

Comparison of Two Soil Salinity Extraction Methods

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ABSTRACT

Saturated paste and 1:1 soil to water extracts are commonly used by laboratories in assessing soil salinity for field remediation. Correlation of electrical conductivity (EC) and other analytes between these methods is not well documented. This study was conducted to further examine these relationships using a wide variety of soils. Saturated paste (SP) and 1:1 soil to water extracts (1:1) were prepared from soil samples received by the Soil, Water and Forage Analytical Laboratory at Oklahoma State university and analyzed for EC, major cations (Na^+ , K^+ , Mg^{2+} , Ca^{2+}) and major anions (Cl^- , NO_3^- , SO_4^{2-}). Relationships of all analytes for both methods were established using linear regression. In general, analytes from 1:1 soil to water extracts and saturated paste extracts were highly correlated, but were affected by soil texture (fine and coarse textural groups) and ionic charge (mono-valent vs. divalent). Findings from this study can be useful in minimizing analysis cost and time by allowing accurate conversion of 1:1 analysis to saturated paste result basis.

INTRODUCTION

Oil and natural gas production are important sectors of economy in Oklahoma. One major environmental concern with oil and gas exploration is the impact of oil and brine on soil and water quality. Two primary effects of brine on soil and vegetation are degradation of soil structure and alteration of the osmotic gradient between plant roots and the soil (Nelson, et al., 1997; Duel and Holliday, 1997). As a result, contaminated sites will exhibit loss of vegetation and soil erosion (Barzegar et al., 1997). The remediation of oil and produced salt-water contaminated sites has been a priority of oil and gas industry in recent years. Remediation recommendations are based upon soil analysis, therefore remediation can only be as effective as are the analyses. Testing methods must then be maintained and improved to enable competent management of contaminated areas. Currently regulations in Oklahoma call for remediation of those areas defined as contaminated based on TDS evaluations (OCC, 1998). A quick more quantitative method of analysis could in combination with TDS evaluation, assist in timely responses to specific needs of an area. Environmental stewardship requires responsible, respectful care of our natural resources including minerals, soil, and water. Improved testing methods can assist in this stewardship.

Good relationships have been observed between 1:1 and saturated paste extracts (Wagenet and Jurinak, 1978) though currently the accepted method for precise soil salinity extraction evaluation is saturated paste extraction (USDA, 1954). Saturated pastes attempt to simulate a naturally occurring state of soil saturation. In this saturated condition ions have increased solubility and phytoavailability (Longenecker and Lylerly, 1964). Though 1:1 does not simulate this naturally occurring condition, simplicity and objectivity make it a method potentially useful in salinity characterization. A 1:1 can also avoid some difficulties encountered in saturated paste preparation (USDA, 1954; Fowler and Hamm, 1980; Longenecker and Lylerly, 1963).

Results of a 1:1 extract are generally different from those saturated paste extract. Over half of the 2,500 soil salinity samples annually analyzed in Oklahoma are analyzed using the low cost 1:1 method. Most of those samples are from salt-water contaminated sites associated with oil and gas exploration. The same remedial recommendations are made for both the 1:1 and saturated paste method after conversion of 1:1 to the equivalent saturated paste. The recommendations will be more accurate and consistent upon the development of more appropriate conversion factors. The lack of such a standard conversion makes results difficult to compare. Currently, the electrical conductivity (EC) and ions from the 1:1 method are converted to those of saturated paste by use of conversion factors from Table 2 of Handbook 60 (USDA, 1954). These factors are 2.78 for monovalent ions, (Cl^- , NO_3^- , Na^+ , K^+), 1.67 for divalent ions (SO_4^{2-} , Mg^{2+} , Ca^{2+}), and 3 for EC. Those conversion factors were based on chemical solubility in aqueous systems. The impact of soil texture, salt content and organic matter content were not considered, therefore, the conversion factors may not be accurate when applied to different soils (Franzen et al., 1994). This is due to the lack of well examined relationships between the two methods and factors that have not been experimentally verified. Some experimentally generated conversions have been recorded. Franzen (1994) considered EC (mS/cm) in textural divisions and arrived at conversion factors for coarse (sp=3.01(1:1)-0.06), medium (sp=3.01(1:1)-.77), and fine soils (sp=2.96(1:1)-.95). Hogg and Henery (1984) examined relationships to derive factors for EC (mS/cm):

(sp=(1.56(1:1)-0.06), Na⁺: (sp=.95(1:1)-30.5), Mg²⁺ and Ca²⁺: (sp=.7(1:1)-9.39), Cl⁻: (sp=.95(1:1)+5.31) (all in ppm). Wide differences in conversion factors exist among previous studies. Further examination and comparison of the two methods are needed, especially for different textural soil groups. These factors could assist laboratories in producing reliable interpretations using the less expensive 1:1 soil-water extract.

The objective of this study was to determine appropriate factors for converting 1:1 results to the equivalent results of a saturated paste using a wide variety of soils.

MATERIALS AND METHODS

Soil salinity characteristics were evaluated using 1:1 soil to water and saturated paste extraction methods. Approximately 200 samples from around the state of Oklahoma consisting of brine contaminated and other salt affected areas were used. This allowed for diversity in origin, chemical compounds, concentrations, and in textures of the samples used.

Saturated Paste Extraction:

A saturated paste was prepared by adding deionized water to samples in a condition as they were received (US Salinity Laboratory, 1953). Water was added to the sample until it reached a condition of complete saturation. The sample was then allowed to equilibrate for 18 hours. An extract from the saturated paste was acquired using a low pressure filter press (Fann Equipment, Low Pressure Filter Press, Houston, TX). This extract was analyzed for Na⁺, K⁺, SO₄²⁻, Mg²⁺ and Ca²⁺ using an Inductively Coupled Argon Plasma spectrometer (Spectro Cirros, ICAP, Fitchburg, MA). A Lachat Quickchem 8000 flow injection analyzer (Zellweger Analytics, Milwaukee, WI) was used to measure NO₃⁻ and Cl⁻ concentrations. A dipping type electrode was used to determine electrical conductivity (Orion, 162A Conductivity Probe, Beverly, MA).

1:1 Soil Water Solution Extraction:

Prior to the extraction, a 125g of the saturated paste sample was taken to prepare 1:1 soil to water mixture. Twenty-five g of the 125g sample was oven dried overnight at 105°C to determine percent moisture. The appropriate amount of water was added to the remaining 100g saturated paste to create a 1:1 soil to water ratio. The 1:1 sample was allowed to equilibrate for 18 hours. Analytes in extracts were obtained using the same methods as with the previously discussed saturated pastes.

RESULTS AND DISCUSSION

Basic soil salinity characteristics of all samples study are shown in Table 1. The ranges of electrical conductivity and ion concentrations suggest that diverse samples were included in the study.

Table 1 Summary of soil salinity data collected from 205 samples by 1:1 and saturated paste extraction.

	EC μS/cm	Cl ⁻ ppm	NO ₃ ⁻ N ppm	SO ₄ ²⁻ ppm	Mg ²⁺ ppm	Ca ²⁺ ppm	Na ⁺ ppm	K ⁺ ppm
Saturated Paste Extract								
Avg	17787	3746	9.4	446	812	238	4066	40
Min	634	5	1	1	5	1	10	3
Max	216500	45659	45	10700	8487	1865	43200	193
1:1 Extract								
Avg	8189	1771	5.4	236	354	89	1695	25
Min	23	5	1	0	2	0	2	1
Max	81000	15609	35	4131	3341	697	17880	130

A quality control measure was implemented in order to maintain accuracy and credibility within the data set. A cation/anion balance was used to check the data set (Table 3). The error of cation and anion balance of both 1:1 (7.8%) saturated paste (16%) were with acceptable limit.

Table 2 Average anions and cation balance for 1:1 and saturated paste extracts (Data are in milliequivalent).

Cation and Anion Balance			
Anion	Cation	Difference	% Error
1:1			
7454	6891	563	7.8
Saturated Paste			
21946	18619	3326	16.4

Relationships were observed using EC, major anions, and cations collected from 1:1 and saturated paste extracts. General trends were observed for more broad characterizations such as the importance of considering ionic charge and solubility among different ions (Figures 1-5). The samples were also divided into textural groupings in order to achieve more specificity and precision in conversion. Textural differences did indeed seem to contribute to difference in relationships. Coarse textured soils exhibited the need for a larger conversion factor than fine soils with respect to all analytes. Despite previous work creating three textural divisions (Franzen et al., 1994), it seemed only two textural divisions were needed to accurately describe relationships (Figures 1-5). Textural divisions were evaluated by feel and defined as fine and coarse. Coarse samples contained more than 60% sand (particle size >0.05mm), and fine had less than 60% sand (Donahue et al., 1983).

The relationships of 1:1 and saturated paste presented were highly significant ($p < 0.01$). Conversion factors previously recommended by US Salinity Lab (1954), Franzen, et al. (199, and Hogg and Henery (1984) are different from those observed in this study. It seems a more precise conversion can be made by distinguishing individual ions in combination within a textural group. Conversion factors for all parameters studied are contained in Table 3.

Table 3 Correlation coefficients between 1:1 soil to water extract and saturated paste extract for all the data, and for fine and coarse textural groups.

	Fine	Coarse	All Data
EC	Sp = 1.94 (1:1) - 170	Sp = 2.59 (1:1) + 1542	Sp = 2.11 (1:1) + 1094
Cl⁻	Sp = 2.26 (1:1) - 386	Sp = 2.88x (1:1) + 30	Sp = 2.25 (1:1) - 246
NO₃⁻	Sp = 1.48 (1:1) + 0.055	Sp = 3.68 (1:1) - 2	Sp = 1.56 (1:1) + 1
SO₄²⁻	Sp = 1.05 (1:1) + 66	Sp = 2.40 (1:1) - 53	Sp = 2.09 (1:1) - 66
Na⁺	Sp = 2.21 (1:1) - 269	Sp = 4.58 (1:1) - 738	Sp = 2.88 (1:1) - 828
Mg²⁺	Sp = 2.64 (1:1) - 23	Sp = 3.88 (1:1) - 7	Sp = 2.92 (1:1) - 23
Ca²⁺	Sp = 2.07 (1:1) - 16	Sp = 4.26 (1:1) - 135	Sp = 2.50 (1:1) - 75
K⁺	Sp = 1.43 (1:1) + 1	Sp = 2.15 (1:1) + .45	Sp = 1.54 (1:1) + 2

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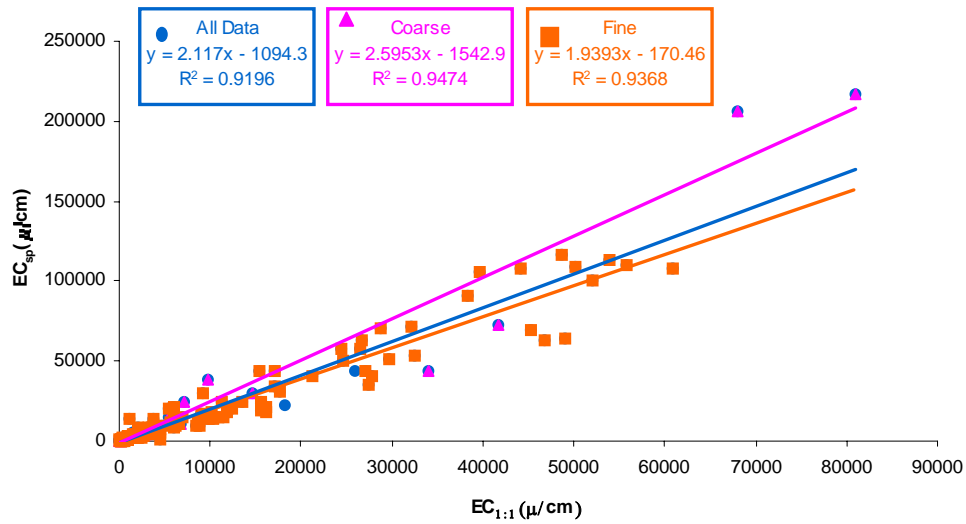


Figure 1 The regression plot of EC_{sp} (y values) and $EC_{1:1}$ (x values) with textural divisions of coarse and fine with an additional line of the entire data set plotted also.

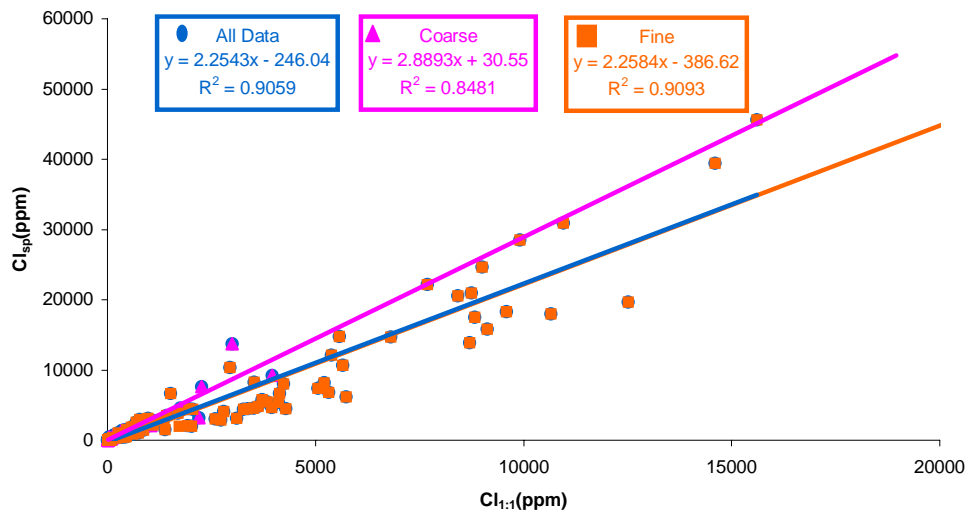


Figure 2 The regression plot of Cl_{sp} (y values) and $Cl_{1:1}$ (x values) with textural divisions of coarse and fine with an additional line of the entire data set plotted also.

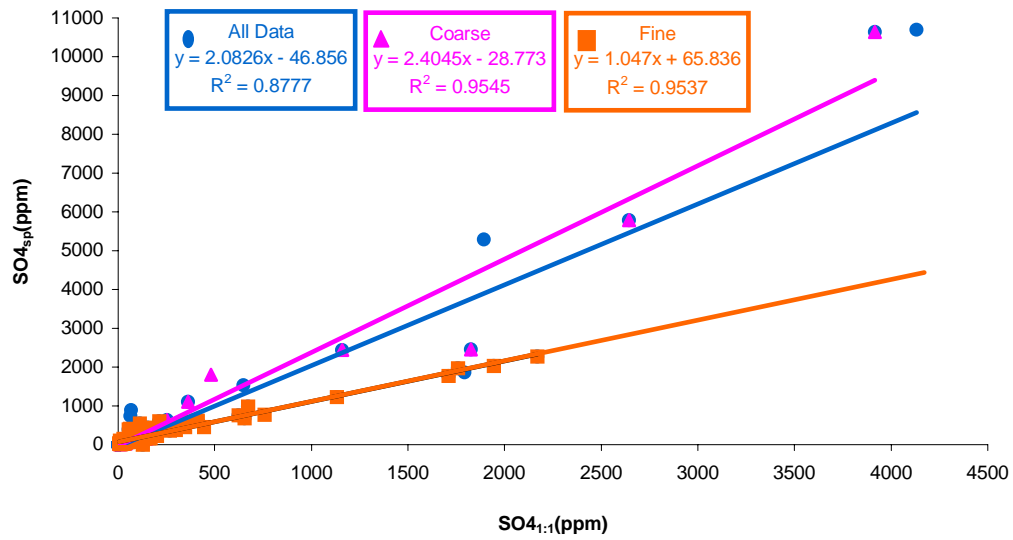


Figure 3 The regression plot of $\text{SO}_4^-_{\text{sp}}$ (y values) and $\text{SO}_4^-_{1:1}$ (x values) with textural divisions of coarse and fine

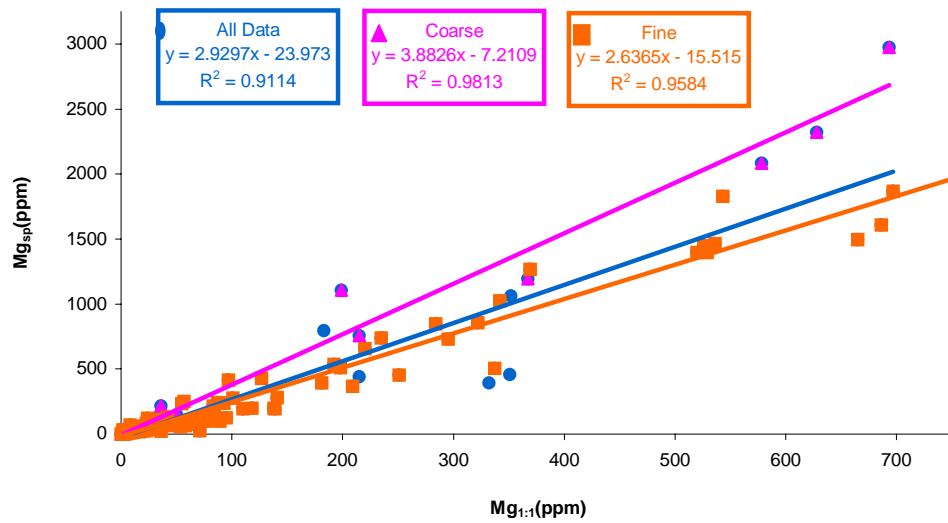


Figure 4 The regression plot of $\text{Mg}^{2+}_{\text{sp}}$ (y values) and $\text{Mg}^{2+}_{1:1}$ (x values) with textural divisions of coarse and fine with an additional line of the entire data set plotted also.

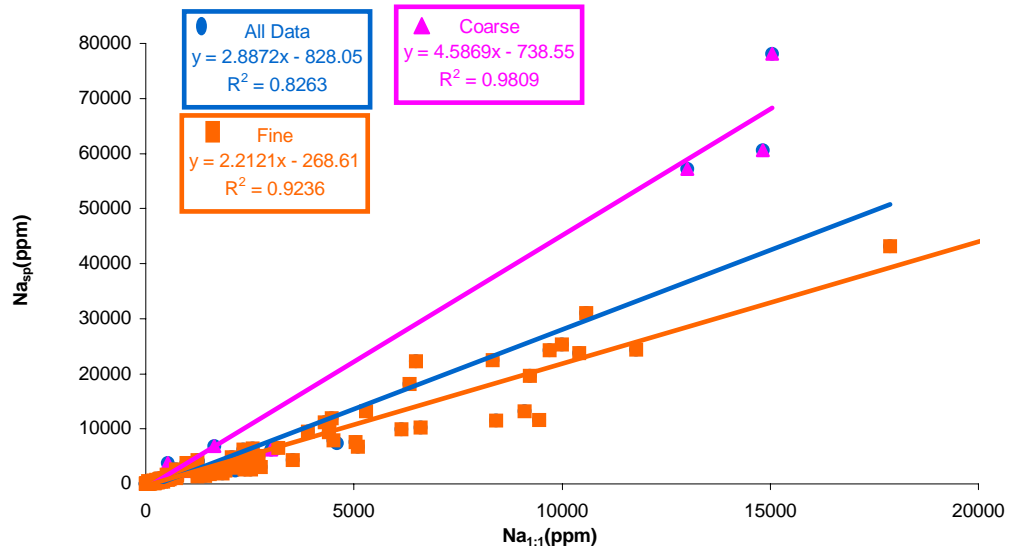


Figure 5 The regression plot of Na_{sp}^+ (y values) and $Na_{1:1}^+$ (x values) with textural divisions of coarse and fine with an additional line of the entire data set plotted also.