National Aeronautics and Space Administration

STEMonstrations

Education in Action on the International Space Station

Classroom Connections

Water Filtration

For more STEMonstrations and Classroom Connections, visit www.nasa.gov/stemonstation.

Water Filtration
Teacher Background

WARNING!
Do not allow students to drink the water.

Grade Level: **5th-12th**

Suggested Time: **(2–3) 50 minute periods**

Next Generation Science Standards (NGSS):

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.*
Grade: *Middle School (6-8)*

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.*
Grade: *Middle School (6-8)*

HS-ETS1-1. Engineering Design: *Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.*
Grade: *High School (9-12)*

Background

This lesson challenges students to create and test a water filtering system. The activities in this lesson focus on water recovery and management.

The astronauts aboard the International Space Station join those of us on Earth in the recycling effort. Astronauts recycle their water. This includes urine, moisture they exhale, sweat and the water they use to shower and shave. These waste waters are purified, and used as drinking water.

The Environmental Control and Life Support System (ECLSS) is a system of regenerative life support hardware that provides clean air and water to the ISS crew and laboratory animals through artificial means. The ECLSS allows for the accommodation of more crew on the space station, extends the time crew can stay in space and significantly reduces the cost of operating the space station. The ECLSS consists of two key components, the Water Recovery System (WRS) and the Oxygen Generation System (OGS). The WRS provides clean water by recycling astronaut urine, cabin humidity condensate, and Extra Vehicular Activity (EVA) wastes. The reclaimed water must meet stringent purity standards before it can be utilized to support the crew, laboratory animals, EVA and payload activities. The WRS uses filtration and temperature sterilization to ensure the water is safe to drink. Water is checked often to ensure it meets the water quality requirements and monitored closely for bacteria, pollutants and proper pH. The pH scale ranges from 0 to 14 and is a tool used by scientists to measure the strength of an acid or base. To maintain homeostasis the water we drink should be around a pH of 7, or neutral.

Public water systems have to meet a pH level of 6.5 to 8.5. The space station water is required to be within the range of 6.0 to 8.5. The recycled water on the station is sterile, and there is no odor or bad taste. Water recycling will be imperative for long-duration missions such as aboard the International Space Station or possible trips to the Moon and Mars. A spacecraft on a lengthy trip to the Moon and Mars would be limited to the amount of water it could carry because of weight restrictions. In this experiment, you will create and test a water filtration system.

- <u>Acid</u>: Any of a class of substances that yields hydrogen ions (H+) when dissolved in water. The greater the concentration of hydrogen ions produced, the more acidic the substance. Acids are characterized by a sour taste and the ability to react with bases and certain metals to form salts.
- <u>Base</u>: Any of a class of substances that yields hydroxide ions (OH-) when dissolved in water. The greater the concentration of hydroxide ions produced, the more basic the substance. Bases are characterized by a bitter taste, a slippery feel and the ability to react with acids to form salts.

- Conductivity: Conductivity is a measure of a material's capacity to conduct electricity. Conductivity is a standard method to measure the purity of water, specifically the quantity of inorganic contaminants (which conduct electricity). Completely pure water will not conduct electrical current. Thus, the smaller the amount of current that flows through the treated wastewater, the lower the concentration of inorganic contaminants. The water recovered and purified by the WRS on the space station has an average conductivity of approximately 1 µmho/cm, most of which is due to the residual iodine added to the water.
- Homeostasis: An organism's ability to maintain equilibrium of parameters that define their internal environment.
- Litmus Paper: Indicator used to determine whether a substance is acidic or basic. The pH scale lets you determine the relative acidity of a substance. The pH scale ranges from 1 to 14 where 7 is neutral, greater than 7 is basic, and less than 7 is acidic.
- Water: The water recovered and purified by the WRS on the space station has a pH of 6.0-8.5. This lower pH is a result of the addition of iodine to the filtered water.

Objective

Following this activity, students will be able to:

- Design, build and test a water filtration device.
- Describe how water is purified on the International Space Station.

Materials

See Detailed Material List at the end of the lesson.

Procedure

- Inquiry Discussion

Background information should not be given to the students. Ask students the following questions and discuss. Use this discussion to segue into the STEMonstration video.

1. Where does your drinking water at home come from? For some of us it is provided by the city for others through a well. And some of us may only drink bottled water at home.
2. What happens to water before it is safe to drink?
3. What does a filtration system look like?
4. Are filtration systems different for city water compared to well water?
5. Does anyone have additional water filtration systems attached to their kitchen faucet, refrigerator, fish tank, or pool?
6. Now let's talk about astronauts in space on the station Where do astronauts get their water?
7. Do astronauts have to filter their water? If so, how do they filter water?

Let's check out a video from an astronaut on the International Space Station as he explains the importance of water filtration and where their water comes from. He will also discuss how and why the water is filtered.

- Watch and Discuss Video

Watch the video STEMonstration: Water Filtration.

Reinforce how and why astronauts aboard the International Space Station filter their water.

- Activity

Students will complete the water filtration activity over the next 2-3 sessions.

Handouts included at end of lesson.

- Final Discussion

Have groups share their data. Discuss what materials worked best and why. Make the connection back to the WRS on the space station.

Extension Activities

- Research how water is filtered in your city. Take a field trip to the water treatment plant or request an expert to speak to your class in person or online.
- Collect and filter other samples of water. (e.g., rain water, hand wash water, stream or pond water, etc.) Try using other filter media such as polystyrene pieces, potting soil, marbles and popcorn.
- Weight is consistently an issue when launching payloads into low-Earth orbit. As the payload's weight increases, launch costs also increase. Set a weight limit for the filtration device (including filter media) and hold a competition to see which team has the purest water (lowest conductivity and most neutral pH) using the lightest filtration device.
- If equipment is available, instruct student teams to videotape, film, or photograph their work. This can then be used to create an electronic diary and presentation of their filtration device and results. Instruct the teams to share their creation with the class.
- Investigate other water treatment methods, such as desalination or reverse osmosis and conduct classroom experiments using these methods.

Extension Research

NASA Water Filtration Systems Benefit the World
https://www.nasa.gov/content/benefits-for-humanity-water-for-the-world

NASA Water Purification
https://www.nasa.gov/topics/nasalife/pure_water.html

Water on the Space Station
https://science.nasa.gov/science-news/science-at-nasa/2000/ast02nov_1

NASA Environmental Control and Life Support System
https://www.nasa.gov/sites/default/files/104840main_eclss.pdf

Water Filtration Educator Guide
https://www.nasa.gov/pdf/280748main_Water_Filtration_Guide.pdf

STEMonstrations
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Design and Test a Filtration Device

Student Activity

Overview

This is the first session for students to design and build a filtration device. It is important to allow the students enough time to discuss their designs with their team members prior to beginning the actual assembly and testing of their device. You may find that it may take most of one class period for students to gather the materials needed and discuss their designs. If this is the case, there needs to be ample space in your classroom for the teams to store their filtration devices overnight and then begin filtering the wastewater at the beginning of the next class period. To save time, set up all the materials before students arrive. Be sure to have the simulated wastewater made beforehand as well. Directions can be found at the end of the Detailed Materials List.

Remind students of the importance of working as a team and carefully recording information on the Design and Evaluation Sheet.

Objectives

Following this activity, students will be able to:

- Work as a team to design a water filtration device.
- Express their design rationale verbally.
- Have proficiency using the Design and Evaluation Sheet.
- Use a conductivity tester to test the conductivity of a solution.
- Use pH strips to test the pH of a solution.

Materials

View material lists included at the end of lesson.

Session 1: Detailed Steps

1. Designate teams: Pre-designated teams for activities such as this one are recommended, but not required.

2. Discuss possible design solutions: Before each team has assembled their materials, they should spend some time discussing how they want to design their filtration device. Which filter media do they want to use? In what order should they place the materials in the bottle? Should each bottle use the same filter media in the same order? Should cheesecloth, window screen, and/or plastic wrap, be used to secure the mouth of each bottle? These are things the teams should discuss and decide prior to putting anything into or on the plastic water bottles.

   Let students know they do not have to use every media provided. If they only want to use 50 g of uncooked macaroni, then this is acceptable. They should make note of how much of the media they use. The measurements are vital to describing the design. This will aid them when evaluating and redesigning their devices.

   It is important that the activated carbon be used. Hopefully the need for using the carbon will have emerged in the discussion. If not, it is suggested to wait until the second round to tell the students.

NOTE: If there is not enough time left in the class period to complete the remaining steps in this session, this is the point at which it is easiest to stop. Have the students label cups with their team name. The students should put their notes and Design and Evaluation Sheets into the file folder. All other materials need to be neatly stacked together. Designate an area for each team to place their materials.

Session 2: Detailed Steps

1. Teams collect materials for activity.

   Each team will need to gather the materials needed for assembling and testing the filtration device. The lists are provided at the end of this lesson. The students should put their measured quantities of carbon, sand, gravel, and uncooked macaroni into plastic cups (or whatever other container you have chosen). If there are not enough graduated cylinders for each team, the simulated wastewater can be measured with one cylinder and then transferred to plastic cups. The other materials can be easily handled without the need for containers. NOTE: Coffee filters make good containers for dry materials. Plastic cups can be converted to graduated cylinders by placing lines on the outside for every 10 mL of water added (lower accuracy than a graduated cylinder, but good when you're low on the real thing).

   Depending on the size of your class, the number of triple beam balances available and the number of graduated cylinders you have, this part of the session could take 20–30 minutes.

2. Assemble the filtration device.

   Once students have justified their filter media designs and received approval, it is time to start assembling the filtration device. Remind the students to cover the mouth of each bottle prior to putting any filter media into the bottles. The students should use cheesecloth, window screen, plastic wrap or any combination of the three materials to insure the filter media does not fall through the mouth of the bottle. If a team elects to use the plastic wrap, make sure the students remember to punch a couple of holes into it using the straightened paper clip.

   The filtration device should be placed in an Erlenmeyer flask or other container for catching and holding the filtered water. The filtration device should rest on or in the opening of the container but not on the bottom of the container. Make sure the container is stable and there is no risk of toppling. Ring stands and clamps may help keep filtration device bottles upright.

   Remind students to sketch their filtration device onto the Design and Evaluation Sheet prior to beginning the filtration process.

   NOTE: The activated carbon can be reused to save money by using a coffee filter on each side of the carbon. This will separate the carbon from the other materials. Rinse and reuse.

3. Record observations and measurements.

   Each team will need 200 mL of simulated wastewater. Remind the teams they must measure the conductivity and determine the pH of their wastewater before filtering. These values should be recorded on their Design and Evaluation Sheet. Students should also note any odors and the color and clarity of their sample before pouring through their filtration device.

4. Pour on the wastewater.

   It will be necessary to pour the water very slowly and in small increments. If all 200 mL is poured in at one time, it will overflow the bottle. It is also important for students to pour the water in a circular motion so as to use the entire surface of whatever media is on top; do not pour all 200 mL in the exact same spot.

   The wastewater should be allowed to flow naturally through the filtration device. Students should not squeeze, shake, or otherwise put force on the device to increase the flow. The filtration should be slow, with ample time for as much wastewater as possible to flow into the catch container. This will take, on average, 15 minutes. You may want to wait overnight to get ample amounts of water.

Design and Test a Filtration Device

Student Activity (continued)

5. Complete the Design and Evaluation Sheet.

Once the wastewater has run through the filtration device it is time to collect the necessary data to complete the Design and Evaluation Sheet. The filtered wastewater will need to be poured into a graduated cylinder and the volume measured. The pH and conductivity of the filtered water should be obtained and other observations for pre- and post-filtering differences noted (color, clarity, smell, etc.).

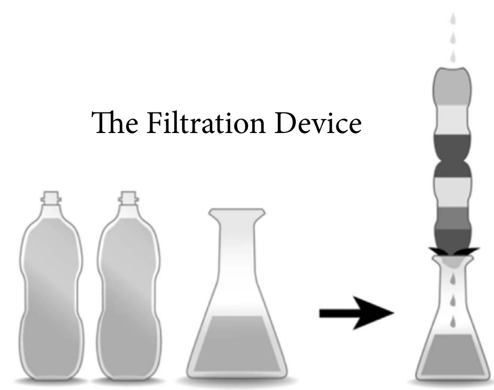
Upon completion of the filtration run, students will need to clean up their areas. Filtered wastewater should be collected in one bucket or container. The activated carbon should be rinsed and spread out on newspaper to dry. The gravel may also need to be rinsed and spread out to dry. The water bottles can also be reused; rinse them and allow them to air dry. All other filter media used should be discarded.

Have each team place their Design and Evaluation Sheet in the team folder. Any notes taken during the design discussion should also be placed in the folder. Each team should elect one person to be responsible for keeping the folder and bringing it to class the next day.

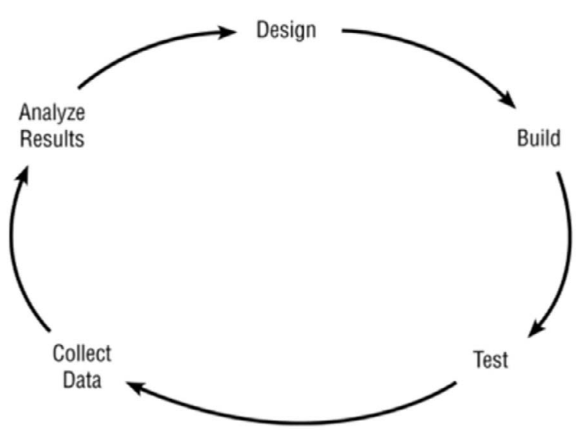
NOTE: It is now time to decide whether or not to allow the students to do a second filtration run. This will require another class period. At the beginning of the period, have students discuss their design and results prior to assembling their next version of the filtration device. It is recommended students do one more run if time allows..

The Conductivity Tester

The Filtration Device



The Engineering Design Process



Name: ______________________________ **Date**: ______________

Group Members: ____

Design Phase

1. Sketch the filtration device. Draw and label the filter media in the order in which they were placed in the device. Label approximately how much was used of each.

2. Why did your team select the above filter media and why was it placed in that order?

Test Results

3. Record the appropriate data.

Data Item	Pre-Data	Post-Data
Volume		
pH		
Conductivity		
Color/Clarity		

4. List team member observations.

5. What did you learn that will help you design the next version?

The purpose of these Detailed Materials Lists is to identify everything you will need to gather in order to implement this challenge. Estimated costs are provided for items you are likely to need exclusively for this project and that are not likely to already be available in your classroom or school. Therefore, no cost estimate is provided for such items as the triple beam balance and the rubber bands. Likewise, no cost estimates are provided for items you or your students might have at home, such as plastic water bottles.

- Table 1 lists the items you will need for the classroom.
- Table 2 lists the items you will need to build a conductivity tester.
- Table 3 lists the items you will need to build the filtration device.
- Table 4 lists the items to be used as filter media in the filtration device.
- Table 5 lists the items you will need to make the simulated wastewater.

Table 1: Materials needed for the classroom.

Item	Quantity	Comments	Estimated Cost
Triple beam balance or alternative	2-3	Students will need to weigh filter media.	
Conductivity tester	3	Students will use the tester to measure the conductivity of their unfiltered and filtered wastewater.	See Table 2.
Sink or bucket for used wastewater	1-2	If no sink is available, 1-2 buckets or large pans will work.	
Graduated cylinder, 250mL	1-2	Students will need to measure the amount of simulated wastewater they are required to use. If you have enough, the students can use these for pouring the wastewater into the filtration device.	
pH test strip	3-4 per team	The strips should have a range of 1–12 or 14. The total number needed depends upon the number of student teams.	$16.50 pkg. of 1,000
Plastic cup, 16oz. or alternative	6-8 per team	In case there are not enough graduated cylinders for each group, a cup will be needed to hold the measured wastewater. The wastewater will be poured from this cup into the filtration device.	$2.00 pkg. of 50
File folder	1 per team	Each team will need a file folder to store their Design and Evaluation Sheets and any notes.	
Newspaper		For drying activated carbon.	
Transparency pen and permanent marker	1 per team		
Large, plastic, wide-mouthed jars	1-2	These are for rinsing gravel and charcoal. Label accordingly on both the lids and sides of jars.	

Table 2: Materials needed for each conductivity tester.

Item	Quantity	Comments	Estimated Cost
Multimeter (digital)	1	The multimeter must be able to measure current in milliamps. Be sure the meter includes test leads.	$10-$20
9 volt battery	1	It is a good idea to have 1 – 2 extra batteries on hand.	$5 for pkg. of 2
Battery snap connector	1	Used to connect the battery to the meter leads.	$2 each
Electrical tape, black	15cm (6")	Needed to hold snap connector wire to multimeter lead.	$0.50 per roll
Wire stripper or knife	1	Needed to strip insulation from battery snap connector.	$5.00

Table 3: Materials needed for each filtration device.

Item	Quantity	Comments	Estimated Cost
Plastic water bottle 0.5 L (16.9 oz)	2	The bottles will need to have the bottoms cut off. The two bottles will be stacked in each other to form the filtration device.	
Rubber band	2	Used to attach cheesecloth, window screen, and/or plastic wrap to mouth of water bottle.	
10cm x 10cm (4" x 4") square of cheesecloth	4	Used to cover mouth of bottle.	$2.50 4 ft. square
10cm x 10cm (4" x 4") square of window screen	4	Used to cover mouth of bottle.	$6.50 36" x 84" roll
10cm x 10cm (4" x 4") square of plastic wrap	4	Used to cover mouth of bottle.	$1.00 200 sq. ft. roll
Container for filtered wastewater	1	You can use an Erlenmeyer flask, a ring stand with a beaker or cup for catching the wastewater, etc. The key is for the wastewater to drip into a container.	
Utility knife or scissors (only if students are cutting the bottles)	1	Each team will need a file folder to store their Design and Evaluation Sheets and any notes.	
Masking tape (only if students are cutting the bottles)	64cm (25")	Used to cover sharp, uneven edges of the bottle once the bottom has been cut.	
Paper clip, straightened (for putting holes in plastic wrap)	1	Needed for making small holes in plastic wrap.	

Table 4: Materials needed for use as filter media. Quantities are for each student team.

Item	Quantity	Comments	Estimated Cost
Cotton ball	10-15		$2.00 pkg. of 300
Coffee filter	6		$1.25 pkg. of 200
Activated carbon (charcoal)	200g (7.1oz)	Granulated carbon is best. The carbon will need to be rinsed a few times prior to use to keep the filtered wastewater from turning black. Simply rinse with tap water and spread evenly on newspaper to dry. Typical drying time is 24 hours. A fan set on low can shorten drying time.	$6.75 64 oz ctn.
Gravel	200g (7.1oz)	Aquarium gravel works best; color of gravel does not matter.	$2.00 5 lb. bag
Sand	200g (7.1oz)	Play sand works best.	$3.00 50 lb. bag
Uncooked macaroni	100g (3.5oz)		

Table 5: Materials needed for simulated waste water. Quantities listed makes 2 liters. Each team will need 200 mL of wastewater for each filtration run they perform.

Item	Quantity	Comments	Estimated Cost
Vinegar, distilled	400 mL (13.5 oz)		
Food coloring	1-2 drops	Yellow gives the appearance of urine, but any color works.	
Sand	50 g (1.8 oz)	Play sand works best. There will be ample sand for the wastewater and for use as filter media in one 50-lb bag.	
Salt	1 tbsp		
Hair		Collect a handfull from a hairbrush.	
Dust		Collect a handfull from a piece of furniture or window sill, etc.	
2 liter beaker	1	Mix simulated wastewater in this container. Students will use graduated cylinders to measure out the amount needed for the challenge.	
Tap water		Place all items in beaker prior to adding water. Fill beaker with water to the 2 liter mark.	
Stirring device	1	The wastewater will need to be stirred prior to each team measuring out their sample. The sand, hair, and dust settle to the bottom when the mixture is allowed to rest.	

Each Group will need 200mL of simulated wastewater for each filtration run. Wastewater from a pond, lake, or river can also be used.

______ 1. Teams collect materials for the activity.

______ 2. Design and diagram a filtration device.

______ 3. Assemble the filtration device.

______ 4. Measure and record the pH and conductivity of the unfiltered wastewater. Make as many qualitative (color, turbidity, smell, etc.) observations as possible.

______ 5. Pour the unfiltered wastewater into the filter slowly.

______ 6. Once filtering is complete, repeat all measurements and observations on the filtered water.

______ 7. Complete the Design and Evaluation Sheet.