Water & Wastewater Treatment

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 four different indicators of water quality: pH, total dissolved solids (TDS), nitrate (NO3), and turbidity, to see if each quality improves.

Here is a brief summary of each of the four 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, however, 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.
- **Nitrate** is a measurement of how many nutrients are in the water. These nutrients usually come from decomposition, and they are harmful because they can cause harmful algae blooms (HBAs). The EPA standard for nitrate is less than 10 mg/L.

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 a Nitrate Sensor to measure the nitrate 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 and *simulated* wastewater samples.
- Compare the drinking water sample to EPA standards shown in the introduction.

MATERIALS

2 LabQuests	100 mL beaker
LabQuest App	funnel (top half of milk jug)
Vernier Conductivity Probe	10 coffee filters
Vernier pH Sensor	baking soda and spoon
Vernier Nitrate (NO3) Sensor	wash bottle with distilled water
Vernier Turbidity Sensor	plastic spoon
Turbidity Cuvette	pH soaking solution in a beaker
Turbidity Standard (StableCal® Formazin Standard 100 NTU)	waste cup
200 mL surface water sample (in 400 mL beaker)	
200 mL simulated wastewater sample (in 400 mL beaker)	

PROCEDURE

Important: Do not drink <u>any</u> of the water that is being treated in this experiment.

1. Obtain a 200 mL sample (in a 400 mL beaker) of untreated ***surface*** 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 9. **Important:** This beaker will need to be undisturbed so that settling can occur during the next 10–15 minutes.

2. Setup the sensors.
   a. Set the selector switch on the side of the Conductivity Probe to the 0–2000 µS/cm range Connect the Conductivity Probe to Channel 1 of the first LabQuest.
   b. Connect the pH Sensor to Channel 2 of the first LabQuest. **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 LabQuest.
   c. Connect the Turbidity Sensor to Channel 1 of the second LabQuest.
   d. Connect the Nitrate Sensor to Channel 2 of the second LabQuest.
   e. On both LabQuests, choose New from the File menu. If you have older sensors that do not auto-ID, manually set up the sensors.

3. Calibrate the Turbidity Sensor.

   First Calibration Point

   a. Choose Calibrate►Turbidity from the Sensors menu and select 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. Enter **0** as the known turbidity value for Reading 1.
   f. When the voltage reading stabilizes, tap Keep.
   g. Remove the cuvette and set it aside for use in Step 6.

   Second Calibration Point

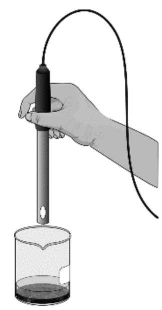
   h. Obtain the cuvette containing the Turbidity Standard (100 NTU) and gently invert it four times to mix in any particles that may have settled to the bottom. **Important:** Do not shake the standard. Shaking will introduce tiny air bubbles that will affect turbidity.
   i. Wipe the outside with a soft, 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. Enter **100** as the known turbidity value for Reading 2.
   l. When the voltage reading stabilizes, tap Keep.
   m. Select OK.

4. Calibrate the Nitrate Sensor.
   a. Your instructor placed the nitrate sensor in the high calibration standard for at least 30 minutes before class.
   b. Choose Calibrate►Nitrate from the Sensors menu and select Calibrate Now.
   c. Type in 100 for Value 1, then tap on “Keep”
   d. Remove the probe from the high standard, and thoroughly rinse the tip with distilled water. Blot it dry with a paper towel.

e. Fully immerse the tip of the probe into the low standard without touching it to the sides or bottom. Wait 60 seconds for the probe to equilibrate.
f. Type in 1 for Known Value 2, then tap on “Keep”.
g. Tap on the “Storage” tab, then tap on “Save Calibration to Sensor”. Tap on “OK”, then “OK” again.
h. Remove the probe from the low standard, and thoroughly rinse the tip with distilled water. Blot it dry with a paper towel.
i. Place the nitrate probe back into the ISE soaking solution until needed.

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 reading.
   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 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 3.
   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. When this value is stable, record it in the data table and proceed to Step 7. **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.

8. You will now measure the nitrate 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 nitrate readings.

   a. Remove the Nitrate Sensor from the nitrate soaking solution.
   b. Hold the Nitrate Sensor over the waste cup and rinse the tip with distilled water.
   c. Place the tip of the Nitrate Sensor into the water sample. Make sure it is fully submerged but is not touching the bottom or sides of the beaker.
   d. When the nitrate value is stable (~60s), record it in the data table.
   e. Rinse the tip with distilled water again.
   f. Return the Nitrate Sensor to its soaking solution.

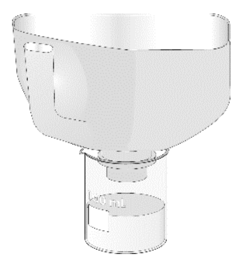
Part II Settled Water

9. You are now ready to make measurements on the *settled water* in the 400 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 400 mL beaker into the 100 mL beaker. As you pour, try to leave most of the settled solid behind.
   c. Repeat Steps 5–8, this time measuring the TDS, pH, turbidity, and nitrate of the *settled water* sample in the 100 mL beaker.
   d. **Important:** Set aside the 400 mL beaker with the remaining water for use in Step 10. Discard the water in the 100 mL beaker. Clean and dry the beaker for use in Step 10.

Part III Filtered Water

10. In this step you will filter the water, and then test the *filtered water* for TDS, pH, turbidity, and Nitrate 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 400 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 5–8, this time measuring TDS, pH, turbidity, and nitrate of the *filtered water* sample.
   f. **Important:** When you have finished making measurements, be sure to keep the remaining filtered water sample for Step 11.

Part IV pH-Adjusted Water

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

   a. Obtain the baking soda container and spoon.
   b. Place the pH Sensor into the filtered water sample from Step 10.
   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 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), Step 7 (turbidity), and Step 8 (nitrate) for the pH-adjusted sample.
h. When you have finished, discard all water samples as directed by your teacher.

DATA TABLE 1

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

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			
Nitrate			

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 11? 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.

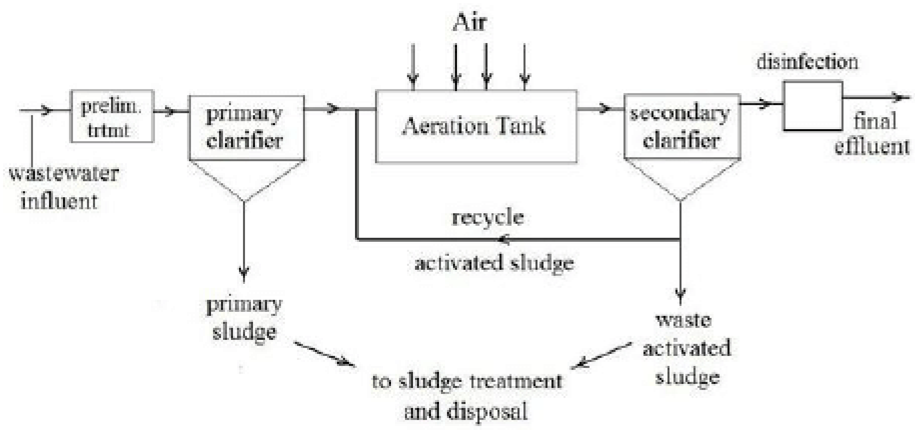
5. Which of the four water quality characteristics, pH, TDS, turbidity, or nitrate, met EPA standards *before* treatment? Which met EPA standards *after* treatment? If you had any that did not meet EPA standards after treatment, suggest ways that you might continue treatment to meet that standard.

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

7. There is one final important step to water treatment before the water is ready for drinking that we have skipped here. Re-read the introduction above. What is it? What is the purpose of this step?

WASTEWATER TREATMENT

You will now use your results from the water treatment activity to test *waste*water. **Wastewater Treatment Plants** are designed to reduce the impurities of water that goes down our drains and toilets before sending it into local streams. Many of the steps are the same.



https://www.researchgate.net/figure/Flow-diagram-of-wastewater-treatment-plant-at-Sanandaj-dairy_fig1_287643591

PROCEDURE

Important: Do not drink <u>any</u> of the water that is being treated in this experiment.

1. Look back over your results from treating water. Which steps had an effect on reducing the pollutants? Design a series of treatment steps that you will use to treat wastewater.

2. Obtain a 200mL sample of ***simulated*** **wastewater** in your 400 mL beaker.

3. Test the TDS, pH, turbidity, and nitrate levels of the simulated wastewater before treatment. Record in Data Table 2 below.

4. Perform the steps you outlined in Step 1 above.

5. Test the TDS, pH, turbidity, and nitrate levels of the simulated wastewater after treatment. Record in Data Table 3 below.

DATA TABLE 3

	Before treatment	After treatment
Total dissolved solids, TDS (mg/L)		
pH		
Turbidity (NTU)		
Nitrate (mg/L)		

PROCESSING THE DATA

1. Which of the four water quality characteristics, pH, TDS, turbidity, or nitrate, met EPA standards *after* treatment?

2. If you had any that did not meet EPA standards after treatment, suggest ways that you might continue treatment to meet that standard.

3. There is one final important step to wastewater treatment before the water is released to the environment that we have skipped here. Look at the figure above. What is it? What is the purpose of this step?