Lesson 2 | Explore

Properties of Soils

At a Glance

Overview

Students examine different types of soil that have been mixed with water and allowed to settle. Next they investigate soil charge and how air space allows soils to hold and transmit water.

Major Concepts

- Soils vary in their compositions.
- Soils are a bank of nutrients.
- Soils contain both organic and inorganic matter.
- Soils are negatively charged.
- Soils contain differing amounts of air space.
- Soils differ in their abilities to hold and transmit water.

Objectives

After completing this lesson, students will be able to

- list aspects of soil composition,
- appreciate that soils are living and dynamic,
- recognize that soils vary in composition,
- describe where nutrients in soil come from,
- recognize that plants generally take up water and nutrients from the soil, and
- recognize that plants can deplete soils of nutrients.

Teacher Background

Consult the following section in *Teacher Background:*

3.0 Properties of Soils

In Advance

Photocopies

Activity 1	Master 2.1, *Soil and Charge* (Make 4 copies per group of 4 students.) Master 2.2, *Soil and Air Space* (Make 4 copies per group of 4 students.) Master 2.3, *Soil and Water* (Make 4 copies per group of 4 students.)

Materials

Soil separation	For the class: 300 mL each of potting soil, local soil, and sand 3 clear, 350 mL plastic bottles Water
Soil and charge	For a group of 4 students: 340 mL each of potting soil and local soil 2 clear, 350-mL plastic bottles 1 pair of scissors 3 pieces of cheesecloth (3 centimetres by 3 centimetres) 3 rubber bands 3 mL of a positively charged dye such as methylene blue 3 mL of a negatively charged dye such as undiluted red food colouring 150 mL water
Soil and air space	For a group of 4 students: 3 clear, 50-mL test tubes 30 mL each of potting soil, local soil, and sand 1 glass marking pencil 120 mL of water
Soil and water	For a group of 4 students: 3 clear or translucent, 100-mL graduated cylinders 120 mL each of potting soil, local soil, and sand 120 mL of water

Preparation

Teacher note

Try to obtain coarse sand such as that used for home improvement products. Clean, fine sand may not allow water to pass as readily as most sands found in soils. The preparations described in this section can be carried out by students if desired.

Soil separation In Step 6, students are asked to observe three different soil types (potting soil, local soil, and sand) that have been mixed with water and allowed to settle. For this demonstration, clear plastic, 350 mL bottles work well. Fill each bottle about $^2/_3$ full of soil. Place potting soil, local soil, and sand in separate bottles. Add water to near the top of each bottle. Place caps on the bottles, shake the contents well, and place the bottles in a location where they will not be disturbed. Prepare at least 1 day before making observations.

Group 1: Soil and Charge Prepare two soil columns per group (350-mL plastic water bottles work well). Cut the bottom off each bottle. Use a rubber band to place 1 layer of cheesecloth over the mouth of each bottle. Invert each bottle so that the mouth is pointing down. Add soil (potting soil in one and local soil in the other) to each so that the soil half fills the bottle. Use masking tape to hold each bottle over a larger container that will collect the filtrate (see Figure 2.3). Note that any charged dyes will work in this investigation. The dyes should be sufficiently concentrated so that when they exit the soil column, they can be easily visualized. A 1 percent concentration of methylene blue (+) and undiluted red food colouring (–) work well. Bromothymol blue (–) also works well.

Group 2: Soil and Air Space Make available three clear test tubes that can hold 50 mL. If these are not available, you can use graduated cylinders. Make available at least 30 mL each of potting soil, local soil, and sand. Also have available a ruler and a container that holds at least 120 mL of water.

Group 3: Soil and Water Make available three 100-mL graduated cylinders that are clear or translucent. Make available at least 120 mL each of potting soil, local soil, and sand. Also have available a container that holds at least 120 mL of water.

a

b

Figure 2.2.
a. Soil separation after sitting for one day
b. Organic material floats on the surface of the water

Procedure

Activity 1: Properties of Soils

Teacher note

Be careful when moving the three bottles with the soils settled in water (Step 6). Excessive movement will cause the soil layers to mix together. Try to keep the bottles undisturbed so that they can be viewed by later classes.

Be aware that determining the charge of soil, performed by Group 1, may take longer to perform than the tasks carried out by Groups 2 and 3. If the flow rate of dyes through the soil is slow, the experiment may take closer to 30 minutes to complete as compared to about 15 minutes for the other two experiments. If this happens, instruct one student to watch the progress of the soil column while the other members of the group observe the activities of students in Groups 2 and 3.

Figure 2.3.
Setup for the soil and charge investigation.

Tip from the field test

The activities in this lesson vary with regard to complexity. You may consider assigning students to groups based on their interests and abilities.

1. **Remind students that in the previous lesson they investigated essential plant nutrients that are found in soils. Ask, "Aside from essential elements, what else do you find in soils?" Write students' responses on the board or on an overhead transparency.**

   At this time accept all answers. Student responses may include rocks, sand, clay, insects, worms, bacteria, bits of wood, and water. If necessary, point out that these materials contain many of the essential elements.

2. **Ask students, "How would you categorize the components of soil?"**

   Student responses will vary. Guide the discussion to bring out the fact that soil consists of nonliving inorganic material such as clay, silt, and sand as well as living and nonliving organic material such as dead plant material, bacteria, insects, and worms.

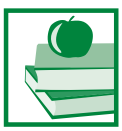
3. **Ask students, "How does soil help plants to grow?" Write student responses on the board.**

   Student responses will vary. Guide the discussion to bring out the following:

   - Soil provides support for plants' root systems.
   - Soil provides essential nutrients.
   - Soil holds water and makes it accessible to plants.

4. **Ask students, "Can healthy soil support the growth of crop plants forever or does it ever go bad?"**

   Student answers will vary. If not mentioned by a student, guide the discussion to bring out the fact that soils are like a "nutrient bank" and that plants growing in them make constant "withdrawals." Over time, the nutrients in a soil become depleted because the nutrients are removed from the ecosystem in the harvest. These nutrients must somehow be replenished (such as through the application of fertilizers) if the soil is to regain its ability to support healthy crop growth. Explain that plants growing in forests, wetlands, and other non-agriculture ecosystems return their nutrients to the soil where they are recycled by soil organisms and reused by plants. In agricultural systems, soil nutrient retention may be promoted by planting cover crops or utilizing no-till systems that return plant matter to the soil.



Expectations:

Students will:

- identify the earth's four spheres (biosphere, hydrosphere, lithosphere, atmosphere), and describe the relationship that must exist between these spheres if diversity and sustainability are to be maintained.
- identify the basic components of soil, water, and air, and describe some of the effects of human activity on soil, water, and air quality.
- explain the concept of the cycling of substances in ecosystems (e.g., fertilizers made from biosolids leach into ground water or run off into rivers and streams, where the chemicals are absorbed by aquatic life, which is in turn consumed by humans).

5. **Explain that a healthy soil can take hundreds of years to form and it is a precious natural resource. Ask students, "What happens to the environment when an agricultural soil loses its ability to support crops grown by farmers?"**

   Student responses will vary. Students may respond that when a soil stops supporting plant growth, farmers will have to clear additional land to grow their crops. You may point out that this is happening in some agricultural soils that formerly supported rain forests. Here, farmers grow food on land until they deplete it of nutrients. They must then clear additional land for their crops. Lack of plant growth increases the rate at which erosion takes place. Over time, such erosion can produce desert areas. Students may have heard of the dust bowl that was created in the North American plains during the 1930s. Drought conditions killed the crops and, without either the crop plants or the natural prairie vegetation that farming replaced to hold the soil together, the topsoil was blown away by high winds.

Expectations:

Students will:

- explain different ecologically sound practices for improving and maintaining soil structure and fertility.
- describe the limiting factors of ecosystems (e.g., nutrients, space, water, energy, predators), and explain how these factors affect the carrying capacity of an ecosystem.
- dentify some factors related to human activity that have an impact on ecosystems (e.g., the use of fertilizers and pesticides; altered shorelines; organic and conventional farming; urban sprawl), and explain how these factors affect the equilibrium and survival of populations in terrestrial and aquatic ecosystems (e.g., fertilizers change the fertility of soil, affecting what types of plants can grow in it.

6. **Show the class the bottles of potting soil, local soil, and sand that were previously mixed with water and allowed to settle. Explain how they were prepared. Ask students to gather around the bottles and make observations about the different soils.**

   Students will observe that the different soils separate differently. At this point, students will not know what is found in each layer. They should record their observations and refer back to them later in the lesson.

   - The potting soil will show a thick layer of dark material on the bottom, a thick layer of cloudy water, and a thinner layer of organic material on the top.
   - Local soils may differ, but a typical soil will show layering similar to potting soil though there may be less organic material floating on the surface.
   - Most of the sand will form a very thick layer in the bottom of the container. There will be a thick layer of clear water and a very thin layer of material on the surface.

7. **Remind students that soils contain both organic and inorganic material. Ask, "Can you identify the organic material in each container?"**

   Responses will vary. If necessary, explain that the organic material is less dense than the inorganic material and floats on the surface of the water.

8. **Explain to students that the cloudiness in the water comes from inorganic particles called clay that are so small that they can remain suspended in the water. Point out that most of the nutrients in the soil are found in the organic material and the clay.**

9. **Ask students, "Do all soils support the growth of plants equally well?"**

   Most students will recognize that since soils differ in their amounts of organic material and clay, they will vary in their ability to support plant growth.

10. **Explain that they are now going to investigate some other properties of soils that affect plant growth. Divide the class into groups of 4 students and direct them to their work areas.**

    Student groups will explore three different aspects of soil. Depending on the size of your class there will be 1 or 2 student groups assigned to each of the three different activities. Therefore, you will need to set up multiple lab stations.

- Group 1: Soil and charge
- Group 2: Soil and air space.
- Group 3: Soil and water.

11. Pass out the appropriate masters to the groups as follows:

- Group 1: Master 2.1, *Soil and Charge* (1 copy per student in group)
- Group 2: Master 2.2, *Soil and Air Space* (1 copy per student in group)
- Group 3: Master 2.3, *Soil and Water* (1 copy per student in group)

12. Instruct students to follow the directions on their handouts, record their observations, and to answer any questions.

Give students approximately 15 minutes to complete their investigations.

Collect students' answers to the questions posed on Masters 2.1, *Soil and Charge,*

2.2, Soil and Air Space, and 2.3, Soil and Water.

Answers to discussion questions:

Group 1, Soil and Charge

1. In light of your observations, what can you conclude about the electrical charge of soil?

   Since the negatively charged dye molecules passed through the soil column (repelled) and the positively charged dye molecules were retained (attracted) in the column, one can conclude that the soil must be negatively charged.

Group 2, Soil and Air Space

1. Why did the final water level differ among the three types of soil?

   The different soil types contained varying amounts of air space within them. The potting soil has about 50 percent air space while the sand has less. The local soil most likely has less air space than the potting soil, but more than the sand. As water enters the soil, it occupies the spaces previously taken up by air. This means that the more air space in the soil, the more water is taken up, and the lower the observed water level.

2. Why is it important for plant growth that soils contain air space?

   The air space provides room for the soil to hold water and dissolved nutrients needed by the plant. The air also provides oxygen, which is needed by the roots of all plants and most (but not all!) microorganisms that live in the soil.

Group 3, Soil and Water

1. Infiltration refers to the ability of soil to accept water. Which of the soils you tested accepted the most water?

   The potting soil and sand likely accepted the most water, with the local soil accepting a lesser amount.

2. Percolation refers to the ability of soil to transmit water throughout its depth. Which of the soils you tested allowed for the fastest water movement? Which allowed water to reach the greatest depth?

   Water should have been transmitted most quickly through the potting soil. Sand is expected to transmit water most slowly, while the local soil transmits water at a rate between that of the potting soil and the sand.

13. **After the groups complete their investigations, reconvene the class and ask each group to take turns reporting their results.**

Student reports will vary. For each type of investigation, summarize the results on the board or an overhead transparency. As necessary, ask guided questions to bring out the following:

Group 1, Soil and Charge: Students should conclude that the soil is negatively charged (see answer to Group 1, Soil and Charge, question 1 above).

Group 2, Soil and Air Space: As water was slowly added to the soil samples students should have noted that both the potting soil and the local soil produced air bubbles that rose to the surface. Fewer air bubbles would be seen when water was added to sand. After the water was allowed to percolate into the potting soil, students should have observed that the final water level was approximately halfway between the surface of the soil and the line drawn on the test tube. This means that the potting soil contained about 50 percent air space. The local soil also would contain a significant amount of air space, though it may be less than the potting soil. The sand would display only a small amount of air space depending on the grain size. Make sure to bring out the following points:

- Soils differ in the amounts of air space that they contain.
- Average soils that support crops consist of nearly 50 percent air space. An astute student may recognize that wetland rice is an exception to this general rule.
- The air space in soil can be occupied by either air or water.
- Soils need both air space and water to support a plant's root system.
- Plant roots absorb nutrients from the soil water.

Group 3, Soil and Water: As water was slowly added to the potting soil students should have noted that water was immediately taken up by the soil and that some water reached the bottom of the graduated cylinder in less than 1 minute. The results with local soil would vary, depending on its composition. Most soils would accept the water less quickly than the potting soil and the rate at which the water percolates through the soil would be somewhat slower. The sand will accept the water almost as quickly as potting soil. Make sure that students recognize that differences in soil texture mean that soils differ in their ability to accept water (infiltration) and transmit it (percolation).

14. **Conclude the lesson by asking students to list properties of soil that are important to support plant growth.**

Write the list on the board or on an overhead transparency. Students should mention the following:

- The soil is firm enough to support the plant's root system.
- The soil contains the essential plant nutrients.
- The soil contains adequate amounts of organic material and clay.
- The soil is negatively charged.
- The soil contains about 50 percent air space.
- The soil allows water to infiltrate and percolate through it.

15. **Explain that in the next lesson, they will investigate how nutrients are absorbed and distributed throughout the plant.**

Optional Homework Assignment 1

Ask students to write a short paper that describes how scientists use the soil triangle to classify different types of soils.

Provide students with relevant information from the *Teacher Background* section.

Optional Homework Assignment 2

Working with a parent/guardian, instruct students to obtain a soil sample from near where they live. They can use the phone book or the Web to find an address for the local county agricultural extension department or state university that conducts soil testing. Students should send in their soil sample for analysis to assess its quality and to see if any essential nutrients are lacking. You can collect the soil analyses obtained by different students and see if there are any differences according to location.

Private soil testing laboratories will usually be willing to provide discounts for soil analyses for use in projects by students for educational purposes. These types of results can be used effectively in long-term and or science fair projects.

M = Involves copying a master

T = Involves making a transparency

Lesson 2 Organizer

Activity 1: *Properties of Soils* **What the Teacher Does**	**Procedure Reference**
Remind students of their previous work on essential elements. Ask students: ■ "What else do you find in soil?" ■ "How would you categorize the components of soil?" ■ "How does soil help plants grow?" ■ Can healthy soil support plant growth forever, or does it go bad?"	Page 69 Step 1and 2 Page 70 Step 3 and 4
Explain that healthy soil is a precious natural resource. ■ Ask, "What happens to the environment when soil loses its ability to support crops grown by farmers?"	Page 70 Step 5
Show the class the bottles of different soils that were mixed with water and allowed to settle. ■ Explain how they were prepared. ■ Have students gather around the bottles and make observations.	Page 71 Step 6
Remind students that soil contains both organic and inorganic material. ■ Ask, "Can you identify the organic material in each container?"	Page 71 Step 7
Explain that the water is cloudy due to tiny particles of clay suspended in it. Point out that most of the nutrients in soil are found in the organic material and the clay particles.	Page 71 Step 8
Ask students, "Do all soils support the growth of plants equally well?"	Page 71 Step 9
Explain that they will investigate some other properties of soils that affect plant growth. Divide the class into groups of four and direct them to their work areas.	Page 71 Step 10
Pass out masters to groups as follows: ■ Group 1: Master 2.1, *Soil and Charge* ■ Group 2: Master 2.2, *Soil and Air Space* ■ Group 3: Master 2.3, *Soil and Water*	Page 72 Step 11 M
Instruct students to follow the directions on their handouts. They should record their observations and answer any questions.	Page 72 Step 12
After students complete their investigations, reconvene the class and ask each group to report their results.	Page 73 Step 13
Conclude the lesson by asking students to list properties of soil that are important to support plant growth.	Page 73 Step 14
Explain that in the next lesson, they will investigate how nutrients are absorbed and distributed throughout the plant.	Page 74 Step 15

Master 2.1, *Soil and Charge*

Name
Date

Procedure

Step 1. As directed by your teacher, set up two soil columns.

Step 2. Slowly add water to each column until the soil is thoroughly wet.

Step 3. Add 2 mL of the positively charged dye to one column and 2 mL of the negatively charged dye to the other column.

Step 4. Add 30 mL of water to each column and allow it to pass through. Enter observations in the table below.

Type of dye	Observations
Positively charged	
Negatively charged	

Discussion question

In light of your observations, what can you conclude about the electrical charge of soil?

Master 2.2, *Soil and Air Space*

Name

Date

Procedure

Step 1. Use the glass marking pencil to label three 50-mL test tubes "potting soil," "local soil," and "sand."

Step 2. Place 20 mL of the appropriate soil into each test tube.

Step 3. Use a ruler to measure the height of the soil in the test tube. Make a mark near the top of the test tube at a position twice the height of the soil.

Step 4. Slowly add 20 mL of water to the tube containing the potting soil. Record your observations in the following table. Repeat, adding 20 mL of water to the tubes containing local soil and sand.

Soil Type	Observations
Potting soil	
Local soil	
Sand	

Discussion questions

1. Why did the final water level differ among the three types of soil?

2. Why is it important for plant growth that soils contain air space?

Master 2.3, *Soil and Water*

Name ______________________

Date ______________________

Procedure

Step 1. Label three 100-mL graduated cylinders "potting soil," "local soil," and "sand."

Step 2. Place 80 mL of the appropriate soil into each graduated cylinder.

Step 3. Slowly add 20 mL of water to the graduated cylinder containing the potting soil. Record your observations in the following table. Note how long it takes water to move through the soil. Repeat, adding 20 mL of water to the cylinders containing local soil and sand.

Soil Type	**Observations**
Potting soil	
Local soil	
Sand	

Discussion questions

1. Infiltration refers to the ability of soil to accept water. Which of the soils you tested accepted the most water?

2. Percolation refers to the ability of soil to transmit water throughout its depth. Which of the soils you tested allowed for the fastest water movement? Which allowed water to reach the greatest depth?