28. Soil pH

Objectives

Determine the pH of three different samples of soil. Through this investigation, students:

- Explain how the pH scale is used to measure the acidity and alkalinity of a soil sample
- Discuss why pH is one indicator of soil health

Procedural Overview

Students gain experience conducting the following procedures:

- Collecting soil samples and preparing them for measuring the soil pH
- Using a pH sensor to measure the pH of soil samples
- Drawing a bar graph that represents the soil pH at each soil sample location

Time Requirement

♦ Preparation time	10 minutes
♦ Pre-lab discussion and activity	20 minutes
♦ Lab activity	90 minutes (45 minutes for each part)[1]

[1]For ideas on how to perform this lab in a 45 minute class period refer to the Lab Preparation section.

Materials and Equipment

For each student or group:

- Data collection system
- pH sensor
- Beaker (2), 50-mL
- Beaker (3), 250-mL
- Graduated cylinder, 100-mL
- Stirring rod
- Wash bottle filled with distilled water
- Digging tool
- Plastic bag (3), sealable, small
- Buffer solution, pH 4, 25 mL
- Buffer solution, pH 10, 25 mL
- Distilled water, 400 mL
- Permanent marker
- Paper towels
- Waste container
- Soil sample (3)[1]

[1]In Part 1, students go outside and collect these three soil samples. See the Related Labs in This Guide section for additional labs that require soil samples.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Basic components of soil
- Plants absorb their nutrients from the soil

Related Labs in This Guide

Labs conceptually related to this one include:

- pH of Household Chemicals
- Air Pollution and Acid Rain

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them (identified by the number following the symbol: "") are on the storage device that accompanies this manual. Choose the file that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system (1.2)
- Connecting a sensor to the data collection system (2.1)
- Calibrating the pH sensor (3.6)
- Monitoring live data (6.1)
- Displaying data in a digits display (7.3.1)

Background

Soil Components

Soil consists of minerals, water, air, and organic matter modified by weather, wind, water, and organisms. Minerals, the main component of soil, anchor plants and provide essential nutrients. The organic fraction of soils derives from dead leaves and branches, animal dung, remains of plants and animals, and microorganisms. Soils form from parent rock materials that are slowly broken down by biological, chemical, and physical weathering.

Soil formation continues as parent rock materials beneath already formed soil break down to add new soil. Regional and local landscapes influence soil types and soil formation. For example, steep slopes often have little or no soil cover because the soil and rock are constantly being moved by gravity. During decomposition, which is part of the nutrient cycle, bacteria and fungi decompose large organic molecules and convert them to small inorganic molecules including

carbon dioxide, water, and nutrient minerals. Continued weathering of parent rock materials replaces some nutrient minerals lost by erosion or agriculture.

Soil pH

Most plants thrive in a narrow range of soil pH conditions. Deviating from that range can dissolve potentially toxic materials from rocks and compromise soil health, leading to a decline in plant growth. Soil pH affects plant growth because it affects the way plants absorb nutrients from the soil. This has a direct implication for agricultural crops, thus pH has become an invaluable tool for measuring soil fitness.

The pH range that crops can tolerate varies. For instance, a pH down to 5.5 for corn, cucumbers or cotton may be acceptable, but for beans, lettuce, or onions the low end of the tolerable pH range is 6.0. Because of the logarithmic pH scale, 5.5 is five times more acidic than 6.0. Similarly, a pH up to 7.0 works for cabbage, carrots, or spinach, but for peanuts, peppers, or strawberries the high end of the tolerable pH range is about 6.5. While a crop like alfalfa can tolerate a pH range between 5.2 and 7.8, a staple like potatoes only tolerates a range from 5.0 to 5.25.

Soil pH depends upon the chemical nature of the parent material, the indigenous plants, the agricultural history, and management practices (such as fertilizing and liming).

Acidic Soil

Problems arise when soils become too acidic. On the pH scale, any pH value less than 7 is considered acidic. A soil is considered too acidic when the pH of the soil is less than the lowest pH value in the acceptable range for a given plant. Acidic soil results from both natural and manmade events such as the use of some fertilizers, the removal of calcium by plants, the addition of carbon dioxide during soil respiration, and acid rain.

Symptoms of acidic soil include stunted plants, deformed young leaves, yellowed leaves, weak and stubby roots (instead of long and drought resistant), and poor crop yields.

Alkaline Soil

Soil that is too alkaline also causes problems. On the pH scale, any pH value greater than 7 is considered alkaline. A soil is considered too alkaline when the pH of the soil is higher than the highest pH value in the acceptable range for a given plant. Alkaline soil is mainly a result of the parent material of the soil (such as limestone). The main manmade cause of alkaline soil is through irrigation, especially with water that contains sodium bicarbonate. Symptoms of high alkalinity are generally associated with nutrient deficiencies.

Pre-Lab Discussion and Activity

Materials and Equipment for Pre-Lab Demonstration:

- Data collection system
- pH sensor
- Dirt sample in a clear container (2 different soils)
- Small containers (2), one of water, one empty of all but air
- Small rock samples, such as gravel or pulverized rock
- Organic matter (such as leaves and sticks)
- Living organisms such as earwigs, sow bugs, earthworms or any fungi

♦ Wash bottle filled with distilled water

Composition of Soil

Show the students a sample of soil in a clear container and guide the students in a discussion about the components of soil. Each time the students mention a component of soil provide a sample of that component isolated from the others.

1. What is soil made up of?

Soil is made up of rocks (minerals) that have been broken into small pieces, organic matter, air, water, and living organisms. (Provide samples of all as they are mentioned by students.)

2. Why does soil look so different in different locations? Are all soils made up of these same components?

Soils look different because they are made up of different types of rock and minerals (different parent material) and because they have varying amounts of soil components. Some soils may have lots of organic matter while other soils have less organic matter.

3. Why is the composition of soils important for plants?

Plants absorb all the nutrients they need to grow from soil. In order for a plant to be healthy it needs soil that can meet its needs.

Soil Health

Engage the students in a discussion about soil health by having the students predict the relative health of the two soils provided.

4. What in your opinion makes a soil "healthy"?

Accept all answers and make a list of their criteria.

5. What soil do you think is healthier?

Students should predict what soil is healthier and give their reasoning.

6. What characteristics of the soil can be measured to determine its health? Why?

Soil moisture, soil salinity, nutrients levels, and soil pH are among the characteristics that can be used to assess the health of a soil. These are important because they affect the way plants absorb the nutrients they need to grow.

7. How does the type of plant being grown relate to the "health" of a soil sample?

Different plants require different conditions in order to grow. Thus soil that is healthy for one type of plant may be unhealthy for another type of plant.

Soil pH

In this lab students will determine the pH of three soil samples. Guide the students in a discussion of pH, the pH scale, and demonstrate the use of the pH sensor.

8. What is soil pH?

Soil pH is a measure of the acidity and alkalinity of a soil sample.

9. What is the pH scale and what does it mean?

The pH scale is a numerical scale between 0 and 14 that compare the acidity and alkalinity of aqueous solutions. Substances with a pH of 7 are considered neutral, a pH of less than 7 is acidic, and a pH greater than 7 is alkaline.

10. The pH scale is a logarithmic scale. What does this mean?

A logarithmic scale is based on multiplication rather than addition. In a typical linear scale the difference between each point on the scale increases by the same amount (typically 1). So on a linear scale the difference between 1 and 2 is one and the difference between 1 and 3 is two (one plus one). In a logarithmic scale the difference between 1 and 2 is 10 and the difference between 1 and 3 is 100 (10 times 10). So a pH of 4 is 100 times more acidic than a pH of 6.

11. How can the pH of a soil sample be determined?

The pH of soil can be determined by mixing a soil sample with water and then measuring the pH of the water using a pH sensor.

12. How do you think the pH of these two soil samples compare?

Students will make their predictions.

Demonstrate the use of the pH sensor by testing the pH of the two soil samples. Demonstrate thorough mixing of the soil solutions: stir vigorously for 2 minutes; allow the mixture to sit for 5 minutes. Clean sensor with the distilled water between each test. Compare the results with the students' predictions.

Lab Preparation

Although this activity requires no specific lab preparation, allow 10 minutes to assemble the equipment needed to conduct the lab.

Teacher Tip: To save time, there are several ways you can have the students perform this lab:

- Collect the soil samples (Part 1) for the students ahead of time and have the students use these samples to complete Part 2 of the lab.
- Have the students collect the soil samples (Part 1) as homework and then have the students use the soil samples to complete Part 2 of the lab.
- Have the students collect the soil samples (Part 1) in one class period and then measure the pH (Part 2) in the next class period.
- Have the students collect extra soil and then save the soil to be used in the two additional labs that require soil samples (see the Related Labs in This Guide section).

Teacher Tip: Students need to obtain permission before collecting soil samples from private property.

Safety

Add these important safety precautions to your normal laboratory procedures:

- To avoid health risks students should *not* collect soil samples in areas high in animal wastes.
- Students should avoid collecting samples at road cuts along busy streets.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Remove any rocks, sticks, or foreign objects from the soil samples and crush the soil into small, uniform pieces.	Obtain three different soil samples and describe the environment each soil sample was taken from.	Determine the pH of the remaining two samples. Be sure to clean the sensor between samples.	Combine 60 mL of distilled water with 60 mL of soil and mix thoroughly. Repeat this step for the other two soil samples.	Determine the pH of the first soil-water mixture.

Procedure with Inquiry

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: Students use the following technical procedures in this activity. The instructions for them (identified by the number following the symbol: "") are on the storage device that accompanies this manual. Choose the file that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

Part 1 – Obtaining samples and initial observations

1. ☐ Look around the area and pick out three locations from which to collect soil samples. Select three areas that you think will exhibit a wide variety of pH. Record the selected areas in Table 1.

Table 1: Detailed observations of soil sample locations

Soil Sample	Soil Sample Location	Observations
1	PASCO parking lot	The soil is dry with minimal plant life. The nearby area contains scattered weeds.
2	Duck pond	Moist, lots of foot traffic The nearby area contains grass.
3	Next to a driveway	Moist, dark brown The nearby area contains shrubbery and small plants along the edge of the pavement and grass.

2. ☐ Why do you think these locations will have different pH readings?

The PASCO parking lot, the duck pond, and next to a driveway will have different pH readings because the soil looks different and there are different plants in each area.

3. ☐ Collect a soil sample from the first site using the following technique:

a. Clean the digging tool.

b. Clear away leaves and any other debris.

c. With the digging tool, loosen the soil as deep as eight centimeters and dig up some of this loosened soil.

d. Fill the plastic bag half-full with soil.

e. Seal the bag to preserve moisture.

f. Label the sample; for example, "Vacant lot", or "Hiking trail".

4. ☐ Record your observations about the location of soil sample 1. Your observations should include the following:

- The appearance of the soil and soil composition, including conditions such as arid or humid
- The appearance and types of plants and other organisms
- Animal tracks and the appearance of animals
- The terrain, holes in the ground, and the geological features of rocks
- Nearby buildings and whether nearby roads are asphalt, cement, gravel, or dirt
- Anything unusual about the area

5. ☐ Collect soil samples from the remaining two locations using the same technique described above and record your observations of each location in Table 1.

6. ☐ Why is it necessary to clean the digging tool before collecting each soil sample?

Cleaning the digging tool is necessary to prevent contamination from soil in one location to soil in another location.

Part 2 – Measuring the pH of the samples

Set Up

7. ☐ Start a new experiment on the data collection system. (1.2)

8. ☐ Connect a pH sensor to the data collection system.. (2.1)

9. ☐ Display pH in a digits display. (7.3.1.)

10. ☐ Place 25 mL of pH 4 buffer solution in a 50-mL beaker and 25 mL of pH 10 buffer solution in a second 50-mL beaker. Use these solutions to calibrate the pH sensor. (3.6)

11. ☐ Label a 250-mLbeaker for each soil sample as you did with the sample bags.

12. ☐ Complete following steps for each soil sample:

- **a.** Remove any rocks, sticks, or foreign objects from the soil.
- **b.** Leaving the soil sample inside the plastic bag, crush the soil using with a clean digging tool.
- **c.** Mix the crushed particulates thoroughly.
- **d.** Use a clean 100-mL graduated cylinder to measure 60 mL of the soil sample.
- **e.** Place the 60 mL of soil in the appropriately labeled beaker.
- **f.** Add 60 mL of distilled water to the soil.
- **g.** Use a stirring rod to mix the soil and water vigorously for 2 minutes.
- **h.** Allow the soil-water mixture to sit for at least 5 minutes.
- **i.** Clean the graduated cylinder and stirring rod.

13. ☐ Why do you need to crush the soil?

The soil needs to be pulverized to increase the surface area that is available, so when water is added, a representative sample of the minerals in the soil becomes dissolved.

14. ☐ Why are you adding water to the sample?

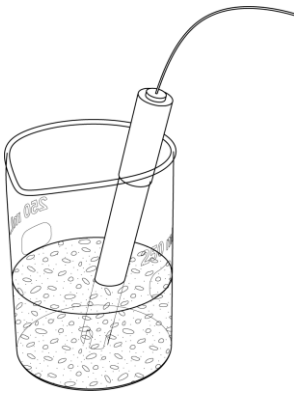
Measuring pH cannot be done with solids. Generally, water must be added to liberate the ions for measurement.

15. ☐ What is the independent variable and the dependent variable in this experiment?

The independent variable is the location of the soil collected. The dependent variable is the pH of the soil.

Collect Data

16. ☐ Rinse the pH sensor with distilled water.



17. ☐ Why is the pH sensor rinsed with distilled water before testing each sample?

Distilled water is used to prevent cross contamination from the other samples.

18. ☐ Place the pH sensor into the first soil sample.

19. ☐ Monitor live pH data in a digits display. ◆(6.1)

20. ☐ Stir the mixture gently with the pH sensor until the reading stabilizes.

21. ☐ Record the soil location and pH in Table 2.

Table 2: Stabilized pH readings for soil samples

Soil Sample	Soil Sample Location	pH
1	PASCO parking lot	6.7
2	Duck pond	6.4
3	Next to a driveway	7.0

22. ☐ Remove the pH sensor from the beaker and wash it thoroughly with distilled water.

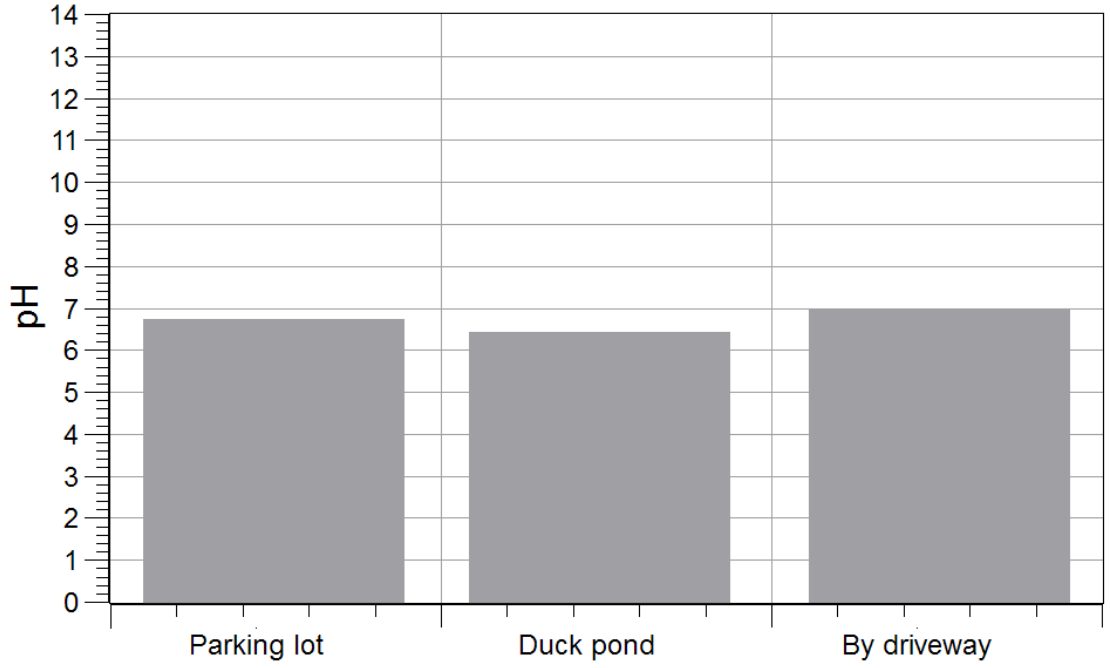
23. ☐ Rinse the pH sensor with distilled water, then repeat the Collect Data steps for the other two soil samples. Record the results in Table 2.

24. ☐ Clean up according to your teacher's instructions.

Data Analysis

1. ☐ Draw a bar graph that represents the pH recorded at each location. Label the axes as well as the overall graph.

Soil pH at Different Locations



Analysis Questions

1. What factors (variables) did you attempt to control in the three trials?

The factors that were controlled were method of soil collection, method of soil preparation, amount of soil used; type of water used; amount of water used; instrumentation variables (since the same instrument was used for all measurements and the measurement procedure was the same for all measurements; temperature during measurement.

2. List the soil location in order from most acidic to most alkaline.

Students' answers will vary. In this sample, the duck pond soil was the most acidic, then PASCO parking lot soil, and the most alkaline was the soil that was collected next to the driveway.

3. Which soil sample was the closest to being neutral? How do you know?

Students' answers will vary. The soil collected from beside the driveway was neutral because it had a pH of 7 which is considered neutral.

4. Based on the pH values measured, would you consider the soils you tested to be healthy? Explain.

All three of the soils tested were found to have pH values close to neutral (6.4 to 7), which means that based on pH the soils were all healthy and would support the nutrient needs of some plants.

Synthesis Questions

Use available resources to help you answer the following questions.

1. Which of the soil samples might be able to effectively neutralize acid rain? Explain why.

Acid rain would be neutralized by alkaline soil. None of the soils sampled were alkaline so these locations would not neutralize acid rain very well.

2. How can you assess the overall quality of a soil sample?

The overall quality of a soil sample can be assessed by determining the pH of the soil, the nutrient content of the soil, soil moisture, and soil salinity. To truly know the health of a soil all of these components need to be measured.

3. What is the pH scale and what does it mean if my soil has a pH of 4.2?

The pH scale is a quantitative scale between 0 and 14 that measures of the acidity and alkalinity of an aqueous solution. A pH of 4.2 means that the soil is very acidic and many plants would not thrive in these soil conditions. The soil would need to be treated in order to make the soil conditions more conducive to plant growth.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. What does pH measure?

A. The acidity and alkalinity of soil
B. The water content of soil
C. The salt content of soil
D. The particle size of soil
E. All of the above

2. A soil with a pH of 9.6 is considered to be _____.

A. Acidic
B. Alkaline
C. Neutral
D. Moist
E. Salty

3. A soil pH of _____ means that the soil is neutral.

A. 3
B. 5
C. **7**
D. 10
E. 12

4. What characteristics should be assessed to determine the health of soil?

A. pH
B. Salinity
C. Nutrient content
D. Moisture levels
E. **All of the above**

5. How can the pH of soil be determined?

A. A pH sensor can be inserted directly into the ground to measure the pH.
B. **A pH sensor can be inserted into a solution of soil and water.**
C. A thermometer can be inserted directly into the ground to measure the pH of the soil.
D. Soil pH can be determined by rubbing the soil between your fingers.
E. All of the above are correct ways to measure pH.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. **Soil** consists of minerals, water, air and **organic** matter. The **mineral** portion of soils is the main component, providing anchorage and essential nutrients for plants. The minerals in soil come from **parent** rock materials that are slowly broken down by biological, chemical, and physical weathering processes in a continuous process that involves interactions between Earth's spheres. The **organic** fraction of soils is derived from dead leaves and branches, animal dung, remains of plants and animals, and microorganisms. Different types of soil exist and some are **healthy** and promote plant growth, while other types of soil hinder plant growth.

2. Soil pH affects a plants ability to absorb **nutrients**. Most plants thrive in a **narrow** range of soil pH conditions. This means that slight changes in **pH** can have serious affects on plant life. Soil pH can be determined by collecting a soil sample, **crushing** it, and mixing it with **water**. A pH sensor is placed in the soil-water mixture and the pH is measured. In general, neutral soils have a pH near **seven**, while acid soils have a pH **less** than seven, and **alkaline** soils have a pH greater than seven. However, we say that a soil will be too **acidic** for a given plant if its pH is

lower than the value known to be acceptable for that type of plant, even if that value is above 7.0. Soil pH is just one of several factors that can be used to assess the **health** of soil.

Extended Inquiry Suggestions

Can certain types of soils neutralize acid rain? Explain why or why not and then design an experiment to determine the answer.

How does soil type (sandy, loam, & clay) affect a soils pH?

How does soil pH affect the growth rate of plants?

How do famers adjust the pH of their soil for different crops?

What affect does fertilizer have on the pH of soil?