LESSON

Greywater Gadgetry

Grade Levels: 6-12

Duration: Two sessions (60 min each)

Learners will work in teams to explore methods for creating a two-part system for filtering greywater. Teams will focus on communication and systems engineering as they build separate components to filter solid and liquid waste and then combine them into one device.

Outline

Session 1: Designing Components	**60 min**
Teams are introduced to the potential uses of greywater, before designing and testing a solution for filtering either solids or liquids from water.	
Session 2: Refining the System	**60 min**
Solids and liquids teams partner up and combine their devices to create a two-part filtration system.	

Grade Levels: 6-12

Duration: Two sessions (60 min each)

Concepts/Skills

Systems engineering, water filtration, water systems, communication, collaboration

Objectives

Students will:

- Consider the potential effects of drought and how greywater could be part of the solution.
- Design a system for filtering out solid waste or liquid waste.
- Consider effective communication strategies with their team.
- Collaborate on their design ideas to create a single two-part filtration system.

Materials and Preparation

Materials

- Systems Engineer Site Visits Handout (2 per team)
- Conference Call: Two-Part Filtration System Handout (1 per team)
- Clipboards (2 per team)
- Pencils (2 per team)
- *Optional*: Device to project a video

Building Materials

In **Session 1: Designing Components**, learners will have access to a different set of building materials, depending on whether they are creating solutions for solid or liquid waste. Some of these materials can be the same, but others will differ due to the different requirements of filtering out solids versus filtering out liquids.

- Arrange the building materials in the room so that each set (those materials needed to filter solids and those needed to filter liquids) is on the side of the room that corresponds with the related testing area (see Test Area Set-up).
- In **Session 2: Refining the System**, building materials can either remain in the same configuration or be placed together, but learners should have access to all of the materials.

Solids and Liquids *(per class of ~32 students)*

Containers *(~20)*

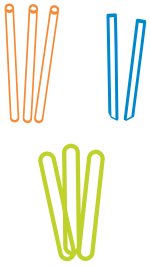
- □ Plastic containers
- □ Empty water bottles
- □ Plastic cups
- □ Plastic berry baskets

Connectors *(~30)*

- □ Rubber bands
- □ Pipe cleaners
- □ Twist ties
- □ Paperclips
- □ Binder clips

Long & Skinny Items *(~20)*

- □ Chopsticks
- □ Straws
- □ Craft sticks
- □ Bamboo skewers



Tools *(1 per group)*

- □ Scissors
- □ Hole punch

Liquids Only *(per class of ~32 students)*

Filtering *(~25)*

- □ Coffee filters
- □ Cloth
- □ Craft foam
- □ Mesh
- □ Sand
- □ Charcoal
- □ Reusable tea bags (for holding small items like sand, charcoal, etc.)

Solids Only *(per class of ~32 students)*

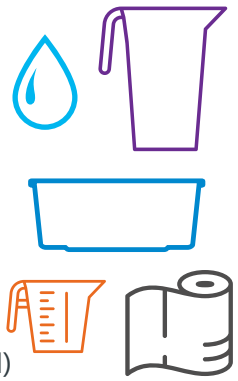
Filtering *(~25)*

- □ Foam sheets
- □ Pebbles or small rocks
- □ Marbles
- □ Loose knit fabric (mesh, burlap etc.)
- □ Clean plastic/foil packaging

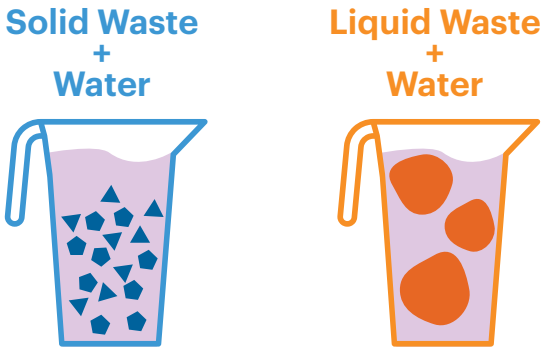
Note: This challenge is all about recycling! Try gathering recycled items ahead of time to use as building materials.

Test Area Supplies *(1 set per group of 4 students)*

- ☐ Water
- ☐ 2 large water containers (pitcher, jug, etc.)
- ☐ 1 shallow plastic tub
- ☐ 1 graduated cylinder or other clear container for checking turbidity
- ☐ 1 Turbidity Chart (printed)
- ☐ 1 cup measuring cup (or plastic cup marked at 1 cup level)
- ☐ Old towels or paper towels (in case of spills)



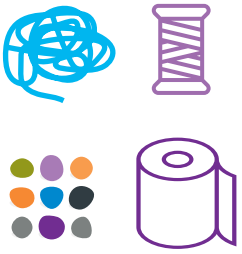
Greywater preparation:



Waste Material(s): You will create your own greywater mixture out of the following options:

Solid waste:

- ☐ Substitutes for hair at different lengths (floss, single strands of thread, easter grass, etc.)
- ☐ Tiny beads (perler beads, etc.)
- ☐ Perlite
- ☐ Pebbles
- ☐ Tissues/toilet paper



Liquid waste:

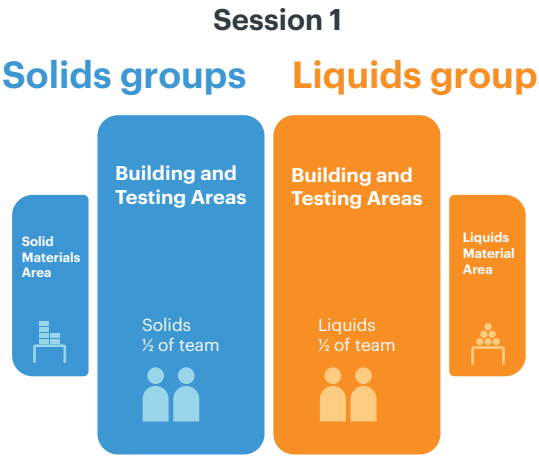
- ☐ Vegetable oil
- ☐ Dish soap
- ☐ Coffee (liquid, not grounds)
- ☐ Black tea (steeped, not leaves)

Note: Avoid using food items that may spoil or attract insects.

Building and Test Area Set-up

In this activity, the materials and testing areas for filtering solid and liquid greywater will need to be set up on opposite sides of the classroom. Try the recommended classroom set-up below, or create your own based on the needs of your space.

1. Arrange the tables used for building, placing an equal number on opposite sides of the room.
2. Make sure there is enough space at each station for two pairs of learners to work independently. (Testing stations can be combined if space is limited.)
3. Set up the solids building materials on a table near the solids building station. Repeat with the liquids materials on the other side of the room.



Preparation

1. Create greywater by mixing water and waste materials in the large water containers.
   - **Session 1: Designing Components:** Each station should have two containers of greywater that is either solids or liquids.
   - **Session 2: Refining the System:** Each station should have two containers of greywater, each with a combination of solid and liquid greywater.

   Note: Wondering how much greywater to make? Each test will take about a cup of water, so it makes sense to have four or more cups of greywater per container.
2. Print **Systems Engineer Site Visits** and **Conference Call: Two-Part Filtration System** handouts and **Turbidity Charts**.
3. *Optional*: Consider establishing the makeup of the teams and their assigned waste material ahead of time.
4. Build a solution (or solutions) yourself, with other educators or kids you know. This will give you practice with the materials and tools to be able to anticipate student questions.

Caution: Safety with Water

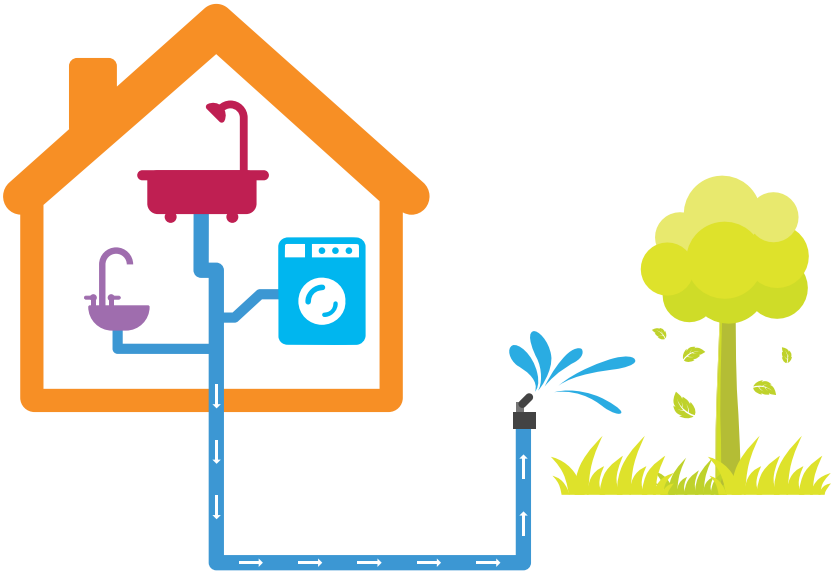
Testing for this design challenge involves pouring water over the device and into a plastic tub, creating the potential for spills. To prioritize safety during prototyping, make sure that students are aware that they should...

- Always bring their device to the designated testing stations before testing.
- Never remove test materials (pitchers, tubs, etc.) from the testing stations.
- Only pour test greywater at the testing stations.
- Clean up any spills immediately.

Background Information

What is greywater?

Greywater usually refers to water that is leftover while using appliances such as washing machines, bathtubs, and bathroom sinks. It does not include wastewater with harsh or harmful substances like toilet water. Greywater often contains solid and liquid waste products, such as dirt, food scraps, hair, and greases. Once these waste products have been filtered out, the remaining greywater can be used as a safe option for watering lawns and outdoor plants. Not only does recycling water help reduce water usage and save homeowners money, it also reduces the chance of greywater ending up in natural water sources and polluting them or harming wildlife.



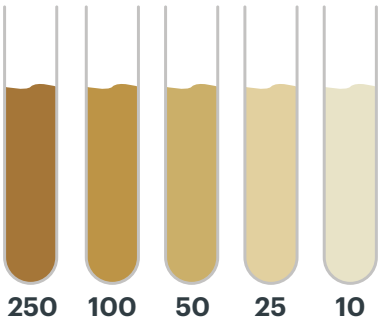
Check out the resources below to learn more about the benefits of using greywater:

- **"About Graywater," Santa Clara Valley Water website**
- **"Grey Water," Water Education Foundation website**
- **"About Greywater Reuse," Greywater Action for a Sustainable Water Culture website**

Measuring Turbidity

To determine if their liquid filtration systems are successful, learners will compare the cloudiness of their water to a **Turbidity Chart**. Turbidity measures the clarity of a liquid by looking at the amount of light that is scattered by substances in the water. The more opaque the water is, the higher the turbidity will be. Turbidity is also a key way to determine the quality of drinking water, with a high turbidity indicating a higher risk of getting sick. Since they are using greywater, which is not used for drinking, the learner's goal is to filter the water so it has a turbidity of 25.

Note: The **Turbidity Chart** will be used first by teams developing a filtration device for liquid waste, while teams filtering solid waste will rely on visual inspection to determine if sold waste has been removed. In **Session 2: Refining the System**, all team members will use the Turbidity Chart to measure device filtration.



*NTU: Nephelometric Turbidity Units, measure the intensity of light scattered at 90 degrees as a beam of light passes through a water sample.

Systems Engineering

In this lesson, students examine the challenges of water filtration and greywater systems through the lens of systems engineering. **Systems Engineers** oversee and implement the manufacturing of products to make sure all the components will work together. When a product is being developed, it is common for the various components to be designed by different teams in separate locations. Communication between these design teams is essential for success. The Systems Engineer works with the design teams to ensure there is a clear line of communication between them and that all of the components of the product will work together.

During **Session 1: Designing Components**, any member of their team can take on the role of the Systems Engineer and do a "site visit" to where the other half of their team is working, then report back.

Additional Resources on Systems Engineering

- **"Fundamentals of Systems Engineering,"** National Aeronautics and Space Administration (NASA) website
- **"Systems Engineer for Environmental Satellite,"** Climate Kids website " *0:00 / 3:12*
- **"What is "Systems Engineering?,"** Computer Aided Three-Dimensional Interactive Application Community video *(3:12)*

Tech Tips: See our **educator guides and videos** for more design challenge facilitation techniques. For this lesson check out:

- **Innovator Mindsets** - Collaboration
- **Prototyping** - Test, Reflect, Iterate

Frame the Challenge

Frame the Challenge	15 min total
Activate Prior Knowledge	5 min
Introduce Systems Engineering Design Challenge	10 min
Design Challenge	**45 min total**
Prototype Components	30 min
Conference Call to Share Solutions	10 min
Debrief	5 min

Activate Prior Knowledge *(5 min)*

1. Begin by asking learners to consider all the ways people use water in their daily lives.
2. Have learners guess what percentage of clean water that comes to their home is actually used for drinking or cooking.
   - *On average, Americans only consume 10% of the water they use. In fact, we use 24 gallons of drinking water a day just to flush our toilets!* (See **"From Wastewater to Drinking Water,"** Columbia Climate School website, for more.)
3. Ask **Guiding Questions** to explore what learners already know about **droughts** and **alternative water sources**:
   - *What are some environmental issues related to our use of water, i.e., droughts, water pollution, etc.?*
   - *What causes these problems?*
   - *What impact can they have on people's daily lives?*
   - *What are some examples of alternative water sources? Where could we safely use them?*
   - *Are they any types of water that we might be able to recycle?*
4. Introduce learners to **greywater** as water that already has been used, such as leftover water generated from washing machines, bathtubs, and bathroom sinks, but not from sources with harsh or harmful substances like toilet water.
   - If learners need more context, refer to some of the **Background Information**.
   - *Optional*: Project the short **animation, "Reuse Your Laundry Water with a Graywater System,"** *(40 sec)* created by **Santa Clara County Water** that demonstrates a household greywater system.
5. Let learners know that some of the waste items in greywater are safe for plants, but not all of them.
   - *What kind of waste items would we need to remove?*
   - *What might help us to filter out the harmful substances?*

Adaptation for Younger Engineers: Down the Drain

Looking for resources on water conservation and safety for learners in grades 3-5? Check out **thetech.org/down-the-drain**. Here you'll find:

- A downloadable infographic on what is safe (and not safe) to send down our drains, presented in partnership with Santa Clara Valley Water District.
- Activity guide for **Build a Storm Drain**, a design challenge where you build a storm drain cover to protect our waterways.
- Link to our Science Labs page, where you can learn more about signing your class up for the **Down the Drain Lab**.

Introduce Design Challenge *(10 min)*

1. Introduce the **design scenario**:

> *The local water company has raised prices to pay for upgrades to their system. In order to keep their water bill down (and help the environment!), homeowners are looking for ways to recycle their greywater. Your engineering team has been tasked with figuring out the best methods for filtering solid waste and liquid waste out of the greywater, but half of the team is working on the other side of the country. Separately, you'll have to figure out how to solve the problem and share your learning with each other, and then bring together multiple components into a single design.*

2. Introduce the design problem, criteria, and constraints:

Design Problem	Design and test one component of a filtration system for greywater.
Criteria	• Device should filter the assigned material (either solid or liquid waste) out of the greywater to meet the following criteria: – **Solids**: Filtered water contains no solid waste. – **Liquids**: Filtered water has a turbidity of 25 or lower. • The device can filter one cup of wastewater without getting clogged or overflowing. • Both devices should be designed to work together.
Constraints	• Use only the materials provided for solids or liquids filtration, respectively. • Limit communications across teams, as if you are not in the same place. • There's a time limit.

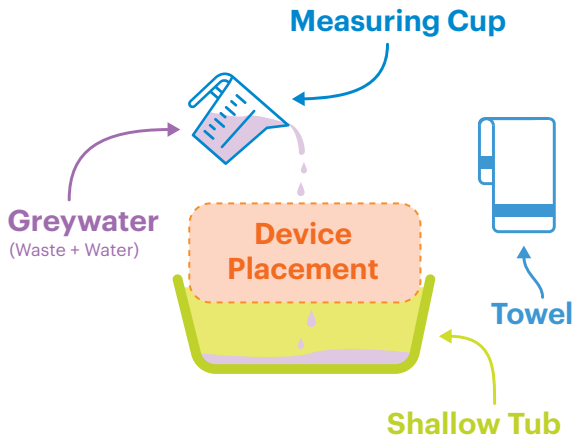
3. Let learners know that there will be two types of prototyping happening simultaneously during this session.
   - Half of their team will need to design a solution to filter solid waste out of greywater, while the other half will design a solution for filtering out liquid waste.
   - In **Session 2: Refining the System**, their whole team will come together to combine their solutions into a single, two-part filtration system. Today, they will be working on separate sides of the country (i.e., the room) and have limited discussion about their processes.
4. Turn learners' attention to the testing stations on both sides of the room.
   - Point out the side of the room for testing solid waste, and the side for testing liquid waste.
     - Make sure they are aware that each side has different building materials that are related to the type of waste they are filtering. In this session, they may only use materials from their side of the room.

- Demonstrate how to test their device. Make sure they are aware that they should:

STEP 1

- Place or hold their filtration device over the plastic tub.
- Pour the greywater over the device so the filtered water lands in the tub.

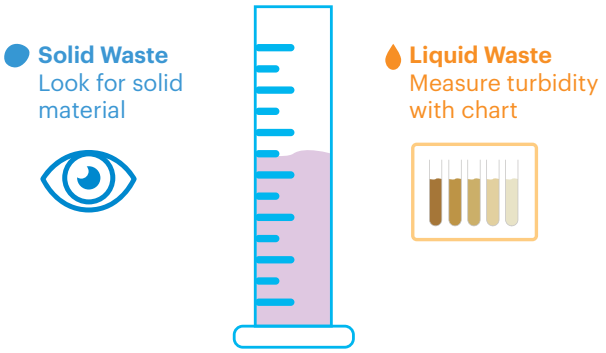
  **Review the procedures for safely testing devices with water (see Preparation)*



STEP 2

- Collect a sample of the filtered water with the graduated cylinder to check the criteria.
- **Solid Waste Teams:** Look to see if they have filtered out all of the solid materials.
- **Liquid Waste Teams:** Use the Turbidity Chart to measure the clarity of the water (The goal is to have filtered water that is 25 or lower.)

Note: Turbidity measurements will be used by all teams in Session 2.



5. Introduce the **Systems Engineer** role.
   - Define a Systems Engineer as a person who oversees the whole production of a product.
     - Systems Engineers can do "site visits" to the other side of the room and talk to the rest of their team.
     - Let them know that anyone on their team can take on the role of the Systems Engineer throughout the session.
6. Show students the System Engineer Site Visits handout.
     - Ask learners to record any notes, sketches, or other relevant information they learned on the worksheet.
     - Note that no materials can travel between teams at this time.
7. Let learners know that at the end of the build time, the whole team will have a chance to discuss their design ideas and collaborate on how they might build a combined device in the next session.

Design Challenge

Prototype Components *(30 min)*

1. Divide learners into teams of four and pass out **System Engineer Site Visits** handouts, clipboards, and pencils (two sets per team).
   - Have them begin by dividing up into pairs and determining which pair will develop a solution for solid waste and which will work on filtering liquid waste.
   - Each pair will then go to their designated building areas.
2. Once they have separated, both pairs can collect building materials from the nearby tables.
   - Remind learners that they may only gather materials from their own materials table, i.e. those for filtering solids or liquids.
   - Encourage teams to spend a few minutes exploring the materials before they begin building.
3. During the prototyping time, walk around and support teams by asking open-ended **Prototype Questions**:

Just Getting Started	• *What features does your device need to filter greywater?* • **Solids group**: *What materials would be best for filtering out small particles like dirt?* • **Liquids group:** *What materials would be best for filtering out liquid waste like oils and grease?*
Still Iterating	• *How might you adjust your design to make the greywater even less turbid?* • *Think ahead if there is time. What modifications could you make so both the solid waste and liquid waste devices work together as one device?*
Communicating Ideas	• *What information do you think the other half of the team will need to know in order to design a system that can be joined with your design in Session 2?* • *How can information be gathered and shared when you are acting as the Systems Engineer?*

4. Teams should be testing often as they build.
5. Encourage teams to send a Systems Engineer to check in with the other half of the team throughout the prototyping time.
6. When the allotted time is up, have solids teams find their liquids team partners. The entire team (solids and liquids) will work together for the rest of the lesson.

Systems Engineer Site Visit Tips

- If learners appear to be relying on "word-of-mouth" to communicate other pair's ideas back to their partner, remind them that taking notes on the handout will help them when planning the combined device.
- As they work, encourage them to think of questions that they might want to ask the other team in a site visit.
- Systems engineers may want to observe the other half of their team (solid or liquid) when they are testing.

Conference Call to Share Solutions *(10 min)*

1. Pass out one **Conference Call: Two-Part Filtration System** handout to each team. Let them know that they will now have time to brainstorm how to combine their devices into a single two-part filtration system.
2. Encourage teams to record details of their original designs for later reference, such as what building materials they used and sketches and labels of their design.
   - They can bring their prototype devices to their brainstorm if they wish, but let them know that they will need to disassemble their device after they brainstorm.
   - After one pair in the team shares, ask the other half of the team to offer positive feedback by saying one thing they liked or noticed.
3. Support team collaboration by asking questions about their devices.
   - *Which parts worked well? Which of those should be included in the two-part system?*
   - *What materials filtered waste well (solid or liquid)? What could you try instead when building your two-part system?*
4. Once they have finished brainstorming, collect their **Conference Call: Two-Part Filtration System** handout and ask them to disassemble their devices if they haven't already.

Debrief *(5 min)*

1. Lead a short debrief with the whole class. Possible **Debrief Questions** include:
   - *How challenging was it to filter the waste materials out of water?*
   - *What similarities did you notice in your designs? Across teams or even in the solutions for different types of waste?*
   - *What challenges might you face as you combine your designs in the next lesson?*

The Tech Academies

This lesson was developed in partnership with educators from **The Tech Academies Fellowship program**. The Tech Academy Fellows learn to be leaders of engineering education while designing and testing science, technology, engineering, and mathematics (STEM) resources to be shared with other educators.

Frame the Challenge

Frame the Challenge	10 min total
Communication Best Practices	5 min
Introduce New Systems Design Challenge	5 min
Design Challenge	**50 min total**
Prototyping Final Product	35 min
Sharing Final Product	10 min
Debrief	5 min

Communication Best Practices *(5 min)*

1. Begin by asking learners how it felt in the last session to design as part of a divided team.
   - Have them think of other jobs that might require people to work in this way (e.g., international teams, teams doing space travel, teams at sea etc.).
2. Let them know that it is very common in engineering for different components of a product to be designed and constructed by different teams in separate locations. This means that communication between these design teams is essential for success.
3. Ask learners about what they learned so far about collaborating while they prototyped different design solutions.
   - *What was it like to communicate with your teammates across the room?*
   - *What do you think will be challenging about combining your design ideas into a two-part filtration system?*
   - *What would you want to remember the next time you need to work with someone(s) who is in a different location from you?*

Introduce New Systems Design Challenge *(5 min)*

1. Introduce the design scenario:

> *The entire engineering team has traveled to the final manufacturing location to complete the production process together. The team needs to find a way to combine their design ideas into one two-part filtration system for testing.*

2. Introduce the new design problem, criteria, and constraints:

Design Problem	Design and build a two-part filtration system for greywater.
Criteria	• Device should filter both solid and liquid materials out of the greywater. • The combined two-part system should filter water to a turbidity of 25 or lower. • Device can filter one cup of wastewater without getting clogged or overflowing.
Constraints	• Use only the materials provided. • There's a time limit.

3. Let learners know that, since their whole team is together now, they will not have the same restrictions on communication that they did in the previous session.
   - The entire team will all work together on developing their device.
   - Everyone has access to all of the building supplies.

4. Turn learners' attention to the testing stations. In this session...
   - All teams will be testing with greywater that has a combination of solid and liquid waste.
   - Teams can test their device at any of the stations.

Design Challenge

Prototyping Final Product *(35 min)*

1. Pass back their **Conference Call: Two-Part Filtration System** handouts. Ask teams to spend a few minutes reviewing their plan from the previous session and decide as a team if they want to make any adjustments to the plan.
2. Once the whole team has agreed on their plan, they can collect their building materials.
3. During the prototyping time, walk around and support teams by asking open-ended **Prototype Questions**:
   - *What components from the last session's solid waste filtration device are being included? From the liquid waste device?*
   - *What modifications did you have to make from your original designs to build a two-part solution?*
   - *How are you making these different components work together as one solution?*
   - *Is the turbidity of the greywater higher or lower than the water filtered by the devices yesterday? If it has changed, why do you think that is?*
4. Encourage teams to test often.
5. Let teams know when there are 10 and 5 minutes left.

Sharing Final Product *(10 min)*

1. At the end of the time limit, have teams stop even if they haven't been able to complete their design.
2. Ask each team to share their design process and demonstrate their two-part filtration system. Possible Sharing Questions include:
   - *Tell us how your two-part filtration system works.*
   - *What did you adjust/change on your original devices in order to combine them?*
   - *What would you change if you had more time?*
3. Have learners give each other positive feedback on their designs. Encourage them to tell the other team one thing they liked or noticed.
4. Remind students to focus on the process and what they learned from the experience overall. Encourage them to reflect on key mindsets like perseverance and collaboration.

Debrief *(5 min)*

Lead a short debrief. Debrief topics can include the innovation design process, communicating and collaborating, and the use of greywater in the real world. Possible **Debrief Questions** include:

- *Can you think of other products or inventions that are made up of components which were designed in separate locations and then assembled? (ex: wind turbines, spacecraft)*
- *What was easier about working as a full group? More challenging?*
- *What kind of impact could using greywater have on our environment?*
- *How could we encourage our community to install greywater filtration systems in buildings and homes?*

Extensions

- **Fast Filtration:** Challenge learners to create a speedy system for filtering greywater. See if they can tweak their devices so it filters the whole container of water in under five seconds.
- **Limited Cash Flow:** Give learners a budget so they can only acquire a certain amount of building materials.

solve for EARTH

Site Visit: Solve for Earth

Come see our Solve for Earth Exhibition at The Tech Interactive and learn more about sustainable approaches to climate change. See water systems in action on our Connections Wall and test your knowledge of water in The H2O show.

Standards Connections

Next Generation Science Standards

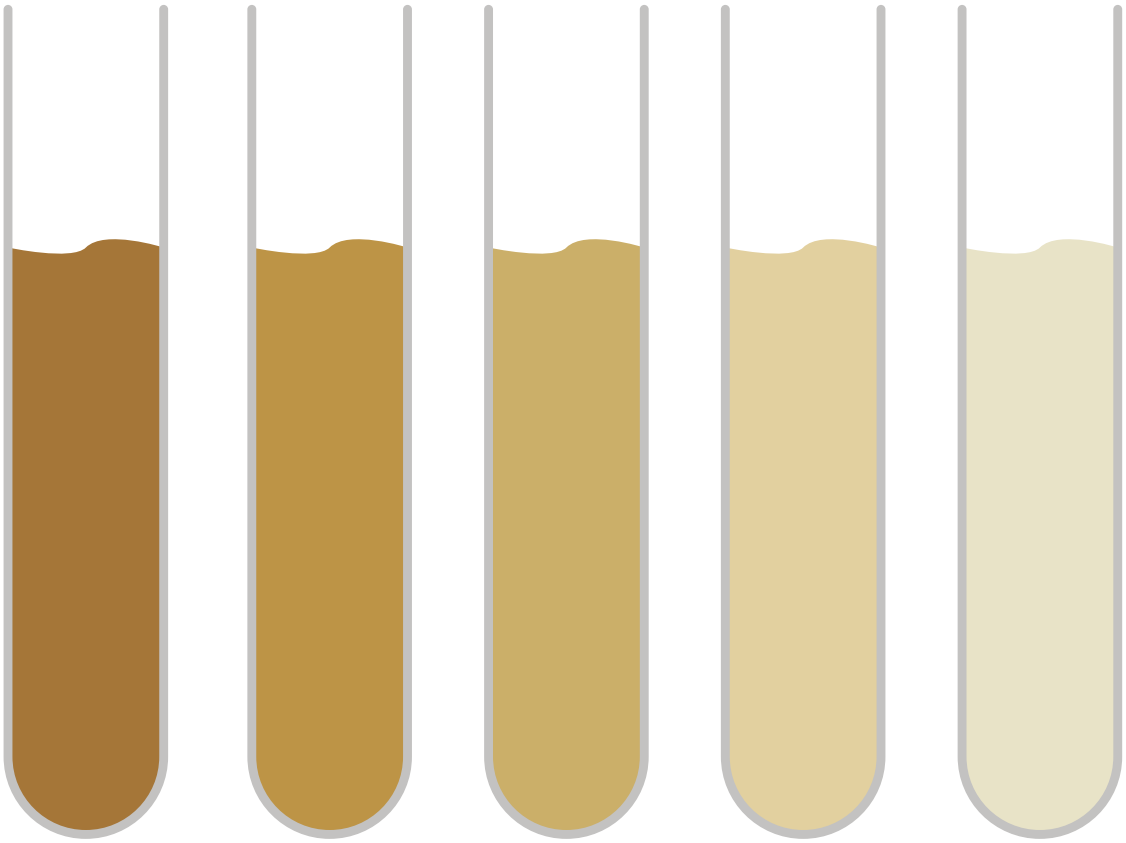
Grade	Standard	Description
HS	ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*
MS	ESS3-3.	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*
Related Standards		MS-ETS1-1 Engineering Design, HS-ETS1-2 Engineering Design
Science and Engineering Practices		Constructing Explanations and Designing Solutions
Cross Cutting Concepts		Cause and Effect

Vocabulary

- **Alternative Water Sources:** Water supplied by sustainable sources that can be used to help offset the use of fresh surface water and groundwater.
- **Drought:** A period of drier-than-normal conditions.
- **Greywater:** Water that has been used, such as leftover water generated by washing machines, bathtubs, and bathroom sinks. It does not include wastewater with harsh or harmful substances like toilet water.
- **Systems Engineering:** Engineering career that involves overseeing and implementing the manufacturing of products to make sure all the components will work together.
- **Turbidity:** The measure of relative clarity in a liquid.

Turbidity Chart

Turbidity
(measured in NTU)*



250 **100** **50** **25** **10**

*NTU: Nephelometric Turbidity Units, measure the intensity of light scattered at 90 degrees as a beam of light passes through a water sample.

Systems Engineer Site Visits

Team Names: **Date:**

Take notes and sketches on what you observe and communicate with the other half of your team. Consider everything from materials to structure and testing.

Think about:

What do you notice? What do you wonder?
What do you need to communicate or coordinate?

Conference Call Two-Part Filtration System

Team Names: **Date:**

Your team is now meeting "virtually" in order to share your progress with each other, just as many teams do in the real world. In the next session, your entire engineering team will "travel" to the final manufacturing location to combine your devices into a two-part filtration system.

Conference Call Agenda

1. Take turns sharing your designs (both solid and liquid filtration systems).
   - What materials filtered waste well (solid or liquid)?
   - What didn't work? What lessons can you learn?
2. Discuss how you could combine the two parts into one system.

Conference Call Notes

In the space below, make sure you take notes on materials and design ideas. Make sure you capture everything you will need when you build your two-part greywater filtration system.