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EVALUATION OF BELBAIS DRAIN WATER QUALITY AND THE POSSIBILITY OF USING IN AGRICULTURAL IRRIGATION PURPOSES IN SHARKIA GOVERNORATE, EGYPT

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ABSTRACT: A total of 8 water samples were collected from beginning, middle and end of Belbais drain, which located at longitudes of N 30° 10' 57.6" and E 31° 20' 20.8" and latitudes of N 30°33' 39.2" and E 31°36' 10.3" and altitude around 11.6 m. relative to sea level, in order to assess the quality of its water and its suitability for agricultural irrigation. Samples were analysed for pH, EC and other parameters. pH was within the permissible limit. EC indicates C3 (high salinity). According to **USDA (1954)**. The soluble sodium percent (SSP) ranged from 67.78% to 41.69%, *i.e.* moderate restriction in using this water. The Sodium Adsorption Ratio (SAR) ranged from 6.74 to 8.44 and according to **FAO (1985)**, water is of low sodium hazard. According to **USDA (1954)**, water is of high salinity medium sodicity (C3S2). Permeability index values varied between 82.52 to 85.34% and based on **Doneen diagram (1962)**, medicating class II *i.e.* no permeability or infiltration problems. Residual Sodium Carbonate (RSC) was < 1.25 $mmol_c\ L^{-1}$, *i.e.* safe for irrigation.

Key words: Belbais drain, water quality criteria, salinity hazard, sodicity hazard.

INTRODUCTION

Water shortage is one of the important issues in the coming century (**Macedonio *et al.,* 2012**) which may threaten food security (**Stikker, 1998; Mosaad, 2017**). Many countries were forced to use unconventional water sources in order to satisfy their water demands (**Angelakis *et al.,* 1999; Ohisson, 2000; Pereira *et al.,* 2002; Bixio *et al.,* 2006; Singh, 2014**). Among various unconventional sources are waste waters of agricultural drains (**Angelakis *et al.,* 1999; Chu *et al.,* 2004; Bixio *et al.,* 2006**).

Using of treated waste water is one of the strategies adopted in order to increase water supply in Egypt to meet the increasing demand for water. Using waste water should be within certain restrictions imposed for environmental protection and to safeguard public health. A set of guidelines and control measures for treated waste water reuse has been improved and issued in the Egyptian Code for reusing treated waste water for agriculture. Treated waste water can be used as a source for agriculture or may be used indirectly through recharging groundwater aquifers in order to be used in future (**Abu Zeid and Alrawady, 2014**).

It is important to take into consideration the extent of salinity hazard of irrigation water and its suitability for crops. People who live in areas with water shortage are dependent on agriculture and crop production, which is highly dependent on good quality irrigation water.

In Belbais region which is located in the Northeastern Nile Delta in Egypt (Sharkia Governorate), many efforts are currently exerted in order to reclaim salt-affected soils and using water resources of the area. Determination of soluble ions and salts in waste waters in Egypt is important for hazard assessment.

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The aim of the present study was to assess the quality of Belbais drain water and its suitability for agricultural irrigation. The results will help both authorities and farmers for managing water resources in an effective way.

MATERIALS AND METHODS

Water Samples Collection and Analysis

Eight water samples were collected from Belbais drain, which is located at longitudes of N 30^{o} 10' 57.6" and E 31^{o} 20' 20.8"and latitudes of N 30^{o}33' 39.2"and E 31^{o}36' 10.3"and altitude around 11.6 m. above sea level, in order to assess their quality for irrigation. The climate of the studied area is a Mediterranean one which is hot arid in summer and warm with low rain in winter.

Sample locations were at start, middle and end of the drain collected every two months during (2016-2017). Study area and the sampling sites are shown in Map 1.

Water samples were collected in capped polyethylene bottles and the size was about one liter. Precautions were considered to avoid water contamination during sampling and handling. Samples for heavy metal analysis were collected in acid-washed polyethylene bottle sand preserved by adding nitric acid (pH<2). Samples were immediately filtered and stored in dark at 4˚C, then subjected to chemical analyses, within 48 hours. Analysis covered salinity following standard methods **(APHA, 2005)**. Calcium and magnesium were determined using standard EDTA procedures. Chloride were determined by $AgNO_3$ titration, bicarbonates were determined by titration with HCl, sodium and potassium by flame photometry and EC and pH were directly measured.

Water Quality Criteria

Salinity, sodicity, alkalinity and toxicity criteria were used to determine the quality of the water for irrigation. The evaluation parameters were 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). Salinity hazard is a very important criterion in determining the quality of the water for irrigation. According to the USDA guidelines, **USDA (1954)** classes of salinity hazard are low (C1), medium (C2), high (C3) and very high (C4) with EC values of less than 0.25, 0.25-0.75, 0.75-2.25 and >2.25 dSm^{-1}, respectively. Water with low salinity can be used for all plants and all soil types. In most cases, water of medium salinity can be used for moderately salt-tolerant plants. High salinity water can be used for irrigation purposes with consideration of management practices. Very high salinity water cannot be used for irrigation purposes except for only extreme salt-tolerant plants.

The FAO guide line (**FAO, 1985**) classifies salinity hazard into 3 classes as follow: C1 "no problems" EC<0.7 dSm^{-1}, C2 "increasing problems" EC 0.7 - 3.0 dSm^{-1} and C3 "severe problems" EC > 3.0 dSm^{-1}.

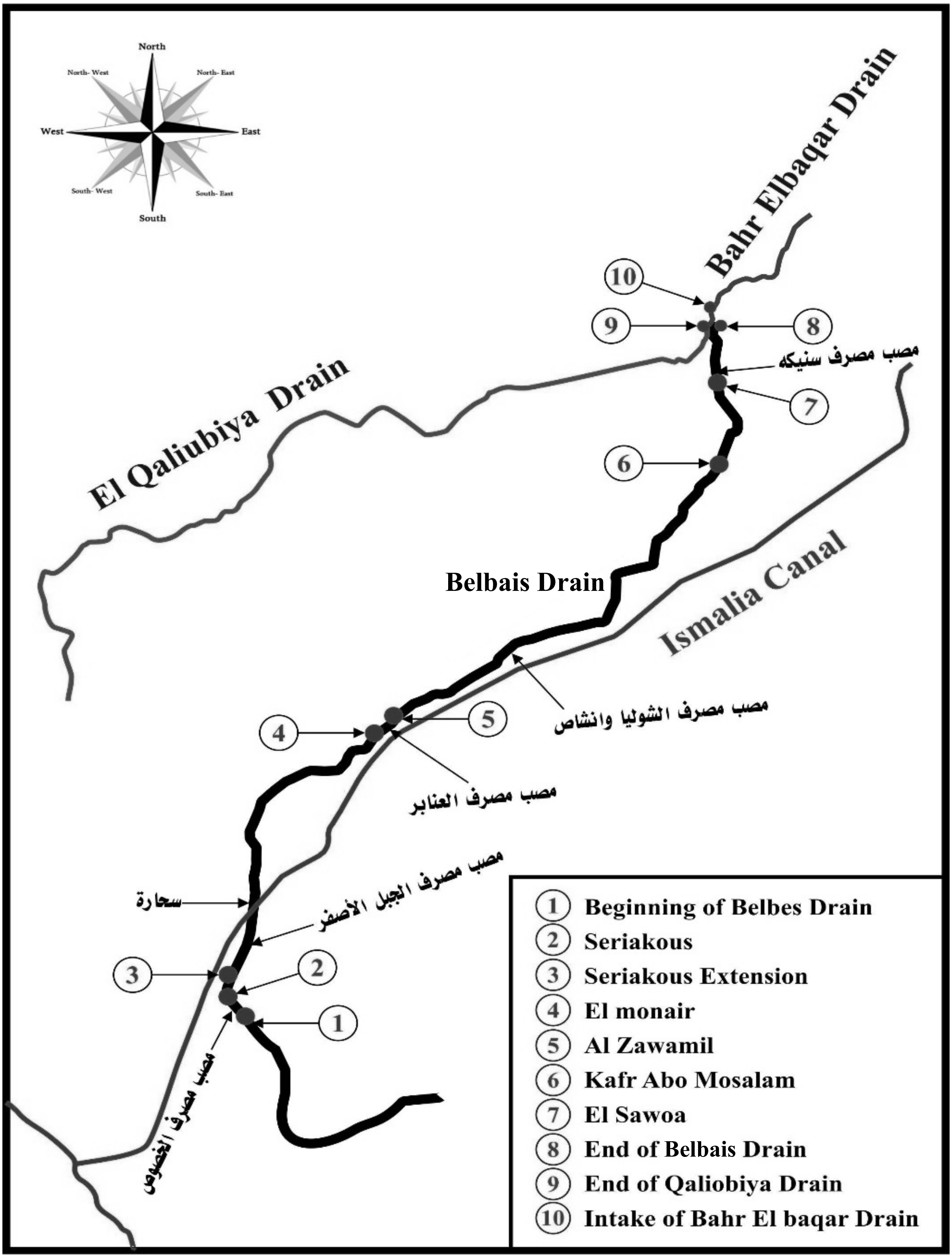
Sodicity hazard is another problem often confronting long-term use of certain water for irrigation and relates to the maintenance of adequate soil permeability so that the water can infiltrate and move freely through the soil. This criterion can be expressed as soluble sodium percentage (SSP) and sodium adsorption Ratio (SAR).

Soluble sodium percentage (SSP) was calculated using the following equation (**USDA, 1954**).

$$SSP = Na^{+} \times 100 / (Na^{+} + K^{+} + Ca^{2+} + Mg^{2+})$$

Where all the ions are expressed in mmolc l^{-1}. According to **Wilcox (1955) and Khodapanah *et al.* (2009)**, the SSP classes include, excelent water for irrigation (<20%), good (20-40), permissible (40-60%), doubtful (60-80%) and unsuitable (>80%). Water with SSP less than 60 is safe with little sodium accumulations that will cause a breakdown of the soil's physical properties (**Fipps, 1998**).

Wilcox (1955) suggested a graphical method regarding suitability of water for irrigation purposes. The proposed method is widely used and is based on percent sodium and electrical conductivity plot. The diagram consists of five



Map. 1. Water samples during (2016 – 2017)

distinct areas *i.e.,* excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable.

Sodium Adsorption Ratio (SAR) is calculated by using the following equation (**USDA, 1954**).

$$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+})/2)]^{½}$$

Where all the ions are expressed in $mmol_c\ l^{-1}$. The SAR classes include, low, S1 (<10); medium, S2 (10–18); high, S3 (18–26); and very high, S4 (>26).

The US salinity lab's diagram (**USDA, 1954**) is widely used for rating irrigation waters on basis of SAR (S) and EC (C). According to US Salinity Lab Staff diagram, water types that are recognized in terms of "CS". Examples are C1S1 "low salinity low sodicity" up to C4S4 "very high salinity very high sodicity".

Excess carbonate and bicarbonate ions over calcium and magnesium ions in water lead to presence of sodium carbonate, therefore sodicity. Residual sodium carbonate (RSC) values were calculated by using the following equation (**USDA, 1954**).

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

All the ions are expressed in $mmol_c\ l^{-1}$. according to **Eaton (1950)**, The RSC classes include, safe (<1.25); Marginal (1.25–2.50); unsuitable (>2.50).

Suitability of water for irrigation purposes is also assessed on the bases of Kelly's ratio. 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 where all the ions are expressed in $mmol_c\ l^{-1}$.

$$KR = (Na^{+}) / (Ca^{2+} + Mg^{2+})$$

The soil permeability is affected by consistent use of irrigation water which increases the presence of sodium, calcium, magnesium and bicarbonate in the soil (**Chandu *et al.,* 1995**). The permeability index (PI) is used to measure the suitability of water for irrigation purpose when compared with the total ions in $mmol_c\ l^{-1}$. The PI is expressed as follows

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

Where, concentrations of all ions are in $mmol_c\ l^{-1}$. The PI classes are as follows: Excellent (>75%), Good (25-75%) and Unsuitable (<25%) **(Al-Amry, 2008)**. Potential salinity (PS) was defined as the chloride plus half of the sulphate ions. (**Doneen, 1962; Gupta, 1990**). Potential salinity values was calculated by using the follows equation.

$$PS = Cl^{-} + ½\ SO_4^{2-}$$

According to **Delgado *et al.* (2010)**, The PS classes are as follows: good (<3), Moderate (3-15) and not recommended (>15).

Total hardness (TH) was calculated by the follows equation which proposed previously by **USDA (1954)** with respecting to all ions used were expressed in $mmol_c\ l^{-1}$

$$TH = (Ca^{2+} + Mg^{2+}) \times 50$$

Waters are commonly classified based on degree of hardness, soft (0-0.75), Moderately hard (75-100), Hard (150-300) and Very hard (>300).

Statistical Analysis

Pearson's correlation test was done using SPSS version 25 to measure the association between the different qualities of water.

RESULTS AND DISCUSSION

Water pH

The normal pH values should range from 6.5 to 8.4 for irrigation water (**FAO, 1985; Kundu, 2012**). Table 1 shows that pH values varied from 7.51 at beginning of Belbais drain area to 7.70 at beginning of the drain in El-Marg.

Salinity Hazard

Table 1 shows that (EC) varied from 1.34 dSm^{-1} at end of Belbais drain in El-Sawoa to 2.09 dSm^{-1} at beginning of the drain in El-Marg with an average of 1.54 dSm^{-1}. According to the **USDA (1954)** the water is within the range of high salinity (0.75 – 2.25 dSm^{-1}). Accordance to FAO Guidelines for irrigation water (**FAO, 1985**), the water is within the C2 class "*i.e.* increasing problem". These findings agree with relative abundance of cations in water shows a pattern of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ **Abdel-Fattah and Helmy (2015)**.

Table 1. Chemical parameters and statistical analysis of the collected water samples of Belbais drain

Location		pH	EC (dSm^{-1})	TDS (mg^{-1})	Cations ($mmol_c\ L^{-1}$)				Anions ($mmol_c$ L-1)			
					Na^+	K^+	Ca^{+2}	Mg^{+2}	CO_{3-}	HCO_{3-}	Cl^-	SO_4^{2-}
Beginning of Belbais drain	**El-Marg**	7.70	2.09	1337.6	14.19	1.08	3.56	2.10	0	4.80	13.26	2.87
	Seriakous	7.51	1.89	1209.6	12.84	0.97	3.22	1.90	0	4.35	12.00	2.58
	Seriakous Ex.	7.59	1.42	908.8	9.61	0.72	2.41	1.42	0	3.25	8.98	1.93
Middle of Belbais drain	**El-Monair**	7.51	1.38	883.2	9.38	0.72	2.35	1.39	0	3.17	8.77	1.90
	Al-Zawamil	7.55	1.35	864	9.13	0.70	2.29	1.35	0	3.09	8.54	1.84
	Kafr Mosalam	7.53	1.43	915.2	9.73	9.73	2.44	1.44	0	3.29	9.08	10.97
End of Belbais drain	**El-Sawoa**	7.63	1.34	857.6	9.06	0.69	2.27	1.34	0	3.07	8.47	1.82
	End of Belbais	7.59	1.42	908.8	9.61	0.72	2.41	1.42	0	3.25	8.98	1.93
Average		7.58	1.54	9.85.6	10.44	1.92	2.62	1.55	0	3.53	9.76	0.40

The average concentration of chloride in water was 9.76 $mmol_c\ l^{-1}$, which is considered unsuitable for plants according to **FAO (1985)**, Chlorides in high contents can cause toxicity to sensitive crops. According to **Chu *et al.* (2004)**, Cl^- concentration below 2 $mmol_c\ L^{-1}$, is generally safe for all plants. Contents of SO_4^{2-} average of 0.40 $mmol_c\ L^{-1}$. Relative abundance of anions was $Cl^- > SO_4^{2-} > HCO_3$.

Sodicity Hazard

Soluble sodium percentage (SSP)

Table 2 shows that SSP ranged from 41.69 at middle of drain at Kafr Mosalam to 67.87 at drain's end or its beginning. According to **Wilcox (1955) and Khodapanah *et al.* (2009)** the results indicates moderate degree of restriction regarding Na hazard in using the waters.

According to relationship between SSP and the EC (**Wilcox, 1955**) shown in Fig. 1 the water in Kafr Mosalam is “Good to permissible” for irrigation, but water in El-Marg is “doubtful to unsuitable” for irrigation. Water in other locations is “permissible to doubtful” for irrigation.

Results indicates a general safe ratio of Mg^{2+}, Ca^{2+}, which play an important role in maintaining a good structure with no permeability problem in soil irrigated with the water. However, the presence of excessive Na^+ in irrigation water had a role in promoting soil dispersion and structure breakdown when Na^+ and Ca^{2+} ratios exceed by 3:1. High Na : Ca ratio (>3:1) results in water infiltration problems, due to lack of sufficient Ca^{2+} to counter the dispersing effect of Na^+ (Table 2). Excessive Na^+ also creates problem in crop water uptake, poor seedling emergence, lack of aeration, plant and root decreases, *etc*. (**FAO, 1985; Halim *et al.*, 2009; Akhtar *et al.*, 2015**).

Sodium adsorption ratio (SAR)

Table 2 shows that SAR ranged from 6.73 at end of drain in El-Sawoa area to 8.43 at beginning of Belbais drain in El-Marg area with an average value of 7.20. According to **FAO (1985)**, water could be classified as low sodium hazard and could be used for irrigation but with problems of soil permeability.

Classification regarding salinity and sodicity shows that all water are of high salinity medium sodicity (C3S2) according to USSL diagram (Fig. 2). Therefore with careful management the water could be used for irrigation.

Kelley ratio (KR)

According to the classification of KR, waters in three drains have KI of > 1; therefore, they could be unsuitable for irrigation.

Table 2. Water quality parameters of the collected water samples of Belbais drain

Location		SAR	RSC	TH	Kelly's (KR)	PS	PI	SSP	Na:Ca	Mg:Ca
Beginning of Belbais drain	El-Marg	8.43	-0.86	283.00	2.507	14.70	82.523	67.80	3.986	0.590
	Seriakous	8.02	-0.77	256.00	2.508	13.29	83.105	67.83	3.988	0.590
	Seriakous Ex.	6.94	-0.58	191.50	2.509	9.95	84.916	67.87	3.988	0.589
Middle of Belbais drain	El-Monair	6.82	-0.56	187.00	2.508	9.72	85.064	67.77	3.991	0.591
	Al-Zawamil	6.76	-0.55	182.00	2.508	9.46	85.261	67.78	3.987	0.590
	Kafr Mosalam	6.98	-0.59	194.00	2.508	14.57	84.819	41.69	3.988	0.590
End of Belbais drain	El-Sawoa	6.73	-0.54	180.50	2.510	9.38	85.337	67.81	3.991	0.590
	End of Belbais	6.94	-0.58	191.50	2.509	9.95	84.916	67.87	3.988	0.589
Average		7.20	-0.63	208.45	2.51	11.38	84.493	64.552	64.55	0.590

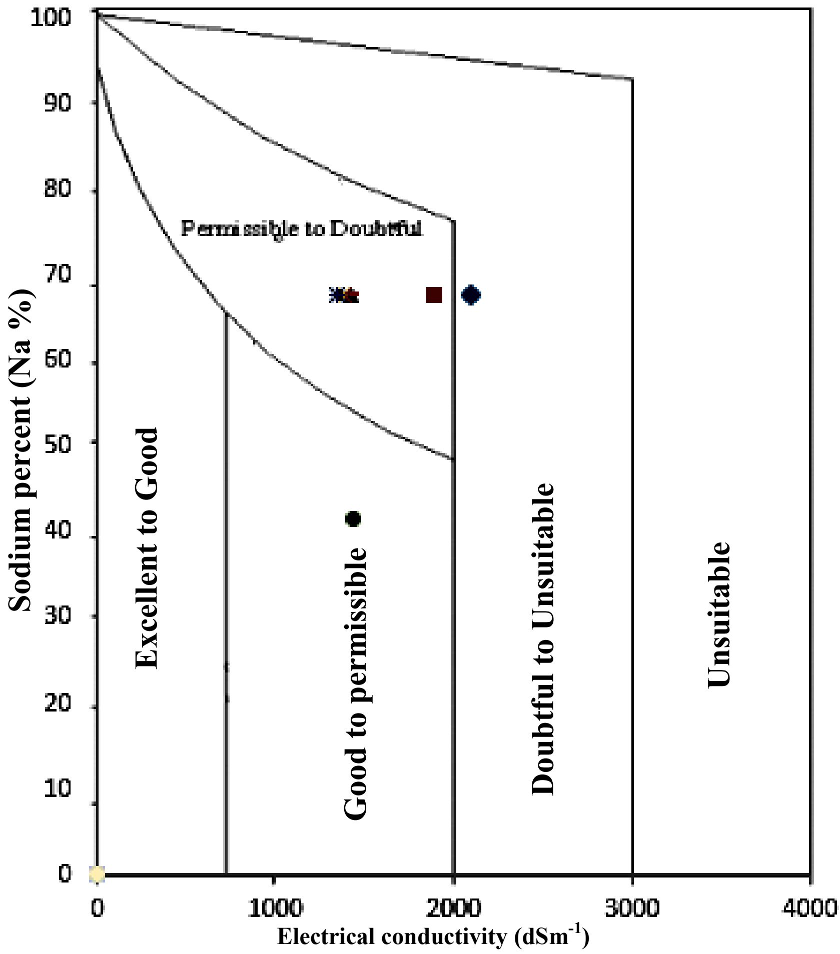


Fig. 1. Wilcox's diagram for drainage water classification of collected samples from Belbais drain

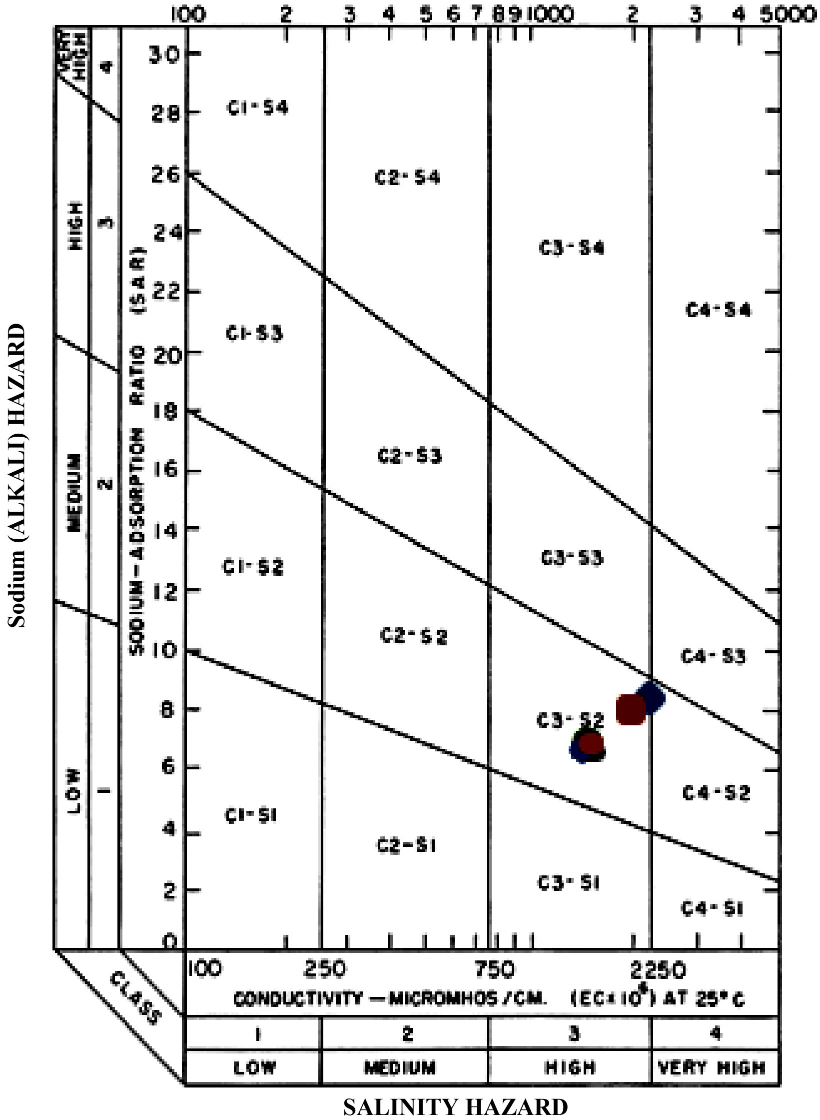


Fig. 2. USSL diagram for classification of irrigation water (US Salinity Laboratory Staff, USDA, 1954)

Permeability index (PI)

PI varied between 82.52 at beginning of drain in El-Marg area to 84.49 at end of drain in El-Sawoa with an average of 84.49 Based on Doneen diagram, waters are class II with no permeability and infiltration problems (Fig. 3).

Residual sodium carbonate (RSC)

In accordance to **USDA (1954)**, the increase of RSC in irrigation water is significantly harmful for plants growth. Results in Table 2 indicate that RSC was Less than 1.25 $mmol_c\ l^{-1}$, therefore, water is safe for irrigation (**Gupta, 1990; Eaton, 1950**).

Total hardness (TH)

TH varied from 180.5 to 283 $mmol_c\ l^{-1}$ with an average value of 208.45 $mmol_c\ l^{-1}$. According to the TH classification introduced by **Ibrahim (2004) and Muhammad *et al.* (2011)**, the water is classified as hard water.

Potential salinity (PS)

The PS ranged from 9.38 at end of drain in El-Sawoa to 14.70 $mmol_c\ l^{-1}$ at beginning of drain in El-Marg (Table 2). All samples are of class II and class III for soils of high and medium permeability.

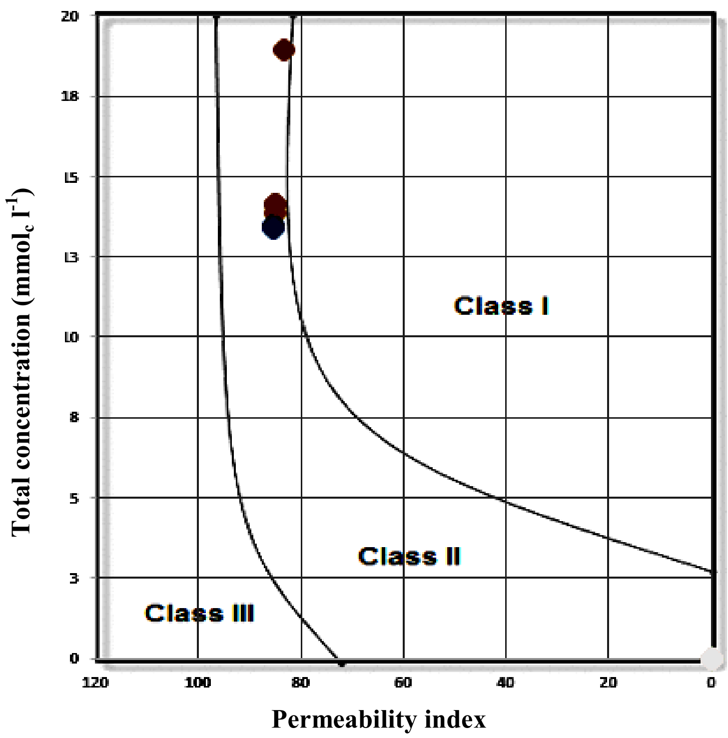


Fig. 3. Doneen diagram for classification of irrigation water

Conclusion

Results shows the pH values were within the permissible limit while salinity of water was high (C3), and can be used for irrigation purposes. The SSP was moderate and calls for restriction in using this water. Regarding SAR water is of low to medium sodium hazard and could be used as irrigation water with increasing problem that may affect soil permeability and according the **USDA (1954)** could be classified as C3S2, medium sodicity high salinity The PI value indicated that waters have no permeability or infiltration problems. The RSC value indicate safe irrigation.

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تقييـم جــودة ميــاه مصــرف بلبيـس وإمكانيــة اســتخدامهــا فــي أغــراض الــري الزراعـــى فـــي محــافظــة الشــرقيــة – مصـــر

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تم تجميع عدد ٨ عينات من بداية ومنتصف ونهاية مصرف بلبيس الواقع بين خطي طول N 30^o 10' 57.6" 31^o E 20' 20.8" وخطي عرض N 30^{o}33' 39.2", E 31^{o}36' 10.3"، والارتفاع عن مستوى سطح البحر حوالي ١١,٦م وذلك بهدف تقييم نوعية هذه المياه وملائمتها للري الزراعي، أظهرت النتائج أن قيم حموضة المياه كانت ضمن الحد المسموح به، وكانت قيم درجة التوصيل الكهربي تقع ضمن فئة الملوحة العالية (C3) طبقاً لمعمل الملوحة الأمريكي، كما أشارت النتائج إلى أن قيم النسبة المئوية للصوديوم الذائب تراوحت بين ٦٧,٧٨% و٤١,٦٩%، وبالتالي تشير النتائج إلى أن هذه المياه لها درجة معتدلة من القيود في الاستخدام كمياه للري، كما تراوحت قيم نسبة الصوديوم المدمص بين ٦,٧٤ و٨,٤٤، وتصنف على أنها مياه ذات مخاطر منخفضة في الصوديوم (S1<10)، ووفقاً لمخطط معمل الملوحة الأمريكي يمكن تصنيف المياه على أنها (C352) أي ذات ملوحة عالية ومتوسطة الصودية، وفقا لمخطط USSL، وبالتالي يمكن استخدامها في ري التربة مع توفير بعض الاحتياطات، حتى مع الصرف الكافي، قد تكون هناك حاجة إلى إدارة خاصة للمراقبة والتحكم في الملوحة وينبغي اختيار النباتات المتحملة للملوحة، وتراوحت قيم مؤشر (دليل) النفاذية بين ٨٢,٥٢ و٨٥,٣٤%، واستناداً إلى مخطط Doneen، صُنفت هذه المياه على أنها من الفئة الثانية class II أي أن المياه لا تحتوي على مشاكل نفاذية، وفقا لنتائج كربونات الصوديوم المتبقية أشارت إلى أن مستويات SCR كانت أقل من ١,٢٥ ملليمول شحنة لتر$^{-1}$ لذلك تعتبر مياه آمنة للري.

المحكمـــــون:

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