# Chapter 10

# Recommended Methods for Measuring Soluble Salts in Soils

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*Soluble salts*, for soils, is technically defined as those dissolved inorganic solutes that are more soluble than gypsum ($CaSO_4 \bullet 2H_2O$; solubility of 0.24 g/ 100 mL at $0^oC$). The most common soluble salts in soils are the cations calcium ($Ca^{+2}$, magnesium ($Mg^{+2}$), and sodium ($Na^+$) and the anions chloride ($Cl^-$), sulfate ($SO_4^{-2}$), and bicarbonate ($HCO_3^-$). Smaller quantities of potassium ($K^+$), ammonium ($NH_4^+$), nitrate ($NO_3^-$), and carbonate ($CO_3^{-2}$) are also found in most soils. Sources of soluble salts in soils include commercial fertilizers, animal manures, municipal sewage sludges, soil organic matter, runoff from areas where salt or ice-melt products have been used and irrigation water that is high in dissolved salts. At "normal" concentrations, soluble salts have little harmful effect on plant growth; however, if excessive soluble salts exist, plant injury, such as reduced germination rates and leaf burning, or death may occur.

The usual method to quantify the soluble salts concentration in soils is to measure the *electrical conductivity* (*EC*) of either the soil solution or a soil-water extract. Electrical conductivity refers to the ability of a material or solution to conduct an electrical current. As soluble salts increase in the soil, the soil solution becomes a better conductor of electricity and *EC* increases. The unit most commonly used for *EC* in soil solutions or in soil-water extracts is mmhos $cm^{-1}$ but the official international unit for *EC* is siemens per meter (S $m^{-1}$). One mmho $cm^{-1}$ is equal to 0.1 S $m^{-1}$. Laboratory methods used to quantify soluble salts in soils include:

(1) Measuring *EC* with a conductivity meter in a saturated paste of soil and water.

(2) Measuring *EC* with a conductivity meter in a soil-water extract based on a fixed soil:solution ratio (e.g.1:2 or 1:5).

The saturated paste method provides a more representative measurement of total soluble salts in the soil solution because it more closely approximates the water content of the soil under field conditions. Saturated paste measurements, however, are more time-consuming and more susceptible to error due to variability between analysts in the preparation of the saturated paste. In most soil testing laboratories where large numbers of samples must be processed, measurement of *EC* at a fixed and more dilute soil:water ratio is more suitable because this method has been shown to be rapid, easily done, and reproducible across a wide range of soils. Since *EC* results will vary with the method selected, care must be taken to use the correct interpretive scale to evaluate *EC* results (Rhoades, 1982). The appropriate tables for interpretation of EC measurements by the saturated paste and fixed soil:water extract methods are given in this chapter.

# Methods for Measuring Soluble Salts

## Soluble Salts by the Saturated Paste Method
***(US Salinity Laboratory Staff, 1954)***

### Equipment:

1. No. 10 (2 mm opening) sieve
2. 150-mL beaker
3. 250-mL vacuum flask with Buchner funnels
4. Vacuum pump
5. Filter paper, Whatman No. 5 or equivalent
6. Conductivity bridge with 0 to 1 million ohms capacity
7. Conductivity cell, pipette type
8. Thermometer, 0-100$^{o}$C

### Reagents:

1. **0.01 *N* KCl standard solution:** Dissolve 0.7456 g of oven-dried (105$^{o}$C) potassium chloride (KCl) in a 1L volumetric flask containing ~800 mL of de-ionized water. Dilute to volume with de-ionized water and mix at 25$^{o}$C. This standard solution has an electrical conductivity of 1.4118 mmhos cm$^{-1}$ at 25$^{o}$C.

2. **De-ionized water.**

### Procedure:

1. Add a small amount of de-ionized water to the beaker. Next, fill the beaker approximately 2/3 full of dried, sieved soil. Add de-ionized water to the soil in the beaker while stirring with a spatula. **At saturation, the soil paste glistens as it reflects light, flows slightly when the container is tipped, and the paste slides freely and cleanly off the spatula for all soils but those high in clay.**

2. After mixing, the samples should be allowed to stand for an hour or more, and then the criteria for saturation should be re-checked. Free water should not collect on the surface nor should the paste stiffen markedly or lose its glistening appearance on standing. If the paste is too wet, additional dry soil may be added. If the paste is too dry, add additional water. For clay soils, the water should be added with a minimum of stirring. Peat and muck soils require an overnight wetting period to obtain a definite endpoint for the saturation paste.

3. Transfer the saturated paste to a Buchner funnel with filter paper in place. Apply a vacuum and collect the saturated paste extract in a 250-mL vacuum flask.

4. Measure the temperature of the extract.

5. Standardize the conductivity meter using the standard KCl solution following manufacturer's instructions. Set the temperature compensation dial on the conductivity meter to the temperature of the extract.

6. Rinse the conductivity cell, fill with the soil extract and then read the electrical conductivity of the saturated paste extract in mmhos $cm^{-1}$. If temperature compensation is not an option on the meter, adjust conductivity reading to $25^oC$ to ensure correct interpretation. Report conductivity values of less than 1 mmho $cm^{-1}$ to two decimal places. Conductivity values of 1 mmho $cm^{-1}$ or more should be reported to three significant figures.

7. The extract may now be analyzed by other techniques to determine specific constituents of soluble salts.

## Interferences:

1. Water contents higher or lower than saturation point will affect conductivity measurement.

2. Electrical conductivity increases as temperature increases. Ensure that conductivity readings have been adjusted to $25^oC$ for correct interpretation.

## Interpretation:

**Table 10-1. Interpretation of the saturated paste soluble salts test (Dahnke and Whitney, 1988).**

| Degree of Salinity | Electrical Conductivity |
|---|---|
| | - mmhos $cm^{-1}$ - |
| **Non-saline** | 0.0 - 2.0 |
| **Slightly Saline** | 2.1 - 4.0 |
| **Moderately Saline** | 4.1 - 8.0 |
| **Strongly Saline** | 8.1 - 16.0 |
| **Very Strongly Saline** | 16.1 + |

## Soluble Salts by the 1:1 (V:V) Soil:Water Extract Method

***(Dahnke and Whitney, 1988)***

### Equipment:

1. No. 10 (2 mm opening) sieve
2. 10 $cm^3$ soil scoop
3. 50-mL beaker
4. 20 mL pipette
5. Conductivity bridge with 0 to 1 million ohms capacity
6. Conductivity cell, pipette type, 2-3 ml capacity
7. Thermometer, 0-100$^o$C

### Reagents:

1. **<u>0.01 *N* KCl standard solution:</u>** Dissolve 0.7456 g of oven-dried (105$^o$C) potassium chloride (KCl) in a 1L volumetric flask containing ~800 mL of de-ionized water. Dilute to volume with de-ionized water and mix at 25$^o$C. This standard solution has an electrical conductivity of 1.4118 mmhos $cm^{-1}$ at 25$^o$C.

2. **<u>De-ionized water.</u>**

### Procedure:

1. Using the 10 $cm^3$ scoop, measure two scoops of dried, sieved soil into the beaker.

2. Add 20 mL de-ionized water and stir thoroughly.

3. Allow the suspension to equilibrate for 15-20 minutes.

4. Standardize the conductivity meter using the standard KCl solution following manufacturer's instructions.

5. Measure the temperature of the extract.

6. Rinse the conductivity cell and fill with the soil extract. Set the temperature compensation dial on the conductivity meter to the temperature of the extract. Read the electrical conductivity of the extract in mmhos $cm^{-1}$. If temperature compensation is not an option on the meter, correct the reading to 25$^o$C. Report conductivity values of less than 1 mmho $cm^{-1}$ to two decimal places. Conductivity values of 1 mmho $cm^{-1}$ or more should be reported to three significant figures.

## Interferences:

1. Electrical conductivity increases as temperature increases. Ensure that readings have been adjusted to 25$^{o}$C for correct interpretation.

## Interpretation:

With the 1:1 (V:V) soil:water extract method, the relationship between *EC* and crop growth varies with soil texture (Dahnke and Whitney, 1988).

**Table 10-2. Interpretation of the soluble salts test, [1:1 (V:V) soil:water extract] (Dahnke and Whitney, 1988).**

| | Degree of Salinity | | | | |
|---|---|---|---|---|---|
| **Soil Texture** | **Non-saline** | **Slightly Saline** | **Moderately Saline** | **Strongly Saline** | **Very Strongly Saline** |
| | ------ *EC* (mmhos $cm^{-1}$) ------ | | | | |
| **Coarse sand to loamy sand** | 0-1.1 | 1.2-2.4 | 2.5-4.4 | 4.5-8.9 | 9.0+ |
| **Loamy fine sand to loam** | 0-1.2 | 1.3-2.4 | 2.5-4.7 | 4.8-9.4 | 9.5+ |
| **Silt loam to clay loam** | 0-1.3 | 1.4-2.5 | 2.6-5.0 | 5.1-10.0 | 10.1+ |
| **Silty clay loam to clay** | 0-1.4 | 1.5-2.8 | 2.9-5.7 | 5.8-11.4 | 11.5+ |

## Soluble Salts by the 1:2 (V:V) Soil:Water Extract Method
***(Dellavalle, 1992b)***

### Equipment:

1. No. 10 (2 mm opening) sieve
2. 10 $cm^3$ soil scoop
3. 50-mL beaker
4. 20 mL pipette
5. Conductivity bridge with 0 to 1 million ohms capacity
6. Conductivity cell, pipette type, 2-3 mL capacity
7. Thermometer, 0-100$^oC$

### Reagents:

1. **<u>0.01*N* KCl standard solution:</u>** Dissolve 0.7456 g of oven-dried (105$^0$C) potassium chloride (KCl) in a 1L volumetric flask containing ~800 mL of de-ionized water. Dilute to volume with de-ionized water and mix at 25$^o$C. This standard solution has an electrical conductivity of 1.4118 mmhos $cm^{-1}$ at 25$^o$C.

2. **<u>De-ionized water.</u>**

### Procedure:

1. Scoop 10 $cm^3$ of dried, sieved soil into the 50-mL beaker.

2. Add 20 mL de-ionized water and stir thoroughly.

3. Allow the suspension to equilibrate for at least 30 minutes or long enough for the solids to settle.
4. Standardize the conductivity meter using the standard KCl solution following manufacturer's instructions.

5. Measure the temperature of the extract.

6. Rinse the conductivity cell and fill with the soil extract. Set the temperature compensation dial on the conductivity meter to the temperature of the extract. Read the electrical conductivity of the extract in mmhos $cm^{-1}$. If temperature compensation is not an option on the meter, correct the reading to 25$^o$C. Report conductivity values

of less than 1 mmho $cm^{-1}$ to two decimal places. Conductivity values of 1 mmho $cm^{-1}$ or more should be reported to three significant figures.

## Interferences:

1. Electrical conductivity increases as temperature increases. Ensure that readings have been adjusted to $25^{o}C$ for correct interpretation.

## Interpretation:

**Table 10-3. Interpretation of the soluble salts test, [1:2 (V:V) soil:water extract] (Dellavalle, 1992b).**

| Degree of Salinity | Electrical Conductivity |
|---|---|
| | - mmhos $cm^{-1}$ - |
| **Non-saline** | <0.40 |
| **Very Slightly Saline** | 0.40-0.80 |
| **Moderately Saline** | 0.81-1.20 |
| **Saline** | 1.21-1.60 |
| **Strongly Saline** | 1.61-3.20 |
| **Very Strongly Saline** | >3.20 |

## References

1. Dahnke, W.C and D.A. Whitney. 1988. Measurement of Soil Salinity. pp. 32-34. *In* W.C. Dahnke (ed.) Recommended chemical soil test procedures for the North Central Region. North Dakota Agric. Exp. Stn. Bull. 499.

2. Dellavalle, N.B. (ed.). 1992a. Determination of soil-paste pH and conductivity of saturation extract. *In* Handbook on Reference Methods for Soil Analysis. Pp. 40-43. Soil and Plant Analysis Council, Inc. Athens, GA.

3. Dellavalle, N.B. (ed.). 1992b. Determination of specific conductance in supernatant 1:2 soil:water solution. *In* Handbook on Reference Methods for Soil Analysis. Pp. 44-50. Soil and Plant Analysis Council, Inc. Athens, GA.

4. Rhoades, J.D. 1982. Soluble Salts. *In:* A.L. Page (ed.) Methods of soil analysis, Part 2 Chemical and microbiological properties, 2nd edition. Agronomy 9: 149-157.

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