A Plume Problem

Summary
In this lesson you will analyze data to solve a mystery and identify a potential polluter by:

• analyzing data to trace the flow of contaminants in groundwater.
• researching historical practices to solve today’s water issues.

Pre-Activity Questions:
1. What is groundwater? Circle the best answer.
   a. An underground river
   b. Water that pools and flows on the ground when it rains
   c. Water found in spaces between soil underground
   d. The water in lakes and rivers

2. What is a groundwater plume? Circle the best answer.
   e. A contaminant with a starting point and clear pathway
   f. The place where groundwater rises to the surface
   g. A balloon of pollution with no clear path
   h. An aquifer below ground
**Background information**

As the name implies, groundwater is located in the ground in the spaces between soil particles and rocks. It is a very important source of water for us. Groundwater is the source of about 40 percent of water used for public supplies and about 39 percent of water used for agriculture in the United States.

Groundwater moves very slowly though the rocks and soil—at a rate of 3-25 inches per day in an aquifer. In order to access groundwater we dig wells and pump water out of the ground.

Groundwater plumes occur when groundwater carries a contaminant in its flow.

**Materials**

Please gather these materials before starting.

**Activity**

- A Pencil
- Three different color pens or markers
- Student page Community Map
Procedure

Activity

3. Take out your Community Map Student Page. Read the scenario below about what is happening in the community represented on the Community Map.

A Plume Problem

You are a physician in a small community (about 1,000 residents). Yours is an old family in this area; your great-great-grandfather settled here in the 1800s and was a famous officer in the Civil War. Several members of your family are buried in the local cemetery.

Over the past couple of years, a few members of the community have described to you their puzzling physical symptoms. Recently, a patient presented you with similar but more serious complaints: weakness, tingling and numbness in his hands and feet, and dark warts on the palms of his hands and the soles of his feet.

You listen carefully as your patient responds to questions related to his medical history. He works in the small, local factory (Private Well #6, on the Community Map) that produces wood preservatives. He has lived in the area for about 10 years. He and his wife of 10 months have a private well at their home. His wife has not exhibited similar symptoms. He quit smoking three years ago and does not drink alcoholic beverages. He takes no medications, only vitamins.

You meet with members of the town council and express your suspicions—that the symptoms you have documented over the last few years are related to chronic arsenic poisoning from contaminated drinking water. You advise them that the arsenic standard for drinking water set by the EPA (Environmental Protection Agency) is 10 parts per billion (ppb). The town council votes to budget money for ground water testing that will initially be limited to wells already in existence.

4. The investigation begins on the Southwest side of town. Start there then plot the data of arsenic concentrations located on the side of the Community Map, moving up the map as you go. Time is of the essence, so you have 30 seconds to plot as many well’s data as possible. Your time starts now!

5. Based on your data what is the source of the arsenic pollution?
6. How did you reach this conclusion?

7. It turns out that the factories have been cleared. They have proven that their operations are not responsible for the arsenic contamination. What do we need to do to find the pollution source? Circle the best answer.
   a. Test Factory B again— the data points to it as the culprit!
   b. Get more data points from various locations around town.
   c. Ask everyone to send samples of their drinking water in for testing.
   d. Nothing. The data speaks for itself!

8. The Community Map is laid out as a grid. To get a more accurate picture of the arsenic plume in the groundwater we need to test more locations around town! At each coordinate a test well is drilled. For example, a test well is drilled at B12 and shows arsenic levels at 0 ppb or no arsenic detected.

   Use Data Set 2 to plot more data points on the Map. Keep plotting until you think you know where the source is from. Remember, finding this quickly is important so get as many data points plotted as you can in 30 seconds.

<table>
<thead>
<tr>
<th>Data Set 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B12 = 0</td>
</tr>
<tr>
<td>E12 = 0</td>
</tr>
<tr>
<td>G12 = 0</td>
</tr>
<tr>
<td>I12 = 0</td>
</tr>
<tr>
<td>B10 = 13</td>
</tr>
<tr>
<td>E10 = 20</td>
</tr>
<tr>
<td>G10 = 20</td>
</tr>
<tr>
<td>I10 = 18</td>
</tr>
</tbody>
</table>

9. Based on this additional data where do you think the arsenic contamination originated from?

10. How did you reach this conclusion?
11. Read the article below from *Smithsonian Magazine* then summarize in a sentence or two how arsenic entered the community drinking water.

SMITHSONIANMAG.COM
OCTOBER 30, 2015
By Mollie Bloudoff-Indelicato

**Arsenic and Old Graves: Civil War-Era Cemeteries May Be Leaking Toxins**

*The poisonous element, once used in embalming fluids, could be contaminating drinking water as corpses rot.*

If you live near a Civil War-era cemetery, rotting corpses may be on the attack. While there's no need to fear the walking dead, homeowners should watch out for toxins leaking out of old graves that could be contaminating drinking water and causing serious health problems.

When someone died at the turn of the century, it was common practice to bring a photographer in to take death photos. Also, the people who fought and died in the Civil War came from all over the United States, and families who wanted to bury their kin would pay to have them shipped home.

At the time, ice was the only option to preserve a body, but that didn’t work very well—and no one wants to see a deceased relative partially decomposed.

“We’re talking about the 1800s, so how do you freeze [the bodies] and keep them frozen if they take weeks to transport?” says Jana Olivier, an environmental scientist and professor-emeritus at the University of South Africa.

Thus, embalming in the U.S. became a booming industry during the Civil War era. People willing to try their hand at embalming spent their time following the military from combat zone to combat zone.

“Embalmers flocked to battlefields to embalm whoever could afford it and send them home,” said Mike Mathews, a mortuary scientist at the University of Minnesota.

Embalming fluid is effective, but it's also nasty stuff. Many early recipes for embalming fluid were jealously guarded by morticians because some worked so much better than others, but most commonly contained arsenic, Mathews adds. One popular formula “contained about four ounces of arsenious acid per gallon of water, and up to 12 pounds of non-degradable arsenic was sometimes used per body,” according to the 5th Street Cemetery Necrogeological Study.

Arsenic kills the bacteria that make corpses stinky—if you've ever smelled bad meat, you can imagine how important it is for embalming fluid to do its thing and do it well. But the poisonous element doesn't degrade, so when embalmed bodies rot in the ground, arsenic gets deposited into the soil.

“A Civil War-era cemetery filled with plenty of graves—things seldom stay where you want them to,” says Benjamin Bostick, a geochemist at Columbia University. "As the body is becoming soil, the arsenic is being added to the soil." From there, rainwater and flooding can wash arsenic into the water table.

That means old cemeteries full of deceased soldiers and civilians present a real problem for today’s homeowners. The federal government says it's only safe for us to drink water with 10 parts per billion of arsenic or less. But in 2002, a USGS-sponsored survey in Iowa City found arsenic levels at three times the federal limit near an old cemetery.
“When you have this big mass of arsenic, there’s enough to affect literally millions of liters of water at least a little bit,” Bostick says.

If humans ingest the contaminated water, it can cause significant health problems over time. Arsenic is a carcinogen that’s associated with skin, lung, bladder and liver cancers, says Joseph Graziano, an environmental health scientist at Columbia University. Drinking arsenic-contaminated water has also been linked to cardiovascular disease, lung disease and cognitive deficits in children.

The good news is that arsenic was banned from embalming fluid in the early 1900s. It was causing health problems for medical students who were operating on embalmed cadavers. Also, the presence of so much arsenic made murder investigations almost impossible. Police couldn’t distinguish between embalming fluid arsenic and cases of murder by arsenic poisoning.

“The state stepped in and said [morticians] couldn’t use arsenic anymore. Boy, they outlawed it real quick,” Mathews says. Now, morticians use a combination of gluteraldehyde and formaldehyde—both chemicals that sterilize—to embalm bodies for open caskets, he adds. These chemicals evaporate away before they pose a risk to the water table.

But if you live near an old cemetery, you should get your well water checked for arsenic and other contaminants every few years, Mathews advises. “Sadly, much of the population today isn’t aware of the hazard that arsenic poses,” Graziano says. “Any homeowner should be testing their well water frequently. We need to be vigilant about hazards from drinking water.”

Summarize the article in a couple of sentences. How is the cemetery the source of the pollution?

12. How does groundwater flow in this community based on your data? Draw an arrow on the map below to show the flow of groundwater under town.
13. Draw circles in different colors around the arsenic levels as instructed below. (Use whatever colors you have. If you don’t have different colors, you can mark the areas with different patterns.)

   Above 50 ppb = red  
   30-49 ppb = orange  
   1-29 ppb = blue

14. Congratulations! You have defined the arsenic plumes in the community.

15. Using arsenic in embalming is only one historical practice that affects us today. There are other examples that affect today’s water. Research one of these practices and its effect on watersheds today. Summarize your findings to turn into your teacher as instructed.

   - Historical Mining Practices (The Gold King Mine Spill in Colorado in 2015)
   - Coal Fly Ash—ash from burning coal for energy
   - Agriculture—fertilizer, pesticides and water use
Glossary

Acute: Being short in duration or severe in intensity, such as with an illness or pain. Opposite of chronic.

Aquifer: An underground bed of saturated soil or rock that yields significant quantities of water.

Arsenic: A poisonous heavy metal element that was often used in industry. Its atomic number on the periodic table of elements is 33 and its symbol is As.

Bedrock: The solid rock layer that lies below the soil.

Chronic: Being long in duration or mild to moderate in intensity, such as with an illness or pain. Opposite of acute.

Contaminant: Any substance that when added to water (or another substance) makes it impure and/or unfit for consumption or use.

Groundwater: Water found in spaces between soil particles underground (located in the zone of saturation).

Hydrologist: A professional engaged in the study of the Earth’s water.

Parts per billion: Units typically used in measuring the number of “parts” by weight of a substance in water; commonly used in representing pollutant concentrations.

Pesticide: A synthetic or non-synthetic product designed to control unwanted insects, animals, weeds or pathogens.

Plume: A continuous emission from a point source of contamination that has a starting point and a noticeable pathway.

Seepage: A liquid or gas that has percolated or moved through a porous material slowly.
Concentration of Contaminant (ppb)

DATA SET I
AW1 = 0
AW2 = 39
AW3 = 9
PW1 = 0
PW2 = 0
PW3 = 0
PW4 = 24
PW5 = 35
PW6 = 54
PW7 = 12
PW8 = 21
PW9 = 30
PW10 = 12
PW11 = 3
PW12 = 0
PW13 = 0
CW1 = 22.5
CW2 = 6
CW3 = 15
CW4 = 0

DATA SET II (provided by teacher)

KEY:
AW# = Abandoned well
PW# = Private well
CW# = City well

= Private house
= Factory
= Site of well

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