Computer
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Water Treatment

Every community has a method for pre-treating drinking water from a ground or surface water source. Sometimes the term *water purification* is used for this treatment, but this term incorrectly suggests that the end result of this process will be *pure* water, with no impurities. A better term to describe this process is *water treatment*. In order to be assured that water from a well, stream, or lake has enough impurities removed by water treatment to be used as drinking water, it must go through several water treatment steps. These steps may include settling, filtration, or chlorination. Far from making the water "pure," the treatment will in many cases simply reduce some impurities to a level found to be acceptable by government agencies. Some typical EPA (Environmental Protection Agency) standards for drinking water are shown in this table.

Selected EPA Drinking Water Standards	
Contaminant	**Standard**
pH	6.5-8.5
Total Dissolved Solids	< 500 mg/L
Turbidity	< 5 NTU
Chloride	< 250 mg/L
Nitrate	< 10 mg/L
Copper	< 1.3 mg/L
Lead	< 0.015 mg/L

In this experiment, you will treat an untreated water sample supplied by your teacher. You will use a number of different methods, including settling, filtration and pH adjustment, to treat your water sample. Before and after the treatment, you will monitor three different indicators of water quality: pH, total dissolved solids (TDS), and turbidity, to see if each quality improves.

Here is a brief summary of each of the three measurements you will be making:

- **pH** is a measurement of how acidic or basic a water sample is. The pH scale ranges from 0 to 14. Drinking water with a pH greater than 7 is *basic*, and with a pH less than 7 is *acidic*. It is quite common for drinking water to be slightly basic (between 7 and 8.5), due to the presence of hard-water minerals. EPA standards recommend that drinking water be in the pH range of 6.5-8.5. Because slightly acidic water can cause metal pipes to corrode, if drinking water has a pH less than 7, communities will sometimes adjust that pH to a value that is greater than 7.
- **Total dissolved solids** (**TDS**) is found to be in a wide range of levels in drinking water. The TDS level of a drinking water supply should be less than 500 mg/L, according to EPA standards; however, high level of TDS from dissolved ions is not usually considered dangerous or harmful, and at worst results in water being "hard" (*hard* to make soap suds), or gives it a slightly bitter or salty taste.
- **Turbidity** is a measurement of the cloudiness (or lack of clarity) of water. The EPA standard for turbidity of drinking water is a value of less than 5 Nephelometric Turbidity Units (NTU). Water with readings in this range will appear to be clear. To reach low levels of turbidity during water treatment, it is sometimes necessary to remove particles or suspended particulates by filtration, screening, or flocculation.

OBJECTIVES

In this experiment, you will

- Use a pH Sensor to measure the pH of the pre-treatment and post-treatment samples.
- Use a Conductivity Probe to measure the total dissolved solids (TDS) of the pre-treatment and post-treatment samples.
- Use a Turbidity Sensor to measure the turbidity of the pre-treatment and post-treatment samples.
- Use the test results to see how much the treatment improved the quality of the drinking water sample.
- Compare the drinking water sample to EPA standards shown in the introduction.

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Vernier Conductivity Probe
Vernier pH Sensor
Vernier Turbidity Sensor
Turbidity Cuvette
Turbidity Standard (StableCal® Formazin Standard 100 NTU)
200 mL water sample (in 400 mL beaker)
100 mL beaker
funnel (top half of milk jug)
10 coffee filters
wash bottle with distilled water
plastic spoon
baking soda and spoon
pH soaking solution in a beaker
waste cup

PROCEDURE

Important: Do not drink the water that is being treated in this experiment, either before or after the treatment is completed.

1. Obtain a 200 mL sample (in a 400 mL beaker) of untreated water. In this step, you are going to stir the sample to simulate an *unsettled water* sample, and set aside about 40 mL of this sample for testing. To do this:
   a. Obtain a 100 mL beaker
   b. Use a spoon to thoroughly stir the untreated sample for about 15 seconds.
   c. Before the water sample has time to settle, quickly pour about 40 mL of the unsettled water into the 100 mL beaker. Set this 100 mL beaker aside for making *unsettled water* measurements in Step 5. Rinse and dry the spoon, and then place it in the 100 mL beaker.
   d. Set the remaining sample (in the 400 mL beaker) aside for making *settled water* measurements in Step 8. **Important:** This beaker will need to be undisturbed so that settling can occur during the next 10-15 minutes.

2. Connect your sensors to the computer interface.
   a. Connect the Conductivity Probe to Channel 1. The switch on the Conductivity Probe should be on the 0–2000 μS/cm setting.
   b. Connect the pH Sensor to Channel 2. **Important:** For this experiment your teacher already has the pH Sensor in pH soaking solution in a beaker; be careful not to tip over the beaker when connecting the sensor to the interface.
   c. Connect the Turbidity Sensor to Channel 3.

3. Prepare the computer for data collection by opening the file “14 Water Treatment” in the *Earth Science with Vernier* folder. This file will load a correct calibration for the Conductivity Probe and the pH Sensor. Proceed to the next step to calibrate the Turbidity Sensor.

4. Calibrate the Turbidity Sensor.

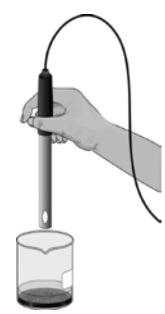
First Calibration Point

a. Choose Calibrate ▸ CH3: Turbidity (NTU) from the Experiment menu and then click Calibrate Now.
b. Prepare a *blank* by filling the glass turbidity cuvette with distilled water so that the bottom of the meniscus is even with the top of the white line. Place the lid on the cuvette. Gently wipe the outside with a soft, lint-free cloth or tissue.
c. Check the cuvette for air bubbles. If air bubbles are present, gently tap the bottom of the cuvette on a hard surface to dislodge them.
d. Holding the cuvette by the lid, place it in the Turbidity Sensor. Make sure that the mark on the cuvette is aligned with the mark on the Turbidity Sensor. Close the lid.
e. Type **0** (the value in NTU) in the edit box.
f. When the displayed voltage reading for Reading 1 stabilizes, click Keep.
g. Remove the cuvette and set aside for use in Step 7.

Second Calibration Point

h. Obtain the cuvette containing the Turbidity Standard (100 NTU) and gently invert it four times to mix in any particles that may have settled to the bottom. **Important:** Do not shake the standard. Shaking will introduce tiny air bubbles that will affect turbidity.
i. Wipe the outside with a soft, lint-free cloth or tissue.
j. Holding the standard by the lid, place it in the Turbidity Sensor. Make sure that the mark on the cuvette is aligned with the mark on the Turbidity Sensor. Close the lid.
k. Type **100** (the value in NTU) in the edit box.
l. When the displayed voltage reading for Reading 2 stabilizes, click Keep, then click Done.

Part I Unsettled Water



5. You will now measure the TDS level of the *unsettled water* sample in the 100 mL beaker, using the Conductivity Probe. **Important:** For the unsettled sample **only**, you will need to stir the sample just prior to taking TDS readings.
   a. Place the tip of the electrode into the sample. The hole near the tip of the probe should be completely covered by the sample.
   b. Monitor the TDS value in the meter.
   c. When stable, record the TDS value (in mg/L) in the data table.
   d. Rinse the Conductivity Probe with distilled water.

6. You will now measure the pH of the *unsettled water* in the 100 mL beaker. **Important:** For the unsettled sample **only**, you will need to stir the sample just prior to taking pH readings.
   a. Raise the pH Sensor from the pH soaking solution.
   b. Hold the pH Sensor over the waste cup and rinse the tip with distilled water.

c. Place the tip of the pH Sensor into the water sample. Make sure the glass bulb at the tip of the sensor is completely covered by the water.

d. When the pH value in the meter is stable, record it in the data table.

e. Rinse the tip with distilled water again.

f. Return the pH Sensor to its soaking solution.

7. You are now ready to measure the turbidity of a sample of *unsettled water* in the 100 mL beaker using the Turbidity Sensor. **Important:** For the unsettled sample **only**, you will need to stir the sample prior to taking turbidity readings.

   a. Empty the distilled water from the cuvette used in Step 4.

   b. Rinse the cuvette with sample water, then fill it with sample water so that the bottom of the meniscus is even with the top of the white line. Place the lid on the cuvette. Gently wipe the outside with a soft, lint-free cloth or tissue.

   c. Check the cuvette for air bubbles. If air bubbles are present, gently tap the bottom of the cuvette on a hard surface to dislodge them.

   d. Gently invert the cuvette four times to mix any particles that may have settled.

   e. Holding the cuvette by the lid, place it into the Turbidity Sensor. Make sure it is in the same orientation in the cuvette slot that it was before. Close the lid.

   f. Monitor the turbidity value in the meter. When this value is stable, record it in the data table and proceed to Step 8. **Note:** Particles in the water will settle over time and show a slow downward drift in turbidity readings. Therefore, take your readings soon after placing the cuvette in the sensor.

Part II Settled Water

8. You are now ready to make measurements on the *settled water* in the 250 mL beaker.

   a. Clean and dry the 100 mL beaker that was used in the previous step.

   b. Carefully decant 40 mL of liquid from the 250 mL beaker into the 100 mL beaker. As you pour, try to leave most of the settled solid behind.

   c. Repeat Steps 5–7, this time measuring the TDS, pH, and turbidity of the *settled water* sample in the 100 mL beaker.

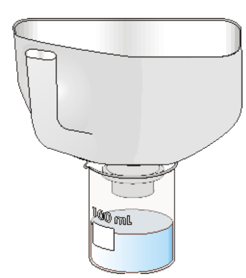
   d. **Important:** Set aside the 250 mL beaker with the remaining water for use in Step 9. Discard the water in the 100 mL beaker. Clean and dry the beaker for use in Step 9.

Part III Filtered Water

9. In this step you will filter the water, and then test the *filtered water* for TDS, pH, and turbidity levels.

   a. Place 10 coffee filters in the funnel (the top half of milk jug). Nest the filters loosely inside each other. Hold the funnel and filters above a sink or other large vessel, and slowly pour about 200 mL of distilled water through the filter to thoroughly rinse it.

   b. Set the funnel on top of the 100 mL beaker as shown here.



   c. Slowly pour the remaining settled water in the 250 mL beaker into the coffee filter. Pour all of the liquid into the filter. It is OK if most of the solid particles remain in the beaker. Do not let the water level go above the top edge of the filter paper.

   d. When most of the water has drained into the beaker, remove the funnel.

e. Repeat Steps 5–7, this time measuring TDS, pH, and turbidity of the *filtered water* sample.

f. **Important:** When you have finished making measurements, be sure to keep the remaining filtered water sample for Step 10.

Part IV pH-Adjusted Water

10. In this step you will adjust the pH of the filtered water, and then test the *pH-adjusted water* for pH, TDS, and turbidity levels.

a. Obtain the baking soda container and spoon.

b. Place the pH Sensor into the filtered water sample from Step 9.

c. Obtain a small amount of baking soda on the tip of the spoon. Important: In this step, you will want to add the baking soda in the *smallest possible amounts* you can; tap the tip of the spoon each time so that just a few grains are added. Add the first small amount of baking soda, stirring thoroughly. (Stir with the spoon you previously used for stirring, not the baking soda spoon.)

d. Monitor the pH after each addition. Baking soda is a mild base, and should cause the pH value displayed in the meter to increase.

e. Continue to add baking soda in small amounts until the pH reaches 6.5, a level that is acceptable by EPA standards.

f. Record the final adjusted pH value in your data table.

g. Repeat Step 5 (TDS) and Step 7 (turbidity) for the pH-adjusted sample.

h. When you have finished, discard all water samples as directed by your teacher.

DATA

	Unsettled water sample	Settled water sample	Filtered water sample	pH-adjusted water sample
Total dissolved solids, TDS (mg/L)				
pH				
Turbidity (NTU)				

PROCESSING THE DATA

1. Examine your data and decide if each of the methods shown below improved the quality (I), decreased the quality (D), or had little or no effect (N). Place an I, D, or N in each of the spaces in the table below to indicate your answer.

	Settling	Filtration	Adjust pH
TDS			
pH			
Turbidity			

2. Based on your results, does filtration appear to remove ions (such as Na^+ and $Cl^–$ ions in salt, or Na^+ and $HClO_3^–$ in baking soda) from a water sample? Explain.

3. What is the purpose of the pH adjustment in Step 10? Is the substance that is added, baking soda (sodium bicarbonate) an acid or a base? Did your solution end up with an acidic, neutral, or basic pH?

4. Were there any water qualities that appeared to get worse as the result of water treatment? Which? Is the change in this property necessarily a bad thing, overall? Explain.

5. Which of the three water quality characteristics, pH, TDS, or turbidity, met EPA standards *before* treatment? Which met EPA standards *after* treatment? If you had any that did not meet EPA standards after treatment, suggest ways that you might continue treatment to meet that standard.

6. Do the results of this experiment suggest that a "clear" appearance indicates high-quality drinking water? Explain.

EXTENSIONS

1. Test tap water (drinking water) from your area, and see how TDS, pH, and turbidity values compare to those you obtained in this experiment.

2. Test surface and ground water samples from wells, lakes and streams in your area, and see how TDS, pH, and turbidity values compare those you obtained in Extension 1 (tap water). You can sometimes tell if your community adjusts its water for pH by comparing pH and TDS levels of local surface or ground water with those of local tap water.

3. Obtain water-softening beads from a local water-treatment company, and see if the process of "softening" drinking water results in changes in pH or TDS.

Experiment
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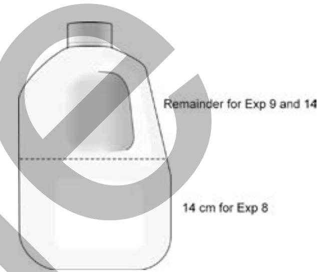
TEACHER INFORMATION

Water Treatment

1. The student pages with complete instructions for data collection using LabQuest App, Logger *Pro* (computers), EasyData or DataMate (calculators), and DataPro (Palm handhelds) can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. The funnel for this experiment can be the top half of a gallon milk jug. Cut the milk jug as shown here. These halves can also be used in Experiments 8 and 9.



3. If you are using calculators for data collection, this activity is ideally performed with a LabPro or CBL 2 and the necessary sensors. It is possible to perform this activity with an EasyLink, however it can be equipment intensive. If you would like to do the activity with an EasyLink, we recommend preparing the four water samples at the beginning of the activity. You can then connect the pH Sensor and measure the pH of all the samples, adjusting the pH of the fourth sample as directed in Part IV. Then, connect the Conductivity Probe and measure the TDS level of each sample. Finally, connect and calibrate the Turbidity Sensor and then measure the turbidity of each sample.

4. The stored calibration for pH works well for this experiment. The Conductivity Probe calibration for 0–1000 mg/L TDS also works well. This calibration corresponds to the switch setting of 0 to 2000 μS/cm. The Turbidity Sensor must be calibrated by students at the beginning of the experiment, using the directions in the procedure.

   If students add too much baking soda in Step 10, their TDS readings may go past 1000 mg/L. The Conductivity Probe can actually take valid readings a little above 1000 mg/L (up to about 1200 mg/L). If the sensor goes above that level, it will be necessary to change the switch setting to the 0–20,000 μS/cm range (0–10,000 mg/L), and load a new calibration for that range. (Choose Show Sensors from the Experiment menu, click on the CH1 Conductivity Probe picture, and choose 10,000 mg from the list.)

5. Here is a recipe for preparing a 200 mL untreated water sample for each lab station. Combine the following amounts in a 400 mL beaker (or equivalent container):

   - 200 mL of distilled water
   - 1 mL of white vinegar
   - 5 g of unwashed sand (about one teaspoon of sand)

   There will be variation in different samples of unwashed sand, but in most cases you should get results similar to those shown on the next page. The advantage of using sand is that students see plenty of settling, as well as suspended solids that initially produce high turbidity levels.

6. Using ten nested coffee filters may seem excessive, but they are inexpensive, and are necessary in order to get turbidity values that approach levels of 5 NTU. The results of the filtration will not improve if standard filter paper is used. It is important to do the pre-rinse of the filter paper with distilled water; this is because the paper in many coffee filters appears to contain some ionic components that yield ions, increasing the TDS value somewhat. Students may observe a small increase in pH after filtration, too.

7. Environmental Protection Agency standards described in the introduction of this experiment can be found at this web site: www.epa.gov/safewater/mcl.html. The standards used in this experiment fall into two categories:
   - *Primary Drinking Water Regulations* are legally enforceable standards that apply to public water systems. Turbidity is a primary standard.
   - *Secondary Drinking Water Regulations* are non-enforceable guidelines regulating contaminants that may cause cosmetic effects or esthetic effects in drinking water. EPA recommends secondary standards to water systems, but does not require systems to comply. Total Dissolved Solids and pH are secondary standards.
8. For additional information about pH, turbidity, and TDS, see the introductions and teacher information in Experiments 11, 12, and 13 of this lab book.
9. The "pH soaking solution" used in this experiment is pH 7 buffer solution. It can be purchased from chemical supply companies. Vernier Software & Technology sells a package of capsules for preparing buffer solutions of pH 4, 7, and 10 (Order Code PHB). We recommend that you remove the pH Sensor from its storage bottle before class. If the pH Sensor is soaking in a beaker with pH soaking solution, students will have an easier time taking measurements.
10. The baking soda used in this experiment is sodium bicarbonate, a weak base. The bicarbonate ion, HCO_3^-, acts as a weak base by reacting with water to produce OH^- ions.

SAMPLE RESULTS

	Unsettled water sample	Settled water sample	Filtered water sample	pH-adjusted water sample
Total dissolved solids, TDS (mg/L)	61.3	61.8	65.3	448.2
pH	3.71	3.74	3.95	6.53
Turbidity (NTU)	132.3	105.4.2	7.4	10.8

ANSWERS TO QUESTIONS

1. N = no effect, I = improved quality, D = decrease in quality

	Settling	Filtration	Adjust pH
TDS	N	N	D
pH	N	N (or D)	I
Turbidity	I	I	N (or D)

2. No, the filtration did not significantly change the level of TDS readings. The reading was 61.8 mg/L before filtering, and 65.3 mg/L after filtering. (Sometimes the level actually increases because the water apparently picks up some ions from the coffee filter itself.)

3. The addition of baking soda is supposed to increase the pH value of the water sample. Baking soda (sodium bicarbonate) is a weak base. The solution in this case ended up slightly acidic (pH of 6.54), but in some cases the pH will end up basic (a pH greater than 7.0).

4. The TDS reading increased from 65.3 mg/L to 448.2 mg/L. It is difficult to adjust the pH without adding additional ions and causing an increase in TDS readings. However, increasing the TDS reading, while keeping the value within EPS guidelines, is not particularly harmful, especially if a less corrosive pH value is achieved.

5. In the sample data, the pH and turbidity readings did not initially meet EPA standards, but the TDS reading did. After treatment, pH and TDS levels met EPA standards, and turbidity was close to meeting the EPA standard of 5 NTU. In cases where EPA standards are not met, repeated filtering, or additions of additional base could help meet the standards.

6. Being "clear" does not assure that a water sample has a high quality. After settling and filtering the water, the sample was within EPA guidelines. However, its pH value was well out of the recommended range (6.5–8.5).