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.

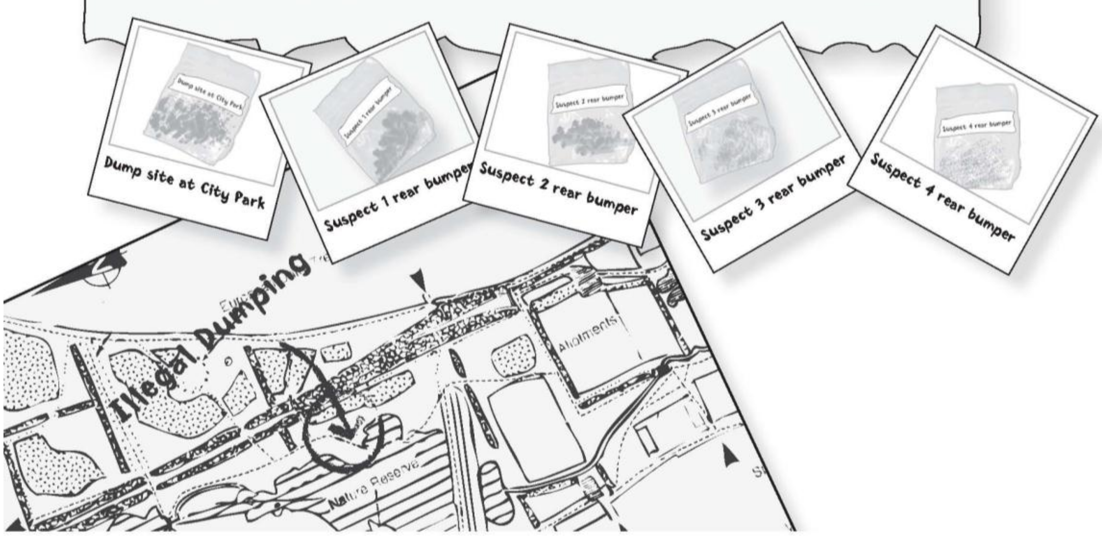
Police Report

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.

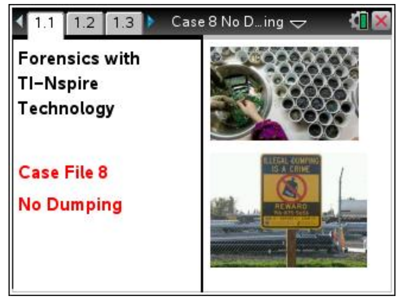
All four suspects deny having been anywhere near City Park in recent weeks.

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.



About the Lesson



- This lab introduces students to the importance of soils and other trace evidence in connecting victims, crime scenes, and suspects.
- Teaching time: two 45 minute class periods

Science Objectives

- Identify characteristics of different soils to demonstrate that a suspect has been at a scene.
- Use characteristic properties to identify a soil sample.
- Measure the pH of soils.
- Measure the water absorbency of soils.
- Measure the conductivity of soils.

Activity Materials

- TI-Nspire™ technology
- *Case 8 No Dumping.tns* file
- *Case_8_No_Dumping_Student.doc* student activity sheet
- Vernier EasyLink™ or TI-Nspire Lab Cradle
- Vernier pH Sensor
- Vernier Conductivity Probe
- magnifying glass
- coarse filter papers (12.5 cm diameter)
- distilled water
- lint-free tissues
- wash bottle (with distilled water)
- 100 mL graduated cylinder
- five 250 mL beakers
- 5 spoons or weighing papers
- 400 mL beaker
- 50 mL beaker
- stirring rod
- large funnel
- balance
- goggles
- five 100 g soil samples

TI-Nspire™ Navigator™

- Send out *Case 8 No Dumping.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Teacher Notes and Teaching Tips

- The student activity sheet and .tns file contain the complete instructions for data collection. All assessment questions are also included in both places giving you the flexibility to either collect the .tns files with student data/answers (using TI-Nspire Navigator) or the student activity sheet.
- This may be a good lab to do with a few stations of each sensor which students can rotate through, but which you have set up initially.
- 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.
- Be sure to demonstrate the pH Sensor cleaning sequence as you pre-lab the experiment.
- The procedure has students record pH values from the live meter (without actually selecting "start" on the DataQuest page)
- Conductivity readings are normally reported in microsiemens per centimeter, or µS/cm. This SI derived unit has replaced the conductivity unit, micromho/cm.
- Students are instructed to rinse the probe with distilled water between samples. They are told to blot the probe tip dry—however, the directions also remind them that they do *not* need to blot dry the inside of the hole containing the graphite electrodes. It is cumbersome to do so, and leaving a drop or two of distilled water does not significantly dilute the next sample.
- The procedure has students record conductivity values from the live meter (without actually selecting "start" on the DataQuest page)

- If you wish to calibrate the Conductivity Probe to improve conductivity readings at low concentrations, follow these directions:

  First Calibration Point

  a. Set up the data-collection software to calibrate the Conductivity Probe.
     - Connect the probe using Vernier EasyLink or the Lab Cradle. Press [home on] and select **New Document > DataQuest**
     - Select **MENU > Experiment > Set Up Sensors > Calibrate**

  b. For the first calibration point, the Conductivity Probe should simply be in the air (out of any liquid or solution).

  c. Type **0** in the edit box as the conductivity value (in µS/cm).

  d. Wait until the voltage stabilizes, then Keep the point.

  Second Calibration Point

  e. Place the Conductivity Probe into a standard solution that is equivalent to 10,000 µS/cm. **Note:** This standard can be prepared by dissolving 5.566 g of solid sodium chloride, NaCl, in enough distilled water for 1 liter of solution.

  f. Type **10000** in the edit box as the conductivity value for the second calibration point (in µS/cm).

  g. Wait until the voltage stabilizes, then Keep the point. Then select either OK or Done. This completes the calibration.

Allow students to read the forensics scenario on the first page of their student activity sheet.

Procedure

Teacher Preparation (Prior to Lab)

1. 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.

2. Different soils can be made with a variety of materials, including potting soils, compost, topsoil, clay, sand, lime, mud, and peat moss.
3. 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 readings are normally reported in microsiemens per centimeter, or µS/cm. This SI derived unit has replaced the conductivity unit, micromho/cm.

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 also be affected by human and environmental factors, 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.

Part 1 – Preparing the Soil-and-Water Mixtures

Move to pages 1.3–1.6.

Students will prepare the samples for testing by following the directions on the student worksheet or in the .tns file.

Part 2 – 5 – Collecting Data

Move to pages 1.4–3.2.

Students will follow the directions on the student worksheet or in the .tns file and test the pH, conductivity, physical appearance, and the water absorbancy of the soil samples.

Analyzing the Data

Move to pages 4.1–5.13

Students will record the data on the Evidence Record and/or in the .tns file on page 4.1 if you plan to collect the .tns files from students. Students will also answer the Case Analysis questions on pages 5.1-5.13 in the .tns file, student worksheet, or both,

Additional Resources

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://cals.arizona.edu/pubs/garden/mg/soils/index.html

This web site contains notes and summaries of soil identification methods from an international forensic science symposium.

http://www.interpol.int/Public/Forensic/IFSS/meeting13/Reviews/Soil.pdf

Modifications/Extensions

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.

Evidence Record

SAMPLE DATA

Sample	pH	Conductivity (μS/cm)	Water Absorbance (ml/50 g)	General Appearance
Topsoil	7.0	1338	35	Fine particles, small lumps, silver specks
Topsoil acidified	5.8	3462	20	Fine particles, small lumps, silver specks
Topsoil with salt	7.3	4571	25	Fine particles, small lumps, silver specks
Topsoil with base	9.8	2966	28	Fine particles, small lumps, silver specks

Case Analysis

Have students answer the following questions on the handheld, on their activity sheet, or both.

1. What is the range of pH that you found in the five soil samples?

   Answer: 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?

   Answer: High pH means basic, or alkaline, soil; low pH means acidic soil.

3. What can cause a soil to become acidic or basic?

   Answer: 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?

   Answer: 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?

   Answer: 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?

   Answer: 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?

<u>Answer</u>: Answers will vary. For the sample data, soils absorbed 20–35 mL water per 50 g sample.

8. What types of soils have a high water absorbency, and what types of soils have a low water absorbency?

<u>Answer</u>: In 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 to a victim or crime scene?

<u>Answer</u>: 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 can a forensic scientist use to identify and match soil samples?

<u>Answer</u>: They can use microscopes, pH meters, conductivity probes, magnifying glasses, mass spectrometers. Ion specific 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.

<u>Answer</u>: 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.