Activity Three: Experiment With Water Filtration

Educator Notes

Challenge

Students will work as a team to create a water filtration system using an assortment of materials that will produce filtered water with a pH level of 6.5 to 8.5.

Suggested Time

60 minutes

Learning Objectives

Students will

- Measure length and volume using metrics.
- Demonstrate teamwork and communication skills to perform a task.

Curriculum Connection

<table>
<tr><th colspan="2">Science and Engineering (NGSS)</th></tr>
<tr><td>Disciplinary Core Ideas
• MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
– ETS1.B: Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
• MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
– ETS1.B: Developing Possible Solutions: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions.
– ETS1.C: Optimizing the Design Solution: The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.
• MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.
– LS2.A: Interdependent Relationships in Ecosystems: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.
• MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics: Evaluate competing design solutions for maintaining biodiversity and ecosystem services
– LS4.D: Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling</td>
<td>Disciplinary Core Ideas (continued)
– ETS1.B: Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
Crosscutting Concepts
• Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
• Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
• Influence of Science, Engineering, and Technology on Society and the Natural World: All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.
Science and Engineering Practices
• Develop and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
• Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
• Engaging in Argument from Evidence: Argumentation is the process by which explanations and solutions are reached.</td></tr>
<tr><th colspan="2">Technology (ISTE)</th></tr>
<tr><td>Standards for Students
• Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts, and make meaningful learning experiences for themselves and others.
– 3d: Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.
• Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.</td>
<td>Standards for Students (continued)
– 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving.
• Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.
– 7c: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.</td></tr>
<tr><th colspan="2">Mathematics (CCSS)</th></tr>
<tr><td>Content Standards by Domain
• CCSS.MATH.CONTENT.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by:
– CCSS.MATH.CONTENT.6.SP.B.5.A: Reporting the number of observations.
– CCSS.MATH.CONTENT.6.SP.B.5.C: Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.</td>
<td>Mathematical Practices:
• CCSS.MATH.PRACTICE.MP2: Reason abstractly and quantitatively.
• CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others.
• CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically.
• CCSS.MATH.PRACTICE.MP6: Attend to precision.</td></tr>
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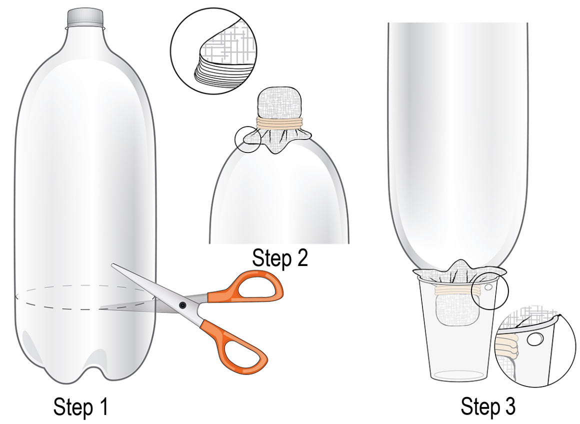
Habitation With Gateway

Preparation Time

45 minutes

- Read the Introduction and Background, Educator Notes, and Student Handout to familiarize yourself with the activity.
- Print copies of the Student Handout for each team.
- Gather and prepare all supplies listed on the materials list. Instructions for the water filtration system structure and the gray water follow here.
  - **Water filtration system structure**: Construct a water filtration system structure for each team of three to four students. (Structures can be reused in subsequent class periods.)
    1. Cut off the bottom of the 2-liter bottle, just above the curve.
    2. Cover the mouth of the bottle with at least 10 layers of cheesecloth and secure with a rubberband.
    3. Punch a hole just below the rim of each of the 4 large plastic cups. This will allow air pressure to escape as water drips into the cups.



  - **Gray water**: Make enough gray water for each team to have its own 600-mL supply (100 mL of Italian salad dressing mixed with 500 mL of water).
    1. Test your tap water before making the gray water solution. Your clean water should have a pH level between 6.5 and 7.5. If your tap water's pH level is not between pH 6.5 and 7.5, use store-bought drinking water.
    2. Mix 1 part Italian salad dressing to 5 parts water in a large, clean container.
    3. Ensure that the pH level of the gray water is about 4. If not, add vinegar until the pH tests to about 4.

Materials

Per student:
- ☐ Safety glasses
- ☐ Copies of Student Handout and blank paper

Per group (3 to 4 students):
- ☐ Water filtration system structure
  - ☐ 2-liter bottle
  - ☐ 10 layers of cheesecloth
  - ☐ Rubberbands
- ☐ 600 mL of gray water
  - ☐ Italian dressing
  - ☐ Tap water or bottled water with a pH level of 6.5 to 7.5
  - ☐ Optional: Vinegar
- ☐ 600 mL of clean water with a pH level of 6.5 to 7.5
- ☐ Metric liquid measuring cup
- ☐ Metric ruler
- ☐ 5 litmus paper strips
- ☐ pH color chart
- ☐ 4 large, clear plastic cups with a hole punched just below the rim
- ☐ 3 paper plates
- ☐ Mesh bag
- ☐ Assorted materials for filtration layers
  - ☐ Aquarium gravel
  - ☐ Play sand
  - ☐ Activated carbon/activated charcoal
  - ☐ Marbles
  - ☐ Cotton balls
  - ☐ Coffee filters, wadded up
  - ☐ Packing materials (Styrofoam™ packaging, packing peanuts, etc.)

Introduce the Challenge

- Discuss with students the importance of water filtration devices to produce clean water both here on Earth and in space.
  - How are processes for recycling water on Earth and in space the same or different?
- Review the concept of pH with students, including base, neutral, and acid.
- Explain the steps for testing pH using litmus paper and pH color charts.
- Define safe pH levels for drinking water. In the United States, public water systems must meet a pH level of 6.5 to 8.5.
- Challenge students to create and test water filtration devices to produce clean water with a pH level of 6.5 to 8.5 using three different types of filtration materials.

Facilitate the Challenge

Ask and Imagine

Engage students with the following discussion questions:

- Why would water filtration devices be crucial to future deep space exploration missions?
- How is water filtered for use on Earth? Where do you get your drinking water?
- Where is potable (safe for drinking) water a problem on Earth?
- Why is it important to run a control test?

Plan

- Each team will choose three types of filtration materials to create their water filtration device.
  - Each chosen material will become a 5- to 8-cm filtration layer within the water filtration system. Note: Some materials may need to be compacted when placed in the water filtration system.
- Teams should use the blank paper to sketch their design and document their plan to build a water filtration device.

Create and Test

1. Teams must follow their plan and design to create their water filtration device.
2. Each team will conduct a control trial and document the results.
3. Next, teams will record their predictions, observations, and results for the functionality and pH level of the water produced by their water filtration system for three experimental trials on the blank paper.

Share

Engage students with the following discussion questions:

- What was the greatest challenge for your team today? How did you address this challenge?
- How did the function of your water filtration device change throughout the trials?
- Which filtration material do you think worked best? Why?
- If you were to create another water filtration device, what would you do differently?
- If your device was used in space instead of on Earth, what would you have to modify? Why?

Extensions

- Add another iteration of the design challenge for teams to create a new water filtration device using what they learned from the first iteration.
- Add another iteration of the design challenge for teams to create a new water filtration device using different materials or a different filtration layer thickness.
- Ask teams to retest their previously filtered water through their water filtration device.
  - Does repeating the filtration process further clean the water?

Reference

Modified from NASA Engineering Design Challenges: Environmental Control and Life Support Systems Water Filtration Challenge.
https://www.nasa.gov/pdf/280748main_Water_Filtration_Guide.pdf

Additional Resource

- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

Share With Students

Brain Booster

On the International Space Station, an entire closed-loop system is dedicated to water recycling. In fact, 93 percent of the water on station is recycled from astronaut urine, sweat, respiration, and leftover wastewater from hygiene. Gateway will use similar technology for wastewater recycling while orbiting the Moon.

Learn more:
https://www.youtube.com/watch?v=BCjH3k5gODI&feature=youtu.be

On Location

The scientists and technical experts at Johnson Space Center’s Toxicology and Environmental Chemistry laboratory play a critical role in establishing safe environmental limits for spacecraft. The team monitors air and water quality aboard current spacecraft and supports technology advancements for future space missions, including research for a next-generation trash bag to contain waste and nasty odors (like vomit) during long-duration missions!

Learn more:
https://www.youtube.com/watch?time_continue=430&v=TDtBT5XL5KQ

Activity Three: Experiment With Water Filtration

Student Handout

Your Challenge

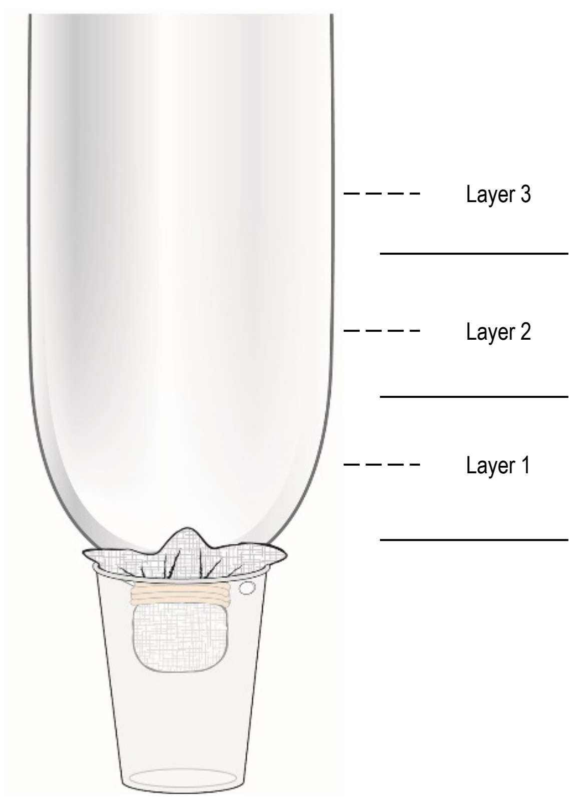
Create a water filtration system using an assortment of materials that will produce filtered water with a pH level of 6.5 to 8.5.

Ask and Imagine

- Why would water filtration devices be crucial to future deep space exploration missions?
- How is water filtered for use on Earth? Where do you get your drinking water?
- Where is potable (safe for drinking) water a problem on Earth?
- Think about the types of materials you will use and the order of placement in your water filtration system.

Plan

1. Choose three types of materials to use for your filtration layers.
   - Each material must be layered to a depth of 5 to 8 cm within your water filtration system.
2. On your own paper, create a sketch of your design like the example below.
   - On your sketch, draw each of the layering materials you have chosen for your filtration system.
   - Remember to label your sketch.
3. Next to your sketch, write your plan for layering your materials within your filtration system. How will your layers interact?

Sketch	Plan
	

Create and Test

1. Assemble your water filtration device.
   – Add your chosen layering materials to the bottle.
   – Set the bottle upside down on one of the four plastic cups. You will use a new cup for each trial.
2. Create a data table on your paper like the example below.
3. Prior to each trial, record your hypothesis (your prediction of what will occur). You will run a control trial followed by three experimental or test trials.
4. Test your water filtration device.
   – Pour the water into the top of the device and let it drip through the layering materials into the plastic cup.
   – Use a litmus paper strip to test the pH of the water in the paper cup. Use the pH color chart to determine the pH level.
5. Record your observations and the final results, including the pH level.

	Hypothesis	Observations	Results
Control Trial Clean water, 200 mL			
Test Trial 1 Gray water, 200 mL			
Test Trial 2 Gray water, 200 mL			
Test Trial 3 Gray water, 200 mL			

Share

- What was the greatest challenge for your team today? How did you address this challenge?
- How did the function of your water filtration device change throughout the trials?
- Which filtration material do you think worked best? Why?
- If you were to create another water filtration device, what would you do differently?
- If your device was used in space instead of on Earth, what would you have to modify? Why?

Fun Fact

The International Space Station's Water Recovery System is designed to recycle crew member urine and wastewater for reuse as clean water. This system reduces the net mass of water and consumables that would need to be launched from Earth to support six crew members by 2,760 kg (6,000 lb) per year!

Learn more: https://www.nasa.gov/stemonstrations-water-filtration.html

Career Corner

Food for Space Flight! Foods flown on NASA space missions are researched and developed by the Space Food Systems group. Food scientists, dietitians, and engineers ensure food is analyzed for use during space missions through nutritional analysis, sensory evaluation, freeze drying, rehydration, storage studies, packaging evaluations, and many other methods.

Learn more: https://www.nasa.gov/content/space-food-systems