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EVALUATION OF SURAFACE WATER IN RIVERNILE AND CANALS FOR IRRIGATION PURPOSES

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Abstract

In this paper we carried out the determination of the different properties of water such as electric conductivity(EC), hydrogen ion concentration (pH), total dissolved salts (TDS), turbidity , major ions as cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (CO_3^{2-}, HCO_3^{-} ,SO_4^{2-}, Cl^{-}). The results indicate that an increase in total, temporary and permanent hardness with increasing water salinity in all surface water according to the change of water type from fresh to saline water. This is mainly attributed to the effect of leaching and dissolution of soluble salts leading to the increase of hardness with particular importance to the effect of NaCl concentration on increasing solubility of Ca^{2+} and Mg^{2+} in water. This does not exclude the contribution of CO_2, influence of salty water and cation exchange process. The results show that the increase in the salinity of river Nile and canals is due to the increase in readily soluble salts (NaCl, Na_2SO_4, $NaHCO_3$) which is generally less than that of permanent and temporary hardness salts [$MgSO_4$, $CaSO_4$, $MgCl_2$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$].

Introduction

Irrigation by highly sodic water has been practiced only in recent years in Iran but has led to impaired productivity of thousands of hectares of agricultural lands. So, the present study was set out to evaluate the effectiveness of different rates and sizes of gypsum as an amendment which improves the physical and chemical properties of soil and crop productivity(1).

Hydrochemical facies using Piper diagram indicate that in most part of this basin, the chemical character of water is dominated by NaCl. However, Na% values indicate that just 53% of samples are permissible for irrigation. The chloride–bicarbonate ratios reveal that salt lake intrusion to this basin is the main source of salinity. It is also found that functional relationships between EC and Cl^{-} are logarithmic(2).

Soluble salts concentrations, K^{+}, Cl^{-}, HCO_3^{-}, Na^{+}, Ca^{2+}, and Mg^{2+}, were significantly increased by the compost treatment. Soil sodium adsorption ratio (SAR) was significantly affected by the salinity levels of the irrigation water (3).

The evaluation of the effect of supplemental irrigation with water is based on calculation sodium absorption ratio (SAR), residual sodium carbonate (RSC), adjusted SAR, sodium hazards (SSP), and measured parameters such as the electrical conductivity (EC), chloride, calcium and potassium concentration, total suspended solids, sodium, trace metal analysis and other parameters of health significance [4 and 5].

Sodicity has increased in soil surrounding the drip tubing, and geochemical simulations show that two pathways can generate sodic conditions. In soil between 45-cm depth and the drip tubing, Na from the irrigation water accumulates as evapotranspiration concentrates solutes. sodium adsorption ratio values >12, measured by 1:1 water–soil extracts, are caused by concentration of solutes by factors up to 13. Low electric conductivity (<0.7 mS cm^{-1}) is caused by rain and snowmelt flushing the soil and displacing ions in soil solution, [6].

Soil below the drip tubing experiences lower solute concentration factors (1–1.65) due to excess water and also contains abundant native gypsum (2.4 ± 1.7 wt.%). Geochemical simulations show gypsum dissolution decreases soil-water sodium adsorption ratio to < 7 and increases the EC to around 4.1 mS cm^{-1}, thus limiting negative impacts from sodicit, [6].

With sustained irrigation, however, downward flow of excess irrigation water depletes gypsum, increasing soil-water SAR to >14 and decreasing electric conductivity in soil water to 3.2 mS cm^{-1}. Increased sodicity in the subsurface, rather than the surface, indicates that deep subsurface drip irrigation can be a viable means of irrigating with sodic waters, [7].

Experimental

Twenty two water samples were collected from the River Nile (22 samples), and Eleven water samples were collected from the canals.

- Total dissolved solids: Tolal dissolved solids of water samples were determined using evaporations method or calculation methed.
- Total hardness (calcium and magnesium hardness): Pipet a volume of sample containing less than 2 mg hardness into a porcelain dish and add one ml (3%) NH_2OH, and add one ml buffer solution and add 2 ml Eriochrone black Tindicator and titrate with Na_2 EDTA until the colour of the solution becomes clear blue.

Results And Discussions

The water quality is equally important as quantity of the surface water supplies used for irrigation. Five indicators are usually used to evaluate the suitability of water for irrigation,[8] these are:

1. Salinity level.
2. Effective salinity (ES).
3. Boron concentration.
4. Residual sodium carbonate.
5. Sodium adsorption ratio.

(1) Salinity level:

The increasing salinity in irrigation water leads to salt concentration in the soil, which, in turn, leads to damage of the growth and yield of the plants. The quantity of salts which can be withdrawn by plants depends mainly upon the type of soil, plant and the ease of drainage. Evaluation of surface water for irrigation on basis of the crops and their salt tolerance is classified according to [9], Table (1).

Table (1): Crops and their salt tolerance.

Sensitive crops (Salinity < 4 mmhos /cm)	Semi-tolerant crops (4-10 mmhos /cm)	Tolerant crops (10-16 mmhos /cm)
Fruits: Orchards, orange, apple, pear, almond, beach, indian lemon, apricot and mango.	Figs, grapes, and pomegranates.	Olive, guavas and date palm.
Vegetables: Celery, radish and strawberry.	Cauliflower, green pepper, tomato, potatoes, lettuces, carrot, onion, peas, squashes, cucumber and watermelon.	Peanut, spinach.
Field crops: Beans.	Sunflower, peanut, wheat, cesium, rice and sorghum.	Cotton, sugar beat clover, barley and cereals.

All Nile and canals water samples are suitable for all kinds of fruits, vegetables and field crops, where EC values are (< 4) mmhos/cm, while the rest of samples (mixed water samples) are unsuitable for irrigating any type of crops, since their salinities are over (16) mmhos/cm.

According to geological survey [10], the natural water is classified into three main categories of total salinity; fresh water (TDS up to 1500mg/1, □ = 0.01 - 0.03); brackish water (1500 to 5000) mg/l, ionic strings (□) = 0.03 - 0.1) and saline water (TDS more than 5000 mg/1, □ more than 0.1).

(2) Effective salinity (ES):

The experimental carried out [11] revealed that; the electrical conductivity of water (EC_w) is not a correct measure for salt accumulation in soil. This is due to the precipitation of $CaCO_3$ and $MgCO_3$ at the highest concentrations of soil solution. Moreover, some soluble salts are precipitated as calcium sulfate in the gypsum form ($CaSO_4 . 2H_2O$).

Therefore, the carbonates of calcium and magnesium as well as calcium sulfate should not be considered in evaluating the hazardous role of soil salinity by electrical conductivity. Other soluble salts in irrigation water are referred to as effective salinity.

Accordingly, the effective salinity in soil is composed of the salts of NaCl and $MgSO_4$, i.e., it can be determined by calculating the sum of chloride ion concentration plus half the concentration of sulfate ion in water (me/l).

$$\textbf{Effective salinity} = Cl^- + \tfrac{1}{2}\, SO_4^{2-}\ \textbf{(m.eq/l)}$$

The relative standards of effective irrigation water salinity are shown in Table (2).

Applying this classification for the surface water samples, the following facts can be deduced:

(1.) In case of irrigating soils with low permeability, all River Nile and canals water samples can be classified as water of the first grade (class I) while the mixed water samples can be classified as water of the third grade (class III) of irrigation water.

(2.) In case of irrigating soils with moderate permeability, all Nile and canals water samples can be classified as water of the first grade (class I) while the mixed water samples can be classified as water of the third grade (class III) of irrigation water.

(3.) In case of irrigating soils with high permeability, all River Nile and canals water samples can be classified as water of the first grade (class I) while mixed water samples can be classified as water of the third grade (class III) of irrigation water.

Table (2): Relative standards of effective irrigation water salinity.

Soil conditions	Grades of effective salinity (me/l)		
	Class (I)	Class (II)	Class (III)
Soil with low permeability, less leaching and slow shallow drainage.	< 3	3-5	> 5
Soil with moderate permeability, limited leaching, slow and deep drainage.	< 5	5-10	> 10
High permeable soil with deep and easy drainage.	< 7	7-15	> 15

Table (3): Evaluation of the studied surface water samples for irrigation according to the effective water salinity as m.eq /l.

The percentages of surface water of the study area with respect to soil types			
	Soils with low permeability	Soils with moderate permeability	Soils with high Permeability
Class (I)	85	85	85
Class (II)	0	0	0
Class (III)	15	15	15

Briefly, regardless of soil types the quality of the majority of surface water samples (85% Nile and canals water) for irrigation according to the effective salinity can be classified in the order; class I while the mixed surface water samples (15% Nile water mixed with sea water) can be classified as water of the third grade (class III) as in Table (3).

(3) Boron contents (B^{3+}):

Boron has largely attracted the attention of agriculturists, because of its strong relationship to plant growth. So, it should be taken into consideration in evaluating water quality for irrigation. Generally, boron is an essential micronutrient to proper plant nutrition, however, a small excess over the needed amount is toxic to some plants, [(12)].

A classification for boron content due to its importance for the plant growth and its effect on many of the physiological activities of plant tissue. Therefore, plant species vary in both boron requirement and also in their tolerance to excess boron.

By comparing the boron content of the surface water samples which ranges between (<0.01to 3.553 mg/l**)** with Leeden's classification in Table (4), the following facts could be deduced: the majority of the studied surface water samples (91 %) are suitable for irrigating different crop types including; sensitive, semi-tolerant and tolerant crops, while the mixed water samples (9%) are suitable only for irrigating both semi-tolerant and tolerant crops, regardless of water salinity**.**

Table (4): Classification of irrigation water on basis of Boron concentration.

Water class	Sensitive	Semi-tolerant	Tolerant
Excellent	<0.33	<0.67	<1
Good	0.33 - 0.67	0.67 -1.33	1 - 2
Permissible	0.67 - 1.00	1.33 - 2	2 - 3
Suitable	1 - 1.25	2 - 2.5	3 - 3.75
Unsuitable	>1.25	>2.5	>3.75

(4) Residual sodium carbonate:

The complications of carbonate precipitation and dissolution cause difficulties in irrigation. To quantify the effects of conta- minations on irrigation, an empirical parameter was devised on the assumption that all calcium and magnesium would precipitate when the sum of carbonate and bicarbonate is in excess of calcium and magnesium [12] This can cause an increase in the proportionate amount of sodium, and so the effect on the soil is high sodium content. The term Residual Sodium Carbonate (RSC) is defined as follows:

$$\mathbf{RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})\ all\ in\ me/l.}$$

By comparing the values of RSC values of the studied surface water samples as in (Table 5) with the classification values according to [13] and Table (5), it is noticed that the majority of surface water samples (82%) have negative values of RSC, indicating no problem of carbonate and bicarbonate content in their use for irrigation.

Table (5): Classification of irrigation water on basis of residual sodium carbonate (RSC) values.

RSC (mg/l)	Hazard
< 0	Non
0 – 1.25	Low, with some removal of Ca^{2+} and Mg^{2+}
1.25 – 2.5	Medium, with appreciable removal of Ca^{2+} and Mg^{2+}
> 2.5	High, with most Ca^{2+} and Mg^{2+} removed causing Na^{+} accumulation

The concentrations of carbonate and bicarbonate anions in the examined surface water samples are very low while the rest of samples (18%) have positive values of RSC (< 1.25), therefore RSC is low, with some removal of (Ca^{2+}) and (Mg^{2+}).

Total carbonate and non carbonate hardness in river Nile water and its canals samples and in mixed water samples are shown in Table (6-8).

Table (6): Total, carbonate and Non carbonate Hardness in River Nile water samples.

Sample No.	Total Hardness	Carbonate Hardness	Non Carbonate Hardness
1	95.59	93.59	2
2	93.59	91.54	2.05
3	93.59	87.59	6
4	95.57	89.34	6.23
5	101.52	94.40	7.12
6	113.44	105	8.44
7	111.90	101.85	9.64
8	131.35	114.84	16.51
9	128.19	114.84	13.35
10	127.38	114.84	12.54
11	131.38	118.13	13.25
12	133.35	118.13	15.23
13	143.23	115.16	28.07
14	153.16	131.25	21.9
15	157.13	123.05	34.08
16	151.18	129.61	21.57
17	151.16	131.25	19.91
18	119.79	113.20	6.59
19	139.28	119.77	19.51
20	141.26	126.33	14.9
21	192.98	159.14	33.84
22	179.02	134.53	44.49
	Range(93.59-179.02) Mean 131	Range(87.59-159.14) Mean 115	Range(2-44.49) Mean 16

Table (7): Total, carbonate and Non carbonate Hardness in canals water samples.

Sample No.	Total Hardness	Carbonate Hardness	Non Carbonate Hardness
1	111.42	95.16	16.26
2	113.42	95.19	18.26
3	131.36	114.84	16.5
4	123.41	113.2	10.2
5	155.15	123.05	32.1
6	155.18	129.6	25.57
7	155.15	124.69	30.46
8	139.26	119.77	19.49
9	133.31	119.77	13.5
10	188.96	149.3	39.67
11	188.96	150.94	38
	Range(111.42-188.96) Mean 145	Range(95.16-150.94) Mean 121	Range(10.2-39.67) Mean 24

Table (8): Total, carbonate and Non carbonate Hardness in mixed water samples.

Sample No.	Total Hardness	Carbonate Hardness	Non Carbonate Hardness
1	6137	122.25	6014.78
2	6184.72	124.39	6060.04
3	1683.83	157.5	1526.3
4	7522.26	124.69	7397.58
5	3464.21	160.78	3303.4
6	3365.98	152.58	3213.4
	Range(1683.83-7522.26) Mean 4726	Range(122.25-160.78) Mean 140	Range (1526.3-7397.58) Mean 4586

(6) Sodium Adsorption Ratio (SAR):

Sodium concentration is quite important in classifying irrigation water because it reacts with soil enriched in fine-sized fractions to reduce its permeability. Sodium adsorption ratio (SAR) is used as an indication for the suitability of the tested water for irrigation [(14)].

High SAR values reflect a light concentration of dissolved solids and indicate a tendency to replace adsorbed (Ca^{2+}) and (Mg^{2+}) with sodium and affect irrigation quality since this replacement causes damaging of soil structure. Sodium adsorption ratio (SAR) is defined as:

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

Where, SAR= sodium adsorption ratio and the concentrations of these cations are expressed in me/l.

According to the U.S. salinity laboratory staff classification diagram, the water is divided into four classes on basis of salinity (C_1, C_2, C_3 and C_4) and four classes on the basis of SAR (S_1, S_2, S_3 and S_4) giving a total of sixteen possible quality classes (C_1-S_1, C_1-S_2, C_1-S_3, …etc.) as indicated in Table (9).

Table (9): The water quality classes according to the U. S. salinity laboratory Staff.

EC	Quality	Range	Usage
C1	Low salinity water	100-250	Can be used for irrigation of most crops in most soils with little likelihood that soil salinity develops.
C2	Medium salinity water	250-750	Can be used if a moderate amount of leaching occurs.
C3	High salinity water	750-2250	Cannot be used on soil with restricted drainage even with adequate drainage, special management for salinity control may be required and plants with good salt tolerant should be selected.
C4	Very high salinity	>22500	Is not suitable for irrigation under ordinary conditions, but may be used occasionally under special conditions as the soils must be permeable, and drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching.
SAR	Quality	Range	Usage
S1	Low sodium water	0-10	Can be used for irrigation of almost all soils with little changes of the development of harmful levels of exchangeable sodium.
S2	Medium sodium water	10-18	Will represents an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil.
S3	High sodium water	18-26	May produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching and organic matter condition.
S4	Very high sodium	26-100	Is generally unsatisfactory for irrigation purposes except at low and perhaps land perhaps medium salinities.

Note: 1- C2-S3 and C3-S3 water can be improved by adding gypsum to the soil.
2- C2-S4 may be improved by the addition of gypsum to the water

By applying this classification on surface water samples that appended in Table (9) it is noted that**:**

- Three samples of River Nile water, (8%,Nos.2,3,4) ,at (Aswan and Kom Ombo) lie in good class water (C1-S1). This water class can be used for irrigation of most crops in most soils with little likelihood that soil salinity develops.
- Thirty water samples (77%) belong to good water class (C2-S_1) . This class can be used if a moderate amount of soil leaching occurs.
- Six samples of mixed water (15%) do not agree with this classification and these samples lie out of scale, Fig. (16) and generally they are unsuitable for irrigation purposes, where EC ranges between 14510-56600 µ mhos/cm.

Briefly; According to this classification which depends on SAR and water salinity (EC, µmhos/cm), the majority of surface water samples (85%), belongs to the good water class for irrigation. On the other hand, the rest of samples (15 %, Nos. 34, 35, 37, 38 and 39) are unsuitable for irrigation purposes**.**

The (EC), (ES), (RSC) and (SAR) of River Nile water samples, its canals and mixed water samples as in Table (10, 11 and 12).

Table (10): Electric conductivity (EC), effective salinity(ES),residual sodium carbonate(RSC) and sodium adsorption ratio(SAR) of River Nile water samples.

Sample No.	RSC	ES	SAR	EC
1	-0.0086	0.4336	0.6864	257
2	0.0640	0.3671	0.6080	244
3	0.0640	0.4134	0.7204	241
4	-0.0082	0.441	0.6774	242
5	0.0040	0.5670	0.8733	299
6	-0.1686	0.7182	0.8423	315
7	-0.0291	0.6669	0.8375	308
8	-0.0634	0.7700	0.8278	351
9	-0.2665	0.8999	0.9516	351
10	0.1491	0.9216	1.0525	394
11	-0.2647	0.8911	0.9444	359

Continual Table (10): Electric conductivity(EC),effective salinity (ES), residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) of River Nile water samples

Sample No.	RSC	ES	SAR	EC
12	-0.3042	0.9355	0.921	372
13	-0.0036	0.8552	1.0911	392
14	-0.4376	1.5776	1.4257	475
15	-0.2813	1.3954	1.3267	473
16	-0.4309	1.5928	1.4470	473
17	-0.3977	1.5776	1.4461	473
18	-0.1315	1.0538	1.2441	388
19	0.0097	1.0961	1.1759	437
20	-0.298	1.3976	1.3379	428
21	-0.6761	2.1545	1.6888	665
22	-0.2228	2.0667	1.6414	613

Table (11): Electric conductivity(EC),effective salinity(ES), residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) of canals water samples.

Sample No.	RSC	ES	SAR	EC
1	-0.0585	0.5106	0.6688	285
2	-0.0984	0.4930	0.6628	286
3	0.0697	0.7487	1.0836	350
4	0.1957	0.7867	0.9590	339
5	-0.3750	1.4366	1.3407	491
6	-0.5108	1.6351	1.3482	490
7	-0.3422	1.5451	1.3945	485
8	-0.3894	1.1971	0.9440	389
9	-0.2705	1.2340	1.0816	393
10	-0.5261	2.5471	2.0732	686
11	-0.0937	2.2586	2.0914	700

Table (12): Electric conductivity (EC), effective salinity (ES) ,residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) of canals water samples.

Sample No.	RSC	ES	SAR	EC
1	-120.1754	584.765	65.7174	52400
2	-120.4137	592.7634	64.3572	51600
3	-30.4960	143.9222	28.1850	14510
4	-147.8037	664.78	60.4053	56600
5	-66.0025	311.4076	42.2569	31200
6	-64.2038	319.466	43.6186	29900

Generally**,** the evaluation of surface water for human, live-stock drinking and irrigation according to the above different classifications shows that the majority of surface water samples (Nile and canals) are suitable for drinking and irrigation purposes while only few surface water samples(mixed water) are unsuitable. On the other hand, all surface water samples are suitable for domestic and laundry uses after heating. In conclusion, it is clear that the mixed water samples suffer from the problem of high salinity that is unsuitable for drinking of the population and irrigation as in Fig.(1).

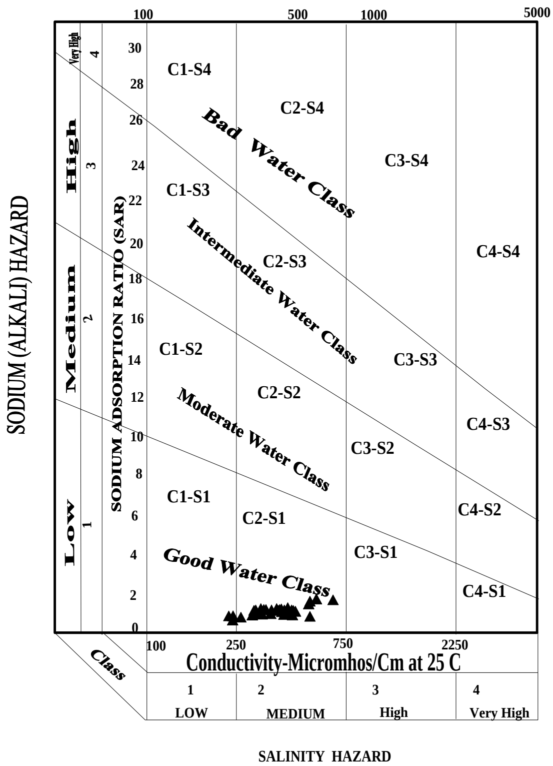
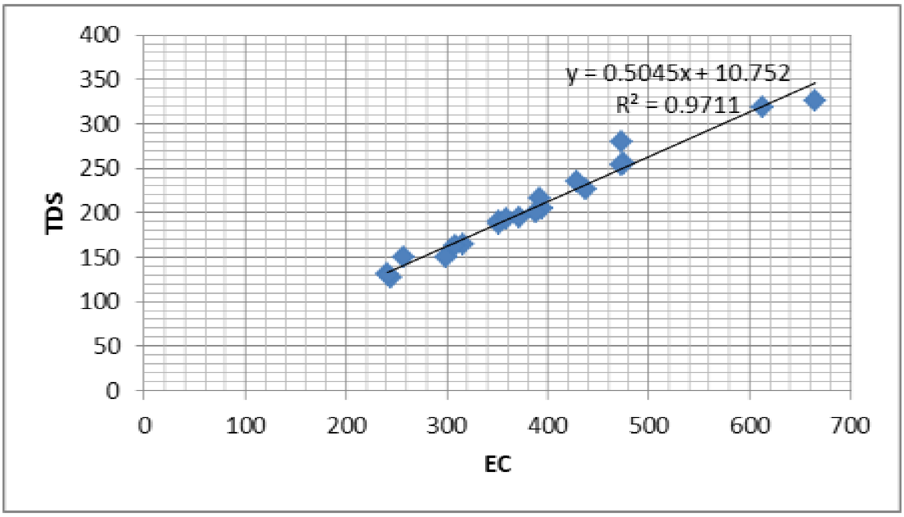
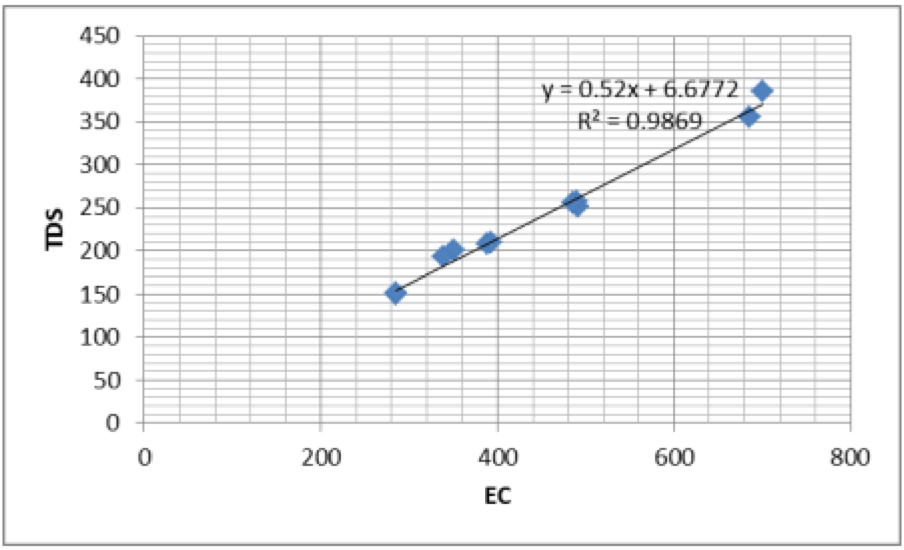


Fig.(1): Classification of surface water for irrigation purposes.

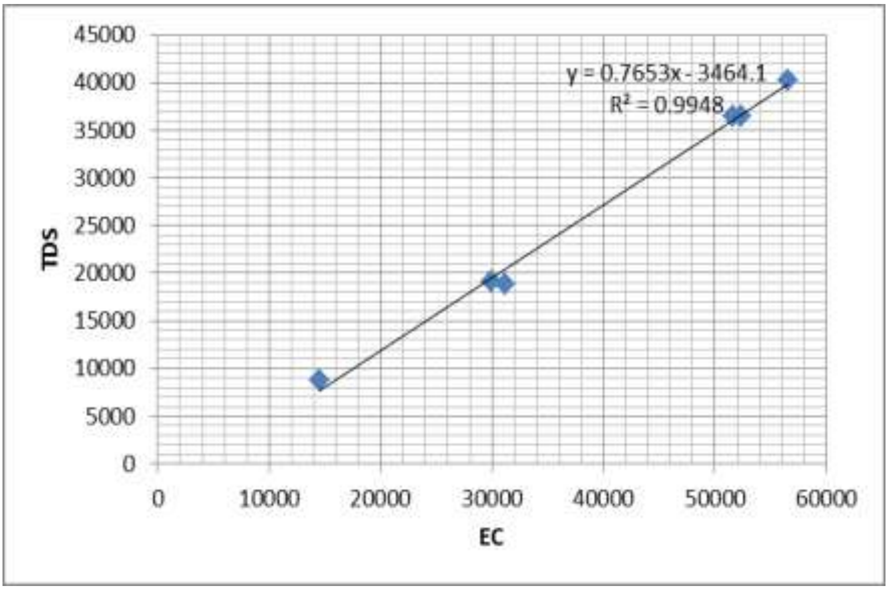
The results of the relation between electrical conductivity and total dissolved salts in River Nile water samples Fig (2), and the relation between electrical conductivity and total dissolved salts in canls water samples and mixed water samples as in Fig (3 and 4). Also the results of electrical conductivity, in the River Nile and its canals and mixed water samples agasinst different co cations as in Fig (5).



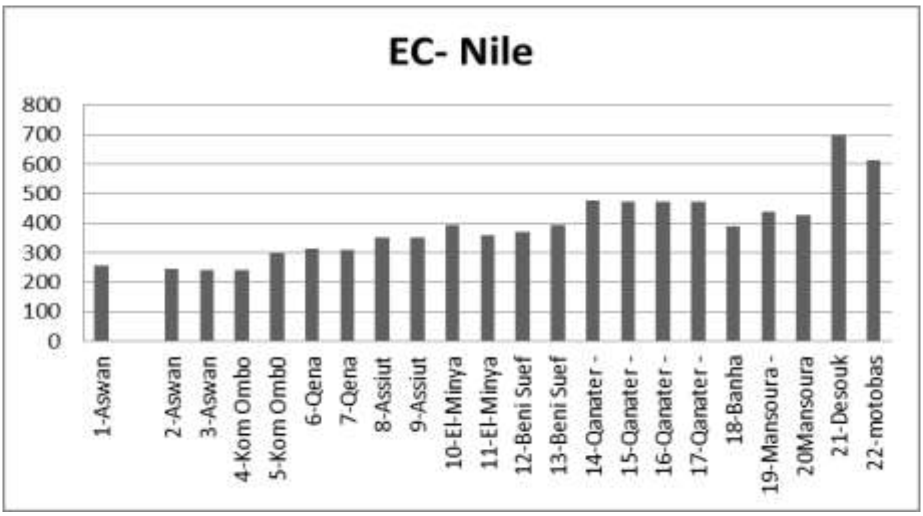
(Fig.2): Relation between Electrical Conductivity and Total dissolved salts in River Nile water samples.



(Fig.3): Relation between Electrical Conductivity and Total dissolved salts in canals water samples.



(Fig.4): Relation between Electrical Conductivity and Total dissolved salts of mixed water samples.



(Fig.5): Results of Electrical Conductivity against different locations of River Nile water samples.

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