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Evaluation of 1:5 soil to water extract electrical conductivity methods

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ABSTRACT

Conducting a 1:5 soil:water extract to measure electrical conductivity (EC) is an approach to assess salinity and has been the preferred method in Australia, but not commonly used in the United States where the 1:1 soil to water ratio is preferred. The objectives of this research were to 1) compare methods of agitation for determining $EC_{1:5}$ and 2) to determine optimal times for equilibration for each method across a range of salinity levels determined from EC values achieved from saturated paste extracts (EC_e). Soils evaluated for this study were from north central North Dakota (USA) and had EC_e values ranging from 0.96 to 21.2 dS m^{-1}. For each method, nine agitation times were used, up to 48 h. The three agitation methods were shaking plus centrifuging, shaking, and stirring. Agitation methods resulted in significantly different $EC_{1:5}$ values for 13 out of 20 soils across the three agitation methods, and shaking plus centrifuging was significantly different ($p=0.05$) from stirring for all soils. In addition, 75% of the shaking plus centrifuging soils were significantly different from shaking. Based on these results, methods were analyzed separately for optimal equilibration times. The agitation times required for the three methods to reach 95 and 98% of equilibration were a function of the level of soil salinity. For soils with EC_e values below 4 dS m^{-1}, over 24 h was needed to obtain both 95 and 98% of equilibration for the three methods. However, less than 3 and 8 h were needed to reach 95 and 98% equilibration, respectively, across methods for soils having EC_e values greater than 4 dS m^{-1}. These results indicate that investigating the effect of agitation methods and times is important to help reduce variations across $EC_{1:5}$ measurements.

1. Introduction

Electrical conductivity (EC) of a soil extract is the most widely used parameter for describing soil salinity (USDA, 1954). Electrical conductivity estimates the concentration of ions in the soil, and consists predominately of the cations Na^+, Ca^{2+}, K^+, and Mg^{2+} and the anions Cl^-, SO_4^{2-} and HCO_3^- (Rayment and Higginson, 1992; Sumner and Naidu, 1998). The standard laboratory method for determining the EC of a soil is by using a saturated paste extract (EC_e) (Rhoades et al., 1989; USDA, 1954). Due to the difficulties encountered in determining the appropriate water saturation point when preparing a saturated paste extract (Longenecker and Lyerly, 1964), soil to water ratios of 1:1, 1:2, 1:2.5, 1:5, and 1:10 have been used to determine the EC values of soils (Hogg and Henry, 1984; Slavich and Petterson, 1993; Sonmez et al., 2008). The 1:5 ratio is the preferred method for determining soil EC in Australia and China (Rayment and Lyons, 2011; Wang et al., 2011). The 1:5 ratio has the advantage of simplicity, reduced time, and cost compared to saturation paste extracts (Franzen, 2007) and also dissolves larger amount of solutes than the saturation paste extracts, especially for sparingly soluble salts (Reitemeier, 1946).

Both mechanical shaking and stirring methods have been used to prepare 1:5 extracts. For example, the standard 1:5 method used in Australia is by mechanically shaking the required amount of soil sample (20 g) and deionized water (DI) (100 mL) for 1 h, followed by 20–30 min of undisturbed settling before measurement of EC (Rayment and Higginson, 1992). Other 1:5 procedures include agitation methods of shaking, and stirring, and agitation times between 20 min and 24 h (Chi and Wang, 2010; USDA, 1954; Visconti et al., 2010) followed by undisturbed settling, centrifuging, or filtration prior to EC measurement (Al-Mustafa and Al-Omran, 1990; Chi and Wang, 2010; Hurrass and Schaumann, 2006; Khorsandi and Yazdi, 2007; Loveday, 1974; Marion et al., 1991; Notario del Pino et al., 2008; Rayment and Higginson, 1992; Rhoades, 1982; USDA, 1954; Visconti et al., 2010). Detailed information about agitation methods and times used in studies from different countries are shown in Table 1.

Although many $EC_{1:5}$ methods have been reported, influences on EC by different agitation methods and times for equilibration are likely to occur. The objectives of this research were to (1) compare three methods of preparation and extraction (shaking plus centrifuging, shaking, and stirring) for determining $EC_{1:5}$ and (2) to determine

Abbreviations: EC, electrical conductivity; $EC_{1:5}$, electrical conductivity of 1:5 soil to water extract; EC_e, electrical conductivity of saturated paste extract.

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Table 1
Specific agitation methods, equilibration times, and times prior to $EC_{1:5}$ measurements from different studies.

Method	Agitation time	Settling method and time prior to EC measurement	References
Mechanically shake 15 min, stand at least 1 h, agitate again for 5 min, filter and take EC	20 min	Filtration	USDA (1954); Chi and Wang (2010)
Mechanically shake, suspensions were filtered, and take EC	–	Filtration	Wang et al. (2011)
Mechanically shake for 1 h, settle for 20–30 min, and take EC	1 h	Naturally settling 20–30 min	Loveday (1974); Rayment and Higginson (1992)
Mechanically shake for 24 h, centrifuge for 10 min, and take EC	24 h	Centrifugation 10 min	Visconti et al. (2010)
Mechanically shake for 1 h, or shake by hand for 1 min at least 4 times at 30 min intervals, filter, and take EC	1 h	Filtration	Rhoades (1982); Marion et al. (1991); Khorsandi and Yazdi (2007)
Mechanically shake for 1 h, suspensions were centrifuged, supernatant is filtered, then take EC	1 h	Centrifugation and filtration, no specific time	Notario del Pino et al. (2008) and Marion et al. (1991)
Mechanically shake for 12 h, then filtered with 0.45 μm filter paper, take EC	12 h	Filtration	Hurrass and Schaumann (2006)
Stir over a period of 1 h, then filtered for extract, and take EC	1 h	Filtration	Al-Mustafa and Al-Omran (1990)
Shake for 1 min of soil and rain water slurry(soil is placed into graduated bottle 100 mL mark and rain water is added to 600 mL mark), settle 1 min, and take EC, determine by pre-made table	1 min	Naturally settling 1 min	Henschke and Herrmann (2007)
Shake greater than 30 min, settle 15 min prior to take EC	>30 min	Naturally settling 15 min	Walker (2008)

optimal times for equilibration for each agitation method across a range of soil EC_e.

2. Materials and methods

2.1. Soil preparation

Soil samples used in this study (n = 20) were collected from the 0 to 30 cm and 0 to 90 cm depths from soils in Benson and Ramsey counties in North Dakota, USA, (approximately 48°15′84″–48°33′48″ N, 98°59′76″–99°59′76″ W). All samples were Mollisols but had different suborder classifications and the five textural control sections ranged from fine (the particle size range is from 0.002 to 0.05 mm) to sandy over loamy (>45% of sand, <50% of silt, and <20% of clay) (Table 2). Each sample was air-dried, ground to pass through a 2 mm sieve, and stored in plastic bags until analysis. Saturated pastes were made following the methods outlined by USDA (1954) and electrical conductivity of saturated paste extract (EC_e) was determined on each extract.

2.2. Extract preparation and analysis

Soil suspensions were prepared using 35 mL of ultra-pure water (water was treated to remove organic contaminants and ions before use) and 7 g of soil into 50 mL plastic centrifuge tubes (Cat. No. 06-443-18, Fisherbrand). Treatments included three different agitation methods, nine agitation time levels, and four replications. Agitation methods included shaking plus centrifuging, shaking, and stirring. Soil suspensions were agitated in a mechanical shaker (132 rev min^{-1}) for the shaking and shaking plus centrifuging methods. For the stirring method, each sample was stirred using a glass rod for 10 s initially and at the end of each of the times listed in the following paragraph.

Suspensions were agitated for 5, 15, 35, 75, 175, 355, 715, 1435, and 2875 min (48 h) following the agitation times used in the studies of Chi and Wang (2010), Hurrass and Schaumann (2006), Rhoades (1982), and USDA (1954). For the two shaking methods, after each agitation time level, the soil solutions assigned on each time were removed from the shaker and were allowed to settle for 5 min or were centrifuged for 5 min at a relative centrifuge force (RCF) of 4870 × g for the shaking and shaking plus centrifuging methods, respectively. After the prescribed settling time EC was determined using a conductivity probe (Sension 378; Hach Co., Loveland, CO, USA). For the stirring method, samples dedicated to the specific agitation time were also allowed to settle for 5 min after the stirring interval. All samples for each agitation time and method were used for only one EC measurement during this study.

For each agitation time and method, a 1.413 dS m^{-1}standard solution (KCl) (Rayment and Higginson, 1992) and one blank (ultra-pure water only) were analyzed following the respective settling method and time criteria. Although temperature may affect EC readings, the EC meter used for this study was not influenced by possible temperature differences between the agitation methods (Briese, 2010). The EC meter was calibrated by NaCl solution (1 dS m^{-1}) (Cat. No. 2243–16, Ricca Chemical Company, Arlington, Texas) prior to each agitation time measurement.

Table 2
Taxonomic information and EC_e of soils used in this study.

Soil no.	Series in map unit	Soil taxonomy	SP[b] %	EC_e[a] dS m^{-1}
1	Hamerly Barnes	Hamerly; Fine-loamy, mixed, superactive, frigid Aeric Calciaquolls Barnes; Fine-loamy, mixed, superactive, frigid Calcic Hapludolls	35.60	0.96
2	Hamerly Barnes		43.10	1.24
3	Hecla	Hecla; Sandy, mixed, frigid Oxyaquic Hapludolls	32.40	2.05
4	Hamerly Wyard	Wyard; Fine-loamy, mixed, superactive, frigid Typic Endoaquolls	48.30	2.91
5	Towner	Towner; Sandy over loamy, mixed, superactive, frigid Calcic Hapludolls	41.30	3.14
6	Hamerly Wyard		46.20	4.66
7	Bearden Lindaas	Bearden; Fine-silty, mixed, superactive, frigid Aeric Calciaquolls Lindaas; Fine, smectitic, frigid Typic Argiaquolls	58.90	5.33
8	Hamerly Tonka	Tonka; Fine, smectitic, frigid Argiaquic Argialbolls	54.20	6.91
9	Overly	Overly; Fine-silty, mixed, superactive, frigid Pachic Hapludolls	56.40	7.06
10	Hamerly Cresbard	Cresbard; Fine, smectitic, frigid Glossic Natrudolls	52.10	7.12
11	Hamerly Tonka		49.90	9.02
12	Bearden	Bearden; Fine-silty, mixed, superactive, frigid Aeric Calciaquolls	66.10	9.23
13	Hamerly Cresbard		47.30	11.29
14	Bearden		60.90	13.13
15	Cresbard Barnes		44.10	13.83
16	Bearden		48.10	16.81
17	Cresbard Svea	Svea; Fine-loamy, mixed, superactive, frigid Pachic Hapludolls	61.20	16.83
18	Cresbard Barnes		45.10	17.06
19	Cresbard Svea		52.00	19.60
20	Bearden		68.10	21.20

[a] EC_e, electrical conductivity determined from saturated paste extracts.
[b] SP, saturation percentage.