Science Unit: *Water Quality*
Lesson 2: *Water Filtration*

School year:	2004/2005
Developed for:	Laura Secord Elementary School, Vancouver School District
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Grade level:	Presented to grade 6; appropriate for grades 4 - 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes
Notes:	Follow-up experiments include *Water Filtration with Plants* and *Water Filtration Challenge*

Objectives

1. Introduce how to do a science experiment.
2. Learn about methods used to purify drinking water in municipal water treatment plants.
3. Test different solid materials (e.g. sand, pebbles, rocks) for their utility to physically filtrate water containing different contaminants (e.g. mud, soap, oil).

Background Information

When water is obtained from uncontaminated reservoirs fed by clear mountain streams (surface water) or from deep underground wells (ground water), it requires minimal treatment to make it safe to drink. However, most cities obtain their water from surface water sources (e.g. lakes and rivers) that may contain pollution from industrial or natural sources. Consequently, water from surface water sources must be "cleaned" before it can be consumed by people. Water treatment plants typically clean water by taking it through the following processes: (1) aeration, (2) coagulation, (3) sedimentation, (4) filtration, and (5) disinfection.

Vocabulary

Independent variable:	The variable which is manipulated or selected by the experimenter to determine its relationship to an observed phenomenon (the dependent variable). In other words, the experiment will attempt to find evidence that the values of the independent variable determine the values of the dependent variable (which is what is being measured).
Dependent variable:	The factor whose values in different treatment conditions are compared. That is, the experimenter is interested in determining if the value of the dependent variable varies when the values of another variable – the independent variable – are varied, and by how much.
Turbidity:	A cloudiness or haziness of water (or other liquid) caused by individual particles that are too small to be seen without magnification.
Aeration:	To supply with air or expose to the circulation of air.
Coagulation:	The process of adding chemicals to water to make dissolved and suspended particles bind together, forming larger particles that will settle out of the water as a sludge.

Flocculation: A process where a solute comes out of solution in the form of a “floc” or “flake”.

Sedimentation: The deposition by settling of a suspended material. Sediment is any particulate matter than can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bottom of a body of water or other liquid.

Filtration: The process of using a filter to mechanically separate a mixture.

Disinfection: The destruction of pathogenic and other kinds of microorganisms by physical or chemical means. The ideal disinfectant would offer complete sterilization, without harming other forms of life, be inexpensive, and non-corrosive.

Materials:

- vegetable oil
- duct tape
- alum (potassium aluminum sulfate, found in spice aisles of grocery stores)
- fine, plastic mesh
- liquid dish soap
- clean rocks, larger than pebbles (may rinse with clean water in advance)
- clean pebbles of varying sizes (may rinse with clean water in advance)
- coarse, clean sand (may rinse with clean water in advance)
- fine, clean sand (may rinse with clean water in advance)
- mud
- 1-litre graduated cylinders
- elastic bands

Each group of students will need the following:

- 2-litre clear plastic pop bottles (two per student)

In the Classroom

Introductory Discussion

1. Begin by asking the students where they obtain their drinking water. Common sources include nearby lakes, rivers, rainwater, underground wells, etc.
2. Ask the students if water taken from these sources is safe to drink without any type of purification or treatment. In most cases, water from the sources listed above must first be treated before it is safe for use as drinking water.
3. Ask the students what methods can be used to purify drinking water. Common approaches used in municipal water treatment plants include: aeration, coagulation, sedimentation, filtration and chemical disinfection.
4. Before starting the hands-on experiment with filtration, the teacher or scientist should demonstrate the first three steps of the water purification process. Aeration can be demonstrated simply by adding 500 mL of a water-mud mixture to a 2-litre pop bottle, securing the screw cap and shaking vigorously for 30 seconds. Then pour the mixture between two large cups back and forth 10 times. Ask the students to describe any changes they observe. Explain to the students that aeration is the addition of air to water. It allows gases trapped in the water to escape and adds oxygen to the water.
5. The second step of the purification process is coagulation or flocculation, which is the process by which dirt and other suspended solid particles are chemically “stuck together” into floc so that they

can be removed from the water by settling. To demonstrate this add 20 grams of alum (potassium aluminum sulfate) to 500 mL of a water-mud mixture and slowly stir for 5 minutes. According to Material Safety Data Sheets (MSDS), alum is an irritant to the skin and eyes and therefore should not be directly handled by students. Ask the students to describe any changes they observe. Explain to the students that the addition of alum promotes particles to chemically "stick together", helping the resulting floc to settle more quickly (see #6 below).

6. The third step of the purification process is sedimentation, which is the process that occurs when gravity pulls the particles of floc (clumps of alum and sediment) to the bottom of the pop bottle. Allow the water-mud-alum mixture from step #5 above to stand undisturbed in the pop bottle and ask the students to observe the mixture at 5-minute intervals for a total of 20 minutes and record their observations. For comparison, a second mixture that lacks the addition of alum can be prepared and observed. During this time the students can prepare their filtration units for the fourth step in water purification (i.e. sedimentation). The fifth step, disinfection with chlorine, ozone or ultraviolet light, is used to kill harmful microorganisms and is best discussed with the class without any demonstration.

7. Review how to do a science experiment.
   - Make an observation and then ask a question OR start with a question: what is the best combination of physical materials to filter contaminated water?
   - Think about what will happen if only fine sand is used, if only coarse sand is used, if only pebbles are used, if only rocks are used, or if some combination of the four is used. Write down what you think will happen. This is your prediction.
   - Set up an experiment (water filtration), and treat everything the same way except for one thing - what you want to test (the type of physical material for filtration). Discuss why you only change one thing (a variable).
   - Make observations.
   - Collect data, record and examine results (think about why things happened the way they did).
   - Make conclusions and explain results (compare results to predictions to help you think deeper).
8. Communicate results and conclusions (i.e. your lab report).

Experiment Title: Effect of different physical filtering materials on water quality.

Purpose of Experiment: To compare fine and coarse sand, pebbles and rocks for their ability to filter or purify different types of contaminated water.

Experimental Treatments:

Test treatment 1	Fine sand only
Test treatment 2	Coarse sand only
Test treatment 3	Pebbles only
Test treatment 4	Rocks only

Methods:

The day of the lesson:

Divide the class into groups of 3-4 students. Each group will construct four filtration units consisting of two 2-litre pop bottles each.

1. Using scissors, remove the bottom from both bottles, and the top from one bottle.

2. Tape the two bottles together with duct tape and secure the unit vertically with the tapered end pointing down to the floor and the open end pointing up to the ceiling (either clamp the cylinder to a table or secure between the backs of two chairs). In total each group should prepare four filtration units.

3. Secure fine plastic mesh around the outside of the opening at the tapered end with an elastic band. The mesh should be sufficiently fine to prevent sand from escaping, but not too fine to contribute significantly as a filter itself.

4. Assign each group to test one type of contaminated water (i.e. mud and water, soap and water, oil and water). The teacher or scientist may also want to construct their own filtration units using the four filtering materials and test uncontaminated water alone to determine if any particles are released from the filtration units themselves during the filtering process. The results of the test can then be shared and discussed with the class.

5. Have each group prepare four filtration units, each containing 1500 mL of one of the four test filtering materials. The independent variable is type of filtering material added.

6. The teacher or scientist can prepare the mixtures of mud and water, soap and water, and oil and water for the entire class. The total volume required for each contaminated water mixture is: 500 mL X 4 filtration units X the number of groups in the class testing that type of contaminated water mixture. To minimize “messiness” in the experiment, only add a small volume of mud (e.g. 50 mL), oil (e.g. 25 mL) or liquid soap (e.g. 1 mL) per each 500 mL volume of water.

7. To test the effectiveness of each of the filtration units, have each group add 500 mL of their contaminated water to each filtration unit and separately collect the eluted liquid with clear 1-liter graduated cylinders. Note: each group will test only one type of contaminated water (i.e. mud and water, soap and water, oil and water). The data from all groups can then be pooled for a class-wide comparison.

8. Record the cumulative volume eluted after 1, 3, 5 and 10-minute intervals for each filtration unit.

9. After the final volume is collected, have the students compare the turbidity of their eluted liquid against an unfiltered tap water control and the three unfiltered starting mixtures. This is a qualitative measurement. The dependent variable is the quantity of liquid eluted at each time point, and the qualitative assessment of water purity.

10. Please note that the filtered water recovered is not safe to drink.

Science Journal: Activity sheets with different sections can be prepared for students to record:

- Their predictions for each type of filtering material (volume recovered and water quality)
- Their drawings of the filtration apparatus
- Their observations (volume recovered) after 1, 3, 5 and 10 minutes and a qualitative description of the turbidity or quality of the water recovered
- Their conclusions (what happened and why did it happen)

Closure Discussion

1. Review the five steps involved in water purification at a water treatment plant.

2. Discuss predictions and observations for the effectiveness of the different types of filtering material used to clarify the three types of contaminated water mixtures.
3. Discuss what happened and why it happened.
4. Discuss how the filtration units could be improved? For example, using different combinations of the four filtering materials in layers, trying new filtering materials, increasing the volume of filtering materials etc.
5. Review how to do a science experiment and discuss variability in the results across the class and possible sources of error in the experiment.

References

1. http://www.epa.gov/safewater/kids/teachers_4-8.html (U.S. government Environmental Protection Agency site with several activities on water resources. In particular, please see the "Water Filtration" activity upon which this activity is based.).
2. http://en.wikipedia.org/wiki/Sewage_treatment (provides a detailed overview of how water treatment plants work).

Extension of Lesson Plan

Follow-up experiments include *Water Filtration with Plants* and *Water Filtration Challenge* (see lessons 3 and 4 in the Water Quality science unit, Earth Science curriculum area, available from the Scientist in Residence Program website http://www.scientistinresidence.ca).