Water Filtration

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In this Activity, students make a water filtration column using a 2-liter plastic bottle that contains layers of gravel, sand, and activated charcoal. They contaminate a sample of water and examine the filtration ability of the column. A movie of a column as it filters a sample is available in this issue of *JCE Online*.

Background

Water sources such as lakes, rivers, and groundwater supply much of the water for domestic use. Some of the water that reaches our household faucets has also been used for other purposes. Water from these various sources is treated to remove impurities and to make it suitable for human consumption. Several steps can form the treatment process. Large items and particles can be filtered out using screens. Some particles may be allowed to settle out. This can be aided by first adding lime (CaO) to produce a basic solution. Alum ($KAl(SO_4)_2$) is then added, which reacts with hydroxide ions (OH^-) to form $Al(OH)_3$, a precipitate that settles out of solution, taking small particles with it. An experiment that demonstrates the purification of water using lime and alum is available *(1)*. Additional particles can be removed by filtration through sand. Activated charcoal has been treated to increase its porosity and surface area, and is used to adsorb odors and some colored substances. Certain impurities, including carbon-based particles and chlorine, are attracted to the charcoal and remain trapped in the pores. A sample of activated charcoal can become saturated with impurities and eventually will lose its filtering capability. Water is also disinfected using chemical treatments, commonly chlorine. A previous *Journal* article discusses the treatment of wastewater *(2)*.

Integrating the Activity into Your Curriculum

This environmental chemistry Activity can be used to complement a celebration of Earth Day, April 22, 2004. This year's theme is "What do you know about H_2O?" It can be used in a discussion of water quality and pollution and the treatments water undergoes before it reaches the faucet. Instructors could also discuss the use of commercially available water filters that are used for tap water, such as Brita filters *(3)*. Instructors might have students keep track of their water use for a period of time with a personal water use chart *(4)*. An experiment similar to this Activity shares related information about water purification at the international space station *(5)*.

About the Activity

Activated charcoal is available in pet stores in the aquarium section. Cheesecloth is available in grocery and craft stores. Students could use smaller capacity plastic bottles to reduce the quantities of materials used. Additional layers could be added to the filtration column, such as a layer of larger rocks above the layer of gravel. Rust is prepared in step 1 over a period of 2–3 days; students could use rust from a rusty metal object instead.

photo by J. J. Jacobsen and E. K. Jacobsen

Answers to Questions

1. The filtration column removes leaves, dirt, cooking oil, rust, and vinegar. The filtered water contains no leaves, has no oil layer, has no noticeable vinegar smell, and the majority of the soil and the rust color is gone. If the filtered water is not completely clear and colorless, some rust and soil particles may remain. The pH changes from acidic toward neutral. pH results will vary depending on the initial pH of the tap water.
2. Large items such as leaves collect on the surface of the gravel and slow down the filter. A removable wire screen could be placed above the gravel layer to collect these items and dispose of them periodically.
3. None of the materials used in the filter removes bacteria from water. Water can be treated with chemicals such as chlorine or water can be boiled for several minutes to kill bacteria.
4. Answers will vary. The filtering capacity of the column is unknown; students could test it by filtering additional measured samples of contaminated water and observing when the column allows contaminants to pass through.
5. The ground next to a stream could be composed of materials such as sand and gravel. If the hole were close to the stream, water would seep through the ground and fill the hole, passing through the sand and gravel, which would serve as a makeshift filter.

References, Related Activities, and Demonstrations *(accessed November 2003)*

1. Borgford, Christie L.; Summerlin, Lee R. *Chemical Activities, Teacher Edition;* American Chemical Society: Washington, DC, 1988, pp 179–181.
2. Dhawale, S. W. Introducing the Treatment of Waste and Wastewater in the General Chemistry Course. Applying Physical and Chemical Principles to the Problem of Waste Management. *J. Chem. Educ.* **1993,** *70,* 395–397.
3. Brita International. *http://www.brita.com*
4. Personal water use chart. *http://k12science.ati.stevens-tech.edu/curriculum/drainproj/personalwaterusechart.html*
5. Clean water... where does it come from? Water purification for the international space station. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/International.Space.Station.Clean.Water/Water.Purification.for.the.ISS.pdf*

***JCE Classroom Activities* are edited by Erica K. Jacobsen**

Water Filtration

Clean and pure water is something many of us may take for granted. Simply turn on the faucet and water that's fit to drink comes gushing out. Much of the water that reaches our faucets has been used for other purposes and has passed through various treatments to purify it for human consumption. You may have used some products to purify water while camping or hiking, such as a pump and filter or tablets that you add to the water. In this Activity, you will make your own water filtration column to filter impure water and examine its filtering ability and convenience.

Try This

You will need: clean, empty 2-liter plastic bottle, ruler, scissors or knife, cheesecloth, rubber band, sand, gravel, activated charcoal, soil and leaves, cooking oil, large spoon, steel wool, household vinegar (5%), disposable cup and plastic fork, measuring cups, two large clear, colorless containers, two sheets of white paper, tap water, ring stand and ring.

Be Safe! Do NOT consume any of the water in this Activity, including the filtered water. Harmful contaminants may remain.

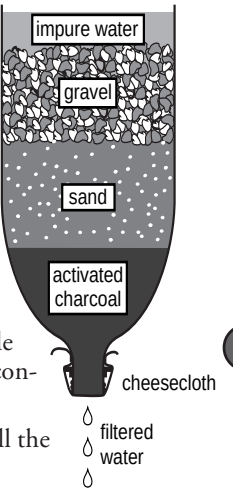
__1. Place a steel wool pad in a disposable cup. Saturate the pad with household vinegar and leave exposed to the air. Stir or turn daily with a disposable plastic fork for 2–3 days until only rust is visible.

__2. Measure 4 cups (960 mL) of tap water into a large clear, colorless container. Add these items to the water and then stir thoroughly with a large spoon:

1/2 teaspoon (2.5 mL) of the rust prepared in step 1; 1/2 teaspoon (2.5 mL) soil; 2 or 3 small leaves; 1 tablespoon (15 mL) household vinegar (5%); 1 tablespoon (15 mL) cooking oil

__3. Place a sheet of white paper under the container of water from step 2. Observe and record the properties of the water. How does it look? How does it smell? Using pH paper, measure and record its pH.

__4. Prepare a water filtration column by cutting off the bottom 5 cm of a clean, empty 2-liter plastic bottle with a pair of scissors or a knife. Remove and discard the bottle label. Cut two 7-cm × 7-cm squares of cheesecloth. Layer the two squares one on top of the other. Use the layered squares to cover the mouth of the bottle where the cap is normally attached. Secure the cheesecloth over the mouth of the bottle with a rubber band. Invert the bottle (mouth pointing down) and mount it in a ring stand with an empty, large, clear, colorless container beneath it to collect filtered liquid.



__5. Place 2 cups (480 mL) of activated charcoal into the water filtration column (this layer will fill the neck and shoulders of the bottle).

__6. Place 2 cups (480 mL) of sand into the water filtration column as the next layer.

__7. Place 2 cups (480 mL) of gravel into the water filtration column as the final layer.

__8. Pour 3–4 cups (720–960 mL) of tap water onto the layer of gravel so the water passes through the column and cleans out any small particles of dirt and charcoal. Discard the water that drains into the collection container.

__9. Measure and pour 3 cups (720 mL) of the unfiltered water from step 2 into the column, pouring it onto the layer of gravel. Observe the water as it passes through the filter. Place a sheet of white paper under the container of filtered water. Observe and record the properties of the filtered water. Using pH paper, measure and record its pH. Compare its appearance with the water that remains from step 2. Measure how much filtered water was collected. Is it the same volume that you placed into the filter?

Questions

1. Which impurities did the water filtration column remove? Which were left behind? How could you tell?
2. What are some of the drawbacks of this method? Suggest some ways that the filtration column could be improved.
3. Would this type of filter remove harmful bacteria from water? What processes remove harmful bacteria from water?
4. How many liters of water do you think could be purified with this column? Explain your answer. How could you test the column to find out?
5. Some participants in a camping group are taught to dig a hole in the ground next to a stream if they are in the wilderness without a means to filter water. How would this method work?

Information from the World Wide Web *(accessed November 2003)*

Emergency disinfection of drinking water. *http://www.epa.gov/ogwdw000/faq/emerg.html*

Water treatment cycle. *http://www.epa.gov/OGWDW/kids/treat.html*

What is activated charcoal and why is it used in filters? *http://www.howstuffworks.com/question209.htm*

Home drinking water treatment systems. *http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/he419.html*