

# Forensic Groundwater Contamination Kit

## Introduction

Who is contaminating the groundwater? Become a forensic scientist and help determine the culprit!

## Background

At the molecular level, water is engaged in an endless cycle; from streams, to lakes, to rivers, to oceans, then to be evaporated, carried aloft and returned to the surface as precipitation. The water cycle is one of the major biogeochemical cycles upon which all living things on our planet depend.

When rain falls on the ground where does it go? To put it simply, some of it evaporates, some runs off to streams, and some soaks into the soil. Some of what soaks into the soil is taken up by plants, transpired, and returned to the atmosphere. The remainder continues to percolate down through the soil and becomes groundwater. As this water percolates downward it passes first through what is called the aerated zone. The *aerated zone* is characterized by having mostly open pore spaces with some residual water held by surface tension. Water continues down through the aerated zone to the *saturated zone*—where all of the pore spaces are completely full of water. The upper boundary of the saturated zone is known as the water table (see Figure 1).

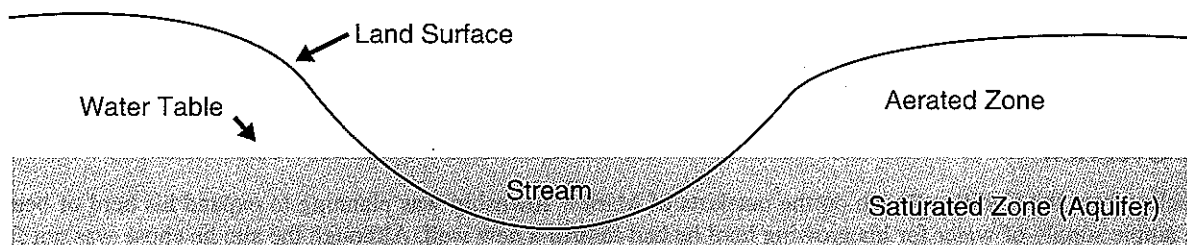


Figure 1.

The lower boundary of the saturated zone is usually an impermeable layer of rock or clay preventing further downward percolation of the water. The saturated zone can be likened to an underground, flowing reservoir and is commonly called an aquifer. Where the land surface falls below the level of the water table, the aquifer will be visible as a lake, pond, or stream. The flow of water in these underground systems is driven by gravity and will be in the same general direction as that of the surface waters. Rates of flow may range from millimeters to meters per day.

Groundwater provides one-fifth of all the freshwater used in the United States and one-half of the drinking water. In some regions of the country it provides more than one-half of the freshwater used for crop irrigation, industrial processes, and livestock. Its importance as a major source of fresh and potable water cannot be overstated.

Withdrawal of groundwater can occur by either active or passive means. *Active withdrawal* requires drilling wells to the depth of the water table or saturated zone and pumping the water to the surface. *Passive withdrawal* simply requires tapping a free-flowing spring—where the pressure of water trapped between impermeable layers of rock or clay is sufficient to force it to the surface. As most groundwater systems are in a state of dynamic equilibrium, with water flow into the system ultimately equivalent to water flow out of the system, any significant withdrawal is going to alter that equilibrium. If withdrawal remains steady at a low enough rate the result will be a new equilibrium at a lower water level. If withdrawal exceeds a certain rate, and continues to increase, the result is a condition known as *overdraft*. Under overdraft conditions wells will run dry, land may subside as it settles to fill the void left by the water, and in coastal areas saltwater may intrude into the aquifer. Any of these conditions can have severe consequences.

Groundwater naturally contains microorganisms (decomposers naturally present in the soil), gases produced by metabolic processes and decomposition, and dissolved organic and inorganic compounds. Groundwater is by no means pure and all of the basic properties used to describe water are due to naturally present constituents. Hardness is a measure of the levels of calcium and magnesium ions; salinity is defined by the quantity of dissolved salts; and color, taste, and odor are caused by a wide variety of compounds.

Water quality is an abstract concept that relates the suitability of water to a particular use. Water being considered for a particular use is subjected to a battery of tests to measure concentrations and levels of a number of constituents and properties. To “pass” these tests the results must fall within defined parameters—or else the water may be judged unsuitable. As an example, water that is too salty is unfit to drink and would be considered contaminated. Drinking water with excessive levels of lead, mercury, or pesticide residues would also be considered contaminated. These examples illustrate that contaminants can be either natural or caused by man.

Major sources of non-natural groundwater contaminants vary regionally. A few of the most recently cited include: waste from over-applied agricultural and domestic fertilizers, pesticides, sewers, landfills, septic systems, industrial wastewater lagoons, leakage from petroleum transport and storage systems, chemical spills, illegal dumping, and highway de-icing salts.

A contaminant follows the same route to the aquifer as the water itself. Percolating down through the soil, the contaminant reaches the saturated zone and enters the normal flow-pattern. The contaminant will move downstream, in most cases tending to fan out and form a plume. As such, contaminant concentration is greatest nearest its source, decreasing as it radiates downstream and away. The contaminant may arise either from a discreet, localized, “point” source or from a dispersed non-point source. An example of a point source would be a leaking pipe or compound dumped down a well. An example of a non-point source would be an agricultural chemical spread over many acres.

Once entering the soil numerous possible fates await contaminants. The contaminant may form insoluble precipitates with soil constituents and be rendered harmless. The contaminant may be adsorbed onto various substrates present in the soil and spread no further. Or the contaminant may be biologically or chemically degraded, converted, or decomposed. The contaminant may also be either diluted to harmless levels or mechanically filtered out as it passes through the soil. Any one, or none, of these processes may take place to offset the potential harm caused by the contaminant.

Detection and treatment of contaminants can be understandably very difficult. Aquifers may run tens, hundreds, or thousands of feet below the surface making extensive testing and monitoring of the water challenging and extremely costly. There may be no sign or indication of potential sources when and where a contaminant is detected, necessitating painstaking procedures to trace it. If the interval of distance or time between contaminant detection and its source is too great, tracing it may be impossible. Testing must also be conducted carefully to determine the boundaries of the contaminant plume and the affected area. Also, random testing may not analyze for a particular contaminant that might be present.

## Activity Overview

A rancher from the Cadillac Ranch on the outskirts of Marion Township was planning to expand his herd of beef cattle. To ensure an ample supply of water for his growing herd he had to drill a new well. Although the site he chose was not far from the Eagle River, he had no land rights adjacent to the river and was forced to drill for groundwater. Being a responsible rancher, he thought it might be a good idea to have the water tested by a nearby laboratory.

Routine tests at the local laboratory turned up some irregularities so the samples were forwarded to a state facility for more sophisticated analysis. The results from the state laboratory were disturbing. A potentially toxic compound was detected at a level of 25 parts per billion (ppb). The normal background level of this compound is in the range of 0-10 ppb, and a level of 25 ppb suggested a potentially dangerous contamination source.

The Marion town council convened with a groundwater expert from the State Environmental Agency in attendance. Once the expert made it clear that the well may have been dug on the fringes of a contaminant plume, and that levels within the plume nearer the source would likely be much higher, the council decided to act. A large sum of money was allocated from an emergency fund and a well drilling and testing company was contracted to determine the extent of the problem and, if possible, to trace the source of the contaminant.

In this activity, your group will be asked to use forensic problem-solving skills to determine the source of the groundwater contamination.

## Materials

Reaction plate	Indicator solution, approximately 2 mL
Beral-type pipets, graduated, 2	Toothpicks, 6
Well-site solution containers, 40	Well-site master map
Testing solution, approximately 50 mL	Groundwater Contamination Worksheet

## Safety Precautions

The well-site and testing solutions are corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Remind students to wash their hands thoroughly with soap and water before leaving the laboratory.

## Procedure

1. Obtain a Well-Site Master Map.
2. The current budget only allows for six wells to be drilled and tested. Two phases of drilling will be performed. The first phase will include three well sites.
3. Determine which three well sites your group would like to test first. Record the site numbers on the Groundwater Contamination Worksheet.
4. Go to the well-site solution containers and, using the graduated pipet assigned to the first selected site, extract a 1 mL sample.
5. Place this 1 mL sample in one of the reaction plate wells. Record the position of the sample solution in the reaction plate on the Groundwater Contamination Worksheet.
6. Repeat steps 4 and 5 for the next two selected samples. Record the positions of the sample solutions in the reaction plate on the Groundwater Contamination Worksheet. Do not mix the samples.
7. Using a clean graduated pipet, add 1 drop of indicator solution to each sample.
8. Obtain three toothpicks. Use a separate toothpick and stir the solution in each well. Keep toothpicks separate for the next step.
9. Fill a new, clean graduated pipet with testing solution. Add this solution dropwise, using the appropriate toothpick to swirl after each drop. Count the drops as they are added until the color changes from yellow to purple irreversibly. Record the drop count on the Groundwater Contamination Worksheet.
10. Drop counts correspond to the contaminant levels as follows:

1 to 2 drops	0–10 ppb
3 to 5 drops	25 ppb
6 to 12 drops	50 ppb
12 drops or higher	200 ppb

11. Record the drop counts and the results (in ppb) for the first three samples on the Groundwater Contamination Worksheet.
12. Use the results from the first three sample sites to determine three more sites your group would like to test. Record the drop counts and the results (in ppb) on the Groundwater Contamination Worksheet.
13. Repeat the testing procedures in steps 4–10 for the last three sampling sites. Record the drop counts and the results (in ppb) on the Groundwater Contamination Worksheet.
14. Plot the results (in ppb) on the Well-Site Master Map. Draw dotted lines connecting your sampling sites and their corresponding contamination levels on the Well-Site Master Map.
15. Use all results and the Well-Site Master Map to try to determine the source of groundwater contamination.
16. Record the conclusion on the Groundwater Contamination Worksheet.
17. Compare your results with other groups in the class.

## Disposal

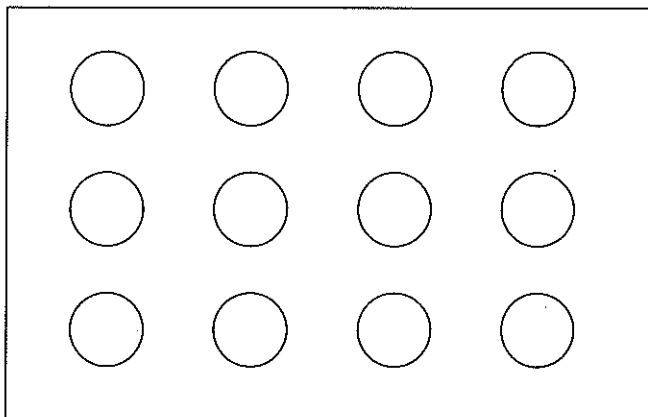
Consult your instructor for appropriate disposal procedures.

Name: \_\_\_\_\_

# Groundwater Contamination Worksheet

First three well sites to be tested # \_\_\_\_\_ # \_\_\_\_\_ # \_\_\_\_\_

Location of well-site solutions in well plate.



Last three well sites to be tested # \_\_\_\_\_ # \_\_\_\_\_ # \_\_\_\_\_

Sample Site No.	Number of Drops of Testing Solution	ppb

1. Why did you pick and analyze three test sites and then pick and test three more?
2. After the first three results, how did you pick the next three sites?
3. What was the source of contamination?

# Well-Site Master Map

