# A Plume Problem (aka A Grave Mistake)

## Tips for Educators Using this Lesson at Home

*Note: This lesson is called "A Grave Mistake" in the* Project WET Curriculum and Activity Guide 2.0*. We renamed it "A Plume Problem" for this student self-paced lesson to prevent ruining the discovery moment of the lesson.*

This lesson is correlated to Grades 5-12 and recommended for middle school and high school aged children. The lesson is correlated as written in the *Project WET Curriculum and Activity Guide 2.0*. Correlations are meant to show how activities support a standard, performance expectation and/or three-dimensional learning. NGSS correlations are provided in detail in a separate document to demonstrate how the content of this activity provides a three-dimensional learning experience. Common Core State Standards correlations for grade spans assume that teachers will be familiar with the standards for their respective grade level(s) and be able to apply them judiciously.

**Summary:** Students 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.

**Common Core**: *ELA*: RH.6-12.7; RST.6-12.4; SL.6-12.1; SL.6-7.2; *Math*: 5.G.2

**NGSS**: 5-ESS3-1, MS-ESS3-3, MS-LS2-4

### Instructions for Educators

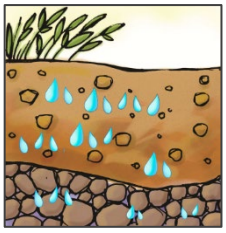
1. Distribute the PDF lesson or assign the eLesson of A Plume Problem to students.
2. Have them complete the lesson as instructed.
3. Ask students to turn in the completed lesson and Community Map to you.
4. Talk to students after the lesson. Were they surprised by the source of arsenic? Discuss how not having enough data can lead to the wrong conclusions.
5. What did students learn in their research of other historical practices that have let to contamination of water?
6. See Answer Key on the following pages.

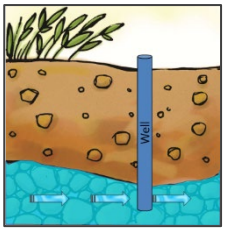
**Pre-Activity Questions:**

1. What is groundwater?
    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?
    a. A contaminant with a starting point and clear pathway
    b. The place where groundwater rises to the surface
    c. A balloon of pollution with no clear path
    d. An aquifer below ground

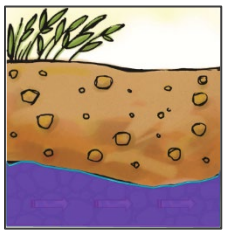
**Background information**






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.

## Procedure

### *Activity*

1. 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.

2. 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!


3. Based on your data what is the source of the arsenic pollution?

Most students will say Factory B as that is what the data points to. There is not a correct answer here.

4. How did you reach this conclusion?

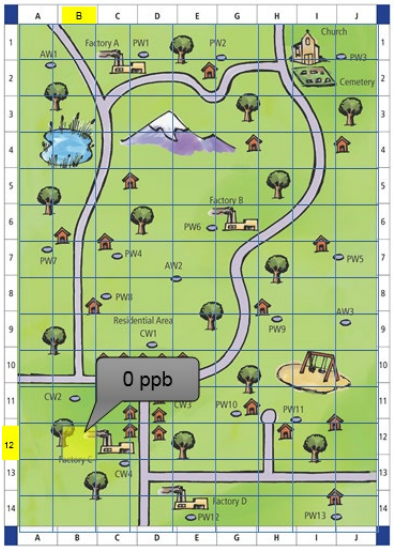
   Answers will vary but should mention that the higher concentrations of arsenic are around Factory B

5. 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?

   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!

6. 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.




| Data Set 2: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| B12 | = | 0 | B8 | = | 18 | B4 | = | 6 |
| E12 | = | 0 | E8 | = | 38 | E4 | = | 32 |
| G12 | = | 0 | G8 | = | 42 | G4 | = | 65 |
| I12 | = | 0 | I8 | = | 33 | I4 | = | 70 |
| B10 | = | 13 | B6 | = | 15 | B2 | = | 0 |
| E10 | = | 20 | E6 | = | 42 | E2 | = | 0 |
| G10 | = | 20 | G6 | = | 61 | G2 | = | 0 |
| I10 | = | 18 | I6 | = | 48 | I2 | = | 78 |

See Community Map Answer Key for all data points.

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

   The Cemetery

8. How did you reach this conclusion?

   Higher concentrations of arsenic below the cemetery.

9. 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.

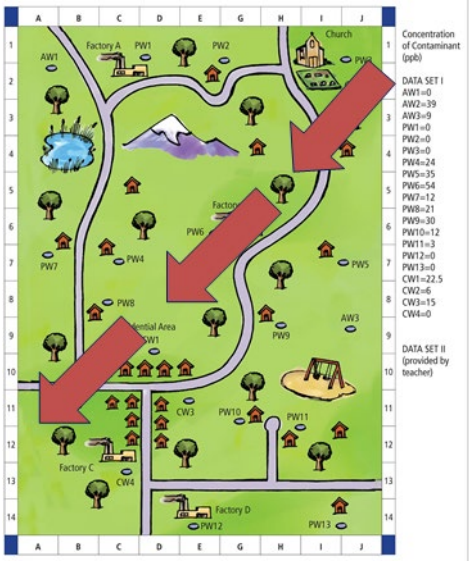
"The state stepped in and said [morticians] couldn't use arsenic anymore. Boy, they outlawed it real quick," Mathews says. Now, morticians use a combination of gluteraldehyde and formaldehyde—both chemicals that sterilize—to embalm bodies for open caskets, he adds. These chemicals evaporate away before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

Answers will vary but should mention that before 1900 arsenic was used as embalming fluid and is now seeping into groundwater from the decomposing bodies.

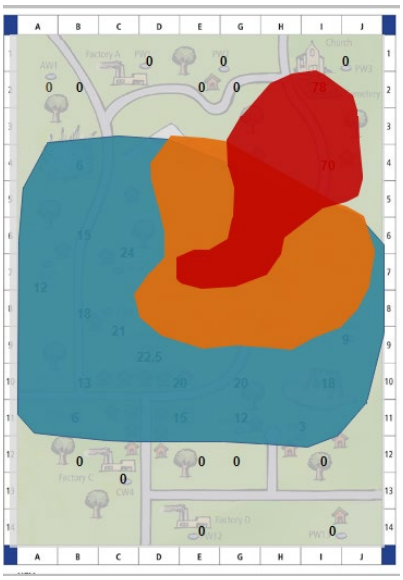
10. How does groundwater flow in this community based on your data? Draw an arrow on the map below to show the flow of groundwater under town.




Water flows from the Northeast to Southwest from high elevation to low elevation.

11. 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



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

13. 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

**Community Map Answer Key**