Cemetery Consequences

Adapted from: A Grave Mistake. The Project WET Curriculum and Activity Guide (pg. 311-314).

Grade Level: Intermediate, Advanced

Duration:
30 minute preparation time,
50 minute activity time

Setting: Classroom

Summary: Students plot data to determine a source of arsenic contamination and determine possible actions for fixing the problem

Objectives:
1) Trace contaminated groundwater flow by analyzing data
2) Realize actions taken in the past may create problems for today

Vocabulary:
Groundwater, plume, water table

Related Module Resources:
- Groundwater Simulator
- Related Activities: Discover the Source

Materials (Included in Module):
- Plastic lid
- Sand
- Grape-flavored drink powder
- Spray bottle
- Copies of the Community Map

Materials not included in module
- None

ACADEMIC STANDARDS:

7th Grade

4.1.A Explain the role of the water cycle within a watershed.
- explain the water cycle

10th Grade

4.1 E Identify and describe natural and human events on watersheds and wetlands.
- Identify the effects of humans and human events on watersheds

12th Grade

4.2.B analyze factors affecting the availability of renewable and nonrenewable resources
- Evaluate the use of natural resources and offer approaches for using them while diminishing waste

BACKGROUND: (*Do not read this section to students until the activity has been done*)

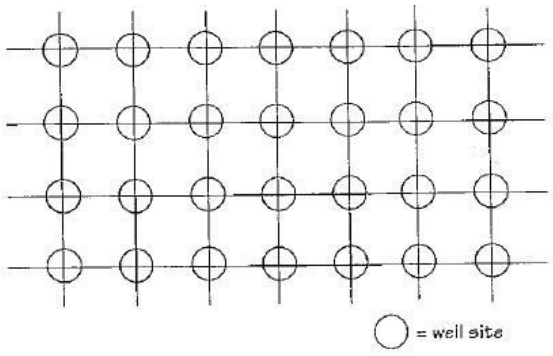
Arsenic is a natural occurring, highly stable element that is naturally found in bedrock throughout the world. **Groundwater** contains a natural minute concentration of arsenic from bedrock. Groundwater is merely water that percolates through the soil to the **water table**, where it fills in the spaces between rock particles and within bedrock fractures. Natural high concentrations of arsenic in groundwater are rare, limited to areas of high geothermal activity (Alaska, Northwest & Southwest USA). High concentrations of arsenic (>50 parts per billion) are usually due to industrial pollution. Industries use arsenic today to produce pesticides and wood preservative products.

This toxic chemical was commonly used as a treatment to certain diseases and as an embalming fluid. During the civil war (1880), physicians commonly used an embalming fluid that contained arsenic to preserve dead soldiers instead of ice because arsenic does not melt. This has become problematic today because arsenic is a very stable compound that can take decades to degrade into a non-toxic state. The

deceased were commonly buried in wooden or metal coffins that degraded after a few short years, allowing the arsenic to seep out of their containers and contaminate surrounding groundwater. Arsenic was discontinued as an embalming fluid in 1910 after toxicologists discovered that it is toxic to life. Therefore, cemeteries containing graves buried from 1880-1910 are potential contributors of arsenic contamination in groundwater.

Symptoms characteristic of acute (high concentration and short exposure time) symptoms of arsenic poisoning include vomiting, diarrhea, shock, coma, and even death. Non-cancerous skin lesions and numbness of the soles and palms commonly occur to those exposed to low concentrations of arsenic over an extended time. This condition is called neuritis.

To detect changes in groundwater quality and quantity over time, scientists monitor a grid pattern of wells. Scientists gain access to well water by drilling new wells or by sampling city wells, domestic wells, or irrigation wells. The accuracy of the ground water assessment is dependent upon the number of samples taken: more samples improve accuracy. The pattern of the wells sampled is also important; a grid pattern creates a three dimensional image of the ground water system that is easy to map.



OVERVIEW: Students are the physicians for a small town that is stricken by a mysterious illness. The disease is diagnosed as exposure to the toxic chemical arsenic. Groundwater testing begins to locate the source of contamination. The community initially blames a local factory for contaminating the groundwater.

PROCEDURE:

Warm Up Exercise (***Strongly recommended***)

Groundwater Simulator also effective here.

1) Draw a diagram similar to Fig. 1. Ask students, based upon the diagram, if nitrates are found within the family's well water, where should they look for the source of the contaminant? Remember that animal wastes are high in nitrates.
2) To illustrate how the nitrates may have seeped into the family's well water, you can demonstrate a **plume**. A plume, which is a form of point-source pollution, occurs when pollutants are leaked and infiltrate into the groundwater. A plume may spread for thousands of feet and persist for many years *after* the source is removed.
3) Fill a glass-baking dish 1-inch deep with sand.
4) Bury grape-flavored drinking powder (the contaminant) at one end of the dish.
5) Elevate the end with the powdered drink 1.5 inches.
6) Thoroughly wet the sand with the spray bottle (don't pour H_20 to simulate groundwater) the mix should spread throughout the sand (creating the plume).
7) Ask students what conditions could have promoted this particular plume event? Examples of point source pollutants include a leaking waste storage container, a drainage pipe from a sewage treatment plant, an industry, or a street pipe.

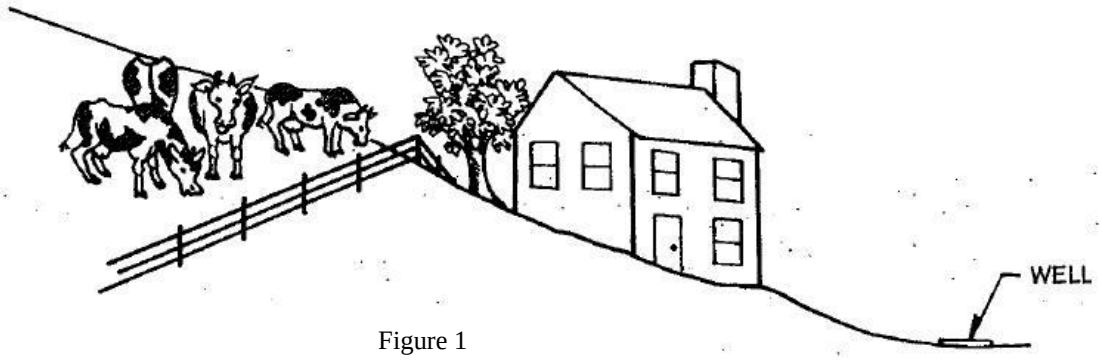


Figure 1

The Activity:

1) Read the students the following scenario:

You are a physician in a town of 1500 residents. Your family has resided here for generations, dating back to the Civil War. Several members of your family happen to be buried in the town's cemetery.

Over the past couple of years, members of your community have described to you a rather identical but puzzling set of physical symptoms. Recently, a patient presented you with similar but more serious complaints: weakness, tingling, and numbness in the 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 about his medical history. He works in the town's small local factory (Private well 6 on the Community Map) that produces wood preservatives. He has lived in the area for ten years, his newly wedded wife joining him 10 months ago. His wife has not exhibited similar symptoms. He quit smoking three years ago and does not drink alcoholic beverages.

You meet with members of the town council and inform them of your suspicions: that the symptoms you have been documenting over the last few years are due to chronic arsenic poisoning from contaminated drinking water. You advise them that a safe level of arsenic in the ground water is 50 parts per billion. As a result, the town council votes to budget money for ground water testing to wells already in existence.

2) Distribute copies of the Community Map with contamination level data (Data Set 1). Inform the students that the top right-hand corner of the map is highest in elevation gradually declining to the lowest point on the map, the bottom left-hand corner.
3) Have students indicate what direction groundwater will move (From highest to lowest elevation or from the upper right-hand corner to the bottom left-hand corner). Explain that the contamination data were collected via tests conducted at existing wells—abandoned, private, and city wells.
4) Instruct students to begin on the southern border of the map (the bottom) and plot contamination levels from the bottom of the map to the top. As soon as they believe they know the source of arsenic, they should stop plotting data and alert the teacher. (Tell students that this is a race against time; they are competing to be the first to identify the source of pollution).
5) The students will probably make the error that Factory B is releasing the arsenic into and thus contaminating the groundwater. Remember that this is a valid guess since arsenic is required to produce wood preservatives. After their guess, divide students into groups and ask them to write response answers to the following questions:

- What should the town do with your information?
- What options should the factory be given? The factory in question (B) is a major employee for people within the community. May this affect your resolution with the factory?

6) Have students share their answers with the class.
7) After class discussion, reveal to the class that the factory owner has proven that 100% of the arsenic coming into and exiting the factory is accounted for. A second monitoring agency confirmed their

statement by drilling test wells around the wood preservative factory. They are not responsible for the arsenic contamination.

8) Have students determine what should be done now? They may conclude that they do not have enough data to determine the arsenic source. However, the source of the arsenic must be located if the town is to survive. The city has budgeted additional funding to locate the source. New wells designed specifically for water quality monitoring are required to continue the study.
9) Inform students that each group now represents a separate water quality-testing agency. Each agency is competing against one another to determine the arsenic source first.
10) Direct the students' attention on the border of the map. Explain how the magnitudes (letters and numbers) on the map can be used to plot coordinates on the map. At each of these coordinates a test well has been drilled.
11) You will provide the different agencies with the data for these newly drilled wells (Data Set 2). Each agency will send one representative to you to collect one coordinate at a time. After the representative has received their data, have them return to their agency to analyze the data. The individual agencies will have to determine when they have gathered enough data to determine the correct source. It is important that the students keep their data secret from the other groups.

DATA SET 2
(in parts per billion)

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

12) Students should gradually determine that arsenic concentrations are highest north of the factory, just south of the cemetery. Discuss other possible sources of the arsenic. Could the cemetery be the cause? Share the background information with the students at this time.

DISCUSSION:

- Have students discuss what action the town should take now that the source of the arsenic has been determined. Remind students that they and many other members of the town have family members buried in the cemetery. (*Perhaps the coffins may be dug up and bodies transferred to modern coffins that won't degrade*.) Additionally, remind students that even after the source of the arsenic has been removed, it may take years for all of the arsenic to be removed from the groundwater (plume example).
- Here are a series of questions dealing with the patients suffering from arsenic poisoning. After reviewing the patients' medical histories again, ask the students the following questions:
- Q: Why didn't the wife of the patient with severe arsenic poisoning symptoms also show symptoms?
  A: *Couple was recently married, she had only been living with him for 10 months. Possible that she would also suffer from symptoms if she was exposed to it for a longer tim*e.
- Q: Why didn't the physician identify arsenic poisoning earlier as the problem if he had seen similar symptoms in other patients?
  A: *Many physicians are unaware today of the symptoms of many toxic chemicals (arsenic, lead, etc.) because their use has been discontinued today. Additionally, several people in the same family*

drinking the same water might react differently to the toxicant depending upon their physical conditions and their habitats.

- Reinforce how benevolent actions taken in the past can cause problems in the present. Ask students how the statement: "Past solutions sometimes become present problems." Ask students if they can think of any other examples.

EVALUATION:

Students should be able to:

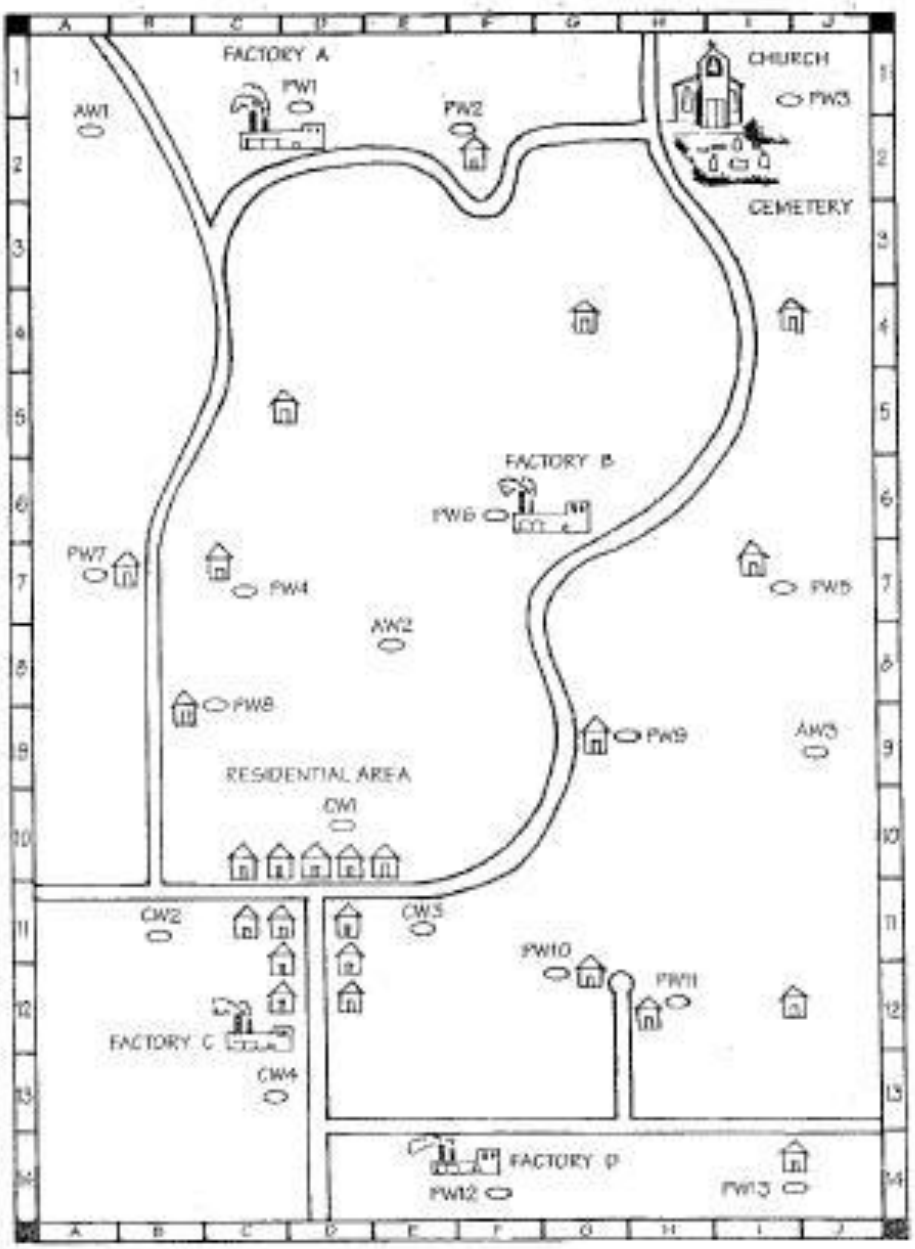
- Plot data to determine the source of the arsenic contamination (steps 4 & 11)
- Determine that insufficient data can lead to inaccurate conclusions (step 8)

EXTENSIONS AND MODIFICATIONS:

- Have students investigate who is responsible for monitoring water quality within their town. Can they think of any industries or activities that may be polluting their groundwater?
- Take students to a local cemetery to count how many people were buried from 1880-1910 (years arsenic was used as an embalming fluid). Could that cemetery possibly be a source of arsenic contamination?

NOTES (PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS IN THE FUTURE):

Community Map



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
= SITE OF WELL
= FACTORY