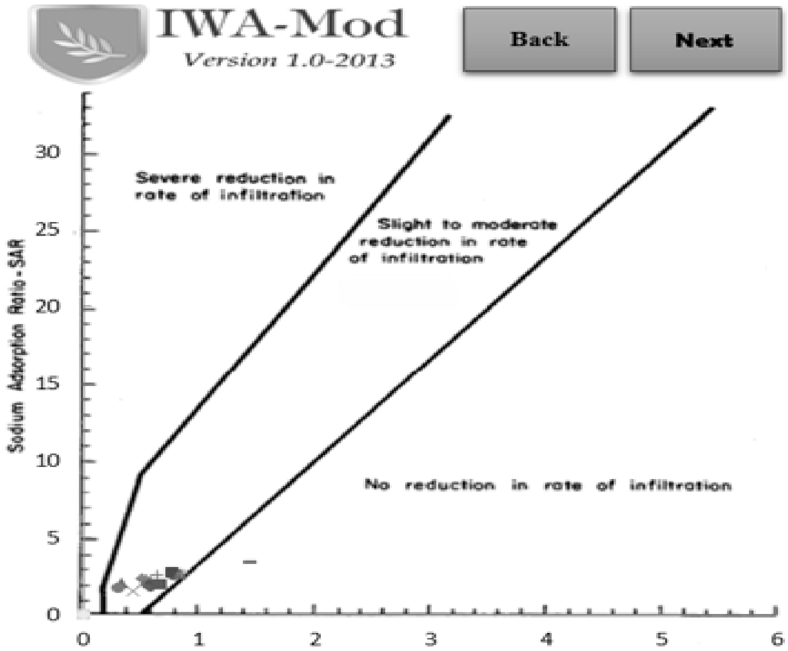

Fig. 10. Relative rate of water infiltration as affected by salinity and sodium adsorption ratio for groundwater samples abstracted from different wells (Adapted from Rhoades, 1977; Oster and Schroer, 1979)

6 classes follows: 1.none (<5), 2. normal (5-10), 3. low (10-20), 4. medium (20-30), 5. high (30-40), and 6. veryhigh (>40).All samples are of no hazarde and can be used for irrigating most soils for all crops (**Gupta and Gupta, 1997; Abdel-Fattah and Helmy, 2015**).

Kelly ratio (KR)

Results of IWA-Mod indicate that the KR ranged from 0.88 to 1.59 (Table 4). Therefore, since the KR is low < 3, waters are suitable for irrigation (**Kelly, 1940; Abdel-Fattah and Helmy, 2015**).

Mg ratio

Mg ratio values of irrigation water, were between 37 and 43, therefore all samples are suitable for irrigation.

Permeability index (PI) and Doneen's diagram

Long time use of irrigation water containing Na^+, could affect the physical properties of soil and impair soil permeability. Permeability Index (PI) may by controlled by water and its sodium content. **Doneen (1962)** combined PI and salinity in one diagram, divided into three areas representing each class of water. The samples fall into the class II category of the **Doneen's (1964),** Fig. 11. The PI of wells 4, 9, 12 and 16 are class I, while wells 1, 2, 5, 6, 7, 8, 10, 11 and 13 are class II, and wells 3 and 15 are class III. The PI values (Fig. 11), show that samples have no permeability and infiltration problems except samples 3 and 15.

Potential salinity (PS)

Based on the potential salinity measure introduced by **Doneen (1962),** the water are in 3 classes (Table 5). The IWA-Mod results indicate that the PS ranged from 1.79 to 4.95 mmolc L^{-1}. and that 37.5% of water samples fall in class1 and 62.5% of samples fall in classe2 in the case of soils of low permeability. All samples are of class1 for soils of high and medium permeability.

Sodicity and Hazards

Residual sodium carbonate (RSC)

Results of IWA-Mod indicate that RSC levels were less than 1.25 mmolc L^{-1}; therefore, all samples are safe for irrigation (**Gupta, 1990; Eaton, 1950**).

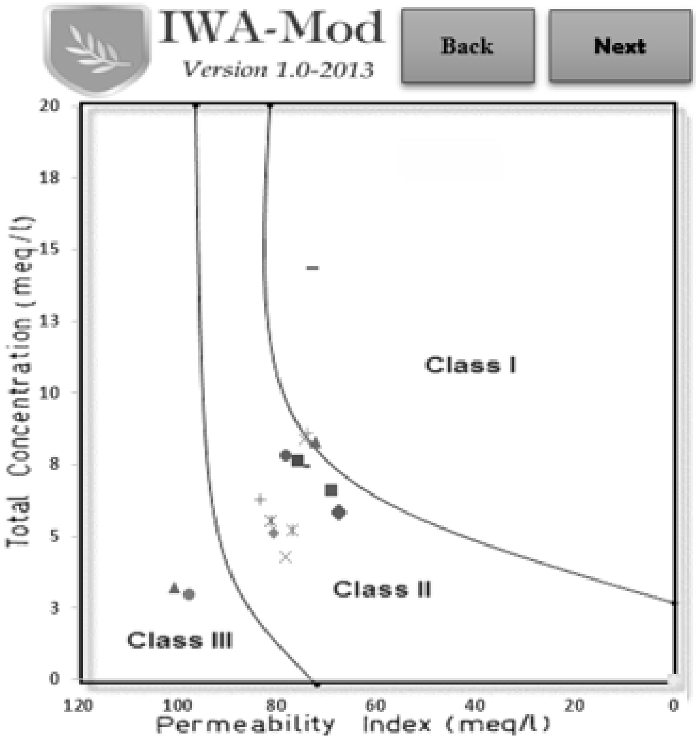

Fig. 11. Doneen diagram for classification of groundwater samples abstracted from different wells

Table 5. Classification of irrigation water based on potential salinity (Doneen, 1961)

Soil permeability	Class I	Class II	Class III
Low	< 3	3- 5	< 5
Medium	< 5	5 – 10	< 10
High	< 7	7 – 15	< 15

Residual sodium bicarbonate (RSBC)

Since carbonate ions do not occur very frequently in appreciable contents, and as bicarbonate ions do not precipitate magnesium ions, **Gupta (1990)** suggested that alkalinity hazard should be determined through on index called residual sodium bicarbonate (RSBC). Based on RSC/RSBC ratio there are 6 proposed alkalinity classes, 1. non-alkaline (-ve), 2. normal (0 mmolc L^{-1}), 3. low alkalinity (2.5 mmolc L^{-1}), 4. medium alkalinity (2.5-5.0 mmolc L^{-1}) 5. high alkalinity (5.0-10.0 mmolc L^{-1}), and 6.very high alkalinity (> 10.0 mmolc L^{-1}).

Based on the Gupta classification, the samples of non-alkaline category are in wells 3, 4, 5, 6, 7, 9, 15 and 16. Those of medium alkalinity are samples 1, 2, 11 and 12. The high alkalinity category are samples 8, 10 and 14 and The very high alkalinity is sample, 13.

Non alkaline waters can be safely used for irrigation on almost all soils for all crops for indefinitely long periods without any problems. Medium alkalinity waters of (RSC/RSBC 2.5-5 mmolc L-1) can be used for irrigation on almost all soils with little danger of sodicity hazards. Optimum yield of several alkali tolerant crops are obtained with RSBC of this range (**Gupta**

and Gupta, 1997 and Abdel-Fattah and Helmy, 2015).

High alkalinity waters with of RSC/RSBC (5-10) can be used for irrigation on soils provided with good drainage such of leaching faction less than 0.3, for growing semi-tolerant and tolerant crops to sodium and EC should be <3.0 dSm^{-1} and SAR < 10 (**Gupta and Gupta 1997**). Rainfall should be appreciable and effective (>400 mm) and evaporation must be (<2000 mm) for the prolonged successful utilization of such waters (**Gupta and Gupta 1997**). If SAR is >10, use of gypsum may be required. Very high alkalinity waters (RSC/RSBC >10 mmolc L^{-1}). are not suitable for irrigation but may be used in cycles (**Gupta and Gupta 1997**).

Specific ions toxicity

Guideline for irrigation water quality established by **FAO (1985)** was used to evaluate, irrigation water toxicity (Fig. 4). Sodium, to chloride, boron, nitrate and bicarbonate were used as indicators for irrigation water toxicity. Based on Na adjusted SAR results of IWA-Mod show that the value ranged between 1.29 and 0.86, Thus, wells. 1, 2, 3, 5, 10, 13, 14 and 15 are of "no problem", while wells. 4, 6, 7, 8, 9, 11, 12 and 16 are of "increasing problems"

Regarding chloride ions, all samples have less than 4 mmolc L^{-1} (Table 3) therefore they are of no- problem class and are of no- problems and safe for irrigation except wells with. 4, 6, 9 and 16 where the bicarbonate class is of "increasing problems" (Table 3).

Regarding to boron toxicity, results of IWA-Mod indicate that the boron is < 1.0 mg L^{-1} thus all samples are of no problems

Regarding No3 all samples are of no problems class (**FAO, 1985**).

Conclusion

The quality of groundwater in the study area is of good quality with respect to their content of salts or alkalinity and sodicity hazard. These types of groundwater can be safely used for irrigation purposes in area located at the end of irrigations canals, where the access of surface water by farmers is insufficient. They could be used as a supplemental irrigation to overcome water shortage in the summer to meet the water requirements of crops. Such waters may be used for other purposes such drinking, for livestock, poultry and industry. However, further studies are required on groundwater, particularly with regard to regulating wells drilling and water withdrawing. Farmers must take all measures that could alleviate accumulations of salts in soil root zone such as sufficient leaching requirements, good drainage system and suitable crops.

REFERENCES

Abdel-Fattah, M.K. and A.M. Helmy (2015). Assessment of water quality of wastewaters of Bahr El-Baqar, Bilbies and El-Qalyubia drains in East Delta, Egypt for irrigation purposes. Egypt. J. Soil Sci., 55 (3): 287-302.

Al-Amry, A.S. (2008). Hydro geochemistry and groundwater quality assessment in an arid region: A case study from Al Salameh area, Shabwah, Yemen. The 3rd Int. Conf. Water Res. and Arid Environ. and the 1st Arab Water Forum.

Allam, N.M. and I.G. Allam (2007). Water resources in Egypt: Future challenges and opportunities. Water Int., 32: 205-218.

APHA (1995). Standard Methods of Analysis of Water and Wastewater (19th Ed.),American Public Health Association (APHA), Washington DC, USA

Ashour, M.A., S.T. El-Attar, Y.M. Rafaat and M.N. Mohamed (2009). Water resources management in Egypt. J. Eng. Sci., Assiut Univ., 37 (2): 269-279.

Ayers, R.S. and D.W. Westcot (1985). Water quality for agriculture. FAO Irrigation and Drainage Paper 29 Food and Agric. Organization (FAO) of the United Nation, Rome, Italy.

Brown, R.M., N.I. Mcclelland, R.A. Deininger and R.G. Tozer (1970). A water quality index: do we dare? Water and Sewage Works, 117: 339-343

Clawson, M., H.H. Landsberg and L.T. Alexander (1971). The agricultural potential of the Middle East. Elsevier, N.Y.USA

Doneen, L.D. (1962). The influence of crop and soil on percolating waters. Proc. of 1961

Biennial Conference on Groundwater Recharge, 156-163.

Doneen, L.D. (1964). Notes on water quality in agriculture. Water Sci. and Eng: Paper No. 4001, Dept. of Water Sci. and Eng. Univ. California, Davis. USA.

Eaton, F.M. (1950). Significance of carbonate in Irrigation Water. Soil Sci., 69 (2): 123-33.

El-Fakharany, Z.M.A. (2002). Management of conjunctive use of surface water and ground water, M.Sc. Thesis, Fac. Eng., Helwan Univ., Egypt.

El-Arabi, N.E., J. Khalil and M.A. Dawoud (2000). Conjunctive use as a tool for integrated water resources management in Egypt, Int. Conf. Wadi Hydrology, Sharm El Sheikh, Egypt.

FAO (1985). Guidelines: Land evaluation for irrigated agriculture - Soils Bul. 55. Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

FAO (2013). Monitoring of climate change risk impacts of sea level rise of groundwater and agriculture in the Nile Delta.

Fipps, G. (1998). Irrigation water quality standards and salinity management. The Texas A and M Univ. System, Texas, USA

Gupta, I.C. (1990). Use of saline water in agriculture: a study of arid and semi-arid zones of India. Oxford and IBH Pub, New Delhi India.

Gupta, K.M., V. Singh, P. Rajawanshi, M. Agarwal, K. Rai, S. Srivastava, R. Shirivastav and S. Dass (1999). Groundwater quality assessment of Tehsil Kheragarh, Agra (India) with special reference to Flouride. Environ. Monit. and Ass., 59: 275–285.

Gupta, S.K. and I.C. Gupta (1997). Management of Saline Soils and Waters (2nd Rev. Ed). Scientific Pub, Jodhpur, India.

Hem, J.D. (1985). Study and Interpretation of the Chemical Characteristics of Natural Water, 3rd Ed. Sci Publ, Jodhpur, India.

Hussien, M.M. (2007). Environmental impacts of new settlements on the groundwater in a region in Delta. M.Sc. Thesis, Fac. Eng. Zagazig Univ., Egypt.

Kashef, A.I. (1981). The Nile-one River and nine countries. Journal of Hydrology: 53–71.

Kelly, W.P. (1940). Permissible composition and concentration of irrigated waters. In: Proceedings of the ASCF 607.

Khodapanah, L, W.N.A. Sulaiman and N. Khodapanah (2009). Groundwater quality assessment for different purposes in Eshtehard district, Tehran, Iran. Europ. J. Sci. Res., 36 (4): 543-553.

Kumar, M., K. Kumari, A.L. Ramanathan and R. Saxena (2007). A comparative evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, India. Environ. Geol., 53:553-574.

Kundu, S. (2012). Assessment of surface water quality for drinking and irrigation purposes: a case study of ghaggar river system surface waters. Bulletin of Environ., Pharmacol. and Life Sci., 1 (2): 1-1.

Morsy, W.S. (2009). Environmental management to groundwater resources for Nile Delta region, Ph.D. Thesis, Fac. Eng., Cairo Univ., Egypt.

Oster, J.D. and F.W. Schroer (1979). Infiltration as influenced by irrigation water quality. Soil Sci. Soc. Ame. J., 43: 444-447.

Paliwal, K.V. (1972). Irrigation with saline water, Monogram No. 2 (Newseries). New Delhi, India.

Perparim, L., R. Smajl and I. Alban (2016). Assessment of irrigation water quality of Dukagjin basin in Kosovo. J. Int Sei Pub. Agric. Fd., 4.

Piper, A.M. (1944). A graphic procedure in geochemical interpretation of water analyses. Trans Ame. Geophys. Union, 25: 914 - 923.

Rhoades, J.D. (1977). Potential for using saline agricultural drainage waters for irrigation. In: Proc. water management for irrigation and drainage. ASCE, Reno, Nevada., 20 (22): 85-11.

Rhoades, J.D. (1982). Cation exchange capacity. *In*: A.L. Page (ed.) Methods of Soil Analysis.

Part 2: Chemical and microbiological properties (2nd Ed.) Agron. Series, 9 : 149-157.

Rouabhia, A., F. Baali and C.H. Fehdi (2009) Impact of agricultural activity and lithology on groundwater quality in the Merdja area, Tebessa, Algeria. Arab J Geosci. Springer, Berlin. doi:10.1007/ 12517-009-0087-4

Samak, S.A.M.A. (2007). Groundwater management in Delta, M.Sc. Thesis, Fac. Eng., Zagazig Univ., Egypt.

Sheinberg, I. and J.D. Oster (1985). Quality of irrigation water. Int. Irrigation Information Cent., 8.

Suarez, D.L. (1981). Relation between pHc and sodium adsorption ratio (SAR) and an alternative method of estimating SAR of soil or drainage waters. Soil Sci. Soc. Ame. J., 45: 469-475.

Sundaray, S.K., B.B. Nayak and D. Bhatta (2009). Environmental studies on river water quality with reference to suitability for agricultural purposes: Mahanadi river estuarine system, India- a case study. Environ. Monitor. Assess, 155: 227¬243.

Todd, D.K. 1980. Groundwater hydrology. Wiley, Ny, USA.

Todd, D.K. and L.W. Mays (2005). Groundwater Hydrology. 3rd Ed., John Wiley and Sons, Inc. Ny, USA

USDA (1958). Diagnosis and Improvement of Saline and Alkali Soils. United states department of agriculture (USDA) Handbook 60, US Gov. Printing Office, Washington, DC, USA.

Wilcox, L.V. (1955). Classification and Use of Irrigation Waters. USDA, Circular 969, Washington, DC, USA.

تقييـــم نــوعيــــة الميــــاه الجــوفيــــة لإستخدامها في ري بعض مناطق محافظة الشرقية، مصر

أكرم حسين محمد صقر - أحمد سعيد متولي - السيد أحمد حسن الناقه - محمد كمال عبد الفتاح

قسم علوم الأراضي - كلية الزراعة - جامعة الزقازيق - مصر

تم جمع عينات مياه جوفية شهريًا من آبار مختلفة، تقع في محافظة الشرقية، مصر لمدة ١٢ شهراً، من مايو ٢٠١٥ حتي أبريل ٢٠١٦ وذلك بهدف تقييم جودة هذه المياه لإمكانيه استخدامها في الري الزراعي أو الري التكميلي لبعض مناطق محافظة الشرقية، مصر، تم تسجيل مواقع العينات (خطوط الطول والعرض) بواسطة جهاز GPS، كان حجم كل عينة حوالي ١ لتر لكل بئر، تم أخذ الاحتياطات اللازمة لتجنب تلوث العينة، تم تحليل العينات وتقدير الأيونات الرئيسية (الكاتيونات والأنيونات) طبقا لـ (APHA، 1995)، تم استخدام موديل IWA-Mod 1-2013 لحساب بعض مؤشرات الحكم علي صلاحية المياه للري، أوضحت النتائج أنه لا توجد مشكلات حادة في هذه المياه من ناحية الصودية أو القلوية أو السمية عند استخدامها لأغراض الري الزراعي أو التكميلي في حين أن المشكلة الحقيقية تكمن في خطورة الملوحة، وبالتالي عند استخدام هذه المياه للري الزراعي التكميلي، لذا ينبغي اتباع ممارسات الإدارة السليمة لمنع تراكم الأملاح في التربة.

المحكمون :

١ـ أ.د. علي أحمد عبدالسلام أستاذ الأراضي المتفرغ – كلية الزراعة بمشتهر – جامعة بنها.

٢ـ أ.د. كــرم فـؤاد موســى أستاذ الأراضي المتفرغ – كلية الزراعة – جامعة الزقازيق.