



Environmental Analysis Program

Pomona College
Biogeochemistry Laboratory

SOP-L402

Soil pH and Salinity

Standard Operating Procedure

SOP Number	SOP-L402
Revision	0.1
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Date	2026-06-26
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1. Purpose

This procedure describes the measurement of soil pH and electrical conductivity (EC, as a proxy for salinity) on soil-water and soil- CaCl_2 extracts. Soil pH controls nutrient availability, metal solubility, microbial activity, and the fate of contaminants. Soil salinity (estimated from EC) affects plant growth, soil structure, and is a primary criterion for classifying saline, sodic, and saline-sodic soils. The methods follow Thomas (1996) for pH and Rhoades (1996) for EC, as described in the *SSSA Methods of Soil Analysis, Part 3* (Rhoades, 1996; Thomas, 1996).

For meter operation, calibration, and electrode maintenance, see [SOP-L300 pH and Conductivity – Bench-Top Measurements](#).

2. Scope

- **Applies to:** Air-dried, sieved (less than 2 mm) mineral soils from all EA Program sites; compost and potting media (with appropriate extraction ratios noted in Section 6)
- **Does not apply to:** In situ field pH measurements with portable probes (see [SOP-F200](#)); water sample pH and conductivity (see [SOP-L300](#)); saturated paste extraction for formal salinity classification of irrigation water
- **Location:** EA Program laboratory, SGM 133

3. Definitions

- **Cation exchange capacity (CEC):** The total capacity of a soil to hold exchangeable cations; closely related to soil pH buffering capacity (see [SOP-L416](#)).
- **Electrical conductivity (EC):** A measure of a soil extract's ability to conduct electricity, proportional to total dissolved ion concentration; expressed in dS m^{-1} or mS cm^{-1} ; used as a surrogate for soluble salt content.
- **Paste extract (saturated paste):** A soil-water mixture prepared at the saturation moisture content; the USDA standard extract for measuring soil salinity.
- **pH:** The negative base-10 logarithm of the hydrogen ion activity; soil pH is measured in a defined soil-to-water or soil-to- CaCl_2 suspension and controls nutrient availability and microbial activity.
- **Salinity:** The total concentration of dissolved salts in soil solution; high salinity reduces plant-available water and can be toxic to salt-sensitive crops; typically characterized by EC of the saturation extract (EC_e).

- **Soil-to-water ratio:** The ratio of soil mass to water volume used in pH and EC measurements (e.g., 1:1, 1:2, 1:5); must be reported alongside the result because pH and EC values differ between ratios.

4. Responsibilities

Role	Responsibility
Lab PI	Approve SOP, ensure training compliance
Lab Manager	Maintain meter and electrodes, stock reagents
Trained Personnel	Prepare extracts, measure and record results
New Students	Complete training before independent use

5. Safety and Hazards

Hazards

- **Chemical:** 0.01 M CaCl_2 is a mild irritant. pH buffer solutions and conductivity standards are low-hazard but should not contact eyes.
- **Physical:** No significant physical hazards beyond standard glassware handling.

5.1. Required PPE

- ☐ Safety glasses
- ☐ Lab coat
- ☐ Nitrile gloves

5.2. Emergency Procedures

For buffer or chemical splashes, flush with water. Refer to [SOP-L002 Laboratory Safety](#).

6. Equipment and Materials

6.1. Equipment

Item	Notes
pH/conductivity meter	Calibrated per SOP-L300
pH combination electrode	Glass bulb with refillable KCl junction preferred
Conductivity cell	With automatic temperature compensation
Analytical balance (0.01 g)	See SOP-L102

Item	Notes
Beakers (50–100 mL)	Clean; one per sample plus blanks
Graduated cylinder or dispenser	For volumetric delivery of water or CaCl_2
Glass stirring rods	One per sample or rinsed between samples
Timer	For equilibration period

6.2. Reagents

Reagent	Preparation / Notes
Deionized water (Type I or II)	From SOP-L11
0.01 M CaCl_2 solution	Dissolve 1.47 g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ in 1 L DI water
pH buffer solutions (4.01, 7.00, 10.01)	For pH meter calibration
Conductivity standard (1413 $\mu\text{S}/\text{cm}$)	For conductivity meter calibration

7. Procedure

7.1. Sample Preparation

1. Air-dry the soil at room temperature until constant mass (typically 24–48 hours)
2. Pass the dried soil through a 2 mm sieve. See [SOP-F400 Soil Sampling](#) for details on sieving and homogenization.
3. Store the sieved soil in a labeled bag or container at room temperature

7.2. Selecting the Extraction Ratio

Two standard soil-to-solution ratios are used. The choice depends on the project objectives and the need for comparability with published data:

Ratio	Method	When to Use
1:1	10 g soil : 10 mL water (or CaCl_2)	Most common in agronomic soil testing; closest to field conditions
1:5	10 g soil : 50 mL water (or CaCl_2)	Useful for saline soils, compost, or when more extract volume is needed for subsequent analyses

Note

Soil pH measured in 0.01 M CaCl_2 is typically 0.3–0.5 units lower than pH measured in DI water because the salt displaces H^+ and Al^{3+} from exchange sites. CaCl_2 pH is less sensitive to seasonal variation in soil salt content and is preferred for monitoring studies where consistency over time matters (Thomas, 1996). Record the extraction medium (water or CaCl_2) and ratio with every result.

7.3. Preparing the Soil Slurry (1:1 Method)

1. Weigh 10.0 g of air-dried, sieved soil into a clean beaker
2. Add 10 mL of DI water (for pH_{water} and EC) or 10 mL of 0.01 M CaCl_2 (for $\text{pH}_{\text{CaCl}_2}$)
3. Stir vigorously with a glass rod for 30 seconds
4. Allow to stand for 10 minutes
5. Stir briefly again before measurement

7.4. Preparing the Soil Extract (1:5 Method)

1. Weigh 10.0 g of air-dried, sieved soil into a clean beaker
2. Add 50 mL of DI water (or 50 mL of 0.01 M CaCl_2)
3. Stir vigorously for 30 seconds
4. Allow to stand for 30 minutes, stirring occasionally
5. For EC measurement on the 1:5 extract, allow the soil to settle and insert the conductivity cell into the clear supernatant. For pH, insert the electrode into the slurry while still partially suspended.

7.5. Measuring Electrical Conductivity

! Important

Always measure EC before pH on the same aliquot. The pH electrode's KCl reference junction leaks electrolyte into the sample and will artificially elevate the EC reading (APHA et al., 2012).

1. Calibrate the conductivity meter per [SOP-L300](#), Section 6.3
2. Rinse the conductivity cell with DI water and blot dry
3. Insert the cell into the supernatant (1:5 method) or into the settled portion of the slurry (1:1 method). Tap gently to dislodge air bubbles.
4. Allow the reading to stabilize with automatic temperature compensation active
5. Record the specific conductance ($\mu\text{S}/\text{cm}$ at 25 C), sample ID, and extraction ratio
6. Rinse the cell with DI water between samples

7.6. Measuring Soil pH

1. Calibrate the pH meter with a three-point calibration per [SOP-L300](#), Section 6.2
2. Rinse the pH electrode with DI water and blot gently
3. Insert the electrode into the slurry so that the glass bulb and reference junction are fully immersed. For the 1:1 method, the electrode should contact the settled soil.
4. Allow the reading to stabilize (typically 30–60 seconds; may take 2–3 minutes for poorly buffered soils)
5. Record the pH value, extraction medium (water or CaCl_2), ratio, and sample ID
6. Rinse the electrode with DI water between samples

7.7. Converting 1:5 EC to Estimated Saturated Paste EC (EC_e)

The saturated paste extract (EC_e) is the standard for soil salinity classification, but the 1:5 extract is quicker to prepare. An approximate conversion can be made using the following relationship, though the factor varies with texture (Rhoades, 1996):

$$EC_e \approx EC_{1:5} \times f$$

where f is an empirical factor:

Soil Texture	f (approximate)
Sand	6 – 8
Loam	8 – 10
Clay	10 – 13

Warning

These conversion factors are approximate and site-specific. For formal salinity classification (e.g., land-use planning, irrigation suitability), prepare an actual saturated paste extract per USDA Handbook 60.

8. Quality Control and Acceptance Criteria

8.1. Interpretation of Soil pH

pH Range	Classification	Agronomic Significance
Less than 4.5	Extremely acidic	Toxic Al^{3+} levels; few crops tolerate
4.5 – 5.5	Strongly acidic	Low P availability; Mo deficiency; lime recommended
5.5 – 6.5	Moderately acidic	Suitable for most crops; some nutrient limitations
6.5 – 7.5	Neutral	Optimal for most crops and nutrient availability
7.5 – 8.5	Moderately alkaline	Common in arid soils; Fe, Mn, Zn may be limiting
Greater than 8.5	Strongly alkaline	Possible sodicity; Na toxicity

8.2. Interpretation of Soil Salinity (EC_e)

EC_e (dS/m)	Classification	Plant Response
0 – 2	Non-saline	No yield reduction for most crops

EC _e (dS/m)	Classification	Plant Response
2 – 4	Slightly saline	Sensitive crops affected
4 – 8	Moderately saline	Many crops affected
8 – 16	Strongly saline	Only tolerant crops survive
Greater than 16	Very strongly saline	Few plants survive

8.3. Saline, Sodic, and Saline-Sodic Classification

Class	EC _e (dS/m)	SAR / ESP	pH
Normal	Less than 4	SAR less than 13 / ESP less than 15	Variable
Saline	4 or greater	SAR less than 13 / ESP less than 15	Usually less than 8.5
Sodic	Less than 4	SAR 13 or greater / ESP 15 or greater	Usually greater than 8.5
Saline-sodic	4 or greater	SAR 13 or greater / ESP 15 or greater	Variable

SAR = sodium adsorption ratio; ESP = exchangeable sodium percentage. Full SAR/ESP determination requires cation analysis beyond the scope of this SOP.

8.4. QC Requirements

- Calibrate the pH meter before each measurement session (three-point). Acceptable slope: 90–102% of theoretical.
- Calibrate the conductivity meter before each session
- Re-read pH 7.00 buffer after every 10 samples; recalibrate if drift exceeds +/- 0.05 pH units
- Re-read the conductivity standard after every 10 samples; recalibrate if drift exceeds +/- 5%
- Run a DI water blank and a laboratory reference soil (if available) with each batch
- Run duplicate measurements on at least 10% of samples. Acceptable precision: +/- 0.1 pH units and +/- 5% relative percent difference for EC.
- Record extraction medium, ratio, calibration data, and QC results in the lab notebook

9. Waste Disposal

Waste Type	Disposal Method
Soil slurry waste (non-hazardous)	Standard trash once settled
CaCl ₂ extract solutions	Drain with copious water (non-hazardous)
Used pH buffer solutions	Collect in waste container per SOP-L300
Used conductivity standard	Drain with copious water
DI water rinses	Drain

10. References

- Thomas, G.W. (1996). Soil pH and soil acidity. In: Sparks, D.L. et al. (Eds.), *Methods of Soil Analysis, Part 3: Chemical Methods*. SSSA Book Series No. 5. pp. 475–490.
- Rhoades, J.D. (1996). Salinity: Electrical conductivity and total dissolved solids. In: Sparks, D.L. et al. (Eds.), *Methods of Soil Analysis, Part 3: Chemical Methods*. SSSA Book Series No. 5. pp. 417–435.
- USDA. (1954). *Diagnosis and Improvement of Saline and Alkali Soils*. USDA Agriculture Handbook No. 60. U.S. Salinity Laboratory, Riverside, CA.
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Rhoades, J. D. (1996). Salinity: Electrical conductivity and total dissolved solids. In D. L. Sparks, A. L. Page, P. A. Helmke, & R. H. Loeppert (Eds.), *Methods of soil analysis, part 3: Chemical methods* (pp. 417–435). Soil Science Society of America.

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11. Training Record

Before measuring soil pH and EC independently, personnel must:

1. Read this SOP and [SOP-L300](#) in full
2. Complete [SOP-L002 Laboratory Safety](#) training
3. Demonstrate pH meter three-point calibration with acceptable slope
4. Demonstrate conductivity meter calibration
5. Prepare 1:1 and 1:5 extracts and measure a set of at least 5 practice soils under supervision with acceptable duplicate precision
6. Be signed off by the PI or lab manager

12. Appendix A: Example Calculation and Reporting

```
library(tidyverse)

# Example data entry
soil_data <- tibble(
  sample_id = c("PV-01", "PV-02", "PV-03", "PV-04", "PV-05"),
  pH_water_1_1 = c(6.82, 7.45, 5.91, 8.12, 7.03),
  pH_CaCl2_1_1 = c(6.48, 7.10, 5.55, 7.78, 6.68),
  EC_1_5_uS_cm = c(245, 1820, 85, 3450, 310),
```

```
texture = c("loam", "clay", "sand", "clay", "loam")
)

# Estimate EC_e from 1:5 EC using texture-based conversion factors
conversion <- c(sand = 7, loam = 9, clay = 11.5)

soil_data <- soil_data %>%
  mutate(
    EC_e_dS_m = (EC_1_5_uS_cm / 1000) * conversion[texture],
    salinity_class = case_when(
      EC_e_dS_m < 2 ~ "Non-saline",
      EC_e_dS_m < 4 ~ "Slightly saline",
      EC_e_dS_m < 8 ~ "Moderately saline",
      EC_e_dS_m < 16 ~ "Strongly saline",
      TRUE ~ "Very strongly saline"
    ),
    pH_class = case_when(
      pH_water_1_1 < 4.5 ~ "Extremely acidic",
      pH_water_1_1 < 5.5 ~ "Strongly acidic",
      pH_water_1_1 < 6.5 ~ "Moderately acidic",
      pH_water_1_1 < 7.5 ~ "Neutral",
      pH_water_1_1 < 8.5 ~ "Moderately alkaline",
      TRUE ~ "Strongly alkaline"
    )
  )

print(soil_data %>% select(sample_id, pH_water_1_1, pH_CaCl2_1_1,
                          EC_e_dS_m, salinity_class, pH_class))
```

13. Appendix B: Reagent Preparation

13.1. M CaCl₂ Solution

1. Weigh 1.47 g of CaCl₂·2H₂O (MW 147.01) on the analytical balance
2. Dissolve in approximately 800 mL of DI water in a 1 L volumetric flask
3. Bring to 1 L with DI water and mix thoroughly
4. Label with concentration, preparation date, and preparer's initials
5. Store at room temperature in a capped polyethylene or borosilicate bottle. Stable indefinitely.

14. Appendix C: Troubleshooting

Symptom	Probable Cause	Corrective Action
pH reading drifts continuously	Poorly buffered soil; electrode junction fouled	Allow longer equilibration (up to 5 min); clean electrode per SOP-L300
pH in CaCl ₂ higher than pH in water	Measurement error; contaminated CaCl ₂ solution	Verify CaCl ₂ concentration; recalibrate meter; re-measure
EC reading unexpectedly high	Fertilizer residue; saline soil; contaminated beaker	Verify with a blank; use acid-washed glassware (SOP-L101)
EC reading near zero	Electrode not fully immersed; air bubble in cell	Reposition cell; tap to dislodge bubbles
Large difference between 1:1 and 1:5 EC	Normal; dilution effect	Report both with the ratio clearly stated; convert to EC _e using appropriate factor
pH calibration slope below 90%	Aged electrode; dirty glass bulb	Soak in cleaning solution or 0.1 M HCl for 15–30 min; if slope does not recover, replace electrode