

PREDICTION OF SALINITY AND ION CONCENTRATIONS IN SATURATION PASTE USING 1:1 SOIL: WATER EXTRACTS IN LACUSTRINE SOILS OF EGYPT

R.I. Fayed, K. A. Rateb and H. M. El-Kouny

Soil Salinity Res. Lab., Alex.; Soil, water and Enviro. Res. Institute; Agric. Res.
Center, Egypt.

(Received: Sep. 5, 2010)

ABSTRACT: *Saturated paste (SP) and 1:1 soil: water extractions are commonly used to assess soil salinity and ion concentrations in laboratory. Despite, the differences in results between the two methods, many soil salinity samples are analyzed using a 1:1 extract because of simple, rapid, low-cost and well handling procedure for screening problems of soil salinity in different sites. The aims of the present study are to predict the electrical conductivity (EC) and Na^+ , Ca^{2+} , Mg^{2+} and Cl^- concentrations for the soil saturation paste extract by means of 1:1 soil: water extract data using simple regression equations. This study examined these relationships using 180 samples from agricultural soils developed from lacustrine deposits at El-Bosaily Village south of Idko Lake. The electrical conductivity (EC) and Na^+ , Ca^{2+} , Mg^{2+} and Cl^- concentrations in 1:1 soil: water extract were used as independent variables to predict electrical conductivity (EC) and Na^+ , Ca^{2+} , Mg^{2+} and Cl^- concentrations for soil saturation paste extract as dependent variables. Saturated pastes and 1:1 extracts were prepared and analyzed for EC and Na^+ , Cl^- , Mg^{2+} , Ca^{2+} concentrations. The obtained data show both ions concentration and EC in 1:1 soil: water extracts are typically lower than those of SP extracts this trend due to dilution increase. Relationships between the two methods using linear regression equations were established. The correlation coefficients are highly significant ($R^2 = 0.92$, $P < 0.001$). for the relation between SP extract EC (EC_{SP}) and 1:1 EC ($\text{EC}_{1:1}$) extract. Also highly significant relationships were obtained for Na^+ , Ca^{2+} , Mg^{2+} and Cl^- concentrations ($R^2=0.99$, 0.93 , 0.96 , 0.96 respectively) between SP and 1:1 extracts. An independent validation set of 35 samples showed that the means of EC and concentrations of Na^+ , Ca^{2+} , Mg^{2+} and Cl^- for SP and 1:1 extracts are used to compare between the predicted EC and Na^+ , Ca^{2+} , Mg^{2+} and Cl^- concentration of saturation paste equivalents from 1:1 extract measurements and direct SP extract measurements. These relationships were not significant suggesting that the regressions developed can accurately assess soil salinity in lacustrine soils using 1:1 extract analysis instead of using the more expensive and time-consuming SP extraction.*

Key words: *Saturation paste (SP), 1:1 soil/water extracts, Lacustrine soils, Linear regression equations*

INTRODUCTION

Salinity is an inverse problem when enough salts accumulate in the root zone to an extent negatively affect plant growth. Excess salts in the root zone hinder plant roots from withdrawing water from the surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone (Sumner 1993).

Two different criteria are currently recognized in the scientific literature as indices of soil salinity. These are the soil Electrical Conductivity (EC) and the soil Sodium Adsorption Ratio (SAR). The soil electrical conductivity is abbreviated as EC with units of dS m⁻¹ or mmhos cm⁻¹. Both are equivalent units of measurement and give the same numerical value (Page *et al.* 1982). The soil sodium adsorption ratio is abbreviated as SAR and is defined as Eq. (1) (Sumner 1993; Rengasamy and Churchman 1999 and Quirk 2001):

$$\text{SAR} = \frac{\text{Na}^+}{\left[\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2} \right]^{0.5}} \quad (1)$$

Where SAR = Sodium adsorption ratio, and Na⁺, Ca²⁺, Mg²⁺ refers to the concentrations of the designated soluble cations expressed in meq/ liter.

As shown in Eq. (1), for determining soil SAR, it is necessary to have soluble Na⁺, Ca²⁺ and Mg²⁺. But, as these parameters are often determined using laborious and time consuming laboratory tests, it may be more suitable and economical to develop a method which determines soil SAR indirectly from a more simple soil salinity index such as soil EC.

Soil salinity is conventionally defined and measured in aqueous extracts of saturated soil pastes (Richards 1954). This soil/water ratio is used because it takes into account the field water-holding characteristics and can therefore be related to plant response. However, reproducibility can be a problem of human variability in mixing the pastes and in determining the proper saturation end-point (Longenecker and Lyerly 1964).

Currently, two widely used extraction methods for soil salinity analysis are a 1:1 extraction and SP extraction (USDA, 1954 and Rhoades, 1982). Saturated paste (SP) extraction attempts to simulate the environment of naturally occurring moisture-saturated soil. Of the extraction methods available, results from SP extraction are thought to be the best predictor of plant and soil response to salinity (USDA, 1954; Longenecker and Lyerly, 1964 and Vaughn *et al.*, 1995).

Laboratories measure EC on different ratios of soil to water extracts because of their convenience to the laboratory. The most common commercial laboratory measurements are made on extracts from either a saturated paste or a 1:1 by weight soil : water extract. The saturated paste extraction is a more precise method used by the scientific community, but it is time-consuming and expensive. The 1:1 soil: water extract method is a simple, rapid, low-cost and excellent procedure for screening problems of soil sites.

Prediction of salinity and ion concentrations in saturation past.....

Unlike the SP method, the 1:1 extraction method does not attempt to simulate natural soil conditions. Due to the consistency in the amount of water used and objective nature of the method. The 1:1 extraction method can reduce the difficulties in sample preparation and reproducibility often encountered with SP extractions (USDA, 1954; Longenecker and Lylerly, 1964; Sonneveld and Van Den Ende, 1971 and Fowler and Hamm, 1980).

Other extraction ratios can also be used to estimate soil salinity. These ratios are not as well related to field soil moisture contents, but do have the advantage of convenience, rapidity and removal of variability in preparation of pastes. A major disadvantage of using these extraction ratios is the effect of the soil/water ratio on the solubility of sparingly soluble salts such as gypsum (Reitemeler 1946). However, good relationships have been obtained between the conductivity values of saturation extract and 1:1 (soil:H₂O) extract (Waqenet and Jurinak 1978), 1:1 (soil: water) suspension (Fowler and Hamnr 1980), 1:2 (soil:H₂O) extracts (McKenzie *et al.* 1983) and 1:5 (soil:water) extract (Agarwal *et al.* 1961).

The type of salt and soil texture determine to some extent the relationship between the conductivity of saturation extract and that of other soil water ratio extracts (Lebrusq and Loyer 1982; Richard and Gouny 1965 and Richards 1954).

Currently, the EC and major ions concentration acquired using the 1:1 method are adjusted with conversion factors of USDA Handbook 60 (USDA, 1954). These conversion factors are based on soil moisture holding capacities and the theoretical and actual chemical solubility of ions in aqueous systems (USDA, 1954) but not the impact of soil texture, salt concentrations, and organic matter content on ion concentrations and EC. The exclusion of these soil properties in the conversion factors, coupled with the lack of extensive examination of relationships between the two methods and minimal experimental verification, could contribute to imprecise adjustment of 1:1 analyses when applied to a variety of soils (Franzen, 2003).

Because of the relative ease of the 1:1 method, theoretical relationships have been developed to convert 1:1 extraction results to a SP extraction equivalent (USDA, 1954 and Freidman, 1998). Despite the reports of highly correlated relationships between the two methods, adjustment of 1:1 results to SP approximations are often imprecise and inaccurate (Wagenet and Jurinak, 1978 and Franzen, 2003). Therefore, further study upon the relationship between the results generated by 1:1 and SP extractions is needed to improve soil remediation strategies based on adjusted 1:1 analysis of soil salinity.

Hogg and Henry (1984) indicated that the regression coefficient relating the conductivity of 1:1 and 1:2 extracts and suspensions to that of the saturated paste extract decreased in going from coarse to medium to fine soil textures. The concentrations of Na⁺, Ca²⁺, Mg²⁺ and Cl⁻ in 1:1 and 1:2

(soil:H₂O) extracts were highly correlated with the amounts in the saturation extract, were the obtained values of r^2 ranged from 0.93 to 0.99 .

El-Arquan *et al.* (1985) studied the relationship between soluble salts in soil water extract 1:5 and soil saturation extract and found that the dilution occurred in the case of 1:5 had led to the decrease of EC 1:5 soil: water extract four times than the EC of saturation paste extract. Franzen (2003) divided EC conversion factors into three textural divisions and arrived at conversion factors for coarse, medium, and fine soils. Also, Zhang *et al.* (2005) reported that saturated paste extract EC (EC_{SP}) was highly correlated with that of 1:1 extract EC ($EC_{1:1}$) ($r^2 = 0.85$). Significant relationships also existed ($r^2 > 0.73$) between different ions in SP and 1:1 extracts.

The present study was carried out to obtain regression equations which can be the used in prediction of the EC and major ions concentration of saturation paste extracts using simple obtained data from 1:1 (soil: water) extracts for lacustrine soils

Abbreviations: EC, electrical conductivity • SP, saturated paste extraction • $EC_{1:1}$, 1:1 soil: water extract electrical conductivity • EC_{SP} , saturated paste electrical conductivity • $Ca^{2+}_{1:1}$, calcium in 1:1 soil: water extracts • Ca^{2+}_{SP} , calcium in saturated paste extracts • $Mg^{2+}_{1:1}$, magnesium in 1:1 soil: water extracts • Mg^{2+}_{SP} , magnesium in saturated paste extracts • $Na^{+}_{1:1}$, sodium in 1:1 soil: water extracts • Na^{+}_{SP} , sodium in saturated paste extracts • $Cl^{-}_{1:1}$, chloride in 1:1 soil: water extracts • Cl^{-}_{SP} , chloride in saturated paste extracts •

MATERIALS AND METHODS

The studied area is located at the north-western part of Nile Delta. It represents soils developed from lacustrine deposits at El-Bosaily south Idko Lake. Behera Governorate

One hundred and eighty soil samples were collected from El-Bosaily village south Idko Lake representing broad range of soil conditions (Table 1). These samples were air-dried, ground and passed through 2-mm sieve. Soil salinity and some water soluble cations and anions concentrations were determined in the saturated paste (SP) extract (Rhoades 1982) and in 1:1 soil: water extract. For the 1:1 soil: water extract the samples were stirred over a period of 1 h and the extracts were obtained by gravity filtration. The following determinations were carried out; electrical conductivity (EC dS/m) using a conductivitymeter, the concentrations of Ca^{++} and Mg^{++} were determined by versenate method, Na^{+} by flame photometer and Cl^{-} by titration with silver nitrate (Page *et al.* 1982).

Statistical Analysis:

Simple linear regression analyses were carried out to calculate prediction equations for EC (dS/m), Ca^{++} , Mg^{++} , Na^{+} and Cl^{-} concentrations for

Prediction of salinity and ion concentrations in saturation past.....

saturation paste extract. Regression analysis was performed according to the COSTAT manual, (CoHort software, 1986).

Calculations

Linear regression equations:

Least squares difference was calculated to get the simple regression equation (Eq.2)

$$Y = a + bX \quad \{2\}$$

Where:

Y: is dependent variable (EC, Ca⁺⁺, Mg⁺⁺, Na⁺ or Cl⁻ concentrations prediction for saturation paste extract)

X: is independent variable (EC, Ca⁺⁺, Mg⁺⁺, Na⁺ or Cl⁻ concentrations measured in the 1:1 extract)

a: is the intercept of Y axis b: is regression coefficient

Validation of empirical relationships between 1:1 and saturated paste

Thirty-five lacustrine soil samples independent of those used to generate the mean of EC (dS/m), Ca⁺⁺, Mg⁺⁺, Na⁺ and Cl⁻ concentrations (meq/L) for this study, were used to validate the relationships between SP and 1:1 methods. To allow for direct comparisons of the predictive capabilities of the regression equations obtained by this study (USDA 1954 and Zhang *et al.* 2005), regression equations that without the y intercept were utilized for the validation study. The USDA (1954) and Zhang *et al.* (2005) equations were used to predict SP equivalents of EC and ion concentrations from 1:1 measurements. The results were then compared with actual SP measurements of these variables.

RESULTS AND DISCUSSION

Electrical Conductivity and Ion Concentrations of Saturated Paste and 1:1 Soil/Water Extracts

Table (1), showed that the values of EC for the soil samples ranged from 1.48 to 30.00 dS/m for the saturation paste (SP) extracts while the EC for the 1:1 soil: water extracts ranging from 1.02 to 15.12 dS/m (Table 1). These data indicate that the EC measurements for 1:1 soil: water extracts are lower than those of SP extracts, which agree with the work of Winsor and Davies (1956). Thus, a wide range in salinity levels was obtained for making comparisons between the SP extract method and the 1:1 soil: water extract. The mean EC values of SP (EC_{SP}) (7.45 dS/m) was greater than that EC 1:1 (4.28 dS/m (Table 1). These results are similar to those reported that the EC_{SP} extracts was greater than the EC of 1:1 (EC_{1:1}) soil: water extracts (USDA, 1954; Hogg and Henry, 1984 and Franzen, 2003). The significant difference between the EC_{1:1} and EC_{SP} extracts is likely due to a dilution effect that has been suggested by Reitemeier (1946); USDA (1954) and Zhang *et al.* (2005). About

38% of the soils had an $EC_{SP} < 4.00$ dS/m while 58 of the soils had an $EC_{1:1} < 4.0$ dS/m. Overall, 34% of the soils had an $EC_{SP} > 8$ dS/m while 12% only of the soils had an $EC_{1:1} > 8$ dS/m (Table 2).

Table (1): Descriptive statistical analysis of some properties for the studied soils

Properties	Soil:water	Min	Max.	Range	Mean	V	S.D	C.V%	Median
EC dS/m	paste	1.48	30.0	28.52	7.45	38.89	6.24	0.84	5.06
	1:1	1.02	15.12	14.1	4.28	7.86	2.80	0.65	3.60
SAR	paste	4.71	71.58	66.87	24.12	302.6	17.39	0.72	19.04
	1:1	4.1	66.96	62.86	23.12	282.5	16.81	0.73	18.12
Ca ⁺⁺ meq/L	paste	1.00	23.50	22.5	4.53	19.1	4.37	0.96	3.24
	1:1	0.5	18.0	17.5	2.90	9.49	3.08	1.06	2.00
Mg ⁺⁺ meq/L	paste	0.60	22.60	22.00	8.43	27.85	5.28	0.62	7.50
	1:1	0.50	18.5	18.00	6.30	17.15	4.14	0.66	5.55
Na ⁺ meq/L	paste	8.55	270.50	261.20	64.47	3835	62.08	0.96	44.12
	1:1	6.55	230.74	224.19	52.03	2595	50.94	0.98	35.06
Cl ⁻ meq/L	paste	4.00	255.00	251.0	51.23	2950	54.32	1.06	52.5
	1:1	3.0	180.00	177.00	36.90	1714	41.40	1.12	20.25
Sand %		9.5	37.5	28.0	17.70	43.6	6.6	0.40	15.6
Clay %		31.3	65.0	33.8	54.00	62.0	7.9	0.20	55.0

V=variance , S.D=Stander deviation, C.V=Coefficient of variance, Range= Max.- Min
C.V(Coefficient of variance)= Stander deviation/ Mean

Table (2): Saturated paste (SP) and 1:1 soil/water EC distributions for 180 soil samples used to establish the relationships between 1:1 and SP extracts.

EC dS/m	SP extracts		1:1 extracts	
	Number of soils	% soils	Number of soils	% soils
0-2	12	6	45	25
2-4	57	32	60	33
4-8	51	28	54	30
8-16	39	22	21	12
16-30	21	12	0	0

The mean values of the concentrations of Ca²⁺, Mg²⁺, Na⁺ and Cl⁻ were 4.53, 8.43, 64.47 and 51.23 meq/L respectively for the SP extracts, and for 1:1 extracts, were 2.90, 6.30, 52.03 and 36.90 meq/L, respectively. These data indicate that, the mean ion concentrations for saturation paste extracts were

Prediction of salinity and ion concentrations in saturation past.....

greater than those in the 1:1 soil/water extracts for all soil samples (Table 1). These results are in contrast with those of Hogg and Henry (1984) who found that concentrations of Cl^- and Na^+ were approximately equal in SP extracts and 1:1 soil/water extracts.

Relationship Between the Electrical Conductivity of the SP and 1:1 soil: water extracts

Table (3) and Fig.(1) indicate that the EC of saturation paste was highly correlated with $\text{EC}_{1:1}$ for all the study soils ($R^2= 0.95$ and 0.92 for with and without y intercept respectively). These results agree with those reported by Hogg and Henry,(1984); and Shirokova *et al.* (2000). Table (4) indicates that, the slope of the present relationship is relatively similar to that obtained by Zhang *et al.* (2005). Thus, the results of our study agree with those reported by Zhang *et al* (2005) who found a slope of 1.85 for the same relationship (Table 5). However, our results differ from those reported by Franzen *et al* (2003) who found a slope of 3.0 (with y intercept) for the relationship (Table 4). Table (5) showed that, the slop of our results (without y intercept) is 1.86 and differs drastically from the theoretically derived relationship published by the USDA (1954),

Therefore, for a more direct comparison, a second regression analysis was performed that forced the regression through zero and without y intercept. The regression line through zero slightly decreased the slope from 2.16 (with y intercept) to 1.86 (without y intercept) for the study soils (Table 3). The slope reported by Franzen (2003) with y intercept and those obtained by the USDA (1954) without y intercept were approximately 28% greater than the one found in our study (Tables 4 and 5). These differences in the results between the two studies may be due to the variations of soil types for these studies.

Table (3): Coefficients of determination (r^2) and regression equations describing the relationship between 1:1 and saturated paste extracts in the lacustrine soils.

Parameter	With y intercept		Without y intercept	
	Regression equation	R^2	Regression equation	R^2
EC dS/m	SP = 2.16(1:1) -1.79	0.95**	SP = 1.86(1:1)	0.92**
Cl^- meq/L	SP = 1.28(1:1)+ 3.9	0.97**	SP = 1.33(1:1)	0.96**
Na^+ meq/L	SP = 1.21(1:1)+ 0.87	0.99**	SP = 1.22(1:1)	0.99**
Ca^{2+} meq/L	SP = 1.36(1:1) + 0.59	0.94**	SP = 1.46(1:1)	0.93**
Mg^{2+} meq/L	SP = 1.26(1:1)+ 0.51	0.97**	SP = 1.32(1:1)	0.96**

**highly significant at the 1% a level.

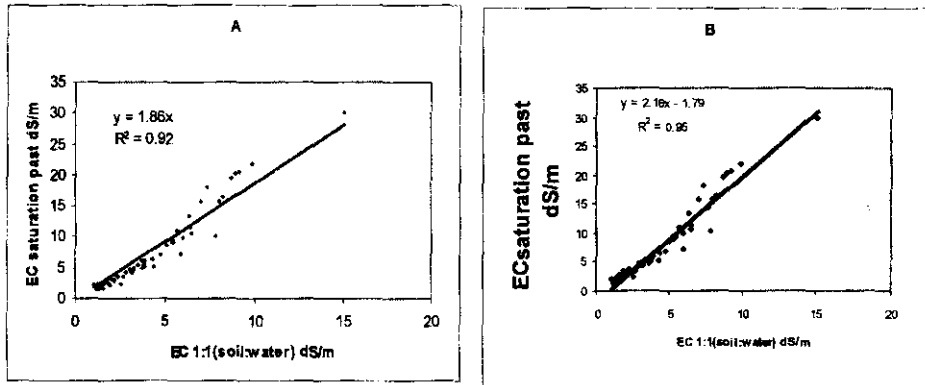


Fig.1: Relationship between EC of SP and 1:1 soil: water extracts:
 A) without y intercept B) with y intercept

Table (4): Correlation equations established by different studies to convert 1:1 soil:water (1:1) measurements to SP equivalents (With y intercept)

Parameter	Hogg & Henry, 1984	Franzen, 2003	Zhang <i>et al</i> 2005	This study
EC, dS/m	SP= 1.56(1:1)-0.06	SP=3.0(1:1)-0.77	SP=1.79(1:1)+1.46	SP=2.16(1:1)-1.79
Cl ⁻ , meq/L	SP=0.95 (1:1) + 5.31		SP =2.03(1:1)+174	SP=1.28(1:1)+3.9
Na ⁺ , meq/L	SP=0.95 (1:1) - 30.5		SP =1.92 (1:1)+27.8	SP=1.21(1:1)+0.87
Ca ²⁺ , meq/L	SP= 0.7 (1:1)- 9.39		SP = 2.1 (1:1)+3.37	SP=1.36(1:1)+0.59
Mg ²⁺ , meq/L	SP = 0.7 (1:1) - 9.39		SP = 2.0 (1:1)+22.8	SP=1.26(1:1)+0.51

Table (5): Correlation equations established by different studies to convert 1:1 Soil: water measurements to SP equivalents (Without y intercept)

Parameter	USDA, 1954	Zhang <i>et al</i> 2005	this study
EC, dS/ m	SP = 3.00 (1:1)	SP = 1.85 (1:1)	SP = 1.86(1:1)
Cl ⁻ , meq/L	SP = 2.78 (1:1)	SP = 2.04 (1:1)	SP = 1.33 (1:1)
Na ⁺ , meq/L	SP = 2.78 (1:1)	SP = 1.91 (1:1)	SP = 1.22 (1:1)
Ca ²⁺ , meq/L	SP = 1.67 (1:1)	SP = 2.10 (1:1)	SP = 1.46 (1:1)
Mg ²⁺ , meq/L	SP = 1.67 (1:1)	SP = 2.08 (1:1)	SP = 1.32 (1:1)

Relationship Between the Concentrations of Na^+ , Ca^{2+} , Mg^{2+} and Cl^- Extracted by the SP and the 1:1 soil: water Methods

The concentrations of Na^+ , Ca^{2+} , Mg^{2+} and Cl^- extracted by the sP method and the 1:1 method are closely related as indicated by linear regression analysis (Tables 3). Highly significant relationships existed ($P < 0.001$) between ions extracted by SP and 1:1 extracts with regression coefficients (R^2) ranging from 0.93 to 0.99 (Table 3). Similarly, Hogg and Henry (1984) found strong relationships existed between Cl^- and Na^+ in SP and 1:1 extracts.

Tables (4 and 5) showed that the slopes of the relationships derived in our study for Cl^- , Na^+ , Ca^{2+} and Mg^{2+} concentrations are different from those reported by Zhang *et al* (2005) with and without y intercept. The slopes of 1.46 and 1.32 obtained in our study for Ca^{2+} and Mg^{2+} are similar to those reported by USDA (1954) without y intercept (Table 5). In contrast, the slopes of 1.22 and 1.33 obtained in this study for Na^+ and Cl^- respectively is different with the slopes reported by USDA (1954) for Na^+ (2.78) and Cl^- (2.78). Overall, the slopes of relationships for ions extracted by SP and 1:1 soil/water in our study are approximately 35, 36, 31 and 37% less than those found by Zhang *et al* (2005) for Cl^- , Na^+ , Ca^{2+} and Mg^{2+} respectively (Table 5). While the slopes of Cl^- and Na^+ relationships for our study are approximately 52% and 56% less than those reported by USDA (1954).

In this study the found data show that, the concentration of the ions extracted from soil decreased as the amount of water used in the extraction increased (Tables 3). These results contrast with those of Hogg and Henry (1984) who found that the concentrations of the ions extracted per unit weight of soil increased as the amount of water used in the extraction increased. Table (3) showed that the decrease was least for Ca^{2+} and Mg^{2+} indicating the presence of sparingly soluble salts such as gypsum. The decrease was greatest for Cl^- and Na^+ indicating the chloride salts are highly soluble and have been found to be totally dissolved in the soil solution regardless of the amount of water used for extraction (Sonneweid and van den Ende 1971). Previous study indicated that the concentrations of the various ions extracted from soils are influenced to some extent by water content at which the extracts is made and the processes involved include exchange of divalent for univalent cations, decreased negative adsorption and increased solution of sparingly soluble salts such as gypsum (Zhang *et al.* (2005)).

Validation of Empirical Relationships Between SP and 1:1 soil: water extracts

Values of EC_{SP} and SP ion concentrations predicted in this study regression equations using, 1:1 extractions were compared with EC and ion concentrations actual measurements in saturation paste (Table 6),

Additionally, EC_{SP} and SP ion concentrations predicted by Zhang *et al.* (2005) and the USDA (1954) regression equations were compared with measured EC_{SP} and SP ion concentrations (Table 7). Mean EC_{SP} predicted by this study regression equation of 13.35 dS/m was not significantly different ($P > 0.05$) than mean actual measured EC_{SP} of 14.52 dS/m in the validation soils (Table 6). However, mean EC_{SP} of 21.54 predicted by the USDA (1954) regression equation was significantly greater ($P < 0.05$) than the mean actual measured EC_{SP} of 14.52 dS/m (Table 7), while mean EC_{SP} of 13.28 predicted by the Zhang *et al.* (2005) regression equation was not significantly different ($P < 0.05$) than the mean actual measured EC_{SP} .

Table (6). Summary of mean comparisons for actual measurements of EC and ion concentrations in saturated paste and those predicted from 1:1 soil: water by this study regression equations

Parameter	Actual measurement	Predicted SP from 1:1 regression equation
EC, dS /m	14.52	13.35 [‡]
Na ⁺ , meq/L	138.28	139.97 [‡]
Cl ⁻ , meq/L	113.61	108.42 [‡]
Ca ²⁺ , meq/L	10.07	10.21 [‡]
Mg ²⁺ , meq/L	10.69	10.08 [‡]

‡ Not significantly different from SP measurement at 0.05

Mean measured concentration of Na⁺ is 138.28 meq/L in SP of the validation soils was not significantly different than Na⁺_{SP} of 139.97 meq/L predicted by this study regression equation but was significantly less than Na⁺ of 318.95 meq/L predicted by the USDA (1954) regression equation (Table 7). Concentrations of Cl⁻ actually measured in SP extracts (113.61 meq/L) and predicted by this study regression equation (102.24 meq/L) were not significantly different while Cl⁻ concentrations predicted by either the Zhang *et al.* (2005) or the USDA (1954) regression equations were greater than measured concentrations (Table 7).

Actual measured concentrations of Ca²⁺ in SP extracts (10.07 meq/L) were not significantly different than concentrations predicted by either the Fayed (10.21 meq/L) or the USDA (11.76 meq/L) regression equation but was significantly less than Ca²⁺ of 14.68 meq/L predicted by the Zhang regression equation (Table 7). Concentrations of Mg²⁺ predicted by the Fayed regression equation were statistically equivalent to those actually measured (Table 6). While concentrations of Mg²⁺ predicted by the Zhang regression equation was significantly great than actual measured concentrations of Mg²⁺ in SP extracts (Table 7).

Prediction of salinity and ion concentrations in saturation past.....

From the above discussion, it can be stated that the fayed regression equations were better at predicting Na^+ , Cl^- , Ca^{2+} and Mg^{2+} concentrations for soil saturation paste from 1:1 soil: water extract than other studies regression equations. Also, these results indicating the clear corresponding between actual measured EC and ion concentrations of saturation paste and EC_{SP} and ion concentrations predicted from 1:1 extracts by the fayed regression equations. This may be due to the similar between soil type using of measured and predicted EC_{SP} and ion concentrations (lacustrine soils).

Table (7). Summary of mean comparisons for actual measurements of EC and ion concentrations in saturated paste and those predicted by the Zhang *et al.* (2005), USDA (1954) and this study regression equations.

Parameter	Actual measurement	Predicted by USDA (1954)	Predicted by Zhang(2005)	Predicted by this study
EC, dS /m	14.52	21.54 [†]	13.28 [‡]	13.35 [‡]
Na^+ , meq/L	138.28	318.95 [†]	234.05 [†]	139.97 [‡]
Cl^- , meq/L	113.61	226.63 [†]	155.70 [†]	108.42 [‡]
Ca^{2+} , meq/L	10.07	11.76 [‡]	14.68 [†]	10.21 [‡]
Mg^{2+} , meq/L	10.69	12.76 [‡]	15.84 [†]	10.08 [‡]

† Significantly different from SP measurement at 0.05.

‡ Not significantly different from SP measurement at 0.05

CONCLUSION

Salinity and ion concentrations of lacustrine soils can be accurately assessed using 1:1soil: water and saturation paste extracts. The high correlation between conductivity and ion concentrations of 1:1 and saturated extracts suggests that these methods could replace the saturation extract as the standard of comparison. It is possible to achieve a higher degree of precision and accuracy in predicting EC and Na^+ , Cl^- , Ca^{++} and Mg^{++} concentrations, which are the dominant ions in lacustrine soils, from 1:1 extracts to their SP equivalents using the conversions generated by this study. Because of the wide range of EC and ion concentrations evaluated by this study, the derived equations have the potential to be used under variety of soil conditions although the appropriateness of these equations for use in other regions also needs to be evaluated.

REFERENCES

- Agarwal, R. R., S. K. Das and C. L. Mehrotra (1961). Interrelationship between extracts and total soluble salts in saline alkali soils of the Gangetic alluvium in Uttar Pradesh. Indian J. Agric. Sci. 31:284-294.

- CoHort Software (1986). Costat statistical software version 3.03, User Manual. California, USA.
- El-Arquan, M.Y.S., S.A. Korkor and D.D. El-Badry (1985). Relationship between soluble salts, quantity and quality in soil water extract 1:5 and soil saturation extract. *Egypt J. Soil Sci.*25: 115-125.
- Fowler, D.B. and J.W. Hamm (1980). Crop response to saline soil conditions in the parkland area of Saskatchewan. *Can. J. Soil Sci.* 60: 439-449.
- Franzen, D. (2003). Managing saline soils in North Dakota. Available online at <http://www.ext.nodak.edu/extpubs/plantsci/soilfert/sf1087-1.htm>. (verified 29 Mar. 2005). North Dakota State University Extension Service, Fargo.
- Freidman, S.P. (1998). Simulation of a potential error in determining soil salinity from measured apparent electrical conductivity. *Soil Sci. Soc. Am. J.* 62: 593-599.
- Hogg, T.J. and J.L. Henry (1984). Comparison of 1:1 and 1:2 suspensions and extracts with the saturation extract in estimating salinity in Saskatchewan soils. *Can. J. Soil Sci.* 64: 669-704.
- Lebrusq, J. Y. and I.y. Loyer (1982). Relationships between conductivity measurements on soil extracts with different soil/solution ratio in Senegal valley cahiers, *STROM Pedologie* 19:293-301
- Longenecker, D.E. and P.J. Lylerly (1964). Making soil pastes for salinity analysis: A reproducible capillary procedure. *Soil Sci.* 97:268-275.
- McKENZIE, R. C., C. H. Sprout and N. F. Clark (1983). The relationship of the yield of irrigated barley to soil salinity as measured by several methods. *Can. J. Soil Sci.* 63: 519-528 .
- Page, A.L., R.H. Miller and R. Keeny (1982). *Methods of Soil Analysis. Part 2. Chemical and microbiological properties.* Agron. Monograph No. 9,ASA, Madison, Wisc., USA.
- Quirk J.P. 2001. The significance of the threshold and turbidity concentrations in relation to sodicity and microstructure. *Australian Journal of Soil Research.* 39: 1185-1217.
- Reitemeier, R. F. (1946). Effect of moisture content on the dissolved and exchangeable ions of soils of arid regions. *Soil Sci.* 61: 195-214.
- Reitemeier, R. F. and L. V. Wilcox (1946). A critique of estimating soil solution concentration from the electrical conductivity of saturated soils. *Soil Sci.* 61: 281-93.
- Rengasamy, P. and G.J. Churchman (1999). Cation exchange capacity, exchangeable cations and sodicity. In Peverill K.I. Sparrow L.A. and Reuter D.J. *Soil Analysis: an Interpretation Manual.* CSIRO Publishing, Collingwood.
- Rhoades, J. D. (1982). Soluble salts. 1r A. L. Page *et al.*, eds. *Methods of soil analysis. Part 2. Chemical and microbiological properties.* 2nd ed. Agronomy 9. Am. Soc. Agron., Madison, Wis.

Prediction of salinity and ion concentrations in saturation past.....

- Richards, R.L. (ed.) (1954). *Diagnosis and Improvement of Saline and Akali soils*. Agriculture Hand Book No. 60, U.S Govt. Printing Office, Washington, USA.
- Richard, M. and P. Gouny (1965). Soil salinity test. *Ann. Agron.* 16:625-635.
- Shirokova, Y., I. Forkutsa and N. Sharafutdinova (2000). Use of electrical conductivity instead of soluble salts for soil salinity monitoring in Central Asia. *Irrig.Drain. Syst.*14:199–205.
- Sonneveld, C. and J. Van Den Ende (1971). Soil analysis by means of 1:2 a volume extract. *Plant Soil* 35: 505–516.
- Sumner, M.E. (1993). Sodic soils: new perspectives. *Australian Journal of Soil Research.* 31: 683-750.
- USDA. (1954). *Diagnosis and improvement of saline and alkali soils*. Agric. Handb. No. 60. United States Salinity Laboratory, Riverside, CA.
- Vaughn, P.J., S.M. Lesch, D.L. Corwin and D.G. Cone (1995). Water content effect on soil salinity prediction: A geostatistical study using cokriging. *Soil Sci. Soc. Am. J.* 59:1146–1156.
- Wagenet, R.J. and J.J. Jurinak (1978). Spatial variability of soluble salt content in a mancos shale watershed. *Soil Sci.* 126:342–349.
- Winsor, G. W. and J. N. Davis (1956). A critical re-examination of the conventional conductivity (pC) test for soluble salts in soils. *Glasshouse crops Res. Inst. Annu. Rep.* 1956. pp.84-92.
- Zhang, H., J. L. Schroder, J. J. Pittman, J. J. Wang and M. E. Payton (2005). Soil salinity using saturated paste and 1:1 soil to water extracts. *SSS Am. J.* 69:1146-1151.

التنبؤ بملوحة التربة وتركيز الأيونات في عجينة الأرض المشبعة مستخدماً مستخلص ١:١ تربة : ماء في الأراضي البحرية بمصر

رجب إسماعيل فايد ، خميس عبد العزيز راتب ، حامد مبروك القونى
معمل بحوث الأراضي الملحية والقلوية بالإسكندرية-معهد بحوث الأراضي والمياه والبيئة-
مركز البحوث الزراعية- مصر

الملخص العربي

مستخلص عجينة الأرض المشبعة و مستخلص ١:١ تربة - ماء هي الطرق الأكثر شيوعاً لتقدير ملوحة التربة (EC) وتركيز الأيونات معيلاً. بالرغم من الاختلافات في النتائج بين الطريقتين فإن العديد من الأبحاث تستخدم مستخلص ١:١ في التحليلات المختلفة وذلك لسهولة تجهيز العينات وتوفير الجهد، الوقت و المال. لذلك تهدف هذه الدراسة إلى استخدام معادلات الارتداد البسيط للتنبؤ بالتوصيل الكهربائي وتركيز أيونات الكالسيوم، الماغنسيوم، الصوديوم والكلوريد في مستخلص عجينة الأرض المشبعة (كمتغيرات تابعة) مستخدماً نفس التقديرات في مستخلص ١:١ تربة - ماء (كمتغيرات مستقلة). تم جمع ١٨٠ عينة من الأراضي الزراعية التي تطورت من رواسب بحيرية عند قرية البوصلى جنوب بحيرة اذكو وتم تجهيز العينات والحصول على مستخلص التربة بالطريقتين (عجينة الأرض المشبعة و مستخلص ١:١ تربة - ماء) وتقدير الأملاح الذائبة (EC) وتركيز أيونات الصوديوم، الكالسيوم، الماغنسيوم والكلوريد في كلا المستخلصين. تركيز الأيونات وكمية الأملاح الذائبة المقدره في مستخلص ١:١ كانت أقل من ميلتها المقدره في مستخلص عجينة الأرض المشبعة وذلك يرجع إلى زيادة التخفيف. تم تحديد العلاقة المشتركة بين الطريقتين باستخدام معادلات الارتداد البسيط. معامل الارتباط كان معنوي جداً ($R^2 = 0.92$) بين التوصيل الكهربائي (EC) لمستخلص عجينة الأرض المشبعة و EC لمستخلص ١:١ وذلك من معادلة الارتداد في كلا المستخلصين. أيضاً يوجد ارتباط معنوي جداً لتركيزات الصوديوم، الكالسيوم، الماغنسيوم والكلوريد ($R^2=0.99, 0.93, 0.96, 0.96$) على التوالي. وتم التوصل

Prediction of salinity and ion concentrations in saturation past.....

إلى معادلات الخط المستقيم التي من خلالها يمكن التنبؤ بتركيز الأيونات والأملاح في مستخلص عجينة الأرض المشبعة مستخدماً مثلثتها في مستخلص ١:١.

لإجراء التحقق والتأكد من صحة النتائج السابقة تم تجهيز ٣٥ عينة أرض وتقدير الملوحة وتركيز الأيونات بها في عجينة الأرض المشبعة وكذلك في مستخلص ١:١ وحساب المتوسط لكل عنصر لكل طريقة ثم عمل مقارنة بين النتائج الحقيقية المقاسة في مستخلص عجينة الأرض المشبعة والمنتبأ بها من مستخلص ١:١ (تربة:ماء). من نتائج التحليل الاحصائي وجد عدم وجود اختلافات معنوية بين الأملاح الذائبة وكذلك تركيز أيونات الصوديوم، الكالسيوم، الماغنسيوم والكلوريد الحقيقية المقاسة في مستخلص الأرض المشبعة والمنتبأ بها من مستخلص ١:١ وهذا يؤكد جدوى وصحة استخدام النتائج التي تم التوصل إليها في هذا البحث للتنبؤ بتركيز الأيونات والأملاح الذائبة لمستخلص الأرض المشبعة من مستخلص ١:١ في الأراضي البحرية توفيراً للوقت والجهد والمال.