Case File 8

No Dumping:
Using soil characteristics to link suspects to a crime scene

Use physical and chemical characteristics of soils to identify a soil sample from a certain area.

Police Report

Early Saturday morning, two local teenagers called police after observing a large, dark blue pickup truck dumping toxic materials in City Park. Due to the dim morning light, the boys were unable to see a license plate number. They did, however, recognize the make and model of the pickup truck. Police quickly apprehended four suspects who drive trucks of this make and model.

All four suspects deny having been anywhere near City Park in recent weeks.

Although tire tracks were found at the scene, the tread patterns were smudged. No toxic residue was found in the payloads of any of the trucks, but police were able to collect soil samples from underneath the bumpers.

Police suspect that an organized crime network is illegally dumping toxic material in exchange for large payoffs from local chemical company ZenCorp. We must identify the perpetrators in order to crack this ring.

Forensics Objective

- identify characteristics of different soils to demonstrate that a suspect has been at a scene

Science and Mathematics Objectives

- use characteristic properties to identify a sample
- measure the pH of soils
- measure the water absorbency of soils
- measure the conductivity of soils

Materials (for each group)

- TI-83/TI-84 Plus™ Family
- Vernier EasyData™ application
- Vernier EasyLink™
- pH Sensor
- Conductivity Probe
- magnifying glass
- coarse filter papers (12.5 cm diameter)
- distilled or deionized water
- lint-free tissues
- wash bottle (with deionized water)
- 100 mL graduated cylinder
- five 250 mL beakers
- 5 spoons or weighing papers
- 400 mL beaker
- 50 mL beaker for deionized water
- stirring rod
- funnel large enough for 50 g of soil and 100 mL of water
- balance
- 100 g each of soil samples for 4 suspects and 1 crime scene
- goggles (1 pair per student)

Procedure

Part I: Preparing the Soil-and-Water Mixtures

CAUTION

Caution: Obtain and wear goggles during this experiment. Tell your teacher right away in case of any spills or accidents.

1. Prepare mixtures of water and soil. For each sample, complete the following steps:
   a) Label a 250 mL beaker with the sample number.
   b) Using a balance, measure 50 g of the soil sample and place it in the labeled beaker. (Note: To avoid contaminating the other samples, use a different spoon or weighing paper for each sample.)
   c) Measure 100 mL of distilled or deionized water in the graduated cylinder. Add the water to the soil in the beaker.
   d) Stir the mixture thoroughly with the stirring rod.
   e) Stir the mixture once every 3 minutes for 15 minutes.
   f) After the final stir, let the mixture settle for 5 minutes before beginning to take readings. (Note: To avoid contaminating the other samples, rinse the stirring rod with deionized water between soil samples.)

Part II: Measuring the pH of the Samples

2. Connect EasyLink to the USB port in your calculator. Then connect the pH Sensor to the port on the EasyLink. (Note: Your teacher already has the pH Sensor in a pH soaking solution in a beaker. Be careful not to tip over the beaker when you connect the sensor to the interface.)

3. Set up the EasyData App for data collection.
   a) Select File from the Main screen.
   b) Select option **1: New** to reset the application. The Main screen should be displayed. The Main screen displays the current reading from the pH Sensor.

> At the bottom of the Main screen are five options (File, Setup, Start, Graph, and Quit). Each of these options can be selected by pressing the calculator key located below it (Y=, WINDOW, ZOOM, TRACE, or GRAPH).
>
> TIP!

4. Use the pH Sensor to determine the pH of the solution in each sample beaker.
   a) Rinse the tip of the pH Sensor with deionized water from the wash bottle, and place it into the liquid in the beaker for sample 1. Be careful not to let the tip of the sensor touch any solid material at the bottom of the beaker.
   b) When the pH reading on the Main screen has stabilized, record the pH of the solution in the Evidence Record.
   c) Repeat steps 4a and 4b for each remaining soil sample. When you are finished, rinse the pH Sensor with deionized water and return it to its storage container.

Part III: Testing the Conductivity of the Samples

5. Replace the pH Sensor connected to EasyLink with the Conductivity Probe. Set the switch on the probe to the 0–20,000 μS setting.

6. Select File from the Main screen, and then select option **1: New** to reset the application.

7. Zero the Conductivity Probe.
   a) Place the probe in a beaker of deionized water. Select Setup.
   b) Select option **7: Zero**. On the resulting screen, select Zero.

8. Collect conductivity data for each of the samples.
   a) Place the tip of the probe into the liquid in the beaker for sample 1. The hole near the tip of the probe should be completely covered by the liquid. Be careful not to disturb any solid material remaining at the bottom of the beaker.
   b) When the conductivity reading has stabilized, record the conductivity of the solution in the Evidence Record.
   c) Rinse the conductivity probe thoroughly with deionized water from the wash bottle.
   d) Repeat steps 8a–8c for each of the remaining samples.

Part IV: The Physical Appearance of the Samples

9. For each sample, use the balance to measure out 50 g on a piece of filter paper labeled with the sample number.

10. Examine the samples through the magnifying glass. In the Evidence Record, make a sketch of each sample and write down some notes about its appearance.

Part V: Determining the Water Absorbency of the Samples

11. Determine how well each sample absorbs water.
   a) Carefully lift the sample 1 filter paper and soil that you prepared in step 9.
   b) Place the filter paper and soil into a funnel.

c) Have your lab partner hold the funnel over a 400 mL beaker.

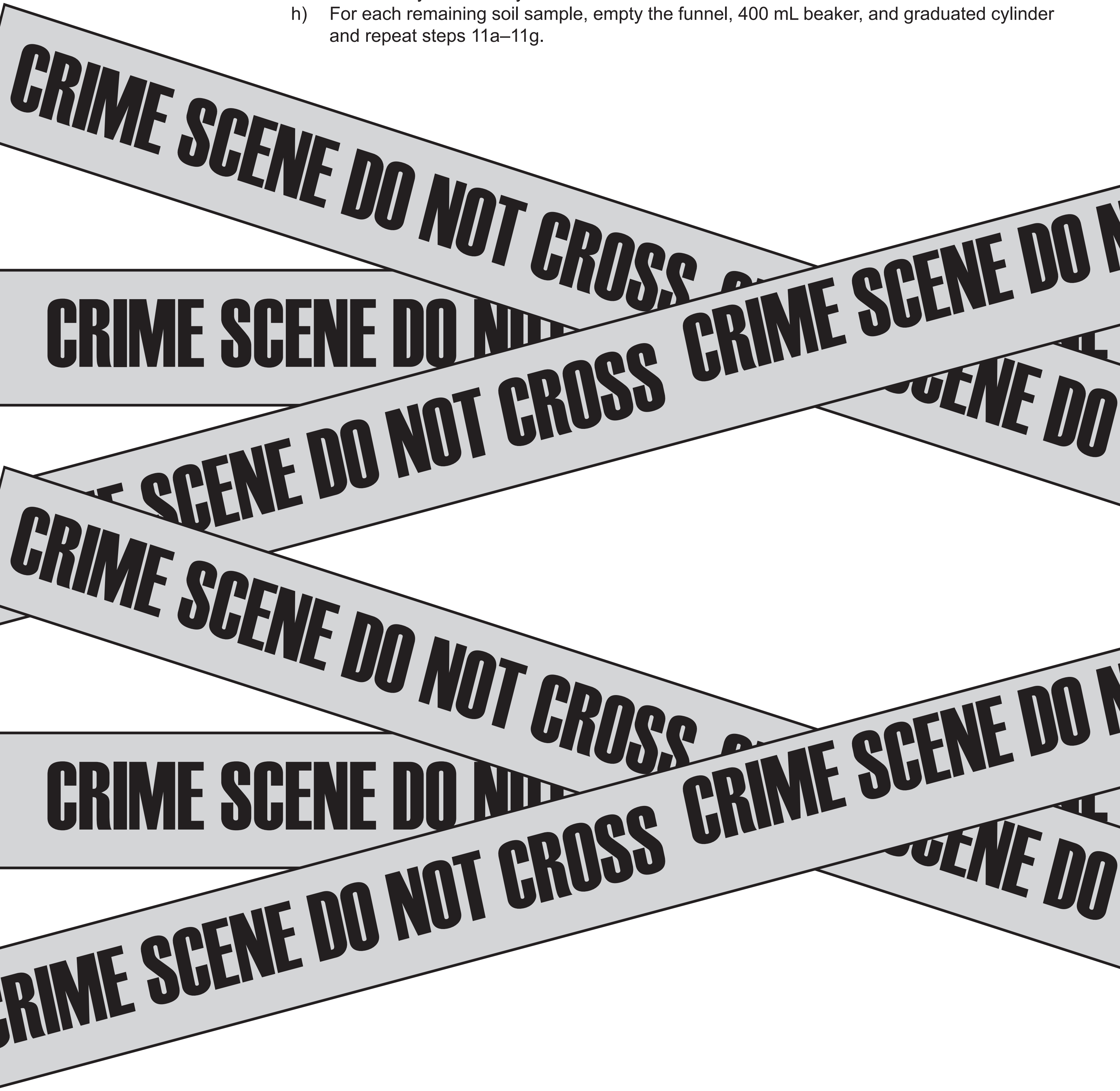
d) Measure 100 mL of deionized water in the graduated cylinder, and pour it through the soil. Collect any water that drains through in the beaker.

e) Let the sample drip for 60 seconds.

f) Pour the water from the beaker into the 100 mL graduated cylinder.

g) Subtract the volume of water in the graduated cylinder from the 100 mL you poured into the soil. This is the amount of water absorbed by the soil. Write this amount in the Water Absorbency column of your Evidence Record.

h) For each remaining soil sample, empty the funnel, 400 mL beaker, and graduated cylinder and repeat steps 11a–11g.



Name: ______________________________________
Date: ______________________________________

Evidence Record

Sample	pH	Conductivity (μS/cm)	Water Absorbency (mL/50 g)	General Appearance
Sample 1				
Sample 2				
Sample 3				
Sample 4				
Crime Scene				

Sketch of Physical Appearance

Sample 1 Sample 2 Sample 3 Sample 4 Crime Scene

Case Analysis

1. What is the range of pH that you found in the five soil samples?
2. What does a high pH mean, and what does a low pH mean?
3. What can cause a soil to become acidic or basic?
4. What is the range of conductivity that you found?
5. What does a high conductivity indicate about the soil?
6. Why is it important to know the pH *and* the conductivity of a soil if you want to know how salty the soil is?
7. What is the range of water absorbency that you found?
8. What types of soils have a high water absorbency, and what types of soils have a low water absorbency?
9. How can an investigator use the physical appearance of a soil sample to link a suspect to a victim or crime scene?
10. What tools can a forensic scientist use to identify and match soil samples?
11. Based on your observations, were any of the suspects' vehicles present at the crime scene? If so, which ones? Explain your answer.

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Teacher Notes

Teaching time: two class periods

This lab introduces students to the importance of soils and other trace evidence in connecting victims, crime scenes, and suspects.

Tips

- To save class time, weigh out soil samples for the students before class.
- Before assigning this activity, you may want to review characteristics of soils and the concepts of pH, conductivity, and water absorbency (see Background Information).
- If you have access to a microscope that is connected to a computer, you can have students print out micrographs of the soil samples and label them to show matching features.
- If pH or conductivity readings do not stabilize, have students collect data in Single Point mode (from the Main screen, select **Setup** and then option **5: Single Point**). When the students select **Start**, the probe or sensor will collect data for 10 seconds and then display an average reading on the screen.

Lab Preparation

- For the samples, you can either use soils from several different sources or develop samples by mixing materials yourself. If you use soils from different sources, the differences in appearance will probably be significant. If you make the samples artificially, the students will have to rely more heavily on the chemical tests to match a sample to the crime scene.
- Different soils can be made with a variety of materials, including potting soils, compost, topsoil, clay, sand, lime, mud, and peat moss.
- To make soil samples that look similar, start with one soil sample and add different chemicals to it to create several different samples. Wetting the soil with a little weak sodium hydroxide (100 mL of 1 M aqueous NaOH to 500 g of soil) will create an alkaline soil. Similarly, wetting soil with a little weak hydrochloric acid (100 mL of 1 M aqueous HCl to 500 g of soil) will make it acidic. You can also add 100 mL of 1 M aqueous sodium chloride to 500 g of soil to increase the salinity without changing the pH. Sand or peat moss can be added to change water absorbency. Mix each sample well to ensure that it is uniform. Make sure the soil is dry before lab day.

Background Information

Soil is made up of tiny particles of rock, mineral grains, and organic matter. The sources of these materials and the quantity of each of them make a particular soil unique. These materials also affect the pH, conductivity, particle size, and water absorbency of the soil. Because soils are unique, matching characteristics from soil samples can help to place a victim or suspect at a particular location.

In many cases, the physical appearance of a soil, including the distinct rock types and plant matter present, can allow a forensic geologist to place someone at a crime scene with a high degree of certainty. The physical appearance of soils in many areas changes over time. For example, the soils along the banks of rivers can change from month to month as water levels fluctuate. In areas with frequent changes, soil matching can sometimes allow investigators to determine even the *time* someone was in a location.

Conductivity (salinity)
Soil conductivity is a measure of how well a soil conducts electricity. Ions in the soil make it conductive, so conductivity is a measurement of the ions present. Because salts produce highly conductive ions, the conductivity of a soil is often referred to as its *salinity*. However, most ions—including hydronium (H_3O^+) and hydroxide (OH^-) ions—can increase the conductivity of the soil, so a soil with a high conductivity is not necessarily extremely salty. By examining both conductivity and pH, you can determine whether a soil has a high salt concentration.

Conductive ions can be introduced to soils by the natural weathering of minerals, irrigation, or runoff from salted roads. Poor drainage and hot, dry weather also contribute to the buildup of salt in the soil. Sodium chloride, NaCl, is the most common salt found, but others, such as calcium chloride ($CaCl_2$) and magnesium sulfate ($MgSO_4$), are often present as well.

Conductivity is measured in the unit *siemens* (S) per meter or centimeter ($1\ S = 1\ kg^{-1}{\cdot}m^{-2}{\cdot}s^3{\cdot}A^2$). In this lab, conductivities are measured in microsiemens per centimeter (µS/cm), although the probe is labeled simply “µS.”

pH
pH is a measure of how acidic or basic a substance is. A substance with a low pH (below 7) is considered acidic, while a substance with a high pH (above 7) is considered basic, or alkaline. A pH of 7 is neutral. The pH of a soil is related to its composition. Soils with large amounts of organic matter tend to be more acidic than soils without organic matter. Some types of minerals can affect a soil’s pH if they dissolve in water. For example, calcite ($CaCO_3$) can produce a basic solution when it dissolves. The pH of a soil can be affected by human and environmental factors also, such as acid rain and fertilizer application.

Water absorbency
Soils can absorb different amounts of water, depending on their composition. Generally speaking, soils that are made of small particles, such as silt, tend to be able to absorb more water than soils made of larger particles, such as sand. The chemical composition of the particles also affects how absorbent a soil is; clay particles tend to have charged surfaces, so they are more attractive to water and more absorbent than other types of minerals. Organic matter can substantially increase a soil’s water-absorbing capacity.

Color
The color of a soil is determined by its composition. Soils with much organic matter in them tend to be dark brown or black. The mineral and rock particles that make up the soil often give soils characteristic colors. For example, the iron-rich mud of the southern United States is red.

Resources

http://cals.arizona.edu/pubs/garden/mg/soils/index.html
The online *Arizona Master Gardener Manual* from the University of Arizona Cooperative Extension provides information on the many different types of soils and their characteristics.

http://www.interpol.int/Public/Forensic/IFSS/meeting13/Reviews/Soil.pdf
This Web site contains notes and summaries of soil identification methods from an international forensic science symposium.

Modifications

- For less-advanced students, the number of tests that are carried out on each sample can be reduced. You can also make the samples less similar in appearance or properties.
- For more-advanced students, you can combine different soil types to make the matching process more difficult. More than four suspect samples can be used. Students can also be encouraged to explore the processes of soil identification and analysis in more detail.

Sample Data

Sample	pH	Conductivity (µS/cm)	Water Absorbency (mL/50 g)	General Appearance
Sample 1 (Topsoil)	7.0	1338	35	Fine particles, small lumps, silvery specks
Sample 2 (Topsoil with HCl)	5.8	3462	20	Fine particles, small lumps, silvery specks
Sample 3 (Topsoil with NaCl)	7.3	4571	25	Fine particles, small lumps, silvery specks
Sample 4 (Topsoil with NaOH)	9.8	2966	28	Fine particles, small lumps, silvery specks
Crime Scene	7.1	4358	23	Fine particles, small lumps, silvery specks

Case Analysis Answers

1. What is the range of pH that you found in the five soil samples?
   Answers will vary. For the sample data, pH ranged from 5.8 to 9.8.
2. What does a high pH mean, and what does a low pH mean?
   High pH means basic, or alkaline, soil; low pH means acidic soil.
3. What can cause a soil to become acidic or basic?
   Mineral composition, the presence of organic matter, and environmental factors can change the pH of a soil.
4. What is the range of conductivity that you found?
   Answers will vary. For the sample data, conductivity ranged from 1338 to 4571 µS/cm.
5. What does a high conductivity indicate about the soil?
   There are many ions in the soil.

6. Why is it important to know the pH and the conductivity of a soil if you want to know how salty the soil is?
   Acids and bases can raise conductivity but will also change pH. A soil with a high conductivity and neutral pH is more likely to be salty than one with a high conductivity and extremely high or low pH.
7. What is the range of water absorbency that you found?
   Answers will vary. For the sample data, soils absorbed 20–35 mL water per 50 g sample.
8. What types of soils have high water absorbency, and what types of soils have low water absorbency?
   I***n general, soils with small particles and/or high levels of plant materials like sphagnum moss are highly absorbent. Sand and any nonporous soil with large particles will have low absorbency.***
9. How can an investigator use the physical appearance of a soil sample to link a suspect or victim to a crime scene?
   If the soil has a distinctive color or mineral makeup, then investigators can use that characteristic to match a sample from the crime scene to a sample from a suspect or victim and show that the person was at the crime scene.
10. What tools do forensic scientists use to identify and match soil samples?
    They can use microscopes, pH meters, conductivity probes, magnifying glasses, mass spectrometers, ion probes, and chemical tests.
11. Based on your observations, were any of the suspects' vehicles present at the crime scene? If so, which ones? Explain your answer.
    Answers will vary. In the case of the sample data, sample 3 seems to match the crime scene: It has similar values for pH, absorbency, and conductivity, and it is similar in appearance.