13D - PROJECT: DESIGN A PURIFICATION PROCESS

OVERVIEW

Use household items to purify water that contains macroscopic and microscopic contaminants. Successfully purified water has a clear colorless appearance, acceptable odor with no suspended solids, total dissolved solids below 900 mg/L, turbidity below 150 NTU, and conductivity below 500 µS/cm.

TIME REQUIRED

3 – 5 60-minute class periods.

MATERIALS

- Device with SPARKvue software
- Conductivity sensor
- Colorimeter and Turbidity sensor with cuvettes and 100 NTU solution standard
- Condenser
- Ice
- Heater stirrer Ring
- stand
- 50-mL graduated cylinder 400-mL
- beakers (4)
- 250-mL bottled water sample
- 250-mL tap water sample
- 250-mL salt water sample
- 250-mL "polluted" water sample
- 2-L plastic bottle
- Rinse bottle with distilled water
- Permanent marker
- Timer, stopwatch or clock
- Stirring rod
- Filtering material (i.e. mesh, nylon stockings,
- cheesecloth, coffee filter, paper towels, etc).
- Gravel
- Sand
- Activated carbon or charcoal
- Scissors
- Rubber bands
- Tape
- Salt

SAFETY

Follow regular lab safety procedures; do not allow the sample to evaporate completely while heating.

BACKGROUND

Purified water has been mechanically processed to remove impurities. Impurities may alter the taste or appearance of water and/or may contain harmful bacteria making it unsafe to ingest. The most common type of purification process is filtering. Due to the various sizes and quantities of the impurities, multiple filtrations are required to effectively remove the contaminants and make water safe to drink.

Pure water should be tasteless, odorless, colorless and clear in its appearance. More specifically, pure water should be a poor conductor of electricity. When shopping at your local grocery store, you may notice there are two types of bottled water: purified and distilled. Distilled water is cleaned by heating sample of water to boiling, then cooling the resulting vapor back down to room temperature where it is re-condensed and collected in an alternate container. In the process of boiling the water at 100 ^{0}C, the contaminants, which are assumed to have higher boiling points, are left behind in the original container and the newly collected water is mostly free from pollution.

Distilled water has conductance around 500 µS/cm (microsiemens per centimeter) while purified water's conductance is less than 0.055 µS/cm. By contrast, a salt water solution may have conductance values greater than 2000 µS/cm and conduct enough electricity to power a standard household light bulb. Depending on the source, an acceptable turbidity level for drinking water can measure up to 150 NTU (nephelometric turbidity unit). The total dissolved solids (TDS) measurement can reach up to 900 mg/L.

PERFORMANCE CRITERIA

Each group must filter 250 mL of "polluted" water in 15 minutes or less creating purified water that is tasteless, odorless, colorless and/or clear in appearance. Additionally, they must test the conductance of their purified water and achieve conductivity of less than 500 µS/cm. Total dissolved solids must be below 900 mg/L and turbidity must be below 150 NTU.

CONSTRAINTS

Each group will be limited to one 2-L bottle as part of their design and must propose/explain their design to their teacher prior to receiving and/or utilizing any additional materials. The design proposal must show evidence of research conducted.

RESEARCH

Research the purification process to determine what will be needed to remove macroscopic and microscopic contaminants in the "polluted" water supply. Research should include conductivity, turbidity, and total dissolved solids tests of bottled water, tap water, salt water and the polluted water supply for the basis of comparison.

PROCEDURE

1. Open SPARKvue.

2. Connect the Conductivity sensor and the Colorimeter and Turbidity sensor. When prompted, calibrate the turbidity sensor. Use distilled water (solvent) for the first calibration point and use the 100 NTU standard for the second point.

3. Open the 13D Design a Purification Process lab file in SPARKvue under Experiments > Essential Chemistry.

4. In Table 1, record water quality criteria for 250 mL samples of bottled water, tap water and salt water. Rinse the beaker and the conductivity probe thoroughly between samples.

5. When you receive your 250-mL polluted water sample, immediately record in Table 1: sample color, odor, visible suspended solids, conductivity, TDS, and turbidity.

6. Allow the sample to settle for exactly 5 minutes. Repeat your observations without disturbing the sample and record them in Table 1.

ANALYSIS

Table 1: Initial Water Quality of Sample

	Bottled water	Tap water	Salt water	Sample: Immediate	Sample: After Settling 5 min.
Color					
Odor					
Visible suspended solids					
Conductivity (µS/cm)					
TDS (mg/L)					
Turbidity (NTU)					

INITIAL DESIGN

1. Use a permanent marker and a graduated cylinder to draw measurement lines on the side of the 2-L bottle in 50-mL increments up to 300 mL (i.e. 50 mL, 100 mL, 150 mL, etc.).

2. Design a filtration device using only the materials provided by your teacher.

   - Decide on no more than 3 filtration materials that your group will test and/or use to filter the "polluted" water.
   - Cut the top off the 2-L bottle off and invert it so that the cap is inside the body of the remaining container. The top should now appear to be a funnel that will empty into the rest of the 2-L bottle. Be thoughtful of how much of the top you want to cut off. The funnel should be large enough to hold some of your polluted water sample but small enough that it does not touch your purified water when it filters to the bottom.
   - Each layer of filtration should be 2 inches away from the layer before and/or after it. Carefully mark these 2-inch measurements on the bottle before you decide where and how to cut the bottle.
   - Decide the order of placing each material to maximize filtration.

3. Sketch a labeled diagram of your design. Include a brief sentence to explain what material is used and what it is expected to filter out.

4. Present the sketch to your teacher to receive your materials. After consulting with your teacher, you may or may not decide to alter your design for maximum efficiency. If a modification is made, you must re-submit your idea to your teacher for approval BEFORE you start to build.

5. Carefully build your purification apparatus using the approved materials. Do not deviate from your approved design.

6. Once all the materials have been secured, stir the 250-mL polluted water sample to suspend solids.

7. Mark the start time and SLOWLY pour some of your "polluted" water through your filtration apparatus allowing for the "clean" water to collect at the bottom. You must continuously stir the polluted water to keep solids suspended while you pour. The entire sample must eventually be added to your water purification system in 15 minutes or less.

8. Determine the total amount of time required to finish filtering the 250-mL water sample. The process is considered finished when the polluted water is not pooled in the upper chamber(s) of the bottle and the "purified" water drips into the bottom of the filter no faster than 3 drops per second. If 15 minutes have passed and you have not yet added the entire 250-mL sample to the funnel, stop adding polluted water to the system when time is up.

9. Ask your teacher to visit your group when you are ready to record observations of the purified sample. Your teacher will keep their own record while you record observations in Table 2.

PROCEDURE

1. Label a beaker as "Trial 1." Store your purified sample in this beaker.

2. Stir the purified sample and record observations in Table 2. Record observations again after allowing the sample to settle for 5 minutes.

ANALYSIS

Table 2: Water Quality of First Filtered Sample

	Immediate Observations	Observations After Settling 5 min.
Color		
Odor		
Visible suspended solids		
Conductivity **(µS/cm)**		
Total dissolved solids (TDS, mg/L)		
Turbidity (NTU)		

RE-DESIGN

1. Modify your design to address water quality problems in your design with available materials. You are bound to the same design rules and constraints as before. Get teacher approval and then make modifications.

2. Obtain another 250-mL sample of polluted water. Repeat the 15-minute purification process as before.

3. Ask your teacher to visit your group when ready. Stir the purified sample and record observations in Table 3. Record observations again after allowing the sample to settle for 5 minutes.

4. Store the purified water in a beaker. Label the beaker as "Trial 2."

ANALYSIS

Table 3: Water Quality of Second Filtered Sample

	Immediate Observations	Observations After Settling 5 min.
Color		
Odor		
Visible suspended solids		
Conductivity (µS/cm)		
Total dissolved solids (TDS, mg/L)		
Turbidity (NTU)		

PROCEDURE

1. Assemble the condenser as shown. Make sure the temperature sensor opening is closed with a stopper. Add ice to the top; pour salt over the ice.

2. Choose either purified water sample, Trial 1 or Trial 2 to run through a distillation and condensation processes.

3. Dispose of the sample you do not wish to use. Turn on the heater stirrer to high heat and allow the distillation process to proceed. If the ice in the condenser melts, remove the melted water with the pipette and then add more crushed ice. Pour salt over this ice as before.

4. Stop distilling when either most of the water in the beaker has evaporated or when the bottom of the fill line under the spout of the condenser indicates approximately 10 mL, whichever comes first. Allow the sample to cool, and record results.

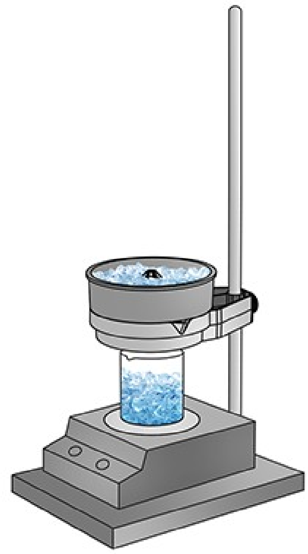

Table 4: Water quality after distillation and condensation

	Observations
Color	
Odor	
Visible suspended solids	
Conductivity (µS/cm)	
Total dissolved solids (TDS, mg/L)	
Turbidity (NTU)	

SUMMARY

Write a 2- to 3-page report that incorporates the background research you conducted before the design project with the results of each phase in this project. Discuss the successes and failures in both of your designs. Discuss in detail the successes and shortcomings you had with each filtration material. Support your discussion with results from the investigation. Explain which material worked best for each contaminant in the sample. Include design recommendations for further modifications to the filter to improve water color, odor, turbidity and conductivity. Decide whether the distillation and condensation phase would be more appropriate before filtration or after filtration. Explain your rationale.

Review the criteria in the grading rubric on the next page for details on how you will be graded.

EXTENSION

For an additional challenge, you may be asked to explore the following options:

1. Use two or more 2-L bottles in a new design to maximize water volume.
2. Use more than 3 filtration devices to ensure a “clean” sample of water.
3. You may be limited to less than 10 minutes to complete the filtration process.
4. You may be awarded additional points for the lowest conductance measurement produced or for a sample with conductance that best matches a bottled water sample.
5. You may be awarded additional points for purifying the most amount of water with the least conductance value in the given 15 minutes of time.

GRADING RUBRIC

Criterion	Criterion Not Met (0 pts.)	Needs Improvement (1 pt.)	Satisfactory (2 pts.)	Excellent (3 pts.)
Flow Rate (Trial 1 or 2)	Group collected under 150 mL of filtered water in 15 min.	Group collected 100-150 mL of filtered water in 15 min.	Group collected 150-200 mL of filtered water in 15 min.	Group collected 200-250 mL of water in 15 minutes or less.
Color and Turbidity	The purified sample of water maintains the same appearance and turbidity as the polluted sample.	The purified sample of water does not appear to have any macroscopic particles floating in it but still has some color or contaminants present. Turbidity is 1 to 35% less than the polluted sample.	The purified sample appears free of contaminants but is not as clear as a standard bottle of water. It may be cloudy or oily. Turbidity is 36 to 71% less than the polluted sample.	The purified sample is colorless and clear. It takes on a similar appearance to the standard bottle of water. Turbidity is >71% less than the polluted sample.
Odor	The purified sample has a foul odor.	The purified sample has a faint but detectable odor of the polluted sample.	The purified sample has a faint odor that may be hard to detect initially.	The purified sample is odorless.
Conductance and TDS	The purified sample has the same conductance and TDS as the polluted sample.	The purified sample has a conductance and TDS value that is 1 to 35% less than the polluted sample.	The purified sample has a conductance and TDS value that is 36 to 71% less than the polluted sample.	The purified sample has a conductance and TDS value that is >71% less than the polluted sample.
Discussion of Design	The student was unable to describe the function of each filtration material used nor were they able to explain any shortcomings and successes in their design upon completion of the filtration process. The student did not support their discussion with data.	The student had limited understanding of the function of each filtration material used. They could discuss some successes and shortcomings in their design upon completion of the filtration process though it is evident, the level of understanding was limited. The student included data in their explanation but it did not support their discussion.	The student could adequately discuss the function of each filtration material used as well as any shortcomings and successes in their design upon completion of the filtration process. While some ideas may have been flawed, the mistakes did not limit their understanding of the process. The student used data to support their discussion.	The student could discuss the function of each filtration material used as well as any shortcomings and successes in their designs in great detail. Additionally, they could propose future modifications to make the process more efficient, demonstrating a strong understanding of the process. The student made strong connections between their arguments and data from the investigation.

DESIGN PROJECT: DESIGN A PURIFICATION PROCESS

Research

Research the purification process to determine what will be needed to remove macroscopic and microscopic contaminants in the “polluted” water supply. Research should include conductivity, turbidity, and total dissolved solids tests of bottled water, tap water, salt water and the polluted water supply for the basis of comparison.

Keep a record of your results below. Attach a separate paper if necessary.

Analysis

Table 1 – Initial water quality of sample

	Bottled water	Tap water	Salt water	Sample: Immediate	Sample: After settling 5 min.
Color					
Odor					
Visible suspended solids					
Conductivity (µS/cm)					
TDS (mg/L)					
Turbidity (NTU)					

Initial Design

Record your response to the following in the space below; attach another paper if necessary:

3. Sketch a labeled diagram of your design. Include a brief sentence to explain what material is used and what it is expected to filter out.

8. Determine the total amount of time required to finish filtering the 250-mL water sample.

   Time elapsed = ___________________

Analysis

Table 2 – Water quality of first filtered sample

	Immediate observations	Observations after settling 5 min.
Color		
Odor		
Visible suspended solids		
Conductivity (µS/cm)		
TDS (mg/L)		
Turbidity (NTU)		

Re-Design

Record your response to the following in the space below; attach another paper if necessary:

1. Modify your design to address water quality problems in your design with available materials. You are bound to the same design rules and constraints as before. Get teacher approval and then make modifications.

❷ 2. Obtain another 250-mL sample of polluted water. Repeat the 15-minute purification process as before.

Time elapsed = ___________________

Analysis

Table 3 – Water quality of second filtered sample

	Immediate observations	Observations after settling 5 min.
Color		
Odor		
Visible suspended solids		
Conductivity (µS/cm)		
TDS (mg/L)		
Turbidity (NTU)		

Table 4 – Water quality after distillation and condensation

	Observations
Color	
Odor	
Visible suspended solids	
Conductivity (µS/cm)	
TDS (mg/L)	
Turbidity (NTU)	

Summary

Write a 2- to 3-page report that incorporates the background research you conducted before the design project with the results of each phase in this project. Discuss the successes and failures in both of your designs. Discuss in detail the successes and shortcomings you had with each filtration material. Support your discussion with results from the investigation. Explain which material worked best for each contaminant in the sample. Include design recommendations for further modifications to the filter to improve water color, odor, suspended solids, conductivity, TDS, and turbidity. Decide whether the distillation and condensation phase would be more appropriate before filtration or after filtration. Explain your rationale.

Review the criteria in the grading rubric on the next page for details on how you will be graded.

Extension

For an additional challenge, you may be asked to explore the following options:

1. Use two or more 2-L bottles in a new design to maximize water volume.
2. Use more than 3 filtration devices to ensure a “clean” sample of water.
3. You may be limited to less than 10 minutes to complete the filtration process.
4. You may be awarded additional points for the lowest conductance measurement produced or for a sample with conductance that best matches a bottled water sample.
5. You may be awarded additional points for purifying the most amount of water with the least conductance value in the given 15 minutes of time.

Grading Rubric

Criterion	*Criterion Not Met (0 pts.)*	*Needs Improvement (1 pt.)*	*Satisfactory (2 pts.)*	*Excellent (3 pts.)*
Flow Rate (Trial 1 or 2)	Collected under 150 mL of filtered water in 15 min.	Group collected 100-150 mL of filtered water in 15 min.	Group collected 150-200 mL of filtered water in 15 min.	Group collected 200-250 mL of water in 15 minutes or less.
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Conductance	The purified sample has the same conductance and TDS as the polluted sample.	The purified sample has a conductance and TDS value that is 1 to 35% less than the polluted sample.	Purified sample has a conductance and TDS value that is 36 to 71% less than the polluted sample.	The purified sample has a conductance and TDS value that is >71% less than the polluted sample.
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