**Soil pH**

**Topics:** Soil Composition, Biogeochemical Cycles

**Length:** 60-70 Minutes

**Grade Level:** 9-12

**Summary:** Students will explore what affects soil pH and why soil pH is important to plant growth in their school garden. After an introduction to acid-base relationships, students will collect soil samples from the garden and measure the pH. Students will also examine the effect of different pH on plant growth using plant cuttings from the garden and various acid or base solutions in the classroom.

**Research Question:** How does pH vary different soils? How does pH affect plant growth?

**Pre-Lab (10-15 min)**

1. Review the concept of pH and acids/bases with your students. This introduction will vary depending on when during a unit you place this lab. ***This introduction should be completed before or concurrently with the pre-lab.***
2. Make sure that your students have a working understanding and definition of the following vocabulary words: pH scale, acid, base, neutral, and alkaline. ***Students will record their definitions during the pre-lab.***
3. Frame the lab using the problem that students must investigate the pH of the school garden and determine if it is suitable for growing plants. ***This will be more engaging if the students have spent time in the garden before.***  An alternative framing issue is that of Acid Rain, which impacts soil pH and plant growth across the Eastern Seaboard.
4. Soil pH influences plant growth through a series of mechanisms. Decide which of these mechanisms to share based on the prior understanding and comprehension of your students. ***Students will record selected mechanisms of pH on plant growth during the pre-lab.*** 
   * **Soil Bacteria:** bacterial activity best in the pH range of 5.5 - 7.0 and is critical for making nitrogen available to plants.
   * **Nutrient Leaching:** important nutrients leach out of soil much more rapidly in acidic soil, pH below 5.0, in part because of decreased bacterial activity.
   * **Nutrient Availability:** plants are best able to absorb nutrients in the pH range of 5.5 - 6.5
   * **Toxic Elements:** below a pH of 5.0, plants are vulnerable to toxic levels of Aluminum.
   * **Soil Structure:** Clay soils with optimal pH ranges, 5.5 - 7.0, are granular and easy to work compared to sticky clays that are highly acidic or alkaline.
5. Students will then create a pH scale that they can reference later. Make sure students label 0-7 “***acidic***,” 7 “***neutral***,” and 7-14 “***basic***”or “***alkaline.***” Use the chart below to give the students examples of common objects’ pH to label on the pH scale.

|  |  |
| --- | --- |
| **Object** | **pH** |
| Lemon Juice | 2.0 |
| Tomato Juice | 4.0 |
| Human Saliva | 6.0 |
| Distilled Water | 7.0 |
| Baking Soda | 9.0 |
| Ammonia Solution | 11.0 |
| Bleach | 13.0 |

**Getting Ready**

**Materials List:**

* Soil Core or Shovel
* Container For Soil Samples
* Deionized Water
* pH monitor or Litmus Test Strips
* Acid, Base, Neutral Solutions
* Plant Cuttings From Garden (Green Onion Suggested)

**Procedure:**

1. Collect 100 ml soil samples from inside the garden and an area just outside the garden using a soil core or hand shovel.
2. Record observations about the soil samples.
3. Mix 50 ml of distilled water into each soil sample and stir. Make sure the water is completely mixed into the soil.
4. Place a Litmus Strip into the soil and water mixture. Following the directions on the Litmus Paper, use the color of the litmus paper to measure the soil pH.
5. Take a small cutting from a plant in the garden. If you grow Spring of Green Onions in your garden, we suggest taking 3 onions as your samples.
6. Return to the classroom, and pour 300 ml of distilled water into 3 beakers. Mix 100 ml of white vinegar\* into one beaker. Place 200 ml of white vinegar\* into the second beaker, stir until mixed. Do not add anything to the third beaker this is our control. (Use pH strips to obtain solutions of pH 4, 6, and 7\*\*)
7. Use Litmus Paper to test the pH of each of the Beakers. Record your data.
8. Place a plant cutting or Green Onion into each of the beakers, making sure that the plant is partially underwater. If possible, place the beakers near a sunny window.
9. After 3-5 days, remove the plant cutting or Green Onion. Using a dissecting scope or magnifying glass, make observations about the root growth. Use a ruler to measure 3 roots or areas of new growth that you pick at random.

**Data Collection (45 min)**

**Prediction**: What do you think the pH of the garden soil will be? How will the pH of the garden soil compare to soil not from the garden?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Observations**:

Record two *qualitative* observations about your soil sample from the garden.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Record two *qualitative* observations about your soil sample from outside the garden.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Record Your Data:**

pH of the Garden Soil: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pH of Non-Garden Soil: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Hypothesis**: How will placing plant cuttings in distilled water with vinegar or (other vinegar samples) affect root growth?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Record Your Data:**

Label each beaker with either: **Distilled Water (pH 7)**, **Vinegar (pH 6)**, **Vinegar (pH 4)**, and **Vinegar (pH 2.4)**.

Fill each beaker halfway full with the solution (pH 2.4, 4, 6, or 7) that your teacher has prepared.

Include a drawing of how each of your beakers look with the plant cutting.

Beaker 1 Beaker 2 Beaker 3 Beaker 4 

( ) ( ) ( ) ( )

pH of Beaker 1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Root Growth of Beaker 1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

pH pf Beaker 2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Root Growth of Beaker 2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

pH of Beaker 3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Root Growth of Beaker 3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

pH of Beaker 4: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Root Growth of Beaker 4: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Observations:** After 3-5 days, make 1 *quantitative* and 1 *qualitative* observation about each.

Beaker 1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Beaker 2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Beaker 3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Beaker 4: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Post-Lab (10-15 min)**

**1**. What does pH measure? What does it mean if a soil is acidic?

***Note:*** Student responses should align with the introduction and definitions given during the pre-lab. These responses will vary depending on the student’s prior knowledge and depth of understanding about pH.

**2.** Why is it important to know the pH of soil when planting a garden? What was the pH of the soil samples taken from our garden?

***Note:*** A complete student response should reference several of the mechanisms (soil bacteria, nutrient leaching and availability, toxicity, or soil structure) linking soil pH and plant growth discussed during the Pre-Lab. Students may also respond that plants have different tolerances for soil pH and therefore knowing the soil pH is important when deciding what to plant in the garden.

***Note:*** Students should be able to transfer the garden soil pH from the Data Collection section to this answer. It may be helpful to compare garden soil pH values create to discuss variability and create an average pH value. This can be done on the board or overhead as a whole class.

**3.** Create a bar graph comparing the root growth of the plant samples in distilled water and water with vinegar or baking soda. (water type on the x-axis, root length in mm on the y-axis)

***Note:*** A student constructed graph should look similar to the sample given below. Each axis should be titled and labeled with the appropriate units. The graph should be an appropriate scale and show general neatness and attention to detail.

***Note:*** Depending on student experience constructing graphs, they may need additional scaffolding to complete an accurate bar graph. This may mean giving step-by-step written and verbal instructions or constructing the graph as a class on the board or document camera.

**4.** Evaluate your hypothesis about placing plant clippings in different pH solutions. Were you right? Give one piece of evidence that either proved you were right or wrong.

***Note:*** Student responses should directly reference their hypothesis from the Data Collection section. Supporting evidence could consist of either a quantitative or qualitative observation.

**5.** Using the table below of optimal soil pH for common garden plants, decide if each plant could grow in the CHS school garden.

What was the average soil pH for the CHS School Garden? **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

|  |  |  |
| --- | --- | --- |
| **Garden Plant** | **Optimal Soil pH** | **Should We Plant It In The CHS Garden? (Yes or No)** |
| **Strawberry** | **6.0-6.5** |  |
| **Cucumbers** | **5.5-7.0** |  |
| **Potatoes** | **4.8 - 6.5** |  |
| **Beets** | **6.5 - 8.0** |  |
| **Tomatoes** | **5.5 -7.5** |  |
| **Lettuce** | **6.0 - 7.0** |  |

***Note:*** Students should use the Garden pH determined during the Data Collection and Post-Lab Question 2.

***Note:*** These optimal pH ranges were taken from the University of Vermont Extension Department of Plant and Soil Scinece: <http://pss.uvm.edu/ppp/pubs/oh34.htm>.

**Modifications:**

*You can extend or differentiate this lesson by incorporating any of these modifications:*

1. Have students systematically sample throughout the garden and create a map or visual representation of the soil pH. This can be done on paper, using google drawing, or GIS.

2. Have students test the effect of various treatments on the soil pH. Based on their results and measurements of the garden pH, students can decide on an application treatment for the garden.

3. Discuss the buffering capacity of different soils and the effect of specific garden plants.

4. Have students research the impact of acid rain. Students can measure the pH of rainwater and evaluate the impact of acid rain on the soil pH and plant growth.