Case Teaching Notes

for

"Get the Lead Out! An Interdisciplinary Case Study for Science Students"

by

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Introduction / Background

This case study was inspired by an actual U.S. Environmental Protection Agency (EPA) Superfund site in the town of Leadville, Colorado. After discovering lead contamination as a result of historic mining operations there, a number of remediation techniques were employed, including phytoremediation. The cleanup is still ongoing. It is our hope that this case will stimulate interest in chemistry and, in particular, the field of environmental science.

The case is designed to be used in the general chemistry curriculum. Ideally, it should be done at the end of the second semester as a special project when students have honed their lab skills over two semesters. Another possibility is a joint project between a general chemistry "team" and an organismal biology or botany "team" that culminates in a joint presentation. The case would also work well in analytical chemistry and instrumental chemistry courses.

The case unfolds as the protagonist, Dr. Barbara Elliot, arrives at a hospital emergency room to find a young patient suffering from chronic flu-like symptoms. We learn that many of Dr. Elliot's pediatric patients have had the same set of mysterious symptoms. With the discovery of high lead levels in the patient's blood, the doctor begins to suspect that the local environment, which is the site of historical mining operations, may be connected to the child's illness. In subsequent parts of the case, students, in the role of chemists, analyze the local groundwater and find lead concentrations well above EPA action levels, then conduct research into appropriate remediation techniques for the highly contaminated local soils.

Students are expected to have the following background knowledge and skills:

- The ability to research scientific information and distill the important points as well as to interpret the results of others and come to conclusions.
- A basic understanding of chemistry, particularly solutions and basic chemistry of complex ions.
- Good lab skills.

Objectives

Upon completion of this case study, students should have an understanding of:

- The nature of mining operations and their effect on the environment.
- The effects of unsafe levels of lead in the human body.
- The theory and application of atomic absorption spectroscopy in lead determination.
- Possible methods of remediating contaminated soil—in particular, phytoremediation.

These specific learning objectives represent only a part of the broader look at the issue of environmental contamination, its effects on society, and the interdisciplinary nature of its detection and remediation.

Classroom Management

This case study is divided into three parts that are completed during four lab periods. Handouts are given to students for each part of the case as the story progressively unfolds.

Part I—Lake County Emergency requires one lab period in which students work in groups of four to research mining operations and the effects of lead in the human body. They are asked to bring in lab aprons for the following lab period and are provided with lab procedures for Part II (see *Lab Handout—Lead Analysis by Flame Atomic Absorption Spectroscopy* in the case study, which is given out to the students; also see separate *Teaching Notes for Lead Analysis Lab* at the end of these teaching notes).

Part II—Water Testing in Lake County requires two lab periods. In the first, necessary glassware and equipment is acid washed. Student groups acid wash their equipment to prepare for the next lab period. Research is then done into the theory of atomic absorption (AA) spectroscopy. In the second lab period, the water sample and lead standards are prepared. Working in their groups, standards and samples are then run on the AA and results are distributed.

Part III—Lead Remediation in Lake County requires one lab period during which students work in groups to research remediation techniques. At the conclusion of the case, students can be told that this is a real-life Superfund site. They can go to the EPA website and research California Gulch Superfund site to see what has been done thus far to clean up the site.

Blocks of Analysis

Atomic Absorption (AA) Spectroscopy

An atomic absorption spectrometer (AA) is used in this experiment to analyze a water sample for toxic levels of lead.

An AA is a very versatile analytical instrument. This technique is used to determine the concentrations of trace amounts of metals in a sample. Most metals on the periodic table can be quantified using this tool because:

- Each metal absorbs and emits a different color of light.
- The more concentrated the sample solution, the more light is absorbed.

Absorption and Emission of Light

When atoms are exposed to outside energy, electrons in the atom move to higher energy levels (or farther from the nucleus) and are thus "excited." They then lose energy by the emission of light, returning to a lower energy level (or closer to the nucleus). The frequency of the light emitted is related to the distance that the electrons in the atom travel—the greater the distance traveled, the greater the frequency of light and vice versa. Every element has unique energy transitions that translate to unique emission spectra or unique frequencies of light for that element.

When an atom is vaporized, it absorbs many of the same frequencies of light as it emits; this is the foundation for atomic absorption spectrophotometry. In the process of absorption, electrons in the sample atoms gain energy from incoming light by undergoing a transition from a lower energy level to a higher energy level. This is the reverse of the emission process.

In atomic absorption spectroscopy, the sample of interest is heated to a temperature that will vaporize it while leaving some of the atoms in an unexcited state. The vaporized atoms are then exposed to emitted light from a light source known as a hollow cathode lamp specific for the element to be measured—in this

case, lead. The sample of interest will absorb these frequencies of light and this absorption is what is being measured.

Some amount of this light from the hollow cathode lamp (called incident light, $\mathbf{I_o}$) will be absorbed by the sample. As a result, only part of this incident light will travel, or be transmitted, through the sample. This transmitted light is called $\mathbf{I_t}$. The ratio of transmitted light to incident light is known as transmittance, **T**.

The AA measures absorbance. Transmittance is related to absorbance in the following way:

$$\mathbf{T} = \frac{\mathbf{I_t}}{\mathbf{I_o}}$$

$$\mathbf{A} = -\log \mathbf{T}$$

Absorbance is related to the concentration of the element being analyzed. For a dilute solution, Beer's Law shows the relationship between the two:

$$\mathbf{A} = \varepsilon \mathbf{bc}$$

where **A** is Absorbance, ε is the molar absorptivity coefficient and is constant for a given wavelength, **b** is pathlength through the sample (also essentially constant because the same pathlength is used throughout the analysis), and **c** is concentration of the element being analyzed. Therefore, absorbance is proportional to the concentration of the element being analyzed in the sample.

Answer Key

Answers to the questions posed in the case study are provided in a separate answer key to the case. Those answers are password-protected. To access the answers for this case, go to the key. You will be prompted for a username and password. If you have not yet registered with us, you can see whether you are eligible for an account by reviewing our password policy and then apply online or write to answerkey@sciencecases.org.

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Teaching Notes for Lead Analysis Lab

Acid Washing (Day One)

Students will collect and acid wash all needed glassware. A carboy of 6 M nitric acid should be available to the students as well as a large container for acid waste. Acid washed glassware should be inverted on clean paper towels to dry until the next lab period.

Standard and Sample Prep (Day Two)

A certified primary standard of 1000 ppm Pb should be available for student use. It is important that this is transferred to their 10 mL beakers and NOT pipetted from the primary standard container itself to prevent contamination. No matrix modifier is needed for this lead analysis.

The instructor will provide "groundwater" samples to each student group. This sample should be prepared in the same way as the standards to have a concentration of approximately 8 ppm using 1% nitric acid as the solvent. They should be tightly sealed and refrigerated until used.

A waste container should be provided for all standards and samples that contain lead ions. Appropriate disposal methods should be followed.

Spectrometer Setup

The spectrometer used in the lab is a ThermoElectron Solaar M6 AA. The settings are as shown below:

Spectrometer Parameters

- Wavelength: 217.0 nm
- Background Correction should be Off
- Bandpass: 0.5 nm
- Lamp Current: 75%

Flame Parameters

- Flame Type: Air/Acetylene
- Nebulizer Uptake: 4 sec
- Burner Height: 7.0 mm
- Fuel flow: 1.1 L/min