



# Rainwater Harvesting

## Module Overview



In this TechXcite: Discover Engineering Module, youth explore rainwater harvesting systems by looking at how rainwater is collected, how roofs protect homes, and how water purification systems work. They will investigate surface tension and capillary action. Youth will use this knowledge to design a roof system that will protect a house and collect the water. Finally, they will design a water filter to purify the collected water.

This curriculum is intended for use with youth in middle grades in informal settings, such as after-school programs and summer camps. However, it has also been successfully implemented in formal school contexts, homeschool content, and with youth in elementary and high school.

**Activity 1:** Youth explore surfactants and their effect on surface tension.

**Activity 2:** Youth explore capillary action and learn where it is found in nature.

**Activity 3:** Youth design and build a roof that will protect a cardboard house from the elements and collect the rainwater.

**Activity 4:** Youth design a filter and test its effectiveness at filtering a water sample.

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## TechXcite: Discover Engineering



TechXcite is an informal engineering program partnering 4-H Youth Development/Family and Consumer Sciences at North Carolina State University, National 4-H Council and the Engineering K-PhD Program at Duke University's Pratt School of Engineering. It was initially funded by a five-year grant from the National Science Foundation.

In 2000, Drs. Ybarra and Klenk created an informal after-school engineering program at Rogers-Herr Middle School in Durham called Techtronics, which spread to additional schools across North Carolina and other states. The TechXcite: Discover Engineering curriculum builds on the Techtronics foundation by implementing hands-on, exploratory, engineering learning modules in 4-H Afterschool programs nationwide. Other after-school programs and even formal in-school and home-school programs have chosen to use the TechXcite curriculum. TechXcite is an engaging, substantive, experiential and inquiry-based curriculum centered on engineering, while using technology, applied science and mathematics learned in school. TechXcite's mission is to encourage youth in both rural and urban settings to pursue careers in engineering and technology.

TechXcite is the product of a collaboration of twelve 4-H leaders at land grant universities, two leaders at National 4-H Council and a team at Duke University.

### Online Support

The TechXcite website ([techxcite.org](http://techxcite.org)) contains additional material to facilitate implementation of this module. There are videos, Facilitator's Guides, Youth Handouts, and kit inventories with vendors and pricing for each item required. Although the curriculum is written with a focus on middle school youth, it has been successfully implemented at both the elementary and high school levels. Anyone can download copies of the Facilitator's Guide and Youth Handouts from our website. There are links to additional resources for information about the module topics and ideas for further activities and exploration.

### Training Videos

Each module comes with a set of training videos found on its curriculum page ([techxcite.org/curriculum](http://techxcite.org/curriculum)). These videos serve as a companion to the Facilitator's Guide. An introductory video provides an overview of the material and concepts. The corresponding video for each activity then covers basic setup, procedure, and helpful tips for facilitating that activity. It's recommended that instructors watch all of the videos before starting the module.

### Using this Guide



The Facilitator's Guide for each activity follows the same format. Below is what you can expect to find in each section. At the beginning, you will be given basic information about the activity. This includes:

- Time Required
- Group Size – Suggested number of students per group.
- Materials List
- Youth Handouts – These will need to be copied.
- Getting Ready – What you need to do before the activity and approximately how much time it will take you.
- Education Standards
- Learner Outcomes
- Vocabulary

#### Introduction and Activity Closure

The Introduction and Activity Closure are scripted. You may read these sections verbatim to students. Instructions that are not to be read to students, as well as answers to questions, are in brackets/italics.

#### Facilitating the Activity

This section contains step-by-step instructions for facilitating the activity. Students have their own procedure in the Youth Handouts.

#### Exploration Questions

Provides possible answers to the Exploration Questions found at the end of each activity in the Youth Handouts. After the students have a chance to answer the questions individually, instructors should hold a class discussion. The main purpose of this section is to encourage critical thinking and to promote the exchange of ideas.

#### Apply

When engaging youth in inquiry-based learning, hands-on activities serve as vehicles for learning new knowledge and skills; however, the application of new knowledge or skills to independent, real-world situations is a critical factor in the learning process. To complete the cycle of experiential learning, this section provides youth with an opportunity to apply the concepts to authentic situations.

# Activity 1: The Magic of Surface Tension



**Time Required:** 45 minutes

**Group Size:** 2

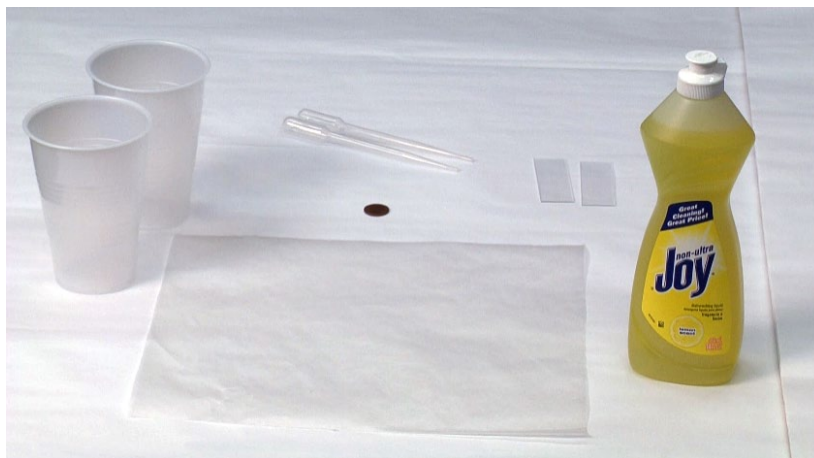
## Materials List

### Each group needs:

- Penny
- 2 Droppers
- 2 Plastic cups
- Wax paper (12" sheet)
- 2 Glass slides

### Each class needs:

- Liquid dish detergent
- Paper towels (Not included in kit)
- Water (Not included in kit)



### Youth Handouts:

- "The Magic of Surface Tension"

## Education Standards

NGSS: HS-PS1-3, HS-PS2-6

## Learner Outcomes

- Explain that surface tension is caused by the attraction between molecules of a liquid.
- Explain that detergents are surfactants that reduce the surface tension of water and therefore have a very useful role in cleaning.

## Vocabulary

Word	Definition
<b>Cohesion</b>	Attractive forces between molecules of the same substance.
<b>Molecule</b>	The smallest unit of a substance with uniform properties.
<b>Polar</b>	Having positive and negative charge at opposite ends.
<b>Surface tension</b>	A result of the attraction between liquid molecules.
<b>Surfactant</b>	A substance that reduces the surface tension of water.

## Activity 1: The Magic of Surface Tension



### Introduction

In this module, you're going to learn about rainwater harvesting. But first we're going to introduce a few of the properties of water. Later, we'll look at how these properties affect building the roof of a house, collecting rainwater, and ultimately, using the rainwater.

Today we will be exploring **surface tension**.

Surface tension is the reason that rain forms into droplets. As each **molecule** of water vapor in the atmosphere condenses into liquid, it's attracted to other nearby water molecules, creating a droplet. When the droplet gets large enough (and heavy enough), it falls to the ground as rain.

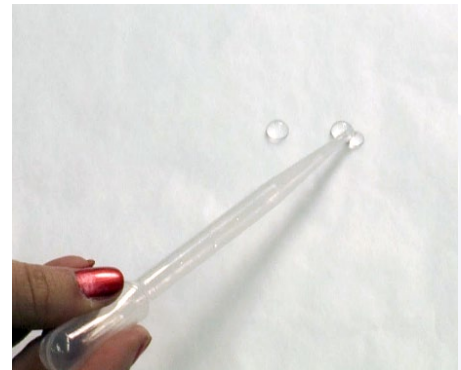
Have you ever seen a video of astronauts drinking a liquid in outer space? In space, water tends to form a large floating sphere and does not easily break into smaller pieces. This is the result of surface tension.

[Have you ever wondered what would happen if you wrung out a washcloth in space? If time allows, consider showing the following video to the class: <https://www.youtube.com/watch?v=o8TssbmY-GM>.]

### Facilitating the Activity

#### Part A: Wax Paper

1. Place students in pairs. These partners will work together throughout the project.
2. Remind students that they are not to drink the water in any of the activities.
3. Give each pair a piece of wax paper, two droppers, and a cup of water. Make sure to have paper towels on-hand to clean up as the water may go through the wax paper.
4. Tell students to drop several droplets of water on the wax paper and use the dropper to make two or more water droplets join together.



Ask, "Why have drops of water have formed on the wax paper?"

5. Instruct students to add a couple of droplets of detergent in a dry place on the wax paper. Tell them to place a couple of drops of water near the drops of detergent.
6. Now ask them to get two or more of the water droplets to join together. To do this, they may want to put a little detergent on the tip of the dropper.

It will become harder to drag the water droplets because they lose their form when the detergent touches them.

7. Tell students to discard the wax paper and wash their droppers.

## Activity 1: The Magic of Surface Tension



### Part B: Glass Slides

8. Give each pair of students two glass slides.
9. Instruct students to gently rub the slides together and notice whether they feel any resistance.
10. Then they will place three drops of water on one slide, put the other slide on top, and gently rub the slides together, noting any resistance. Have them try to pull the slides apart.
11. Finally, they will place two drops of water and one drop of detergent on one slide. After putting the other slide on top, they should gently rub the slides together again and note the resistance.

### Part C: Penny

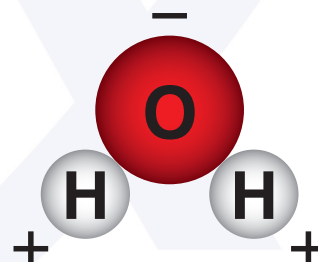
12. Hand out another plastic cup and pennies.
13. Instruct the pairs of students to half-fill each of their plastic cups with water and then add a squirt of dish detergent to one of them.
14. Challenge students to see how many individual drops of clean water they can put on top of the penny using the dropper. The penny should be lying flat on the work surface, heads up. They should place the drops one at a time, counting as they go. Note: it can be difficult to count the drops if there are too many bubbles inside the dropper.
15. Have them record their results in the Youth Handout.
16. Tell students to dry off their penny and place it back flat on their work area, heads up.
17. Now challenge students to see how many individual drops of the water-detergent mixture they can put on the top of the penny using the dropper. They should place the drops one at a time, counting as they go. Record results.



### Activity Closure

To really understand surface tension, we must first examine some basic properties of water. The chemical formula for water is  $H_2O$ . Each molecule of water is made up of two hydrogen (H) atoms and one oxygen (O) atom. [Draw the illustration below on the board.]

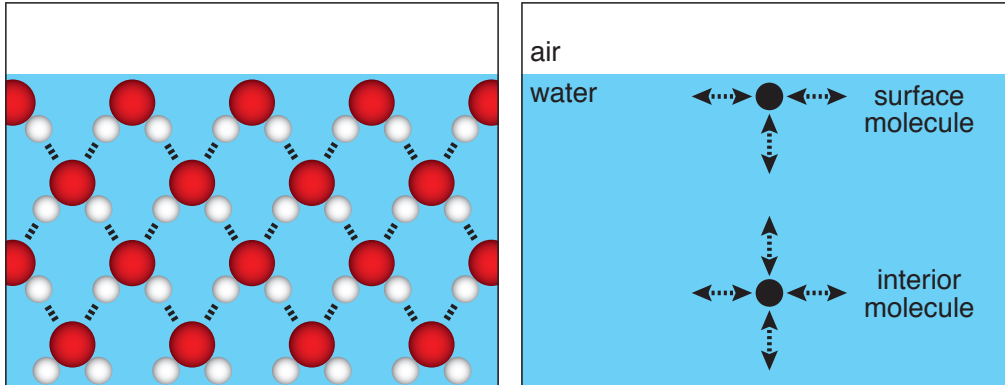
If you examine the water molecule illustration, you'll notice that (1) the atoms are not lined up perfectly straight, (2) the oxygen atom has a negative charge, and (3) the hydrogen atoms have a positive charge. Because of these important characteristics, water is a **polar** molecule, which simply means that the molecule has a negative end and a positive end—similar to a magnet. And just like the way opposites attract with magnets, this polarity causes the individual water molecules to “stick” to each other in a phenomenon called **cohesion**.



Inside a given sample of water, a water molecule experiences cohesive forces with other the molecules equally and in all directions. Surface molecules, however, only experience cohesive forces from the interior of the liquid and the sides. This imbalance creates tension along the surface as the water molecules attempt to pull inwards in an effort to balance the forces.



## Activity 1: The Magic of Surface Tension



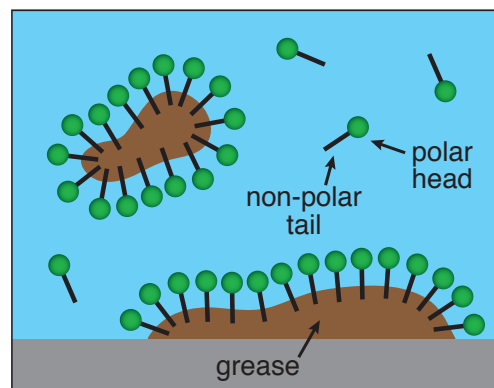
In the last part of the activity, surface tension is what held the water molecules together on top of the penny. Eventually the surface tension broke—causing the water to spill over the sides—when the gravitational force (or weight) of the water became stronger than the cohesive forces holding the molecules together.

Another example of surface tension you may be familiar with is the way certain aquatic insects appear to walk or skate on the surface of the water. This is possible as long as the cohesive forces between the water molecules at the surface are stronger than the forces created by the weight of the bug.

The surface tension of water can also be changed. Substances that reduce the surface tension of water, such as cleaning solutions and detergents, are known as **surfactants** (surface-active agents).



Soap molecules are composed of long chains of hydrogen and carbon atoms. One end of the chain, called the head, is polar and the other end, called the tail, is non-polar. Oil and grease are also non-polar. This means that when soap is combined with dirty water, the polar ends of the soap bond with the water molecules and the non-polar ends bond with the oil and grease. This allows the particle of oil or grease to be pried loose and carried away by the water.



## Activity 1: The Magic of Surface Tension



### Exploration Questions

1. What are some everyday examples of surface tension?

*[Possible answers: overflowing a cup with water, objects able to float even though they have a density higher than water, liquid droplets “beading up” on nonstick pans, waxed cars, wooden decks stained with water sealant, etc.]*

2. When soap is added, does it increase or decrease the resistance between the glass slides? Why?

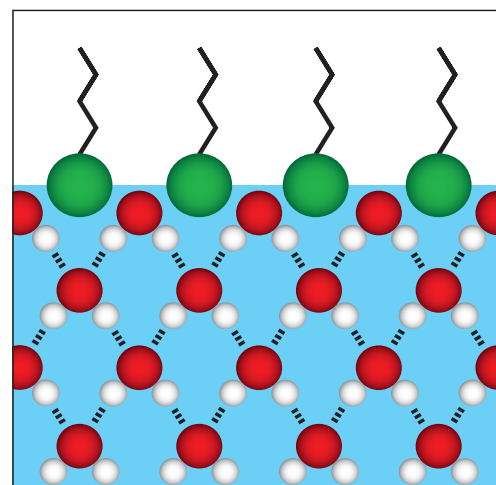
*[When the soap is added, the two slides will move back and forth more easily. This is because the soap gets in between the water molecules and stops them from sticking to each other.]*

### Apply

Now that you understand surface tension and surfactants work, can you guess how the surfactant (soap) reduces surface tension?

*[To understand how soap reduces surface tension you must recall that (1) water molecules at the surface are lacking bonds, (2) this lack of bonds is what creates surface tension, (3) the nonpolar tails of the soap molecules are repelled by water, and (4) the polar heads of soap molecules are attracted to water.]*

*When soap is added to water, the soap tends to gather at the surface because the non-polar tails of soap molecules do not want to be in the water at all and the polar heads of soap molecules want to bond with the surface water molecules. Once the surface water molecules bond with the soap, the forces become more balanced and tension is reduced.*



*Note: The full answer is very complicated and it is unlikely that students will be able to guess it on their own. It is acceptable for students to just say that the surfactant molecules stick to the water molecules at the surface, thereby pushing out other water molecules and weakening the cohesive forces.]*

### References

“The Chemistry of Biology: Water.” Infoplease. <<http://www.infoplease.com/cig/biology/water.html>>.

“Surface Tension and Water.” USGS. <<http://water.usgs.gov/edu/surface-tension.html>>.

“Surface Tension.” HyperPhysics. <<http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html>>.

Hipschman, Ron. “Soap.” Exploratorium. <<http://www.exploratorium.edu/ronh/bubbles/soap.html>>.

“Surface Tension and Soap Bubbles.” California State University Stanislaus: Department of Chemistry. <<http://wwwchem.csustan.edu/chem2000/Exp5/BKG.HTM>>.

Water strider photo by TimVickers [Public domain], via Wikimedia Commons

## Activity 2: Water on the Rise



**Time Required:** 45 minutes

**Group Size:** 2

### Materials List

**Each group needs:**

- Coffee stirrer
- Drinking straw
- Glass capillary tube
- Ruler
- Shallow plastic disposable plate
- Plastic cup
- 6 Sugar cubes
- Paper towels (Not included in kit)

**Each class needs:**

- Food coloring
- Water (Not included in kit)

**Youth Handouts:**

- “Water on the Rise”

### Education Standards

NGSS: HS-PS1-3

### Learner Outcomes

- Explain that capillary action is the result of adhesion.
- Identify a few examples of how capillary action is used at home and in nature.

### Vocabulary

Word	Definition
<b>Adhesion</b>	Attractive forces between dissimilar molecules.
<b>Capillary action</b>	The movement of a liquid along the surface of a solid, in opposition to gravity, as the result of adhesion and surface tension.
<b>Meniscus</b>	The curve at the surface of a liquid caused by adhesion to the walls of its container.
<b>Porous</b>	Full of pores or holes.

## Activity 2: Water on the Rise



### Introduction

Even though we usually think of water as only running downhill, it can also flow up—against gravity—through a process called **capillary action**. You can actually observe the effects of capillary action in your home and in nature. Paper towels, for example, rely on capillary action to “wick” or soak up liquids. In trees and other plants, capillary action enables water and nutrients in the roots to travel up the trunk or stem to reach the leaves.

So how does it work? Well first we’re going to do a few experiments and make a few observations.

### Facilitating the Activity

#### Part A: Paper Towel

1. Put students back with their partners from Activity 1.
2. Distribute plastic cups, coffee stirrers, food coloring, and paper towels.
3. Remind students that they are not to drink the water in any of the activities.
4. Have students half-fill their plastic cups with water, add a few drops of food coloring, and mix with the coffee stirrer.
5. Instruct students to fold the paper towel lengthwise several times and touch the tip of it to the water. What happens?



#### Part B: Sugar Cubes

6. Hand out sugar cubes and plates. Remind students not to eat any sugar cubes.
7. Instruct students to build a pyramid of sugar cubes on the plate (see photo below). The sugar cubes must be touching one another.
8. Ask, “What do you think would happen if you poured water onto the plate around the sugar cubes?”
9. Tell them to pour some of the colored water around the base of the tower and observe what happens.

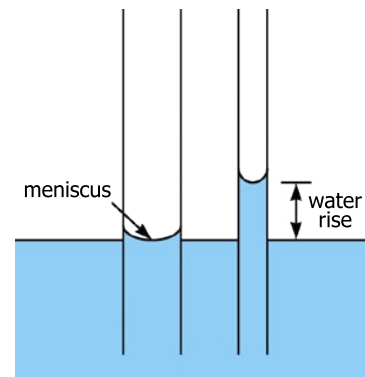


## Activity 2: Water on the Rise



### Part C: Straws

- Collect the plates and distribute a drinking straw, glass capillary tube, ruler, and marker. Students will keep the cups of colored water.
- Have students dip their drinking straw into the water and hold it in place for a few seconds. They should minimize any stirring motion.
- Make sure they notice the water level on the outside of the straw and the inside of the straw. Students will then remove the straw from the water and use a marker or pen to mark the inner and outer water levels.
- Repeat this with the glass capillary tube.
- Finally, they will use a ruler to determine the water rise (difference between inner and outer water levels) in each tube and record.



### Activity Closure

Whereas cohesion is the attractive force between *like* molecules, **adhesion** is the attractive force between *unlike* molecules. If you've ever looked closely at the surface of water in a glass, you may have noticed the edges of the water seem to creep up the sides of the container forming a slight upward curve, called a **meniscus**. This happens because the adhesive forces between the glass and water are slightly stronger than the cohesive forces, or surface tension, of the water molecules.

A similar phenomenon, called capillary action, results when a liquid moves up a narrow tube (or passageway in a porous material) against the force of gravity. Capillary action is the product of both adhesion and surface tension. Adhesion of the water to the walls of the container causes an upward force at the edges and surface tension holds the surface the water together. If the container is narrow enough, the water will continue to rise until the adhesive and cohesive forces are balanced.

### Exploration Questions

- Does the water rise higher in a tube with a smaller diameter or a larger diameter? Why?

*[Smaller diameter. The height that water can rise in a given tube is limited by the weight of the water. As discussed before, adhesion between the water and the sides of the container provide an upward force at the edges and cohesion holds all of the water molecules together. When the adhesive forces are stronger than the cohesive forces, the water level in the tube rises. It stops rising when those forces are equal, aka when the weight of the water in the tube becomes too much for adhesive forces to overcome.]*

*Therefore, the water in a smaller diameter tube can rise higher because the water inside the smaller tube weighs less. For the actual calculation: <http://hyperphysics.phy-astr.gsu.edu/hbase/surten2.html#c6> ]*

- Would adding a surfactant, such as detergent, increase or decrease the amount of water rise in a given tube? Why?

*[Decrease. Surfactants reduce surface tension. Therefore, it would take a smaller volume of water in the tube for the cohesive and adhesive forces to balance.]*

## Activity 2: Water on the Rise



### Apply

Using your knowledge of capillary action, what factors might you consider when designing a shingled roof?

*[First of all, the shingles must be made of a non-porous material, such that it doesn't "suck up" and hold on to water like the paper towel.*

*Second, shingles are overlapped so that there are no gaps when water flows down the roof. They must overlap far enough that water cannot creep up in between the shingles (specifically they must overlap by an amount greater than the height of the water rise due to capillary action). Also, if shingles overlapped the wrong way, water would flow into the gap in between them.*

*This is important when constructing a roof. The roof on your house will last a long time if built correctly. Generally, asphalt and gravel shingles can last up to 30 years, but copper roofs can actually last closer to 100 years!]*

## Activity 3: Rainwater Collection System



**Time Required:** 60 minutes

**Group Size:** 2

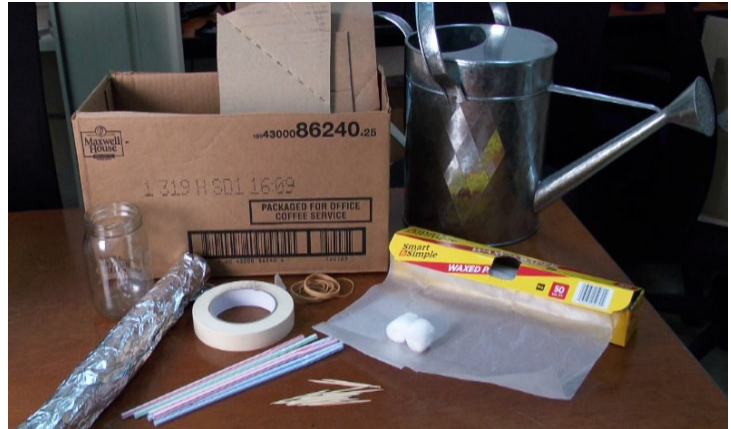
### Materials List

#### Each group needs:

- Aluminum foil
- Corrugated cardboard box
- Scrap cardboard
- Craft sticks
- Foam craft sheet

#### Each class needs:

- Tape
- Water (Not included in kit)
- Measuring cup
- Watering can with sprinkler head
- Glue gun & glue sticks (Optional)
- Additional scrap material, if available (Not included in kit)



#### Youth Handouts:

- “Rainwater Collection System”

### Getting Ready (10 mins)

- Ask each student to bring a cardboard box from home that is about 1-2 ft on each side. Gather some extra boxes in case any students forget.
- Select a place outside where students can test their rainwater collection systems. You will be pouring water on the roofs to see how their construction holds up. A location with a gradual slope can be helpful. If there is a slope, make sure to test from the uphill side of the box house. Be sure there's a convenient source of water for the watering can.

### Education Standards

NGSS: MS-ESS3-3, MS-ETS1-3, MS-LS2-5

### Learner Outcomes

- Explain how rainwater harvesting systems work.
- Explain that water is a scarce resource in many parts of the world.
- Use the engineering design process to design a roof and gutter system.

## Activity 3: Rainwater Collection System



### Vocabulary

Word	Definition
<b>Aquifer</b>	Large, natural underground source of water.
<b>Desalination</b>	The process for removing salt.
<b>Rainwater harvesting</b>	The process of collecting and storing rainwater for later use.

### Introduction

Where does the water in your faucet come from? *[Give students a few minutes to brainstorm water sources.]*

It depends on where you live, but generally the water you use at home comes from rivers, lakes, or **aquifers**. Many towns get their water from man-made lakes. Although the ocean may seem like an obvious source, seawater has a very high salt content and **desalination**—the process to remove the salt—uses a lot of energy. Because desalination is so expensive, it's only done if other freshwater sources are not available.

Another possible, frequently overlooked, freshwater source is precipitation.

**Rainwater harvesting** is the process of collecting and storing rainwater for later use. Although promoted as an innovative new technology, the basic concept of water harvesting has been around for centuries and is still commonly used in places where water is scarce.

In this activity, you're going to design a system to collect the rainwater that lands on a house.

### Facilitating the Activity

1. Put students back with their partners from the previous activities.
2. Distribute handouts and go over them with the class.
  - a. Introduce the design challenge and review the constraints.
  - b. Describe the materials they are allowed to use and show students where to find them. They may use any of the scrap cardboard, wax paper, and aluminum foil available. You may have other materials you would like to offer, such as disposable utensils, straws, or tape.
  - c. Tell them that they will be testing their roofs under a sprinkle from a watering can.
  - d. Give them a time limit. This project can be done in as little as 30 minutes, but students will produce better, more creative projects if you can give them 45 minutes.
  - e. Remind them not to drink any of the water.
3. Set up a demonstration area outside.
4. Begin by pouring water onto an example cardboard model house without a roof. The cardboard will be soaked, as you would expect. This demonstrates the need for roofing materials that are waterproof, shows students how you are going to be pouring the "rain" onto their roofs, and should help them understand how to tailor their design.



## Activity 3: Rainwater Collection System



5. Now, let the students design their rainwater collection system. Some examples of possible designs are shown to the right.
6. To test the roofs, use measuring cups to specify the exact amount of water to be put in the watering can and poured on the houses. After adding the water to the watering can, hold it over the roof, and pour until it's empty. It's okay if some of the water lands next to the house, but most should hit the roof. Do not pour directly into the collector.
7. If it rains the day you want to test the houses, put the houses out in the rain for a few minutes. The collectors will catch some rain on their own but the amount landing on the houses and in the collectors should be roughly the same.
8. Measure and record the amount of water in each collection system.



### Activity Closure

Rainwater harvesting systems consist of three basic components: (1) a collector, (2) a delivery system, and (3) a storage tank. The collector, or catchment, is usually just a large surface, such as the roof of a house. Most roofing materials are acceptable for collecting water, but ideally the roof should be kept clean and should not include any potentially harmful substances, such as asphalt, if the water is ever intended for drinking.

Once you catch the water, you need to be able to transport it to a storage tank for filtration and later use. As you may have discovered in this activity, gutters along the bottom edge of the roof are very effective. A well designed, carefully constructed, and properly maintained gutter system is critical as guttering is often the weakest link in the rainwater harvesting system. It doesn't matter how large your roof is, if your gutter system cannot catch and handle the water flow, the entire system will be compromised.

The last major component of the rainwater harvesting system is a storage container where the water is held until needed. These can range anywhere from a small bucket to 100-cubic-meter tanks in large, community systems.

Other common additions to rainwater harvesting systems are pumps, to deliver the water where it's needed, and filtration/purification systems, to make the water safe for human consumption. Water treatment will be explored the next activity.

## Activity 3: Rainwater Collection System



### Exploration Questions

1. Which of your ideas worked well and which ones didn't? How might you improve your design next time?

*[Allow a few groups to explain their design choices and possible improvements.]*

2. Why might someone install a rainwater collection system?

*[Possible answers:*

- *Conservation*
- *Living in an exceptionally dry region (droughts common)*
- *Living in a country with water restrictions*
- *Reduce extracted water to support native ecosystems*
- *Save on cost*
- *Ideal for washing (low in minerals)*
- *Better for plants (hasn't been treated with chemicals)*
- *Prevent flooding or washout]*

3. Outside of your home, what are some important uses of fresh water?

*[Irrigation and power generation are the two biggest. Also farming, manufacturing, firefighting, etc.]*

### Apply

Pretend you're a real engineer, with the ability to use or create anything you wanted, and design a rainwater harvesting system. Sketch and label your design. Be creative.

*[Allow students at least 10 minutes to brainstorm and design. Encourage them to be creative. They could include a solar powered water pump, feed water through a filter then into faucets, add an unfiltered tank for flushing toilets and washing clothes, etc.]*

### References

"Water Questions and Answers." USGS. <[ga.water.usgs.gov/edu/qausage.html](http://ga.water.usgs.gov/edu/qausage.html)>.

"Human Appropriation of the World's Fresh Water Supply." University of Michigan. <[www.globalchange.umich.edu/globalchange2/current/lectures/freshwater\\_supply/freshwater.html](http://www.globalchange.umich.edu/globalchange2/current/lectures/freshwater_supply/freshwater.html)>.

Worm, Janette. "Rainwater Harvesting for Domestic Use." Agromisa Foundation.

"Rainwater Harvesting Information." San Diego Public Utilities. <<http://www.sandiego.gov/water/conservation/rainwater.shtml>>.

## Activity 4: Building a Water Filter



**Time Required:** 45 minutes

**Group Size:** 2

### Materials List

#### Each group needs:

- Scissors
- 2 Clear plastic cups
- Measuring cup
- 20-Ounce soda bottle (Not included in kit)
- Wax paper or newspaper

#### Each class needs:

- Soil
- Gravel
- Sand
- Limestone rocks
- 2-Liter soda bottle (Not included in kit)



#### Youth Handouts:

- "Building a Water Filter"

### Getting Ready (10 mins)

- Ask students to bring in empty 20-ounce soda bottles.
- Obtain an empty 2-liter soda bottle.

### Education Standards

NGSS: MS-ETS1-3, MS-LS2-5

### Learner Outcomes

- Design and build a water filter.
- Explain how groundwater filtration works.

## Activity 4: Building a Water Filter



### Vocabulary

Word	Definition
<b>Filtration</b>	The mechanical separation of a liquid from the undissolved particles floating in it.
<b>Granularity</b>	The relative size of the particles that make up a substance (coarse = large, fine = small).
<b>Groundwater</b>	Water beneath the surface of the earth, found in the spaces between soil, sand, and rock. Water source for wells and springs.
<b>Potable</b>	Safe to drink.
<b>Purification</b>	The process of removing undesirable chemicals and biological contaminants from contaminated water.

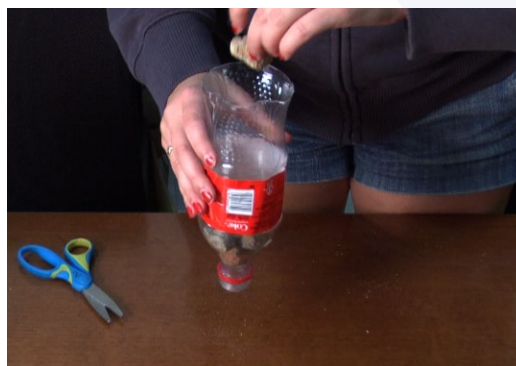
### Introduction

Regardless of how water is acquired, it must first go through the proper **filtration** and **purification** processes to be considered **potable**, or safe to drink. Even rainwater—although it may seem clean—is not fit for drinking without being treated, as it contains pollutants absorbed from the atmosphere and other particulates and bacteria acquired from the surfaces it touches.

In this activity, you will create a filter that can be used to remove particles from a dirty water sample. Your goal is use the materials provided to make the water passing through the filter as clean as possible in the shortest amount of time.

### Facilitating the Activity

1. Put students back with their partners from the previous activities and distribute the handouts.
2. Give each group a cup of soil, sand, rocks, and any other materials you’ve collected to make the filter. Let students know that if they decide they need more of a particular material, they can just ask.
3. Tell students to cut 2 to 3 inches off the bottom of their bottle with the scissors. They can discard this piece along with the bottle cap. The bottle opening will be the filter drain.
4. Place a few larger pieces of gravel at the bottom to hold the components of the filter in the bottle.

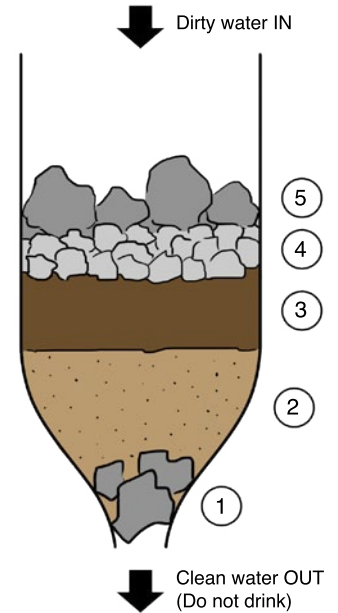


## Activity 4: Building a Water Filter



Note: Make sure students hold the bottle over a piece of wax paper or newspaper to catch any excess materials that fall through.

5. Have students fill the bottle chamber with materials that will filter the water. Let students design their own unique filter by choosing which materials to use and how to arrange them in their bottle. Each group should record in their handouts which materials are added, their quantities, and the order in which they are added to the bottle (see example on the right).
6. As a class, have students fill a single 2-liter bottle with dirt and water and shake the bottle well. Each pair of students should then fill a plastic cup with dirty water. Everyone's cup should be filled to the same level.
7. Instruct teams to pour the dirty water into their filter and collect the water from the filter in their other plastic cup.
8. Let students compare their clean water samples and discuss the materials and quantities they used to make their filter. They should note the approximate amount of time that it took for the dirty water to pass through their filter.



### Activity Closure

The degree to which water needs to be treated depends largely upon its end use, and the complexity of filtration and purification systems ranges from simple debris screens to expensive chemical processes. Fortunately, you don't always need expensive materials and equipment to filter water.

**Groundwater** is naturally filtered by the rocks and sediment it passes through. This filtration is so effective that water from wells is usually clean enough to be consumed without additional treatment. In cities and municipalities, water treatment plants use large filters in combination with chemical and UV (ultraviolet light) treatment to remove bacteria and make water safe for drinking and using.

## Activity 4: Building a Water Filter



### Exploration Questions

1. In the United States, harvested rainwater is generally not used for drinking, so the water does not need to be as clean. What are some non-drinking uses of water in the home?

*[Possible answers: washing clothes, showering, flushing toilets, watering plants]*

2. What determines how fast the water will pass through a filter?

*[The filtration time depends on the size of the contaminant particles and the size, or **granularity**, of the filter materials. Fine-grain materials will filter out smaller contaminants, but it will take longer and the filter may be clogged by the larger contaminants. This reduces the capacity of the filter and slows filtration.]*

3. How should you configure your filter to make it as efficient as possible at removing contaminants?

*[The coarse-grain materials should be at the top of the filter and the fine-grain materials should be at the bottom, near the drain. This configuration ensures that the large contaminants are removed from the water first, and then smaller and smaller contaminants are removed as the water moves through the filter and out of the drain. If the configuration were reversed (with fine-grain on the top and coarse-grain on the bottom), the fine-grain would catch all of the particles at the top and clog the filter very quickly.]*

4. How might you improve your design?

*[Allow a couple students to share their ideas with the class.]*

### Apply

Design a water filtration system for a city that removes particle, chemical, and biological contaminants. Draw and label each step in the process.

*[There is no right or wrong answer, but generally, public water treatment requires four basic steps. In the first step, coagulants like lime and alum are added to the water, which cause the particles in the water to bind together and form larger particles. Next, these large particles are allowed to sink and settle to the bottom of the water supply in a process called sedimentation. Third, the clear water left on top will pass through filters of varying compositions, such as sand, gravel, and charcoal. Finally, after the water has been filtered, a disinfectant like iodine or chlorine is added to kill any remaining bacteria, parasites, and viruses.]*

*This is certainly not the only way to do it though. For example, other possible methods to kill bacteria include exposure to UV light and boiling.]*

## Activity 4: Building a Water Filter



### Optional Extension

Regardless of how clean it may look, you should never drink water directly from streams, lakes, or other natural sources without treating it first.

If you ever find yourself in a survival situation or if your household water supply becomes contaminated (and you don't have bottled water on hand), there are a few simple ways to purify water. First, if the water contains particulates, you can filter it through a clean cloth or allow the particles to settle and pour off the clear water. You should then boil it for at least 3-5 minutes to kill any bacteria.

Out in the wilderness, one way of obtaining clean water is the "well" method. This involves digging a hole a few feet away from a water source and allowing it to fill with naturally filtered groundwater. If no obvious water sources exist, the solar still method, which involves collecting water vapor on a sheet of plastic, is also a possibility. To read more about this method and find out how to build a solar still visit: <http://www.practicalsurvivor.com/solarstill>.

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## Glossary

**Aquifer**

Large, natural underground source of water.

**Adhesion**

Attractive forces between dissimilar molecules.

**Capillary action**

The movement of a liquid along the surface of a solid, in opposition to gravity, as the result of adhesion and surface tension.

**Cohesion**

Attractive forces between molecules of the same substance.

**Desalination**

The process for removing salt.

**Filtration**

The mechanical separation of a liquid from the undissolved particles floating in it.

**Granularity**

The relative size of the particles that make up a substance (coarse = large, fine = small).

**Groundwater**

Water beneath the surface of the earth, found in the spaces between soil, sand, and rock. Water source for wells and springs.

**Meniscus**

The curve at the surface of a liquid caused by adhesion to the walls of its container.

**Molecule**

The smallest unit of a substance with uniform properties.

**Polar**

Having positive and negative charge at opposite ends.

**Porous**

Full of pores or holes.

**Potable**

Safe to drink.

**Purification**

The process of removing undesirable chemicals and biological contaminants from contaminated water.

**Rainwater harvesting**

The process of collecting and storing rainwater for later use.

**Surface tension**

A result of the attraction between liquid molecules.

**Surfactant**

A substance that reduces the surface tension of water.



## Education Standards



### Activity 1: The Magic of Surface Tension

NGSS: HS-PS1-3 - Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

NGSS: HS-PS2-6 - Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

### Activity 2: Water on the Rise

NGSS: HS-PS1-3 - Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

### Activity 3: Rainwater Collection System

NGSS: MS-ESS3-3 - Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

NGSS: MS-ETS1-3 - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

NGSS: MS-LS2-5 - Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

### Activity 4: Building a Water Filter

NGSS: MS-ETS1-3 - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

NGSS: MS-LS2-5 - Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

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