# Comparative Study on Salinity Measurements in Soils of the North Western Coastal Region of Egypt

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## ABSTRACT

Saturated soil paste and 1:1, 1:2, 1:3, 1:4, 1:5 soils to water extracts are used for assessing soil salinity of 36 soil samples collected from the Egyptian north western coastal plain. These soil to water extracts were prepared from the tested soil samples and analyzed for EC, major cations ($Na^+$, $K^+$, $Mg^{++}$, $Ca^{++}$) and major anions ($Cl^-$, $SO_4^=$, $HCO_3^-$). Relationships of all analytes for the tested methods were established using linear and power regressions. The results showed that, analytes from 1: 1 soil to water extracts and saturated paste extracts were highly correlated. The relationship between the EC values in the saturation extract (Y) and the EC of 1:1 soil water extract (X) could be expressed as: Y= 0.11+2.41 X. The statistical relation between ions and its SAR for saturation extract values and other soil water extracts were also calculated and expressed in regression equations. Findings from this study showed that method is considerable an accurate and valid for measuring the salinity of soil as well as the saturated soil extract method. Prediction of the salinity of soil saturation extract can be calculated from data of 1:1 soil-water extract by using regression equations obtained in the study especially for soils of the studied area.

## INTRODUCTION

Soil salinity is the major soil pollution problem in arid and semi-arid regions of the world. The collapse of the Babylonian Empire is considered to be partly the result of failure of irrigated crops due to the accumulation of salts (Hillel, 1992).. The predominant solutes responsible for salinity include the cations, sodium, calcium, and magnesium and anions, sulphate and chloride (Richards, 1954). Minor amounts of potassium, bicarbonate, carbonate, and nitrate may also be present. A number of approaches have been devised to characterize soil salinity. Most conventional methods employ aqueous or direct extraction of the soil solution and subsequent analysis of salt concentrations. The most common method of extraction used universally in the analysis of soil salinity is the saturation paste

extraction (Richards, 1954). This procedure offers advantages of convenience and greater extract volume relative to direct solution extraction. As well, it can be reproducibly related to field soil water contents and compensates for variation in soil moisture retention.

Some investigators employ some other extraction ratios (e.g., 1:1, 1:2, 1:5) which are more convenient to use and yield higher extract volumes without vacuum, but are not as closely relate to field soil moisture contents. The saturation extraction procedure effectively measures total salt concentrations in the soil solution, but it does not accurately reflect ionic composition of the solution, particularly in regard to calcium concentrations (Janzen and Chang,1988). Although the saturation extract remains the standard for measuring total salinity, other extraction ratios have been found to be closely correlated with the saturation extract in a wide range of soils (Hog and Henery, 1984). Extraction using a fixed soil-water ratio may be particularly useful for monitoring relative changes in solute concentrations.

The objectives of this study were to ( i ) explore the relationship between $EC_e$ or the soluble ions in soil saturation paste extract and that in fixed of soil-water ratio extracts for the Egyptian northwest coast plain soils, ( ii )select the optimum extraction method for measuring the electrical conductivity and the soluble ions determinations and ( iii ) find the appropriate equations for converting the results to those equivalent of a saturated paste extract,

## MATERIALS AND METHODS

Thirty six soil samples were collected from 36 sites located in North Western Coastal region of Egypt. The soil sample was collected from the upper soil layer (0-30 cm). As follows: 15 soil samples from the transects start at Km 50, Alexandria- El-Salum desert road till Mattruh (Fig.1), 13 soil samples form Bangr – Elsukar region (Fig.2) and 8 soil samples from Km 80 to Km 115, El-

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Nubaria region. The collected soil samples were placed in plastic bags, sealed, and transported to the laboratory, where they were air-dried and ground to pass through 2mm sieve. Some chemical and physical characteristics of the soil were determined and presented in Table 1. The particle size distribution analysis was determined by the hydrometer method according to Gee and Bauder (1986), calcium carbonate was estimated by collin's calcimeter method (Black, 1965), organic carbon was determined by wet oxidation method of Walkly and Black (Nelson and Sommer,1982) and soil pH was measured in the saturation extracts by glass electrode pH meter. Saturated soil paste and soil water ratios of 1:1, 1:2, 1:3, 1:4 , 1:5 extracts were prepared using a procedure similar to that proposed by Richards, (1954).

The saturation extracts or the different (Soil: Water ratios) extracts were subjected to different chemical analysis as follows: the salinity by electrical conductivity meter, soluble sodium and potassium were determined photometrically using flame photometer, soluble calcium and magnesium were determined by

versenate titration method according to Jackson (1973), soluble carbonate and bicarbonate were determined byaccording to Jackson (1973), chloride according to (Richards, 1954), sulphate was determined turbidmetrically with barium as described by Jackson 1973). The obtained data were statistically analyzed and the regression equations were calculated using linear and power regression analysis (CoHort, 1995).

## RESULTS AND DISCUSSION

The analytical data showed considerable variations in the properties of the tested soils (Table 1). Thus, the data showed different texture classes (Table 1), pH range from 7.26 to 7.87, organic matter contents from 0.24 to 4.74% and calcium carbonate contents from 0.47% to 70.5%. This indicates that the tested soils are alkaline, and they are typic calciorthids, except soils No. 29, 30, 31, 32, 33, 34, 35 and 36, which are sandy soils. The levels of salinity and the soluble ions widely varied among soils (Table2), depending upon soil texture and
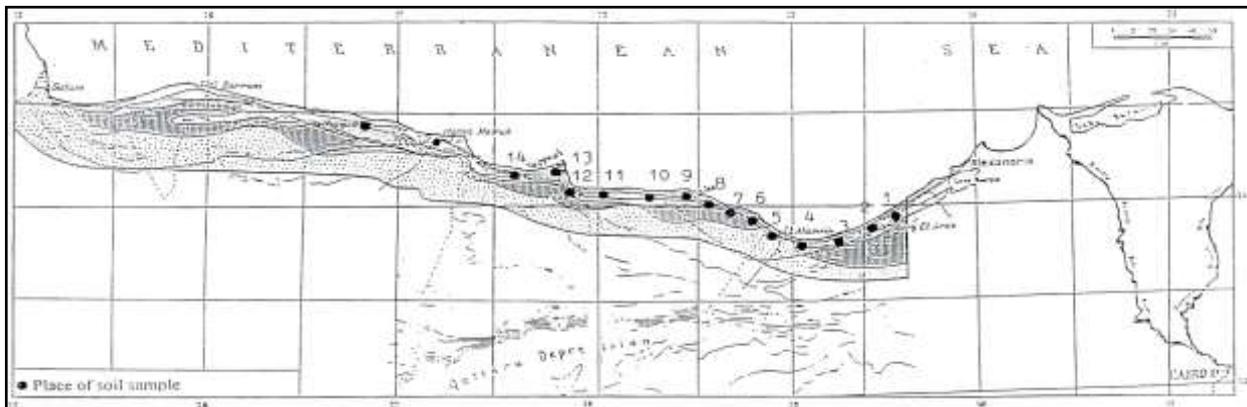


Figure 1. A map for the location of soil sampling sites along the transects start at Km 50, Alexandria-Mattruh desert road till El-Salum.
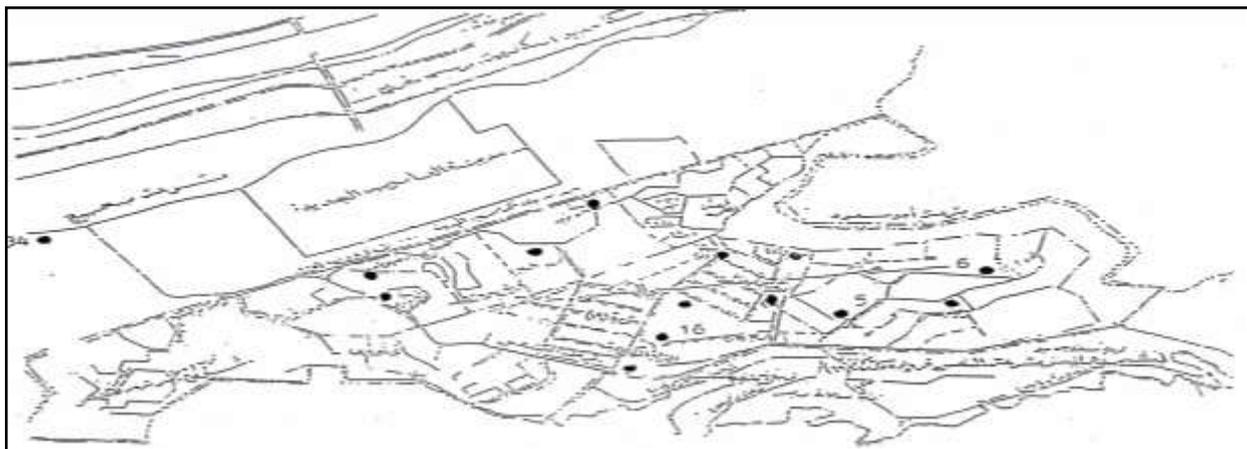


Figure 2. Sketch map for the location of soil sampling sites in sugar beet region.

## Table 1. Some soil properties of the tested soil samples

| Site and sample No. | Location | Particle size distribution | | | Textural class (*) | O.M. (%) | CaCO₃ (%) | pH |
|---|---|---|---|---|---|---|---|---|
| | | Sand (%) | Silt (%) | Clay (%) | | | | |
| 1 | Burg El-Arab | 65.7 | 18.2 | 16.1 | L.S | 1.86 | 70.50 | 7.27 |
| 2 | El-Hamam | 55.0 | 26.6 | 18.0 | S.C.L | 1.32 | 35.01 | 7.58 |
| 3 | El-Hamam | 53.2 | 22.5 | 22.3 | S.C.L | 1.86 | 49.06 | 7.58 |
| 4 | El-Alamain | 79.8 | 12.1 | 8.1 | L.S | 1.32 | 48.50 | 7.57 |
| 5 | El-Alamain | 63.5 | 22.3 | 14.2 | L.S | 1.26 | 36.59 | 7.61 |
| 6 | Sidi Abdel Rahman | 77.8 | 14.1 | 8.1 | L.S | 1.80 | 55.92 | 7.83 |
| 7 | Ain Gazalla | 73.7 | 12.1 | 14.2 | L.S | 1.26 | 51.40 | 7.81 |
| 8 | Alowny sons | 56.2 | 28.5 | 15.3 | L.S | 1.20 | 52.04 | 7.26 |
| 9 | El-Daba | 55.0 | 24.5 | 20.5 | S.C.L | 1.08 | 19.25 | 7.72 |
| 10 | El-Gifyra | 77.8 | 14.1 | 8.1 | L.S | 1.14 | 54.27 | 7.82 |
| 11 | Zawaia El-Awam | 81.8 | 10.1 | 8.1 | L.S | 0.60 | 44.36 | 7.62 |
| 12 | Etnoh | 46.4 | 28.9 | 24.7 | S.C.L | 1.44 | 29.82 | 7.58 |
| 13 | Baggosh | 48.8 | 34.8 | 16.4 | L | 0.72 | 23.90 | 7.52 |
| 14 | Rass El-hykma | 51.3 | 28.4 | 20.3 | L.S | 1.98 | 24.28 | 7.46 |
| 15 | Matruoh | 61.5 | 18.2 | 20.3 | S.C.L | 0.84 | 55.60 | 7.79 |
| 16 | Village No.1 | 48.3 | 24.8 | 26.9 | S.C.L | 1.68 | 29.81 | 7.53 |
| 17 | Village No.5 | 42.7 | 20.5 | 36.8 | C.L | 4.74 | 32.05 | 7.53 |
| 18 | Village No.6 | 42.5 | 20.5 | 37.0 | C.L | 4.14 | 31.22 | 7.53 |
| 19 | Village No.13 | 38.5 | 20.5 | 41.0 | C | 2.88 | 34.53 | 7.52 |
| 20 | Village No.14 | 37.9 | 55.9 | 6.2 | S.L | 2.34 | 33.29 | 7.33 |
| 21 | Village No.15 | 39.9 | 53.9 | 6.2 | S.L | 3.12 | 32.30 | 7.30 |
| 22 | Village No.16 | 31.8 | 18.6 | 49.6 | C | 2.64 | 37.83 | 7.43 |
| 23 | Village No.17 | 44.5 | 20.6 | 34.9 | S.C.L | 3.48 | 30.23 | 7.52 |
| 24 | Central Village | 67.0 | 14.4 | 18.6 | L.S | 1.32 | 28.74 | 7.79 |
| 25 | Al-Zohour Village | 36.1 | 18.5 | 45.4 | C | 2.58 | 41.71 | 7.67 |
| 26 | Mohammed Village | 58.6 | 22.8 | 18.6 | S.C.L | 1.68 | 34.20 | 7.84 |
| 27 | Al-Olaa Village | 28.0 | 22.6 | 49.4 | C | 2.04 | 48.60 | 7.60 |
| 28 | Said Darwish V. | 34.5 | 26.6 | 38.9 | C.L | 1.98 | 39.32 | 7.50 |
| 29 | Al-Nubaria at km 80 | 94.0 | 2.0 | 4.0 | S | 0.36 | 3.71 | 7.52 |
| 30 | Al-Nubaria at km 85 | 94.0 | 2.0 | 4.0 | S | 0.30 | 1.82 | 7.49 |
| 31 | Al-Nubaria at km 90 | 94.0 | 2.0 | 4.0 | S | 0.30 | 5.11 | 7.62 |
| 32 | Al-Nubaria at km 95 | 94.0 | 2.0 | 4.0 | S | 0.48 | 1.09 | 7.52 |
| 33 | Al-Nubaria at km 100 | 96.0 | 2.0 | 2.0 | S | 0.24 | 0.473 | 7.87 |
| 34 | Al-Nubaria at km 105 | 96.0 | 2.0 | 2.0 | S | 0.24 | 0.84 | 7.83 |
| 35 | Al-Nubaria at km 110 | 92.0 | 4.0 | 4.0 | S | 0.24 | 2.296 | 7.73 |
| 36 | Al-Nubaria at km 115 | 91.9 | 4.0 | 4.1 | S | 0.24 | 2.624 | 7.63 |

(*) S.C.L (Sand Clay Loam)   C.L. (Clay Loam)   C. (Clay)   S. (Sand).
S.L. (Silt Loam)   L.S. (Loam Sand)   L. (Loam)

## Table 2. The electrical conductivity and soluble ions of the tested soils

| Sample No. | ECe* dS/m | Soluble cations (meq/L) | | | | Soluble anions (meq/L) | | |
|---|---|---|---|---|---|---|---|---|
| | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | $HCO_3^-$ | $CL^-$ | $SO_4^=$ |
| 1 | 3.14 | 14.95 | 6.96 | 8.85 | 1.00 | 3.83 | 13.98 | 12.20 |
| 2 | 4.74 | 10.25 | 10.22 | 26.35 | 0.70 | 2.56 | 41.38 | 1.62 |
| 3 | 1.53 | 3.10 | 3.09 | 6.93 | 1.75 | 3.30 | 7.78 | 0.98 |
| 4 | 9.21 | 25.16 | 15.90 | 43.44 | 2.28 | 3.82 | 75.40 | 9.28 |
| 5 | 0.64 | 2.97 | 2.25 | 2.60 | 0.45 | 5.97 | 3.34 | 0.56 |
| 6 | 0.65 | 6.30 | 3.65 | 2.43 | 0.73 | 9.20 | 2.98 | 0.69 |
| 7 | 0.68 | 4.96 | 5.11 | 3.79 | 0.49 | 10.19 | 2.10 | 0.50 |
| 8 | 19.21 | 78.45 | 60.10 | 65.32 | 3.14 | 1.66 | 210.13 | 1.44 |
| 9 | 0.79 | 3.39 | 2.04 | 5.15 | 0.72 | 7.08 | 2.70 | 0.88 |
| 10 | 0.62 | 3.50 | 2.30 | 2.82 | 0.75 | 6.26 | 2.71 | 0.65 |
| 11 | 2.27 | 5.90 | 5.30 | 9.16 | 1.01 | 3.17 | 16.14 | 1.13 |
| 12 | 23.91 | 62.10 | 69.35 | 198.60 | 4.70 | 1.86 | 323.31 | 11.93 |
| 13 | 14.30 | 16.80 | 23.75 | 94.71 | 2.16 | 2.33 | 122.49 | 14.93 |
| 14 | 1.51 | 2.09 | 4.70 | 7.24 | 0.97 | 5.21 | 8.79 | 1.04 |
| 15 | 1.65 | 2.35 | 1.50 | 6.25 | 0.84 | 4.80 | 9.78 | 0.58 |
| 16 | 1.60 | 8.36 | 3.51 | 6.43 | 1.68 | 11.20 | 8.41 | 1.33 |
| 17 | 1.63 | 5.55 | 3.53 | 8.30 | 1.02 | 11.91 | 6.20 | 1.19 |
| 18 | 2.73 | 14.20 | 6.95 | 8.32 | 1.79 | 8.26 | 8.13 | 10.41 |
| 19 | 6.33 | 14.20 | 10.70 | 28.49 | 1.76 | 8.39 | 37.08 | 3.57 |
| 20 | 19.30 | 48.70 | 36.35 | 120.07 | 2.47 | 8.12 | 185.70 | 16.60 |
| 21 | 13.08 | 34.05 | 30.08 | 71.00 | 2.17 | 5.49 | 102.01 | 31.65 |
| 22 | 2.37 | 6.45 | 4.96 | 12.33 | 2.17 | 9.35 | 11.24 | 3.80 |
| 23 | 2.38 | 7.13 | 5.40 | 14.17 | 0.97 | 8.35 | 10.04 | 3.01 |
| 24 | 2.59 | 5.06 | 4.50 | 17.54 | 1.25 | 5.61 | 16.93 | 4.26 |
| 25 | 1.79 | 5.93 | 2.95 | 7.97 | 0.49 | 7.20 | 3.78 | 3.26 |
| 26 | 0.54 | 1.86 | 1.36 | 2.56 | 0.49 | 3.27 | 1.55 | 0.54 |
| 27 | 1.07 | 3.75 | 2.40 | 3.87 | 0.48 | 4.41 | 3.70 | 0.73 |
| 28 | 1.74 | 5.00 | 3.05 | 7.09 | 0.98 | 8.21 | 7.47 | 0.86 |
| 29 | 2.14 | 8.50 | 5.20 | 8.10 | 2.70 | 2.51 | 14.62 | 5.38 |
| 30 | 1.92 | 5.35 | 3.46 | 8.54 | 0.93 | 6.84 | 8.60 | 2.04 |
| 31 | 1.66 | 4.50 | 2.56 | 6.36 | 2.35 | 5.16 | 5.89 | 3.82 |
| 32 | 1.73 | 6.35 | 2.05 | 4.70 | 2.07 | 3.01 | 4.92 | 4.39 |
| 33 | 0.80 | 2.25 | 0.90 | 3.20 | 0.49 | 1.90 | 2.34 | 0.90 |
| 34 | 1.34 | 2.65 | 1.70 | 6.40 | 0.61 | 2.24 | 6.15 | 0.66 |
| 35 | 1.34 | 1.50 | 1.55 | 8.59 | 1.36 | 5.07 | 5.17 | 1.36 |
| 36 | 6.01 | 23.85 | 5.65 | 27.83 | 1.08 | 4.53 | 40.43 | 12.26 |

* In saturation soil paste extract

organic matter contents. For all soils, however, the concentrations of soluble ions decreased, as the soil becomes coarse in texture. Thus, a wide range in salinity levels or soluble ions were obtained in the extracts of the saturated paste and the 1 : 1, 1 : 2, 1 : 3, 1 : 4 , 1 : 5 soil : water ratios.

**Electrical conductivity (EC)**

Salinity estimates expressed as electrical conductivity of such soil: water extracts are convenient particularly if the amount of soil sample is limited, or for determination of the change of salinity with time orwith different treatments. A better estimate of soluble salts can be obtained from the conductivity of soil saturation extract. The special advantages of the saturation extract method of measuring salinity, lies in the fact that the saturation percentages are directly related to, so far, the field moisture range.

Table (3) represents the EC range and means values of the 36 soil samples, determined in the extracts of. saturation paste and 1: 1, 1: 2, 1: 3, 1: 4, 1:5  soil- water ratios.

**Table3.The range and mean values of EC (dS/m) in the different extraction methods**

| Extraction methods | Range | Mean |
|---|---|---|
| Saturated soil Past | 0.54-23.91 | 4.42 |
| 1:1 Soil-water ratio | 0.28-9.71 | 1.79 |
| 1:2 Soil-Water ratio | 0.22-6.38 | 1.20 |
| 1:3 Soil-Water ratio | 0.20-4.72 | 0.95 |
| 1:4 Soil-Water ratio | 0.17-3.30 | 0.69 |
| 1:5 Soil-Water ratio | 0.14-2.64 | 0.54 |

The results revealed that the order of magnitude for EC in soils was as follows: saturation extract >1: 1 > 1: 2 > 1: 3 > 1: 4 > 1: 5 soil water ratios.

The analytical data presented in Table 4 are used to study the relationship between the electrical conductivity of the extracts of saturated paste and those of electrical conductivity of different soil: water ratios. The obtained relationships were significant with highly positive correlation coefficients. These coefficients were $0.963^{**}$, $0.943^{**}$, $0.939^{**}$, $0.932^{**}$, $0.904^{**}$ for 1: 1, 1: 2, 1: 3, 1: 4 and 1: 5 soil: water extracts, respectivelyThe regression equations between the electrical conductivity of the different soil: water extracts and that of soil saturation extract were calculated to predict the values of $EC_e$ in the saturation extract (Y) when EC values are determined in the tested soil: water extracts (X) and presented in Table 4.

The best equation was found to be:

$Y = 0.11 + 2.41X$  (1:1 soil: water extract)
$R^2 = 0.93$

Hog and Henry (1984) Found that the electrical conductivity of saturation extract was related to that of 1:1 and 1:2 (soil: water), for a wide range of Saskatchewan soils and that of the saturation extract was closely related to 1:1 and 1:2 extracts ($R^2$= 0.96-0.98). Also, Farag *et al.* (1996) found highly significant interrelationships between the total soluble salts of the saturated paste extract and that of1:1 or 1:5 soil water extract in soils of North Sinai.

**Cationic composition**

Soluble $Na^+$: Table (5) showed that there was a great difference in the concentrations of soluble $Na^+$ between soil saturation extract and 1:1, 1:2, 1:3, 1:4 and 1:5 soils: water extracts. Sodium concentrations in soil saturation extract was approximately higher 2.83, 4.82, 6.79, 11.08 and 11.84 times than its concentration in 1:1, 1:2, 1:3, 1:4 and 1:5 soil: water extract respectively. Accordingly, it could be concluded that the higher concentration of $Na^+$ ions in the soil saturation extract might be due to the dilution effect.

**Table 4. The relationship between $EC_e$ (dS/m) of soil saturation extract and the EC of the tested soil: water extracts**

| Extraction method | Linear regression equations | $R^2$ | Power regression equations | $R^2$ |
|---|---|---|---|---|
| 1 : 1 soil: water ratio | $Y = 0.11 + 2.41 X$ | 0.923 | $Y = 2.198 X^{1.06}$ | 0.837 |
| 1 : 2 soil: water ratio | $Y = 0.14 + 3.55 X$ | 0.888 | $Y = 3.213 X^{1.08}$ | 0.781 |
| 1 : 3 soil: water ratio | $Y = 0.03 + 4.63 X$ | 0.881 | $Y = 4.104 X^{1.15}$ | 0.757 |
| 1 : 4 soil: water ratio | $Y = -0.19 + 6.66 X$ | 0.869 | $Y = 5.658 X^{1.17}$ | 0.699 |
| 1 : 5 soil: water ratio | $Y = -0.06 + 8.30 X$ | 0.817 | $Y = 7.551 X^{1.18}$ | 0.673 |

Y = The EC of the saturation extract.
X = The EC of the Soil: water extracts.

**Table 5. The ranges and means of cations and anions concentrations (meq/L) in the extracts of the different extraction methods**

| Ion | | Saturation extract | Soil : water ratio | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 : 1 | 1 : 2 | 1 : 3 | 1 : 4 | 1 : 5 |
| $Na^+$ | Range | 2.43-198.6 | 1.46-49.7 | 1.12-29.72 | 0.63-20.28 | 0.49-16.08 | 0.41-12.12 |
| | mean | 24.04 | 8.3 | 4.98 | 3.54 | 2.17 | 2.03 |
| $K^+$ | Range | 6.45-4.70 | 0.37-3.04 | 0.16-1.69 | 0.18-1.11 | 0.13-0.92 | 0.08-0.76 |
| | mean | 1.42 | 0.86 | 0.91 | 0.71 | 0.37 | 0.28 |
| $Ca^{+2}$ | Range | 1.5-78.45 | 1.05-30.35 | 0.19-22.88 | 0.58-20.16 | 0.48-17.74 | 0.39-12.98 |
| | mean | 12.71 | 5.88 | 4.05 | 3.53 | 2.7 | 2.14 |
| $Mg^{+2}$ | Range | 0.9-69.35 | 0.77-18.59 | 0.64-11.65 | 0.62-8.06 | 0.37-5.59 | 0.19-4.76 |
| | mean | 9.86 | 3.84 | 2.39 | 1.56 | 1.44 | 1.09 |
| $Cl^-$ | Range | 1.55-323.3 | 0.58-91.16 | 0.40-49.57 | 0.36-35.03 | 0.27-26.45 | 0.24-19.99 |
| | mean | 37.04 | 12.17 | 6.79 | 4.79 | 3.55 | 2.59 |
| $SO_4^{-2}$ | Range | 0.5-316.5 | 0.42-18.56 | 0.35-15.3 | 0.29-12.02 | 0.17-7.97 | 0.11-4.79 |
| | mean | 4.74 | 2.47 | 1.71 | 1.33 | 0.90 | 0.59 |
| $HCO_3$ | Range | 1.66-11.91 | 1.48-8.55 | 1.3-5.9 | 1.22-5.37 | 1.14-4.99 | 0.9-3.94 |
| | mean | 5.75 | 3.25 | 2.7 | 2.42 | 2.18 | 1.89 |

Regression equations were calculated in order to predict the values of $Na^+$ ion contents in saturation extract when it is determined in 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts (Table 6). It is clear that the best equations were found to be expressed as follows:

$$Y = -4.13 + 3.39 X \qquad \text{(1:1 soil: water extract)}$$

$$R^2 = 0.93$$

$$Y = 1.923 X^{1.13} \qquad \text{(1:1 soil: water extract)}$$

$$R^2 = 0.93$$

<u>Soluble $K^+$</u>: Table (5) showed that there were differences in the concentrations of soluble $K^+$ between soil saturation extracted and the different soil: water

**Table 6. The relationship between the cation concentrations in soil saturation extract and in the tested soil: water extracts**

| Cations | Soil: water ratio | Linear regression equations | $R^2$ | Power regression equations | $R^2$ |
|---|---|---|---|---|---|
| | 1 : 1 | Y = -4.13 + 3.39 X | 0.928 | $Y = 1.923 X^{1.13}$ | 0.931 |
| | 1 : 2 | Y = -4.35 + 5.70 X | 0.917 | $Y = 3.349 X^{1.13}$ | 0.882 |
| Na | 1 : 3 | Y = -4.70 + 8.11 X | 0.909 | $Y = 4.927 X^{1.11}$ | 0.860 |
| | 1 : 4 | Y = -4.68 + 10.81 X | 0.902 | $Y = 6.651 X^{1.11}$ | 0.844 |
| | 1 : 5 | Y = -4.74 + 14.15 X | 0.915 | $Y = 8.850 X^{1.19}$ | 0.890 |
| | 1 : 1 | Y = -0.02 + 1.58 X | 0.874 | $Y = 1.533 X^{1.13}$ | 0.898 |
| | 1 : 2 | Y = 0.05 + 1.92 X | 0.871 | $Y = 2.024 X^{1.13}$ | 0.863 |
| K | 1 : 3 | Y = -0.48 + 4.03 X | 0.816 | $Y = 3.309 X^{1.22}$ | 0.800 |
| | 1 : 4 | Y = -0.24 + 4.51 X | 0.842 | $Y = 4.042 X^{1.10}$ | 0.824 |
| | 1 : 5 | Y = -0.003 + 5.06 X | 0.810 | $Y = 4.679 X^{0.97}$ | 0.798 |
| | 1 : 1 | Y = 1.32 + 1.94 X | 0.851 | $Y = 2.293 X^{0.95}$ | 0.810 |
| | 1 : 2 | Y = 2.83 + 2.44 X | 0.691 | $Y = 3.080 X^{0.96}$ | 0.695 |
| Ca | 1 : 3 | Y = 2.64 + 3.06 X | 0.674 | $Y = 3.597 X^{0.94}$ | 0.657 |
| | 1 : 4 | Y = 2.70 + 3.71 X | 0.647 | $Y = 4.229 X^{0.98}$ | 0.626 |
| | 1 : 5 | Y = 3.00 + 4.53 X | 0.557 | $Y = 5.077 X^{1.00}$ | 0.603 |
| | 1 : 1 | Y = -1.99 + 3.09 X | 0.904 | $Y = 1.674 X^{1.20}$ | 0.909 |
| | 1 : 2 | Y = -2.53 + 5.19 X | 0.845 | $Y = 2.520 X^{1.30}$ | 0.805 |
| Mg | 1 : 3 | Y = -3.18 + 7.01 X | 0.841 | $Y = 3.288 X^{1.30}$ | 0.758 |
| | 1 : 4 | Y = -3.19 + 9.07 X | 0.812 | $Y = 4.628 X^{1.27}$ | 0.680 |
| | 1 : 5 | Y = -.2.62 + 11.4 X | 0.781 | $Y = 6.439 X^{1.12}$ | 0.567 |

Y = the concentration of the saturation extract.
X = the concentration of the Soil: water extracts.

extracts. Potassium concentration in soil saturation extract was approximately higher 1.65, 2.25, 3.02, 3.84, 5.07 times than its concentration in 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts, respectively. It was found that $K^+$ concentration of soil saturation extract correlated positively with those of the different extracts (0.935[**], 0.933[**], 0.903[**], 0.918[**] and 0.899[**] for in 1:1, 1:2, 1:3, 1:4 and 1:5 soil: water extracts, respectively). Also, the regression equations were calculated to predict the values of $K^+$ content in saturation extract when $K^+$ ion contents are determined in the tested soil: water extracts (Table 6). The best equations were found to be:

$Y = -0.02 + 1.58\ X$       (1:1 soil: water extract)

$R^2 = 0.87$

$Y = 1.533\ X^{1.13}$       (1: 1 soil :water extract)

$R^2 = 0.90$

Soluble $Ca^{+2}$: Table (5) showed great differences in the concentration of soluble $Ca^{+2}$ between soil saturation extract and 1:1, 1:2, 1:3, 1:4 and 1:5 soil: water extracts. The values of $Ca^{++}$ extracted from the soils by 1:1 soil-water ratio were substantially lower than those of the saturation extract, but often higher than those extracted with 1:2, 1:3, 1:4 and 1:5 extracts. Calcium concentration in soil saturation extract was approximately higher 2.16, 3.14, 3.58, 4.71, 5.95 times than its concentration in 1:1, 1:2 1:3, 1:4 and 1:5 extracts, respectively. This may be due to lack of sparingly soluble salts, especially gypsum; so dilution effect can not lead to increase calcium solubility. It was found $Ca^{+2}$ concentration of soil saturation extract highly correlated with those of the different extracts (0.923[**], 0.831[**], 0.821[**], 0.805[**] and 0.747[**] for the 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts, respectively). The regression equations were calculated, in order to predict the values of $Ca^{+2}$ in saturation extract, when $Ca^{+2}$ ion contents are determined in 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts (Table 6). It is clear that the best equations were found to be:

$Y = 1.32 + 1.94\ X$       (1:1 soil: water extract)

$R^2 = 0.85$

$Y = 2.293\ X^{0.95}$       (1:1 soil: water extract)

$R^2 = 0.81$

The best fitted type of regression was the linear equation using the 1:1 soil water extract method.

Soluble $Mg^{+2}$: Table (5) indicated large differences between soluble $Mg^{++}$ in soil saturation extract and in the other soil: water extracts. Magnesium concentration in soil saturation extract was approximately higher 2.98, 4.09, 6.32, 6.85, 9.05 times than its concentration in 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts, respectively.It

has been noticed that $Mg^{++}$ concentration of the soil saturation extract correlated with those of the different extracts (0.951[**], 0.919[**], 0.917[**], 0.901[**] and 0.884[**] for 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts, respectively). Regression equations were calculated to predict the values of $Mg^{+2}$ in saturation extract, when $Mg^{+2}$ ion contents are determined in the tested soil: water extracts (Table6). The best equations were found to be

$Y = -1.99 + 3.09X$       (1:1 soil: water extract)

$R^2 = 0.90$

$Y = 1.674\ X^{1.2}$       (1:1 soil: water extract)

$R^2 = 0.91$

The best fitted type of regression was the linear equation using 1:1 soil water extract method. Cammerat (1991) used a 1:1 soil-water ratio , while Terman *et al.* (1995) used 1:2 soil water ratio and the concentrations of Na, Ca, Mg and Cl in 1:1 and 1:2 soil: water extracts were highly correlated with the their concentrations in the saturation extract.

**Anionic composition**

Soluble $Cl^-$: The anionic composition showed that the salinization is of a chloridic type, and that the chloride salts dissolve entirely in low moisture content. Table (5) pointed out the decreasing of $Cl^-$ concentration with increasing water content. The $Cl^-$ concentration in soil paste extract is higher than those of 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts, (almost higher 3.14, 5.46, 7.73, 10.43, 14.30 times, respectively). The $Cl^-$ concentration of soil saturation extract correlated positively with those of 1:1, 1:2, 1:3, 1:4 and 1:5 soil : water extracts (0.979[**], 0.962[**], 0.964[**], 0.958[**] and 0.966[**] for 1:1, 1:2, 1:3, 1:4 and 1:5 soil: water extracts, respectively. This result is in agreement with those found by Habib (1962).

Regression equations were calculated to predict the $Cl^-$ levels in saturation extract from soil-water extracts (Table7). The best equations was found to be:

$Y = -0.49\ \ \ + 3.08\ X$       (1:1 soil: water extract)

$R^2 = 0.96$

Soluble $HCO_3^-$: Table (5) showed that the $HCO_3^-$ contents of the tested soil: water extracts were found to be positively correlated with that of soil saturation extract. The concentration of $HCO_3^-$ in the soil paste extract is higher than those of 1:1, 1:2, 1:3, 1:4 and 1:5 soil extract respectively, 1.77, 2.13, 2.38, 2.64, 3.05 times, respectively. The r values were 0.680[**], 0.659[**], 0.635[**], 0.602[**] and 0.599[**] for 1:1, 1:2, 1:3, 1:4 and 1:5 soil extracts. Regression equations were calculated in order to predict the values of $HCO_3^-$ in the saturation

extract when $HCO_3^-$ ion contents are determined in the tested soil: water extracts (Table7). The best equation was found to be:

$Y = 1.666\ X^{1.0}$           (1:1 soil water extract)

$R^2 = 0.61$

Soluble $SO_4^=$: Table (7) indicated that the concentration in soil paste extract was higher than those of the tested soil: water extracts. This could be explained on the basis that the sources of $SO_4^=$ ion in soil are $Na^+$, $Mg^{++}$ and $Ca^{++}$ salts. The first two ions of sulphate salts dissolve entirely in the low level of moisture content. However, the latter salts are sparingly soluble in water as its solubility about 0.24% (Bresler *et al.*, 1982). Therefore, if gypsum is present in the soil in relatively high amount, the dissolved     portion is dependent on the water content, as it increases with the increasing of soil water ration. .It was found that $SO_4^=$ of the tested soil : water extracts were positively correlated with that of soil saturation extract. The r values were 0.919[**], 0.892[**], 0.879[**], 0.882[**] and 0.880[**] for 1:1, 1:2, 1:3, 1:4 and 1:5 soil extracts, respectively. Regression equations were calculated in order to predict the values of $SO_4^=$ in the saturation extract, when $SO_4^=$ soil: water extracts. ion contents are determined in the tested soil : water extracts (Table 7). The best equations were found to be:

$Y = 0.85 + 1.57\ X$           (1:1 soil water extract)

$R^2 = 0.84$

$Y = 1.697\ X^{1.1}$           (1:1soil water extract)

$R^2 = 0.86$

### Sodium adsorption ratio (SAR)

The values of SAR were calculated at different water extraction methods. SAR was significantly larger for the saturation paste method, compared with other extraction methods. On dilution, sodium concentration decreased leading to lower SAR. Values of SAR in the saturation extract varied from 1.09 to 24.5 with an average of 5.88, while in soil water extract ranged from 0.92 to 11.33 with an average of 3.53 for 1:1 soil water extract, from 0.60 to 9.94 with an average of 2.52 for 1:2 extract, from 0.44 to 7.08 with an average of 2.0 for 1:3 extract, from 0.39 to 6.02 with an average of 1.71 for 1.4 extract, and from 0.36 to 5.28 with an average of 1.48 of 1:5 extract. Positive correlation coefficients were found between SAR of saturation extract with SAR of the different soil: water extracts (0.933**, 0.919**, 0.917**, 0.897** and 0.925**, respectively). The regression equations were calculated to express the relationships between soil water extracts and saturation paste extract (Table 8 ). These regression equations were calculated to predict the values of SAR in the saturation extract, when SAR values are calculated in the soil: water extracts. The best equations were found to be:

$Y = -0.83 + 2.01\ X$           (1:1 soil water extract)
$R^2 = 0.87$

$Y= 1.474\ X^{1.1}$           (1:1 soil water extract)
$R^2 = 0.88$

In conclusion, it is obvious that determination of EC in the saturation paste extraction is more precise method

## Table 7. The relationship between the anions concentrations in soil saturation extracts and in the tested soil: water extracts

| Anions | Soil: water ratio | Linear regression equations | $R^2$ | Power regression equations | $R^2$ |
|---|---|---|---|---|---|
| | 1 : 1 | $Y = -0.49 +3.08\ X$ | 0.961 | $Y = 2.803\ X^{0.99}$ | 0.925 |
| | 1 : 2 | $Y = 0.38 + 5.40\ X$ | 0.925 | $Y = 5.110\ X^{0.99}$ | 0.886 |
| Cl | 1 : 3 | $Y = 2.18 + 7.27\ X$ | 0.928 | $Y = 7.273\ X^{1.01}$ | 0.880 |
| | 1 : 4 | $Y = 3.32 + 9.50\ X$ | 0.918 | $Y = 10.135\ X^{1.02}$ | 0.893 |
| | 1 : 5 | $Y = 2.84 + 13.23\ X$ | 0.933 | $Y = 13.63\ X^{1.05}$ | 0.907 |
| | 1 : 1 | $Y = 1.54 + 1.26\ X$ | 0.463 | $Y = 1.666\ X^{1.00}$ | 0.607 |
| | 1 : 2 | $Y = 1.27 + 1.61\ X$ | 0.435 | $Y = 1.934\ X^{1.02}$ | 0.545 |
| $HCO_3$ | 1 : 3 | $Y = 1.36 + 1.76\ X$ | 0.403 | $Y = 2.201\ X^{0.99}$ | 0.477 |
| | 1 : 4 | $Y = 1.67 + 1.81\ X$ | 0.363 | $Y = 2.543\ X^{0.93}$ | 0.431 |
| | 1 : 5 | $Y = 1.37 + 2.21\ X$ | 0.359 | $Y = 2.804\ X^{0.96}$ | 0.429 |
| | 1 : 1 | $Y = 0.85 + 1.57\ X$ | 0.844 | $Y = 1.697\ X^{1.1}$ | 0.855 |
| | 1 : 2 | $Y = 1.42 + 1.94\ X$ | 0.796 | $Y = 2.588\ X^{1.1}$ | 0.730 |
| $SO_4$ | 1 : 3 | $Y = 1.56 + 2.38\ X$ | 0.772 | $Y = 3.370\ X^{1.0}$ | 0.657 |
| | 1 : 4 | $Y = 1.42 + 3.69\ X$ | 0.778 | $Y = 4.780\ X^{1.0}$ | 0.620 |
| | 1 : 5 | $Y = 1.21 + 5.94\ X$ | 0.774 | $Y = 7.140\ X^{1.0}$ | 0.623 |

Y = The concentration of the saturation extract.

X = The concentration of the Soil: water extracts.

**Table 8. The relationship between the SAR of soil saturation paste extracted and the SAR of the soil water extracts**

| Soil: water ratio | Linear regression equations | $R^2$ | Power regression equations | $R^2$ |
|---|---|---|---|---|
| 1:1 | Y = -0.83 + 2.01 X | 0.871 | $Y = 1.474 X^{1.1}$ | 0.878 |
| 1:2 | Y = -2.53 + 5.19 X | 0.845 | $Y = 2.523 X^{1.3}$ | 0.805 |
| 1:3 | Y = -0.47 + 3.18 X | 0.841 | $Y = 2.867 X^{0.95}$ | 0.798 |
| 1:4 | Y = -0.15 + 3.53 X | 0.805 | $Y = 3.423 X^{0.91}$ | 0.778 |
| 1:5 | Y = -0.20 + 4.11 X | 0.855 | $Y = 3.920 X^{0.94}$ | 0.845 |

Y = SAR of the saturation extract.

X = SAR of the Soil: water extracts.

for evaluating soil salinity by the scientific community, but it is time-consuming and expensive. The results obtained in this study showed that the 1:1 soil water extract method is significantly valid and represented precisely soil salinity as well. In addition, it is a simple, rapid, low-cost and valid procedure for screening soil salinity problems. Results can roughly be converted back forth from a 1:1 soil extract to a saturated paste extract, using special equations. Generally the analytical data for electrical conductivity, sodium, calcium, potassium, magnesium, chloride, bicarbonate, sulfate and the calculated SAR of the 1:1 soil water extracts, was very closely related mostly to data obtained by the saturation extract, and therefore offers good and indicative alternative.

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# الملخص العربي

## تقديرات ملوحة التربة في أراضي الساحل الشمالي الغربي لمصر

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استخدمت مستخلصات التربة للعجينة المشبعة ولمخاليط التربة مع الماء بنسبة 1:1، 1:2، 1:3، 1:4، 1:5 لعدد 36 عينة تربة جمعت من الساحل الشمالي الغربي لمصر. وتم تجهيز هذه المستخلصات وتحليلها لتقدير التوصيل الكهربائي والكاتيونات الرئيسية (صوديوم، بوتاسيوم، كالسيوم وماغنسيوم) والأيونات الرئيسية (الكلوريد، الكبريتات والبيكربونات). ولقد تم إيجاد العلاقة بين الخواص المقدرة في مستخلص عجينة التربة المشبعة وبين تلك المقدرة في مستخلصات مخاليط التربة مع الماء باستخدام الأرتداد الخطي والأسي.

وبصفة عامة كانت العلاقة بين الخواص المقدرة في مستخلص 1 :1 والمقدرة في مستخلص عجينة التربة المشبعة الأعلى ارتباطا.

ولقد تم التعبير عن العلاقة بين قيم EC في عجينة التربة المشبعة (Y) وقيم EC في مستخلص التربة والماء بنسبة 1: 1 (X) بالمعادلة التالية:

$$Y = 0.11 + 2.41\ X$$

ولقد تم أيضا حساب العلاقة الاحصائية بين الأيونات في مستخلص العجينة المشبعة وقيمها من SAR وبين هذه القيم في مستخلصات التربة والماء والتعبير عنها بمعادلات الأرتداد. والنتائج المتحصل عليها من هذه الدراسة يمكن أن تكون مفيدة في تقليل تكاليف وزمن التحليل عن طريق تحويل نتائج التحليل المتحصل عليها من خليط التربة والماء بنسبة 1 :1 إلى ما يقابلها من نتائج تحليل عجينة التربة المشبعة.