



Food and Agriculture
Organization of the
United Nations

Standard operating procedure for soil pH determination



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Required citation:

FAO. 2021. *Standard operating procedure for soil pH determination*. Rome.

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VERSION HISTORY

N°	Date	Description of the modification	Type of modification
01	11 February 2021	All comments by RESOLANs and reviewers to the draft SOP were addressed	Finalization of the SOP
02			
03			
04			

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1. Introduction to soil pH

Soil pH (which is an expedite measure of soil reaction) is a measure of the acidity or alkalinity in the soil. Mathematically, pH is the negative \log_{10} of the activity of hydrogen ions (H^+). Soil pH is important due to its influence on several soil factors that affect plant growth such as, the availability and dynamics of plant nutrients and toxicants as well as some biological processes and soil structure. It is also an important parameter for amelioration of problematic soils. The pH value has a significant impact on the redox processes in soils, influencing complexation, precipitation and dissolution reactions. pH determination is also an indispensable means for characterizing soil from the standpoint of nutrient availability and physical condition, structure, permeability, etc. The pH of the soil measured in either water, $CaCl_2$, or KCl systems indicates the degree of H^+ dissociation from cation exchange sites or through aluminum hydrolysis. Soil pH has a far reaching effect on nutrient availability and soil chemistry.

Soils are referred to as being acid, neutral, or alkaline, depending on their pH, with 7 being neutral, below 7 acidic and above 7 alkaline. The pH range normally found in soils varies from 3 to 9. As pH is measured in terms of hydrogen ion activity, pH is thus a measure of only the intensity of H^+ activity and not the amount of acidity present. The desirable soil pH range for optimum plant growth varies among crops. Generally, a soil pH between 6.0-7.5 is acceptable for most plants, as most nutrients are available in this pH range. However, some plants have soil pH requirements above or below this range. An acidic pH may cause higher mobility of toxic elements potentially leaching into ground water or taken up and accumulated in plants. Additionally, inhibited plant growth may be observed in low pH soils due to aluminum toxicity. In higher pH soils, phosphorus and most micronutrients may become less available. As the pH value of many soils correlates with base saturation, it may also be used in the field for preliminary classification purposes.

Soil pH is normally measured in a soil water suspension. However, the presence of soluble salts in a soil sample may affect pH, and for this reason, some prefer to measure it in a suspension of soil in a solution of 1 M ($mol.L^{-1}$) KCl or 0.01 M $CaCl_2$. The presence of salts in these solutions masks the effect of varying soluble salt concentrations in individual samples. The pH measured in 1 M KCl or 0.01 M $CaCl_2$ solution is typically lower than the pH of the same soil measured in water due to the higher concentration of H^+ in the resultant suspension from cation exchange phenomenon. When 1 M KCl is used, extensive ion exchange takes place by aluminium (Al^{3+}), that was on the exchange sites of the soil and is released, making the pH-KCl much lower than the pH- H_2O (up to 1 unit). Measurement in a soil that has been dried (then rewetted using distilled water) will be lower than that obtained when the soil is wet (in situ). When 0.01 M $CaCl_2$ is used, the resulting pH is usually lower than pH- H_2O but not as much as pH-KCl. In this case, giving a value similar to that of natural soil solutions (exceptions are beyond the scope of this SOP).

Measuring the pH of a soil in suspensions of; water, 0.01 M $CaCl_2$, and 1 M KCl provides comparison data useful in defining its character and activity in terms of soil colloids. pH- $CaCl_2$ approximates the pH of the soil solution under field moisture conditions and is minimally affected by the dissolution of soil salts. Thus, its comparison with pH- H_2O at the same soil:solution ratio

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would allow early detection of the presence of Na⁺ in the system (the difference between pH-H₂O and pH-CaCl₂ increases in the presence of Na⁺). On the other hand, the difference between pH-CaCl₂ and pH-KCl is greater when the soil exchangeable complex has a very low saturation.

2. Scope and field of application

This standard details three methods for pH determination, all involving the change in electrical potential of a glass calomel electrode using a pH/millivolt meter at a given temperature (25 °C).

- 1:2.5 (*m:v*) suspension of soil in water (pH-H₂O, Method A);
- 1:5 (*m:v*) suspension of soil in 1.0 M potassium chloride solution (KCl) (pH-KCl, Method B);
- 1:5 (*m:v*) suspension of soil in 0.01 M calcium chloride solution (CaCl₂) (pH-CaCl₂, Method C)

These methods are applicable to most soils used for agricultural purposes.

3. Principle

The soil pH is measured in terms of hydrogen ion concentration (more exactly the activity) of the soil-water or soil-salt suspension system, H₂O molecules dissociate into H⁺ and OH⁻ ions contribute only a small fraction to the solution pH. Under 'normal' conditions only one in 10 million molecules (10⁻⁷) is dissociated.

Chemically, pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity, αH⁺. This definition was adopted because ion selective electrodes used to measure pH respond to activity.

$$\text{pH} = -\log_{10} [\alpha\text{H}^+] = \log (1/[\alpha\text{H}^+])$$

A pH meter consists of a pair of electrodes, a glass electrode and a suitable reference electrode (calomel electrode or silver chloride electrode) connected to a meter capable of measuring small voltages- in the order of millivolts. The voltage (electrical potential) produced by the solution is measured and compared with the voltage of a known standard solution. The difference in voltage (the potential difference) between them is used to calculate the pH. As temperature affects chemical activity, most measurements of pH include a temperature correction to a standard temperature of 25 °C (77 °F). Such temperature correction can be incorporated into the instrument (automatic temperature compensation, ATP) by virtue of an inbuilt auto temperature probe or it can be done manually. Where ATP is incorporated, the probe must always be inserted together with the reference electrode in buffer solutions for calibration or in solutions being measured. In an aqueous solution at this temperature, the theoretical voltage produced across the pH sensitive glass membrane is 59.16 mV for every pH unit change. It should be noted that the reference electrode will not respond to pH or other solution changes. Therefore, the voltage at the membrane constitutes the output of the electrical system. In practice, the pH meter is calibrated (slope and offset values) by immersing its electrode(s) into at least 2 standard buffer solutions

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(test solutions of known pH value). The theoretical offset should be 0 mV at pH 7.00. Calibration is necessary to adjust the slope and offset of an electrode to their true values for measuring the system (Figure 1). The calibration curve is then used to correlate the measured mV values of the electrode to the pH value of the solution measured.

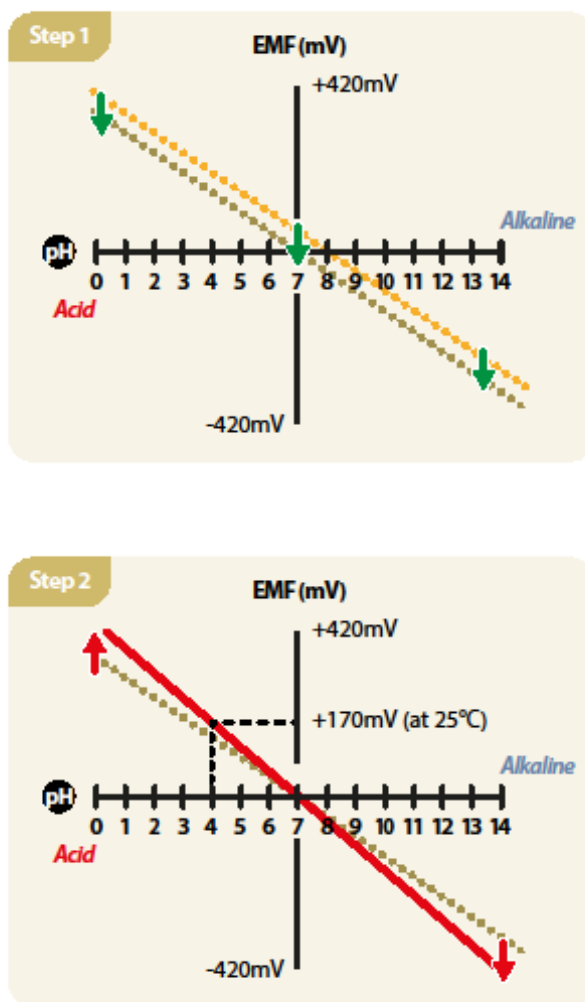


Figure 1. Step 1 is an adjustment of an offset by using pH buffer 7.0 and step 2 is the adjustment of the slope by using pH buffer 4, or 10, depending on the expected pH of the soil samples to be measured.

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4. Apparatus

- 4.1. Precision balance, with a weighing capacity suitable for the weight of the sample, with an readability of 0.01 g.
- 4.2. pH meter with a glass electrode and reference electrode, or a glass-calomel combination electrode with built-in temperature sensor or with a separate temperature probe for Automatic Temperature Compensation (ATC).
- 4.3. Pipette/dispenser 25 mL or 50 mL.
- 4.4. Beakers or polyethylene bottles (with lids, if shaking machine is to be used) 50-mL or 100-mL or 150-mL.
- 4.5. Glass rods or stirring sticks to match number of samples /stirring machine /shaking machine.
- 4.6. Thermometer or temperature probe, capable of measuring to the nearest 1 °C, complying with type C according to ISO 1770:1981 (Optional, required if ATC is not available in pH meter).
- 4.7. Wash bottle (for deionized/distilled water 5.1)

5. Materials

Use only reagents of recognized analytical grade. Depending on preferred choice of soil pH measurement, deionized/distilled water (5.1), Potassium Chloride solution (5.2) or Calcium Chloride solution (5.3), select any one of the three reagent preparation for Method A, Method B and Method C respectively for pH soil-water, pH soil-KCl and pH soil-CaCl₂.

- 5.1. Deionized water/distilled water, It should have a specific conductivity not higher than 0.2 mS/m at 25 °C and a pH greater than 5.6 (or grade 2 water or type II water according to ISO 3696 and ASTM D1193-06, respectively, if this is the quality of water produced in the laboratory).
- 5.2. Potassium chloride solution (KCl) 1.0 M
Dissolve 74.55 g potassium chloride (KCl) in approximately 800 mL of water (5.1) and make up to 1000 mL
- 5.3. Calcium chloride solution (CaCl₂) 0.01 M
Dissolve 1.47 g calcium chloride dihydrate (CaCl₂. 2H₂O) or 1.11 g calcium chloride (anhydrous) in approximately 800 mL of water (5.1) and make up to 1000 mL. This solution may be stored for several months in a refrigerator in a closed glass container.

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- 5.4. Traceable standard buffer solutions of pH 4.0, pH 7.0, and pH 10.0 or standard buffer solutions of known pH prepared in deionized/distilled water (5.1). (see Appendix I).

Buffer solutions should be handled meticulously as Good Laboratory Practice demands for standards or reference materials. They should be stored preferably in polythene vials/containers. They should not be stored for more than 6 months. The pH 10 buffer solution is notably sensitive to carbon dioxide from the atmosphere and may quickly deteriorate and become unreliable. For the same reason it is good practice not to return buffer solutions to the mother container despite the basic fact that buffer solutions are solutions that can resist changes in hydrogen ion concentration to an extent.

6. Health and safety

Safety glasses, gloves and lab coats must be worn when performing this analysis. The unknown potential hazards from the soil chemical and biological hazards as well as toxicities from chemicals used in pH determination should be kept in mind throughout the procedure. (Refer to the specific Material Safety Data Sheet (MSDS) for the hazardous properties of any chemicals or reagents utilized in this analysis). While buffers are not generally considered to contain hazardous material, because of acidity or alkalinity, repeated contact with the skin can cause dryness or cracks. Similarly, accidental contact with the eyes can lead to redness and or swelling. The wearing of a mask particularly during sample preparation should also be encouraged and the same on sample disposal and on cleaning.

7. Sample preparation

Soil samples should be air dried (or dried in a ventilated drying oven at a temperature below 40 °C) and ground to pass a 2 mm sieve (N° 10).

Ensure that the milling equipment, sieves and all the materials used do not introduce contamination to the samples.

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8. Procedure

8.1. Calibration of the pH meter

- 8.1.1. Allow the pH meter to warm up (in most cases 15-20 minutes will suffice).
- 8.1.2. Calibrate the pH meter according to the manufacturer's instructions.
- 8.1.3. Pour the buffer solutions into the beakers, appropriately labeled buffer 4.0, 7.0, and/or 10.0
- 8.1.4. Insert the electrode / electrode + ATC if applicable, into the beaker corresponding to pH 7.0. If necessary and possible, adjust the reading to the exact value of the buffer solution measured.
- 8.1.5. Rinse the electrode / electrode + ATC if applicable with water (5.1) and gently blot using soft, standard lab tissue paper (same applies for separate electrodes if not combined)
- 8.1.6. Proceed in the same way with pH 4.0 or 10.0 (depending on the expected pH value of the sample) as the pH meter should be checked against at least two buffers, one with a neutral pH (7.0) and the other should be chosen based on the expected range of pH values in the soil sample.

A pH meter with ATC reads the true temperature of the buffer and assigns the exact correct value. If an ATC is not available, the temperature of buffers and samples must be measured manually by using a temperature probe and entered into the pH meter before taking the pH measurements. Under such condition, it is strongly advised to bring the temperature of buffers and samples as close as possible to each other and manually set the pH meter temperature (by default 25 °C).

Generally, a slope between 95% and 105% and an offset between 0-30 mV is acceptable and the meter is then ready to test the samples. Calibration should be checked against a pH 6.86 (see Appendix I) buffer to ensure calibration is accurate.

Points to be noted

- a). If the pH meter is not functioning properly, ensure that all electrical connections are secure and that the electrode is not cracked, scratched, or clogged. To check the performance of an electrode, check the response in two standard pH reference solutions.
- b). Since pH measurements are affected by temperature, the temperature of the buffers and suspensions to be analyzed must be the same and must also ideally remain constant during the time of the calibration and measurements.

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c). If the electrode becomes sluggish, it can sometimes be rejuvenated by immersing it in a plastic beaker containing 20% solution of ammonium fluoride for approximately 10-30 sec. Then thoroughly wash the electrode and soak it in water (5.1). This treatment should not be repeated regularly because the glass is already very thin (Thomas, 1996).

d). When using refillable, combination electrodes (typically filled with a saturated KCl solution) be sure the electrode is properly filled as per the manufacturer's specification and that the electrode filling cap is open to the atmosphere during analysis. If the cap is closed during analysis or the electrolyte level is too low, a sluggish response or poor sensitivity may be observed.

e). The recommendation for short term and long term storage of electrode should be followed according to the manufacturer's instruction given in the operation manual.

f). It is deemed bad practice to use the electrode as a stirring rod. When stirring is necessary, the contents of the flask should be stirred with a suitable stir rod, not the electrode, as the tip is thin and easily damaged.

g). Wiping or rubbing an electrode with tissue can cause static electricity build up, removal of the hydration layer on the electrode bulb, or scratching of the electrode surface. If removal of liquid from electrode bulb is required, be sure to blot with lint-free paper towel. or to shake the electrode gently to remove excess moisture.

h). If using a battery powered pH meter, replace battery when the low battery indicator shows.

8.2. Method A: pH measurement in Soil-H₂O system

8.2.1. Weigh 10.0 g of soil sample into 50 or 100-mL beakers or polyethylene bottles (4.4) and add 25 mL of water (5.1) (soil to water ratio 1:2.5 w/v).

8.2.2. Shake the soil–water mixture thoroughly for 60 min. If a shaking machine (4.5) is used, stopper the polyethylene bottles (4.4) accordingly and if glass rods (4.5) are to be used, carefully stir or swirl the suspension intermittently and thoroughly until complete homogenization.

8.2.3. Let the mixture stand for 60 min.

8.2.4. Stir the suspension again with a stirring stick or stirring machine (4.5) for 10 seconds before taking the pH measurement.

8.2.5. Preferably, pH measurement should be performed at 25 °C. Place the electrode into the partially settled suspension to mitigate the suspension effect. Read the pH in the

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suspension when the pH value is stable and record results to 2 decimal places on an air dried soil basis.

In soils that are very high in organic matter content (peats) ratios of 1:5 or 1:10 may be necessary in order to obtain workable slurries (Blakemore *et al.*, 1987).

8.3. Method B: pH Measurement in Soil-KCl system

8.3.1. Weigh 10.0 g of soil sample into 100 or 150-mL polyethylene bottles (4.4), add 50 mL of potassium chloride solution (5.2) (soil to 1.0 M KCl ratio 1:5 w/v).

8.3.2. Shake the soil–KCl mixture thoroughly for 60 min. If a shaking machine (4.5) is used, stopper the polyethylene bottles (4.4) accordingly and if glass rods (4.5) are to be used, carefully stir or swirl the suspension intermittently and thoroughly until complete homogenization.

8.3.3. Let stand for 60 min.

8.3.4. Place the electrode into the unstirred supernatant.

8.3.5. Measure the pH in the supernatant at 25 °C when the pH value is stable, record results to 2 decimal places on an air dried soil basis.

8.4. Method C: pH Measurement in Soil-CaCl₂ system.

8.4.1. Weigh 10.0 g of soil sample into 100 or 150-mL polyethylene bottles (4.4), add 50 mL of calcium chloride solution (5.3) (soil to 0.01 M CaCl₂ ratio 1:5 w/v).

8.4.2. Shake the soil–CaCl₂ mixture thoroughly for 60 min. If a shaking machine (4.5) is used, stopper the polyethylene bottles (4.4) accordingly and if glass rods (4.5) are to be used, carefully stir or swirl the suspension intermittently and thoroughly until complete homogenization.

8.4.3. Let stand for 60 min.

8.4.4. Place the electrode into the unstirred supernatant.

8.4.5. Measure the pH in the supernatant at 25 °C when the pH value is stable, record results to 2 decimal places on an air dried soil basis

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Points to be noted

- a). The electrode should be rinsed with deionized/distilled water (5.1) and blotted with absorbent paper between measurements.
- b). The aqueous medium used to make the suspension, and the ratio used should always be indicated in the soil report.
- c). Calcareous soil samples or those with a high content of organic matter or salts, it is more difficult to reach an equilibrium pH value, therefore they should be left for a longer time before proceeding to their reading.
- d). If samples are stirred manually, separate glass rods one per each sample is required, otherwise with several intermittent shakings and subsequent rinsing the soil/solution ratio will be compromised, due to dilution effect.

9. Calculations

No calculation is needed for soil pH determination as values are directly read from the instrument

The test report should include:

- The reference to this SOP;
- The aqueous medium used to make the suspension (pH in H₂O, pH in KCl solution or pH in CaCl₂ solution);
- The result of the pH determination, with 1 decimal place;

10. Quality Assurance/Quality Control

10.1. Accuracy test

10.1.1 Participation in Inter-laboratory Proficiency Test (PT) at least once a year. The PT z-score should be less than 2. If not, identify root cause, develop corrective and preventive actions.

10.1.2. When available, the use of Certified Reference Materials (CRM) is advisable. Perform replicate analyses of the CRMs (if possible), determine the mean and the standard deviation using a series of replicate tests. Compare results with CRM certified values that are ideally traceable to international standards. Target

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values are considered acceptable when within 95% of the reported confidence interval.

10.2. Precision test

Perform replicate analysis every 10-20 sample in each batch test. Replicate results should fall within 0.1 pH unit. (Rayment & Lyons, 2011).

10.3. Control chart

Analyze at least one duplicate check sample or CRM or Internal Reference Material (IRM) for every batch analysis. Plot the results in a quality Control chart (QC chart). Monitor for Out of Warning Signals ($\pm 2sd$). If Out of Warning Signal/Trend is observed, identify root cause, develop corrective and preventive actions (Van Reeuwijk & Houba 1998; ISO 7870-2:2013)

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11. References

- AOAC.** 1998. *AOAC Peer Verified Methods Program. Manual on Policies and Procedures.* AOAC International Gathersburg. MD, USA. 35 pp
- ASTM D1193–06:** *Standard specification for reagent water.* ASTM International, West Conshohocken, PA. 2006
- ASTM.** D4972-19. *Standard Test Method for pH of Soils.* ASTM International, West Conshohocken, PA. 2019
- Blakemore, L.C., Searle, P.L. & Daly, B.K.** 1987. *Methods for Chemical Analysis of Soils.* NZ Soil Bureau Scientific Report 80. Department of Scientific and Industrial Research. Lower Hutt, New Zealand.
- ISO 1770:1981.** *Solid-stem general purpose thermometers.* 1981
- ISO 3696:1987.** *Water for analytical laboratory use — Specification and test methods.* 1987
- ISO 7870-2:2013.** *Control charts — Part 2: Shewhart control charts.* 2013
- ISO 10390:2005.** *Soil quality – Determination of pH.* 2005
- Peech, M.** 1965. Hydrogen - Ion Activity, In C.A. Black (Ed). 1965. *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties, No 9 Agronomy.* American Society of Agronomy, Inc., Madison, Wisconsin, USA. pp. 914 - 926.
- Rayment, G.E. & Lyons, D.J.** 2011. *Soil Chemical Methods – Australasia.* 495+20 pp. CSIRO Publishing, Melbourne.
- Thomas, G.W.** 1996. Soil pH and Soil Acidity. In D.L. Sparks *et al.* (Eds), *Methods of Soil Analysis: Part 3, Chemical Methods.* Soil Science Society of America, Inc., American Society of Agronomy, Inc., Madison, Wisconsin, USA: pp. 475 – 490. *SSSA Book Series 5.*
- Van Reeuwijk LP and V.J.G. Houba VJG,** 1998. Guidelines for Quality Management in Soil and Plant Laboratories. Chapter 8 Internal Quality Control of Data. Food and Agriculture Organization of the United Nations, Rome.
<http://www.fao.org/3/w7295e/w7295e0a.htm#8> internal quality control of data

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12. Appendix I – Preparation of pH buffer solutions

Commercially available buffer solutions are adequate for use as calibration standards. Alternatively they may be prepared as follows (Rayment and Lyons, 2011; ASTM, 4972-19).

1. Buffer solution, pH 4.00 at 15 to 30 °C.

Dry potassium hydrogen phthalate ($\text{KHC}_8\text{H}_4\text{O}_4$) for 2 h at 110 °C, allow to cool in a desiccator. After drying, dissolve 10.12 g $\text{KHC}_8\text{H}_4\text{O}_4$ in water (5.1) and dilute to 1000 mL. As a preservative, add 1.0 mL of chloroform or a crystal (about 10 mm in diameter) of thymol per liter of buffer solution.

2. Buffer solution, pH 6.86 at 25 °C.

Dry the two phosphate salts, KH_2PO_4 and Na_2HPO_4 for 2 h. at 110-130 °C, allow to cool in a desiccator. After drying, dissolve 3.387 g. of KH_2PO_4 and 3.533 g. of Na_2HPO_4 in water (5.1) and dilute to 1000 mL. As a preservative add 1.0 mL of chloroform or a crystal (about 10 mm in diameter) of thymol per liter of the buffer solution. This solution has pH 6.90 at 15 °C, pH 6.88 at 20 °C, and 6.85 at 30 °C.

3. Buffer solution, pH 7.0 at 25 °C

Preference is to use a purchased solution. Alternatively dissolve 2.721 g KH_2PO_4 and 3.904 g of Na_2HPO_4 (previously dried at 130 °C for 2 h) in water (5.1) and dilute to 1000 mL. As a preservative add 1.0 mL of chloroform or a crystal (about 10 mm in diameter) of thymol per liter of the buffer solution. This solution has pH 7.05 at 15 °C, pH 7.02 at 20 °C, and 6.99 at 30 °C.

4. Buffer solution, pH 10.00 at 30 °C.

Dry the two salts, NaHCO_3 and Na_2CO_3 for 2 h at 130 °C, allow to cool in a desiccator. After drying, dissolve 2.10 g. of NaHCO_3 and 2.65 g. of Na_2CO_3 in water (5.1) and dilute to 1000 mL. This solution has pH 10.12 at 15 °C, pH 10.06 at 20 °C, and 9.96 at 30 °C

Buffer solutions can be stored with protection from CO_2 uptake, contamination and evaporation for up to one month.

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13. Appendix II - Acknowledgments

GLOSOLAN thanks Ms. Nopmanee Suvannang, GLOSOLAN Chair for leading the harmonization of this SOP and the following members of the working group that served as leaders for their regions and contributed to the writing of this SOP: Mr. Sanjay Srivastava from India, Ms. Maria Cristina Suarez Marte from the Dominican Republic, Mr. Rob de Hayr from Australia, Mr. Lauris Leitans from Latvia, Ms. Elena Shamrikova from the Russian Federation, and Mr. Takesure Tendayi from Zimbabwe. GLOSOLAN also thanks the experts that served in the Review Panel and looked after the finalization of the SOP, all laboratories that provided inputs for the harmonization of this method, all experts that technically reviewed this SOP, and Mr. Christopher Lee from the Kellogg Soil Survey Laboratory, USDA-NRCS-NSSC, United States of America for proofreading it.

14. Appendix III - List of authors

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15. Appendix IV - Contributing laboratories

GLOSOLAN thanks the following laboratories for completing the GLOSOLAN form on the method and providing information on their standard operating procedure for the soil pH determination method. This information was used as a baseline for the global harmonization.

From the Asian region:

- Bangladesh Soil Resource Development Institute, **Bangladesh**
- Soil & Plant Analytical Laboratory, **Bhutan**
- Royal University of Agriculture, **Cambodia**
- ICAR-Indian Institute of Soil Science, **India**
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), **India**
- Indonesian Soil Research Institute, **Indonesia**
- Institute for Agro-Environmental Sciences, NARO (NIAES), **Japan**
- Department of Agricultural Land Management, **Lao People's Democratic Republic**
- Mongolian University of Life Sciences, **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**
- Horticultural Crops Research and Development Institute, Department of Agriculture, **Sri Lanka**
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From the Pacific region:

- Department of Environment and Science, Science Division, Chemistry Centre, **Australia**
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- Sugar Research Institute of Fiji, **Fiji**
- Laboratoire des Moyens Analytiques Nouméa, **New Caledonia**
- University of the South Pacific, Aalfua Campus, **Samoa**

From the Near East and North African region:

- Directorate of Plant Wealth, Ministry of Works & Municipalities & Urban Planning, **Bahrain**
- KIMIA AB Environmental and Agricultural Consulting Laboratory, **Islamic Republic of Iran**
- Soil and Water Institute, **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**
- Agricultural Research Institute, **Lebanon**
- Land and Water Research Center, **Sudan**
- General Commission for Scientific Agricultural Research, **Syrian Arab Republic**

From the African region:

- Department of Agricultural Research, **Botswana**
- Institute of Agricultural Research for Development, **Cameroon**
- Institut National pour l'Etude et la Recherche Agronomiques (INERA), **Democratic Republic of the Congo**
- Institut de Recherches Agronomique et Forestière - Département Agronomie Générale, **Gabon**
- Laboratory Analytical Service-Accra Centre (CSIR-SRI), **Ghana**
- Soil Research Institute Analytical Services Laboratory, CSIR-Soil Research Institute, **Ghana**
- Environmental Analytical Laboratory, CSIR-SARI, **Ghana**
- Laboratoire National d'Analyse de Sols, des Engrais, des Végétaux et Eaux du Services National des Sols, **République de Guinée**
- Institut de Recherche Agronomique de Guinée (IRAG), **Guinea Bissau**
- Kenya Agricultural & Livestock Research Organization (KALRO), **Kenya**
- Laboratoire des Radiosotopes, **Madagascar**
- FES – Agrilab, **Malawi**
- Institut National de la Recherche Agronomique du Niger, **Niger**
- National Soil Testing Laboratory Complex, Kaduna, **Nigeria**
- Laboratoire des Sols, Eau, Végétaux et Engrais, Institut Togolais de Recherche Agronomique, **Togo**
- Zambia Agriculture Research Institute, **Zambia**
- University of Zambia, **Zambia**
- Zimbabwe Sugar Association Experiment Station, **Zimbabwe**
- Fertilizers, Seed and Grain, **Zimbabwe**

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From the European region:

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- Austrian Centre for Forests, **Austria**
- REQUASUD, **Belgium**
- Forest Research Institute – BAS, **Bulgaria**
- University of Zagreb, Faculty of Agriculture, Department of General Agronomy, **Croatia**
- University of Zagreb, Faculty of Agriculture, Soil Science Department, **Croatia**
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- Natural Resources Institute Finland, **Finland**
- Laboratoire d'Analyses des Sols, INRAE, **France**
- Laboratory of Soil Monitoring, Thuenen- Institute, **Germany**
- Food Chain Safety Centre Non-profit Ltd., **Hungary**
- Mediterranea University AGRARIA Department, **Italy**
- Latvian State Forest Research Institute "Silava", **Latvia**
- State Plant Protection Service, Agrochemical Laboratory, **Latvia**
- AgroCares Golden Standard Laboratory (Care4Agro BV), **Netherlands**
- Chemisch Biologisch Laboratorium Bodem, Wageningen University, **Netherlands**
- University "St. Kliment Ohridski"-Bitola Scientific Tobacco Institute - Prilep", **Republic of North Macedonia**
- Laboratório de Solos e Fertilidade da Escola Superior Agrária de Castelo Branco (IPCB/ESACB), **Portugal**
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- Lab. of Agricultural Chemistry Rebelo da Silva / Lab. Químico Agrícola Rebelo da Silva (INIAV/SAFSV/LQARS), Portuguese National Institute for Agrarian and Veterinary Research / Instituto Nacional de Investigação Agrária e Veterinária, I.P., **Portugal**
- National Research and Development Institute for Soil Science Agrochemistry and Environment – Department for physical and chemical analysis, **Romania**
- Kmetijski inštitut Slovenije/Agricultural Institute of Slovenia, **Slovenia**
- Rothamsted Research, **United Kingdom of Great Britain and Northern Ireland**

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From the Eurasian region:

- Scientific-Research Centre of Agriculture, **Georgia**
- Institute of Biology of Komi Science Centre of the Ural Branch of the Russian Academy of Sciences (IB Komi SC UB RAS), **Russian Federation**
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- Instituto de Suelos Camagüey, **Cuba**
- Laboratorio de Suelos y Tejidos Vegetales, Universidad de Concepción, **Chile**
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- Agencia de Regulación y Control Fito y Zoonosanitario. AGROCALIDAD, **Ecuador**
- Laboratorio de Suelos del CENTA, **El Salvador**
- Colegio de Postgraduados (LABFER-CPM), **Mexico**
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