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Standard operating procedure for soil electrical conductivity

soil/water, 1:5



Standard operating procedure
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VERSION HISTORY

N°	Date	Description of the modification	Type of modification
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1. Brief introduction to soil electrical conductivity (EC)

The level of soluble salts found in the soil solution can be classified by determining the electrical conductivity (EC) of the solution, or the soil solution can be assayed for its elemental content. The first procedure is more commonly performed. As the level of soluble salts increases, the usual effect is a decrease in plant growth due to reverse osmosis; therefore, soluble salt determination has considerable significance in agriculture, particularly in plant nutrition and plant science in general. Soils affected by high soluble salt levels are also difficult to manage, particularly when sodium (Na^+) is the dominant cation contributing to the high salt level likewise termed as Sodicity (Richards, 1969; Shaw, 1999).

In the natural environment, soils with high soluble salt content are found in low-rainfall areas and where sea water intrusion occurs. In the managed environment, soluble salt problems may result from the use of salt-laden irrigation water, or from improper fertilizer placement, high fertilizer application rates, or accumulation due to repeated fertilizer applications.

Salinity, which results from the high presence of Na-salt, affects about 25 percent of the croplands in the world and is becoming an increasing problem in most irrigated cropland. From the point of view of crop production, the presence of salts determines a series of physical and chemical implications that adversely affect crop growth. In general, salts can produce, both cationic and anionic toxic effects and cause deficiency or toxicity of minor elements that become insolubilized or dissolved with increasing pH. Physically, they affect water quality, since increasing salt percentage increases the osmotic potential of the soil and thus, generates competition for water between soil and plant roots, in which the plants, if they are not salt tolerant, markedly deteriorate their metabolism and therefore their production.

2. Scope and field of application

This method determines the electrical conductivity (EC) of a soil/water suspension in the ratio of one:five (1:5). Aqueous extracts of soil samples are usually made at higher than normal water content for routine characterization purposes, as obtaining soil samples at typical field water contents are not very practical. Considering that the amounts of various solutes are influenced by the soil/water ratio at which the extract is made, the soil:water ratio should be standardized to obtain results that can be applied and reasonably interpreted.

3. Principle

Electrical conductivity (EC) yields a measure of the soil extract's capacity to convey an electrical current. EC is generally related to the total solute concentration and can be used as a quantitative expression of the dissolved salt concentration, although it is also affected by the mobility, valence, and relative concentrations of the individual ions present in the solution.

The determination of EC generally involves the physical measurement of resistance (R). The reciprocal of R is conductance (C). When the cell constant is applied, the conductance measured at a specified temperature is converted to specific C, the reciprocal of the specific R is called electrical conductivity.

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EC (specific conductance) increases with temperature. Conductivity should ideally be determined at 25°C. However, EC can be measured at other known temperatures and corrected to the 25°C reference using appropriate temperature coefficients (usually based on NaCl).

The presence of the major dissolved inorganic solutes, essentially Na⁺, Mg²⁺, Ca²⁺, K⁺, Cl⁻, SO₄²⁻, HCO₃⁻ and CO₃²⁻, in aqueous samples refers to the term salinity which is measured through EC. The EC determination is often sufficient to diagnose, survey, and monitor soil salinity, and to assess the adequacy of leaching and drainage system.

4. Apparatus

- 4.1 Analytical balance, with an appreciation of 0.0001 g or Precision balance, with an appreciation dependent on the weight of the sample.
- 4.2 Reciprocating shaker
- 4.3 Conductivity meter with accuracy of at least 0.01 dS m⁻¹ and automatic temperature compensator at 25 ± 0.1 °C.
- 4.4 Polyethylene bottles with lid, wide-mouth type, 250 mL capacity
- 4.5 Graduated cylinder, 50 mL, 100 mL
- 4.6 Calibrated dispenser; 50 mL, 100 mL
- 4.7 Beaker; 250 mL, 500 mL, 1 L

5. Materials

All chemicals and reagents should be at least of Analytical Grade.

- 5.1 Deionized/distilled water, it should have an EC < 0.001 dS m⁻¹ (ASTM D1193-91 and ISO 3696:1987).
- 5.2 Potassium Chloride (KCl) Solution (NIST traceable or equivalent): 0.084, 0.147 and 1.413 dS m⁻¹ at 25°C (12.880 dS m⁻¹ can be used for higher reading of soil electrical conductivity).

Alternatively, to prepare the reagent (0.01M potassium chloride solution), dry a small quantity of AR-grade potassium chloride at 60 °C for 2 hours. Weigh 0.7456 g of it, dissolve it in freshly prepared deionized/distilled water, and make the volume up to 1 L. This solution gives an EC of 1.4118×10^{-3} , i.e. 1.412 dS m⁻¹ at 25 °C. Other standards can be prepared by factoring out from this method. For best results, select a conductivity standard (KCl solution) close to the sample value.

6. Health and safety

This procedure involves the use of hazardous chemicals. Refer to the laboratory safety guidelines or the Safety Data Sheet (SDS) before proceeding.

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6.1. Personnel safety

Wear proper personal protective equipment. Use a laboratory coat, closed shoes, gas or dust mask, and appropriate gloves and safety glasses when performing chemical analysis to mitigate the harmful effects of chemical exposure. Wash hands and clean other exposed areas with mild soap and running water after using all chemical reagents.

6.2. Chemical hazard

6.2.1. Potassium Chloride is an odourless white inorganic compound that is non-reactive under normal conditions. It is classified as an eye and skin irritant. It must be stored away from oxidizing agents, strong acids or bases; and it is incompatible with bromine tri-fluoride.

7. Sample preparation

Air dry, or dry in an air forced oven below 35 (+-5) °C, the soil sample and grind and sieve to ≤ 2.0 mm size.

8. Procedure

8.1. Calibration of the conductivity meter (determination of the cell constant)

8.1.1 Calibrate the conductivity meter according to the instrument instructions using NIST or other equivalent traceable 0.147dS m⁻¹ KCl solution. When the EC of soil samples is equal to or greater than 0.700 dS/m, recalibrate using 1.413 dS m⁻¹ or higher concentration of KCl solution if needed, and determine again the EC of soil samples.

Alternatively, prepared 0.01 M (with EC of 1411.8 × 10⁻³, i.e. 1.412 dS m⁻¹ at 25 °C) or other appropriate KCl solution can be used for calibration.

8.1.2 Use 25 °C as the temperature if possible or adjust the temperature compensator setting on the instrument (if fitted), otherwise take the temperature of the solution.

8.1.3 Rinse the conductivity cell with deionized/distilled water.

8.2. Electrical conductivity determination

8.2.1. Weigh 20 g of air-dry soil into a 250 mL capacity polyethylene bottle.

8.2.2. Add 100 mL of deionized/distilled water (1:5, w/v) to the container, cover with bottle caps and place horizontally in the reciprocating shaker. Shake for 60 min at 180 osc./min

8.2.3. After shaking, remove from the shaker and let stand for 30 min.

8.2.4. Dip the conductivity cell in the supernatant without disturbing the sediment. Take the reading when it is stable.

8.2.5. Rinse the electrode with deionized/distilled water thoroughly and blot up any excess water.

8.2.6. Report EC (dS m⁻¹) at 25 °C.

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Remarks:

1. The sample weight may be scaled down, but always keep the w/v-ratio on 1:5.
2. The analysis must be done at room temperature, between 20 and 25 °C.
3. Rinse the electrode thoroughly after measurement before proceeding to the next sample.

9. Calculation

Direct measurement from the conductivity meter. Report results in dS m⁻¹.

Note: Convert the EC meter read out using the factor below.

$$1 \text{ uS cm}^{-1} = 0.001 \text{ dS m}^{-1}$$

Example Conversion:

EC meter read out – 250 uS cm⁻¹

$$\frac{250 \text{ uS}}{\text{cm}} \times \frac{1 \text{ mS}}{1000 \text{ uS}} \times \frac{1 \text{ dS}}{100 \text{ mS}} \times \frac{100 \text{ cm}}{1 \text{ m}} = \frac{0.25 \text{ dS}}{\text{m}} \text{ or } 0.25 \text{ dS m}^{-1}$$

10. Quality assurance/quality control

10.1. Accuracy test

10.1.1 Participate in an Inter-Laboratory Proficiency Test (PT) at least once a year. The PT z-score should be less than 2. If not, identify the root cause, perform the correction and develop a corrective action plan, and address the problem.

10.1.2 Perform replicate analyses of the check reference method. Compare the results of your own laboratory with the results of other laboratories, as provided in the performance analysis report, or certified reference material (CRM) certificate. The result from your own laboratory is considered accurate when it falls within the reported 95% confidence interval or the target value.

10.2. Precision test

Perform duplicate analysis of 10 percent of the samples in a test batch. Calculate the Relative Percent Difference (RPD) to determine if the precision of duplicate analyses is within specification.

$$RPD = \frac{|X_1 - X_2|}{(X_1 + X_2)/2} \times 100$$

where,

- RPD = Relative Percent Difference (as percentage)
- |X₁ - X₂| = Absolute value (always positive) of X₁ - X₂
- X₁ = Original sample
- X₂ = Duplicate sample

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For field duplicate precision, a **RPD of = 20%** might serve as a standard rule of thumb for aqueous samples. Field duplicates - To duplicate all steps from sample collection through analysis (Module one: Guidance on Preparing a QA Project Plan, Appendix B p. 21-22., EPA).

10.3. Control chart

Analyze at least a duplicate of the quality control material or check sample for every batch analysis. Plot the result in the control chart. Monitor for out of specified limits. If out of specified limit is observed, identify the root cause, perform the correction and develop a corrective action plan, and address the problem.

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12. Appendix I - Acknowledgements

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14. Appendix III - Contributing laboratories

GLOSOLAN would like to thank the following laboratories for completing the GLOSOLAN form on the method and providing information on their standard operating procedure for soil electrical conductivity (soil/water, 1:5). This information was used as a baseline for the global harmonization.

From the Asian region:

- Soil Research Directorate, Agriculture Research Institute of Afghanistan, Ministry of Agriculture Irrigation and Livestock, **Afghanistan**
- Royal University of Agriculture, **Cambodia**
- ICAR-Indian Institute of Soil Science, **India**
- Indonesian Soil Research Institute, **Indonesia**
- Institute for Agro-Environmental Sciences, NARO (NIAES), **Japan**
- Department of agricultural Land management, **Lao People's Democratic Republic**
- Soil and agrochemistry laboratory, school of Agroecology, Mongolian university of life science, **Mongolia**
- Department of Agricultural Research, **Myanmar**
- Soil Science Division, NARC, **Nepal**
- Fauji Fertilizer Company Limited, **Pakistan**
- Regional Soils Laboratory, Integrated Laboratory Division, Department of Agriculture, Regional Field Office 3, **Philippines**
- Laboratory Services Division - Bureau of Soils and Water Management, **Philippines**
- Horticultural Crops Research and Development Institute, Department of Agriculture, **Sri Lanka**
- Office of science for land development, Land Development Department, **Thailand**
- Laboratory of Soil Science, Dep. of Plant and Soil Sciences, Fac. Of Agriculture, Chiang Mai University, **Thailand**
- Department of Soil Science, Faculty of Agriculture, Kasetsart University, Kamphaeng Sean Campus, **Thailand**
- Soils and Fertilizers Research Institute, **Vietnam**

From the Pacific region:

- DES - Chemistry Centre, **Australia**
- Fiji Agriculture Chemistry Laboratory, **Fiji**
- Sugar Research Institute of Fiji, **Fiji**
- Institute of Applied Sciences, University of the South Pacific, **Fiji**
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From the Near East and North African region:

- KIMIA AB environmental and agricultural consulting laboratory, **Islamic Republic of Iran**
- Soil and Water Research Institute laboratory, **Islamic Republic of Iran**
- Ministry of Science and Technology, Directorate of Agricultural Researches, Soil and Water Resources Centre, **Iraq**
- National Agricultural Research Center, **Jordan**
- Kuwait Institute for Scientific Research, **Kuwait**

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- Agricultural Research Institute, **Lebanon**
- Land and Water Research Center, **Sudan**

From the African region:

- Department of Agricultural Research, **Botswana**
- Institute of Agricultural Research for Development, **Cameroon**
- Institut National pour l'Eude et la Recherche Agronomiques, **Democratic Republic of Congo**
- Laboratory Analytical Service-Accra Centre (CSIR-SRI), **Ghana**
- Soil Research Institute Analytical Services Laboratory, **Ghana**
- Laboratoire National d'Analyse de Sols, des Engrais, des Végétaux et Eaux du Services National des Sols, **Republic of Guinea**
- Kenya Agricultural & Livestock Research Organization (KALRO), **Kenya**
- FES – Agricultural Laboratory, **Malawi**
- Institut National de la Reche Agronomique du Niger, **Niger**
- National Testing Laboratory Complex, Kaduna, **Nigeria**
- Institut togolais de recherche agronomique, **Togo**
- Zambia Agriculture Research Institute, **Zambia**
- Zambia Agriculture Research Institute, **Zambia**
- University of Zambia, **Zambia**
- Zimbabwe Sugar Association Experiment Station, **Zimbabwe**
- Fertilizers Seed and Grain, **Zimbabwe**

From the European region:

- Institute for Land and Water Management Research, **Austria**
- University of Zagreb, Faculty of Agriculture, Department of General Agronomy **Croatia**
- University of Zagreb, Faculty of Agriculture, Soil Science Department, **Croatia**
- Central institute for Supervising and Testing in Agriculture, **Czech Republic**
- Natural Resources Institute Finland, **Finland**
- Laboratory of soil monitoring, Thuenen- institute, **Germany**
- Food Chain Safety Centre Non-profit Ltd., **Hungary**
- Latvian State Forest Research Institute "Silava", **Latvia**
- AgroCares Golden Standard Laboratory (Care4Agro BV), **Netherlands**
- Chemisch Biologisch Laboratorium Bodem, Wageningen University, **Netherlands**
- Laboratório de Solos e Fertilidade da Escola Superior Agrária de Castelo Branco, **Portugal**
- National Research and Development Institute for Soil Science Agrochemistry and Environment – Department for physical and chemical analysis, **Romania**
- University “St. Kliment Ohridski”-Bitola, Scientific Tobacco Institute - Prilep, **North Macedonia**
- Soil and Fertilizer Laboratory, Dept of Soil Sci and Plant Nutrition, Faculty of Agriculture, Ankara University, **TURKEY (SOFREL-TR), Turkey**
- Rothamsted Research, **United Kingdom of Great Britain and Northern Ireland**
- Scientific-Research Centre of Agriculture, **Georgia**

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- Laboratorio de química de suelos/LABOSUELOS-UASD, **Dominican Republic**
- Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA), **El Salvador**
- Colegio de Postgraduados, Campus Montecillo (LABFER -CPM), **Mexico**

From North America:

- Kellogg Soil Survey Laboratory, **United States of America**

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