SUSTAINABLE DEVELOPMENT GOALS

american geosciences institute
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Education for Sustainable Development Kit: Access to Clean Water

Sustainable Development Goal 6: Clean Water and Sanitation

6 CLEAN WATER AND SANITATION

Learner Guide

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Learner Guide

For information contact:

American Geosciences Insitute

Publications/Marketing

4220 King St.

Alexandria, VA 22303

pubs@americangeosciences.org

Generous support for the development of this kit was provided by the SLB Excellence in Education Development (SEED) program

American Geosciences Institute Project Team:

Lauren Brase, Education Specialist

Mark Carpenter, Senior Education Specialist

Sequoyah McGee, Outreach Coordinator

Lindsay Mossa, Education Specialist

Edward Robeck, Director of Education and Outreach

Brenna Tobler, Graphic Designer

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ESD KIT: ACCESS TO CLEAN WATER

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INVESTIGATION 1: WATER AROUND US

Learning Outcome: Model the amount of water from different sources to visualize how little freshwater there is on Earth.

Materials

Per group:

- 8 large clear cups or bottles, at least 500 mL (16 oz)
- masking tape
- marker
- 500 mL water (2 cups)
- dropper
- graduated cylinder

What to Do

1. Consider water on Earth.
   - **a.** What types of water are found on Earth?
   - **b.** Where on Earth is water found?
   - **c.** Where can you get water to drink?
2. Visualize water on Earth.
   - **a.** Using the tape and marker, label each empty cup with a different water source you came up with in 1b.
   - **b.** Label one cup "World's Water." Fill it with 500 mL of water. Imagine all the water in the world could be found in this cup.

c. How much do you think comes from each of the sources you thought of earlier? Make predictions by pouring the "World's Water" into the labeled cups. When you are done, the "World's Water" cup should be empty.

d. Measure your predictions using a graduated cylinder. Write down your predictions.

e. Calculate what percentages you predicted for each water source:

$$\% = \frac{volume\ for\ a\ specific\ water\ source\ (mL)}{500\ mL} * 100$$

3. Consider water in your community.

   a. How is water used in your community?

   b. From where does your community get drinking water? How does your community get water to become drinkable?

   c. How accessible is clean water for different people in your community or region?

4. Sustainable Development Goal (SDG) 6 is all about access to clean water and sanitation.

   a. What do you think about when you hear "clean water"?

   b. What about when you hear "sanitation"?

   c. Why do you think access to clean water and sanitation are important for people around the world?

Consider

1. How did your predictions compare to the actual amounts from each water source? Why might your prediction have been off?
2. What do you notice about the distribution of the world's water among the different sources? Did anything surprise you?
3. Which of the water sources is considered freshwater? How much of the world's water is freshwater and how much is salt water?
4. What are some common uses of fresh water?
5. What are some ways you know of or ways you think saltwater could be used?
6. How might the distribution between freshwater and saltwater change as the Earth's temperature increases?

Extensions

1. **Analyzing Data:** Create 2 pie charts showing where water is located on Earth. For the first pie chart, calculate and display the percentages of fresh vs. saltwater. For the second pie chart, calculate and display the distribution of freshwater. Data about the distribution of the world's water can be found in The Encyclopedia of Climate and Weather: **https://snr.unl.edu/data/water/groundwater/realtime/waterdistribution.aspx**
2. **Applying Concepts:** On a map of your community, identify all the locations where fresh and saltwater can be found. Also, research and then label where the water for your house or community comes from (your water source).

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INVESTIGATION 2: WATER MOVEMENT THROUGH THE ENVIRONMENT

Learning Outcome: Perform a simulation to analyze how water moves through the water cycle.

Materials

Per learner:
- 6-sided die
- unlabeled "Water Cycle Diagram" handout

Per group:
- station instruction sheet

What to Do

1. Act as a water molecule travelling through the water cycle. Mark the path you travel on your copy of the "Water Cycle Diagram." This diagram is a starting place but is incomplete.

   a. Identify the location of each station on the diagram. Draw in any locations that are missing. Label each station on your diagram using the names of Earth's spheres.

      1: Soil/Ground

      2: Ocean

      3: River or Lake

      4: Atmosphere

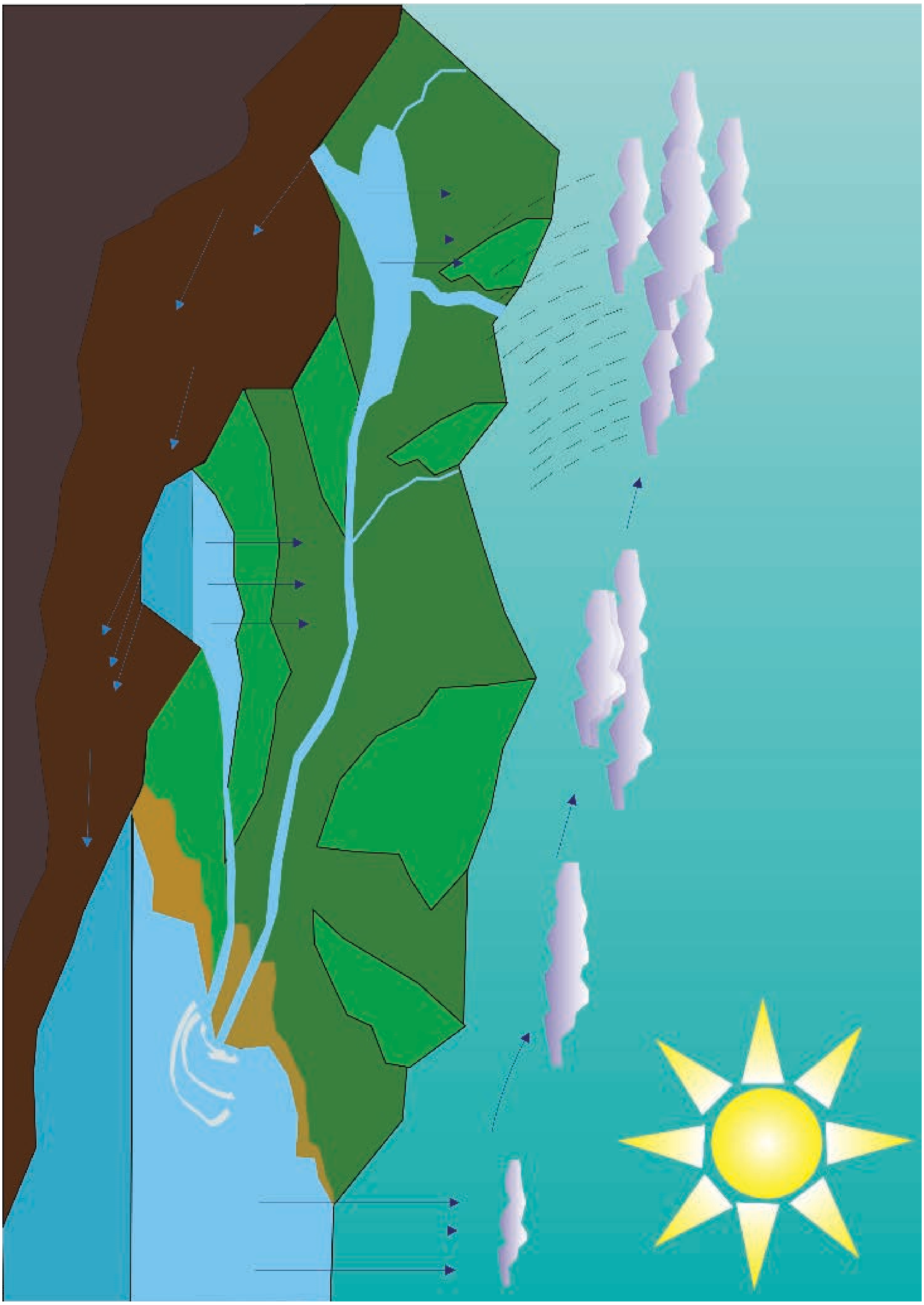
      5: Glacier

      6: Plant or Animal

- **b.** Roll a die to determine your initial location in the water cycle, as indicated by the list in step 1a. On the water cycle diagram, draw an “X” on your starting position.
- **c.** Move to the station you rolled and mark an X on the diagram.
- **d.** Roll again and use the instructions at the station to determine your next location.
- **e.** Draw an X on each location you travel to, even if your roll has you remain at the same location.
- **f.** Draw an arrow connecting each of your movements that take you to a new location.

2. Continue rolling until you have visited all 5 spheres or until instructed to stop.

WATER CYCLE DIAGRAM



Credit: Creative Commons, https://commons.wikimedia.org/wiki/File:Water_cycle_blank.svg

Consider

1. Plants take in water through their roots and release water from their leaves in a process called transpiration. How did your predictions of the demonstration match what happened with each plant's mass? Relate what happened with each plant to the process or rate of transpiration.

   a. What evidence do you have that transpiration occurred?

   b. Describe the flow of water during the process of transpiration using the names of Earth's spheres.

   c. Compare and contrast the results from the four plants. Do you think all the water within the soil goes into the plants? What evidence do you have to support your answer?

2. At which station was there the greatest chance of staying in the same place? Why do you think some stations in the water cycle had more chances to stay in the same location than others?

3. Compare your water cycle to other learners'. How are they similar? How are they different? How do you think this model mimics actual water molecules travelling through the water cycle? How could the model be changed to more closely model the water cycle in the real world?

4. In what location or sphere do you think water is usable for consumption by humans? Why do you think this?

Extensions

1. **Applying Concepts:** The water cycle involves all of Earth's spheres: atmosphere, cryosphere, geosphere, hydrosphere, and biosphere. Recall that the biosphere is living organisms. On your water cycle diagram, label the spheres and include examples of organisms that live in each sphere. Also, include information on how different living organisms contribute to the water cycle.

2. Using *Scratch*®: Create a *Scratch*® game or animation about the water cycle. Here are some projects that you can get ideas from or remix:

   a. For a simple animation of the water cycle: **https://scratch.mit.edu/projects/735011384/**

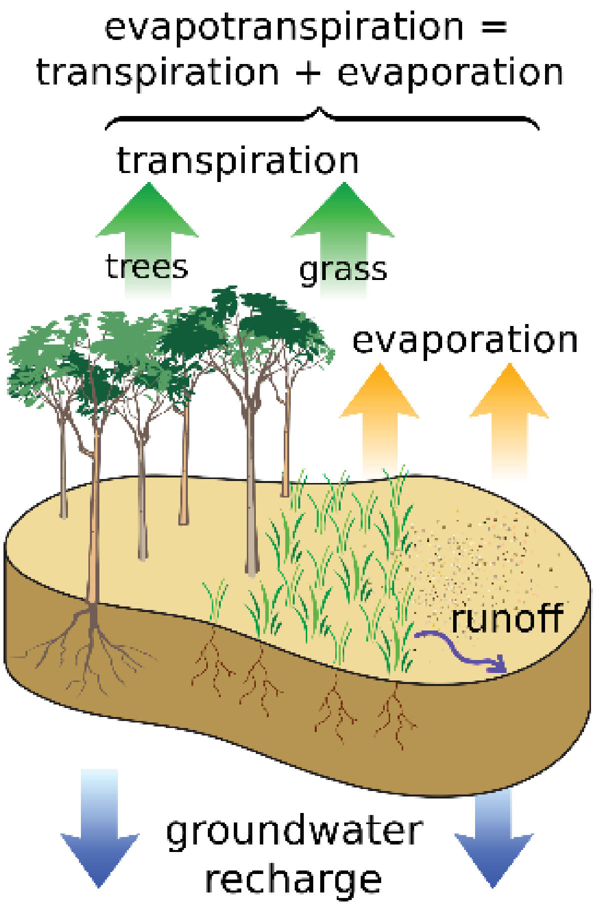
   b. For a more interactive version of the water cycle animation: **https://scratch.mit.edu/projects/735012331/**

   c. For an interactive animation of the water cycle: **https://scratch.mit.edu/projects/735012502/**

   d. To find other *Scratch*® projects on the water cycle: **https://scratch.mit.edu/search/projects?q=water%20cycle**

STATION 1: Soil/Ground Water

If you roll a:	Move by:	Go To
1	Remain groundwater.	Stay at 1
2	Evaporation into the air.	Station 4
3	Diffusion into a plant.	Station 6
4	Runoff into a lake or river.	Station 3
5	Remaining in the soil.	Stay at 1
6	Remaining in the soil.	Stay at 1



Credit: M. W. Toews, Creative Commons, https://commons.wikimedia.org/wiki/File:Surface_water_cycle.svg

STATION 2: Ocean

If you roll a:	Move by:	Go To
1	Diffusion into a plant or consumption by an animal.	Station 6
2	Evaporation into the air.	Station 4
3	Continue circulating in the ocean.	Stay at 2
4	Continue circulating in the ocean.	Stay at 2
5	Continue circulating in the ocean.	Stay at 2
6	Continue circulating in the ocean.	Stay at 2

Credit: M.Milani, https://pixabay.com/photos/ocean-waves-sea-water-blue-nature-4626520/

STATION 3: River or Lake

If you roll a:	Move by:	Go To
1	Entering the soil near the lake or river.	Station 1
2	Evaporation into the air.	Station 4
3	Flowing into the ocean.	Station 2
4	Diffusion into a plant or consumption by an animal.	Station 6
5	Continue flowing through a lake or river.	Stay at 3
6	Continue flowing through a lake or river.	Stay at 3

Credit: Public Domain, https://www.flickr.com/photos/lakeclarknps/25256076866

STATION 4: Water Vapor or Clouds

If you roll a:	Move by:	Go To
1	Precipitation on soil.	Station 1
2	Precipitation on a lake or river.	Station 3
3	Precipitation on a glacier or fall as frozen precipitation.	Station 5
4	Precipitation on the ocean.	Station 2
5	Precipitation on the ocean.	Station 2
6	Remaining in the air or in a cloud.	Stay at 4

Credit: L.C.Mossa

STATION 5: Cryosphere (Glaciers, Icebergs, and Snow)

If you roll a:	Move by:	Go To
1	Sublimating into the air.	Station 4
2	Melting into the ocean.	Station 2
3	Melting into a lake or river.	Station 3
4	Remaining frozen.	Stay at 5
5	Remaining frozen.	Stay at 5
6	Remaining frozen.	Stay at 5

Credit: Creative Commons, https://commons.wikimedia.org/wiki/File:Perito_moreno_glacier_panoramic.JPG

STATION 6: Plants or Animals

If you roll a:	Move by:	Go To
1	Consumption by an animal.	Stay at 6
2	Consumption by a plant.	Stay at 6
3	Excretion into the ocean.	Station 2
4	Excretion into a lake or river.	Station 3
5	Excretion into the atmosphere.	Station 4
6	Excretion into soil.	Station 1

Credit: Public Domain, https://pxhere.com/en/photo/982398

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INVESTIGATION 3A: BUILDING A MODEL WATERSHED

Learning Outcome: Build and experiment with a model landscape to learn about watersheds and how water moves within them.

Materials

Per group:

- baking sheet or other tray with ridges on sides
- white garbage bag or shower curtain
- 2 different colored permanent markers
- newspaper, cardboard, and other supplies to create landscape
- sticky notes (or small pieces of paper with tape)
- spray bottle
- water
- colored drink mix powder, colored powder, or sprinkles
- food coloring (optional)

What to Do

1. Think about the areas around your community:
   a. What are some local landforms near you?
   b. What are some bodies of water (rivers, lakes, swamps, and so on) that are near you?

2. Create a model landscape of your community inside the tray using newspaper, cardboard, or other items and then cover it with a garbage bag.

3. Make some predictions:

    a. Choose a couple locations where you will add water. For each location, how do you think water will move across the landscape? Where might water move faster? Where might it move slower? Draw arrows on the garbage bag where you think water will flow. Draw arrows longer for where you predict the water will move faster, and draw arrows shorter for where you predict water will move slower.

    b. Where do you think water will collect? Using a permanent black marker, draw your predictions on the garbage bag.

4. Simulate rain using a spray bottle. Make it rain across all areas of your model landscape. First, simulate a local storm by spraying repeatedly at specific areas to more clearly see how water travels. Then, spray all over the model to see how rain moves in general across the landscape.

    a. How did the water move? Did it match your predictions?

    b. Where did the water collect? Did it match your predictions?

    c. Work in your group to develop and write a general statement about how water moves and collects based on your model. Compare the statement you develop with those made by other teams.

    d. A watershed is an area of land where any rainfall or other precipitation makes its way to a common area. Have your group pick one body of water that formed on your model and identify the areas that make up that watershed. Spray water on the model to help identify where the boundaries of the watershed are located. If water drains towards the common area, it is in the watershed. If it drains elsewhere, it is in a different watershed.

    e. Depending on your model, there may be more than one watershed. Outline the watershed(s) your group can identify on your model using different colored markers.

    f. In what ways is your model like a real landscape? In what ways is it different? How could you change the model to make it more like a real landscape?

5. Label features like mountains, rivers, streams, lakes, and so on in your model using sticky notes (or pieces of paper tape to the model).

6. Walk around and observe different groups' models. What were some similarities and differences compared to your model?

7. Think about how humans, animals, and plants might impact water flow.

    a. What types of living things are in your community? Where would they generally be located in your model landscape?

    b. Where might the best places be for houses, schools, stores, farms, and so on? Why do you think so?

    c. How might plants, humans, and other animals change the water flow in your model and in real life?

    d. How might humans impact the quality of water in real life?

8. Water contamination is when a substance or substances are in the water that usually aren't, or when the substance(s) are at a higher amount (concentration) than usual. Water pollution is when the contaminant in the water can cause harm to the environment or living things or otherwise makes the water unsuitable for human use and activities.

9. Model pollution by putting some colored powder in a couple locations on your model. Make it rain and see what happens.

   a. How did the rain impact the pollution (colored powder)?

   b. What areas would you consider contaminated after the rain?

   c. How might this impact living things such as humans, animals, and plants in your watershed?

Consider

1. Think about how water was divided in the model. What caused the dividing, or determined the boundaries, of the watersheds? How might this be different in real life, compared to in the model?

2. The garbage bag represents the soil surface and other ground covering in the model.

   a. How is it an accurate representation of, or similar to, the ground covering in our watershed? How is it different?

   b. What could represent soil and other ground covering more accurately? Why do you think so?

   c. If you used a material that represented soil on this model, do you think the water would flow through the model faster or slower? Why do you think this?

3. Think about where water was located in the model and where it is located in real life.

   a. What are some surface water features you saw in your model?

   b. What are some surface water features that exist, but weren't in your model?

   c. Where is water located underground?

4. In what areas was water plentiful? In what areas was water scarce? How might the location of a town determine its access to water?

5. Think about the similarities and differences between pollutants and contaminants. Is a substance one or the other, or can a substance be both? How?

Extensions

1. **Testing Variables:** Deconstruct your model landscape and create a new, different landscape. Flip the garbage bag or shower curtain over so the unmarked side is up and make new predictions. Take a picture of your predictions, and then simulate rainfall. How did the way water move and where it pooled compare with your predictions? How did this model landscape differ from your community model landscape you built previously? How did the changes you made affect the flow of water?

2. **Testing Variables:** Hydroelectricity is a renewable energy source, as it uses the energy of running water to produce electricity without using up the water. Hydroelectricity usually diverts a consistent water flow to a specified location using a dam. Where do you think a good location for a dam might be in your model watershed? How do you think a dam would impact a watershed? Test it out on your model by building a dam using duct tape.

3. **Applying Concepts:** You constructed your model watershed using a garbage bag or shower curtain to represent the ground. In reality, this may not be the best representation of the ground around you. When water was sprayed on the shower curtain, it moved over the top of it. This would make the shower curtain an impervious material, or a material that does not allow water to move into or through it. A pervious material would allow water to move through it, such as cotton fabric. Go outside and conduct tests on the materials around you. Pour a cup of water on the different materials (streets, grass, rocks, and so on) to see where the water moves. Does it stay on top of the surface, or does it flow into the ground? Keep a list of the surfaces you test and if you would classify them as pervious or impervious. Would you consider more areas to be covered with pervious or impervious surfaces? How might those surfaces impact how water moves in your watershed?

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INVESTIGATION 3B: ANALYZING WATERSHEDS

Learning Outcome: Examine topographic and watershed maps to determine the movement of water across landscapes.

INVESTIGATION 3B1: USING TOPOGRAPHIC MAPS

Materials

Per learner:

- "Topographic Maps" handout
- pencil

What to Do

1. Topographic maps show elevation through the use of contour lines. Each contour line represents a specific elevation. Some key lines are labeled with the elevation, and the others are even intervals between the labeled elevations. Examine the topographic maps of two different landscapes on the handout, "Topographic Maps." Both maps display elevation in meters.

   a. What are some things you notice about the topographic maps?

   b. Examine the contour lines on Map A. What change in elevation does each contour line represent? How do you know? What is the highest elevation on the map? What about the lowest?

   c. Examine the contour lines on Map B. What change in elevation does each contour line represent? How do you know? What is the highest elevation on the map? What about the lowest?

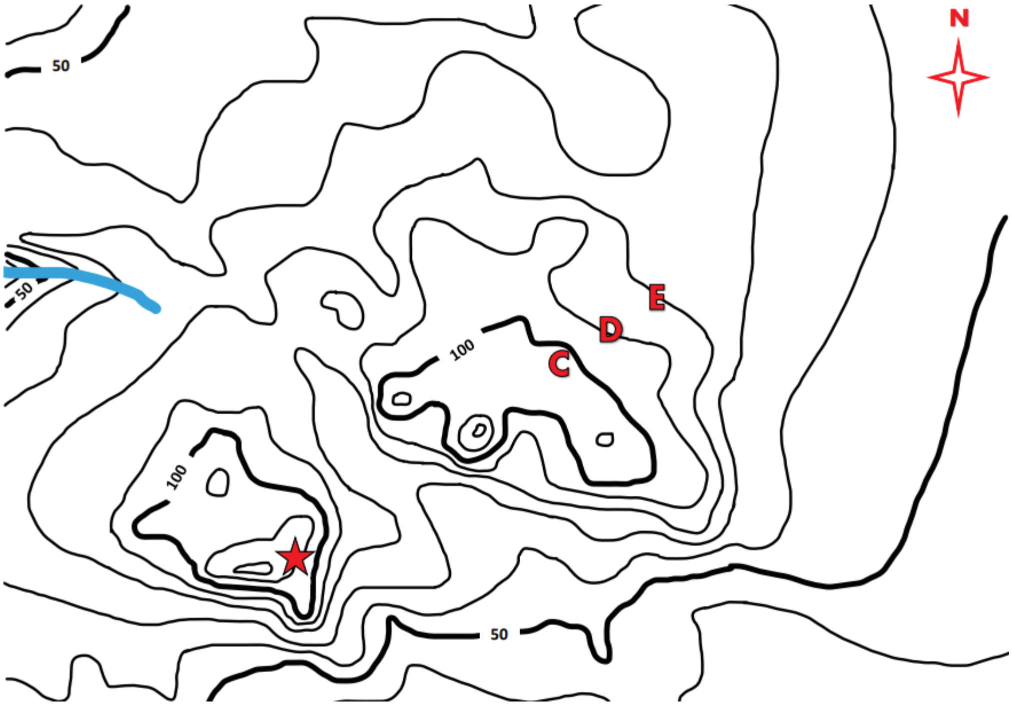
- **d.** One map shows a mountainous area while the other shows a flatter landscape with some hills. Which do you think Map A shows? What about Map B? Why do you think so?
- **e.** Examine the different surface water features, such as rivers and lakes, on the maps. What do you notice about where rivers and lakes form?
- **f.** Label all contour lines the rivers cross. Using this information, which direction do the rivers flow? Draw arrows on the maps to indicate the direction of water flow.

2. Think about how water might move along the landscape for each map. Water typically moves perpendicular to contour lines on topographic maps. Answer the questions below for Maps A and B.

- **a.** Locate labels "C", "D", and "E" and examine the elevations where they are located.
- **b.** If it rained at spot D, would the water flow toward "C" or "E"?
- **c.** Locate the star on Map A.
- **d.** At what elevation is the star located?
- **e.** Identify the "down" direction, or the lower elevation.
- **f.** Use your finger and predict the path that water would take down the landscape until it ends up at a surface water feature or runs off the map. Remember, water will usually move perpendicular to contour lines.
- **g.** Once your group is satisfied with the prediction, draw the path on the map.
- **h.** Repeat with Map B.

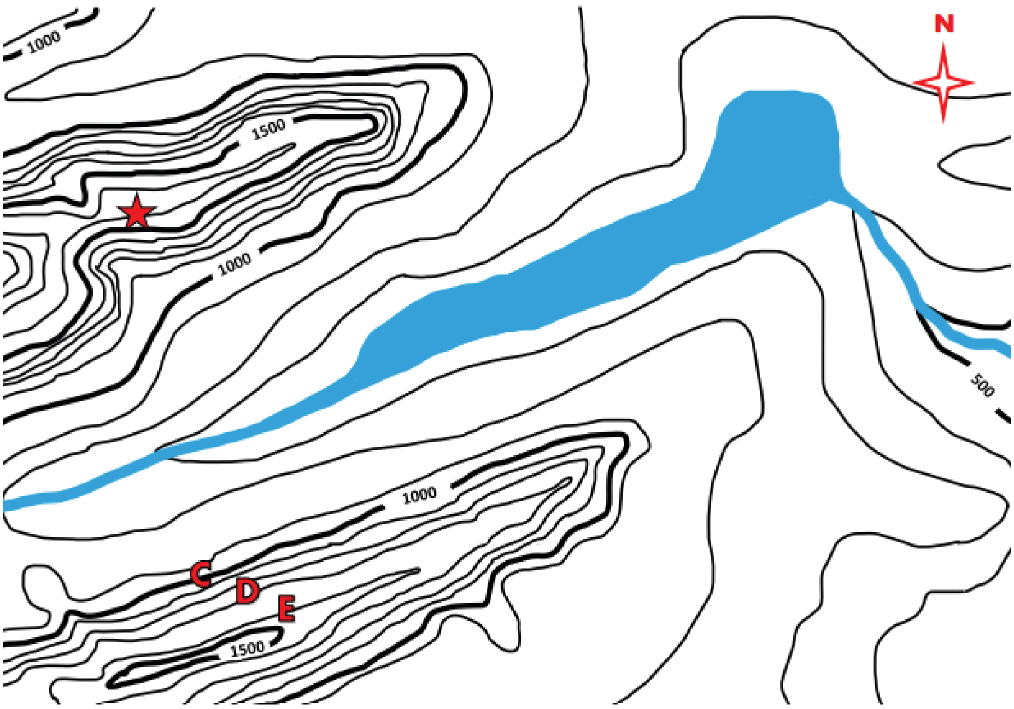
Topographic Maps

MAP A



Credit: L. Brase

MAP B



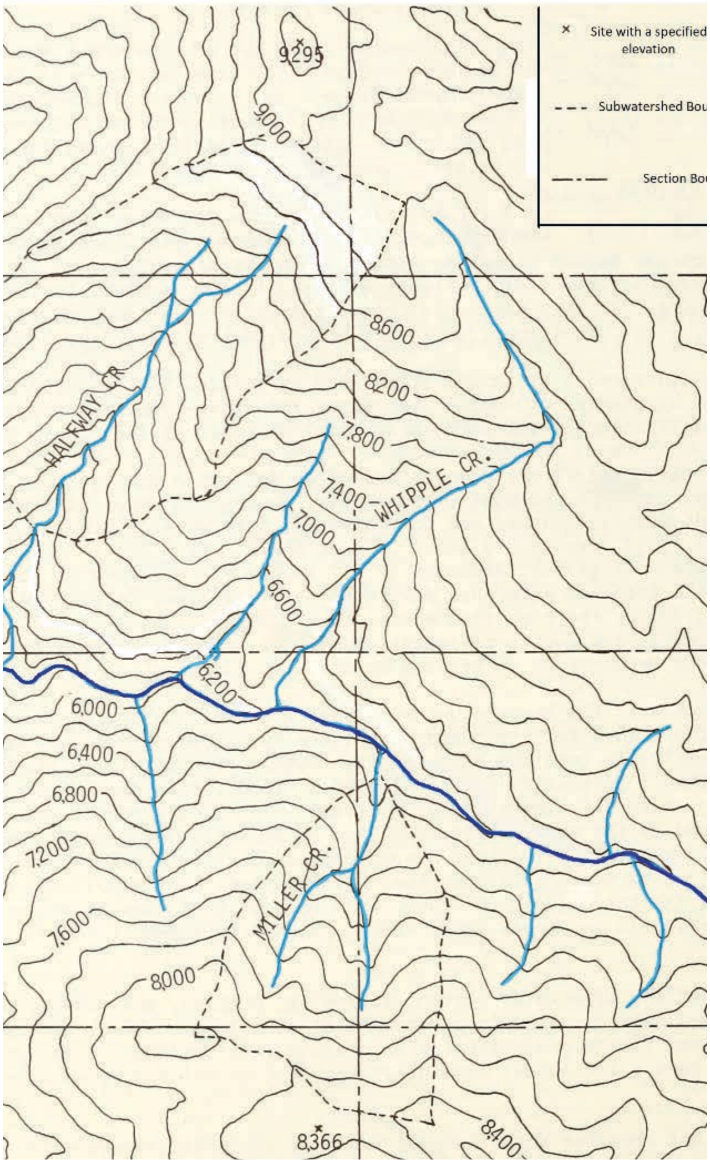
Credit: L. Brase

Consider

1. Think about topographic maps.

- **a.** If contour lines are close together, how would you describe the landscape?
- **b.** What about if contour lines are far apart?
- **c.** How would water move similarly and differently across these types of landscapes?

2. Examine how streams (light blue) and the river (dark blue) are distributed on the following map. In this map, the contour lines are labeled in feet. How would you describe where the surface water features are located and how they are shaped? What trends or relationships do you notice?



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INVESTIGATION 3B2: IDENTIFYING YOUR WATERSHED

Learning Outcome: Analyze a map to learn about your local watershed.

Materials

Per learner:

- copy of local watershed map
- pencil
- colored pencils

What to Do

1. Examine a watershed map which contains your community.
2. Identify where your community is located.
3. Is your community contained in one watershed, or in many?
4. What is the name of the watershed(s) in which your community is located?
5. How would you describe the size and scope of your watershed?
6. What is the common outlet or place where water ends up in your watershed?
7. What other watersheds are near yours? How are they related to your watershed? Are they similar in size? Is one draining into another?
8. Which areas do you think are located at the highest elevations, and which areas are at the lowest elevations? Why do you think so?
9. What are some natural features that define your watershed? What are some human-made features that might have an impact on your watershed?

Consider

1. Do you see any water sources within your watershed where your community could get its drinking water? If so, what are they? Do you think your community actually uses this water source for drinking water? Why or why not?
2. What sorts of materials might water pick up as it moves throughout our watershed? Where will these materials end up, or be deposited? How far could these materials travel from their original position?
3. How might urbanization affect how water moves into, throughout, and out of a watershed?

Extensions

1. **Applying Concepts:** Analyze a topographic map of your community. What are the highest elevations? What are the lowest? Identify the different types of surface water features. Then, place a star somewhere on the map and draw the path you predict the water would take down to a water feature or off the map.

2. Using *Scratch*®: Think about the water sources in your community while playing with the Reservoir *Scratch*® project at **https://scratch.mit.edu/projects/687499359/**. What would happen if the population of your community increased? What would happen if the source of water dried up or produced less water? What other factors in your community could influence a water source? Remix the *Scratch*® project to reflect your community.

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INVESTIGATION 4A: GROUNDWATER MOVEMENT AND POLLUTION

Learning Outcome: Model how contamination gets into groundwater and bodies of water, and how this leads to pollution of drinking water.

Materials

Per group:

- small clear plastic bin (approximately 20 cm x 10 cm x 10 cm [8″ x 4″ x 4″])
- light colored gravel
- light colored sand
- water
- measuring cup
- food coloring
- plastic syringe (20–40 mL)
- plastic tubing (to fit the end of the syringe)
- pump from a soap dispenser
- small piece of mesh fabric (nylon, cheesecloth)
- rubber band
- small plastic cup
- strainer
- large bowl (optional, to hold strainer)
- colored drink mix powder, colored powder, or color tablets, sprinkles (optional)

What to Do

Observing Groundwater:

1. Fill a clear plastic bin approximately halfway with water. Empty this water into a measuring cup or other container to be used later. Add 2–4 drops of blue food coloring to make the water light blue.

2. Fill the bin approximately 1/3 full with light colored gravel.

3. Arrange the gravel to form a depression near the middle of the container and a hill at both ends.

Credit: L.C.Mossa

4. Draw a diagram of your model.

5. Using the measuring cup you filled earlier, slowly pour water onto one of the hills, watching the different pathways water can take.

6. Once water has started to fill the depression in the gravel, start pouring water over the depression. Observe the water level within both the depression and the gravel.

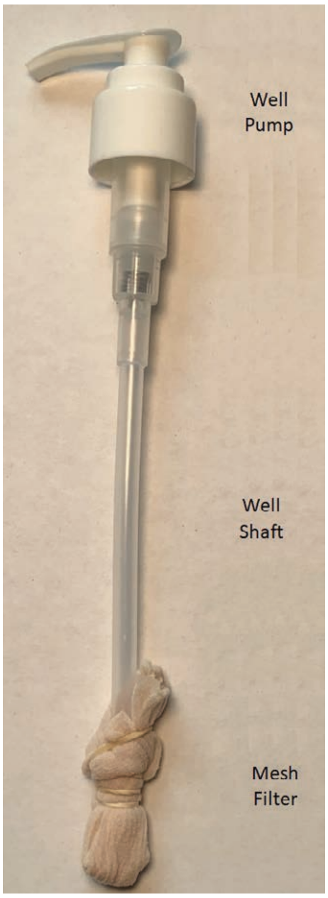
7. Add arrows to your drawing to indicate water movement. Then add the following terms to your drawing: *groundwater, infiltration/percolation, surface water, precipitation/recharge, discharge, and body of water*.

8. Build a well by placing a piece of nylon (or other mesh fabric) over the bottom of a soap dispenser pump. Hold the fabric in place using a rubber band.

    a. The pump at the top will act as the well pump, to draw water up into the well, as well as to the surface,

    b. the tube will act as the well shaft, which allows water to be drawn up to the surface,

    c. and the nylon or mesh fabric will act as a filter that prevents large materials from entering the well shaft.



Credit: L.C.Mossa

9. Insert the well into one of the gravel hills in your model.

10. Start pumping water into a measuring cup. Observe the water table line and the body of water in the middle of the model as you pump water. Add the location of the well and your observations to your diagram.

11. Pump the well to remove as much water as you can from the container. Be sure to keep the well in the same location as you do this. Make note on your diagram where you still see some water in the container.

12. Have one group member pour the water over the same hill where the well is located while another group member pumps the well at a fast rate. You will need a second cup to catch the water from the well pump.

13. Make observations of where the water goes and how it moves. Add these observations to your diagram.

14. Pump out as much water as possible. Repeat steps 12 and 13 two more times, making it rain in different locations:

    a. once over the body of water,

    b. once over the hill opposite the well pump.

15. Remove the well. Pour the contents of the bin into a strainer that has been placed in a sink or collection bowl. Briefly rinse the gravel.

16. Repeat the steps 1–14 using sand.

Confined Aquifers:

1. Add a thin layer of gravel to the bottom of the bin. Add enough water to just cover this gravel.

2. Mold a thin layer of modeling clay and place it into the bin, securing it to the sides of the bin.

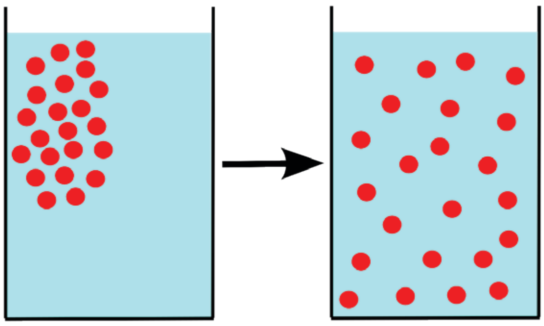
Credit: L.C.Mossa

3. Pour the rest of the gravel over the top of the modeling clay, being careful not to puncture the clay.

4. Rearrange the gravel to form a depression in the middle of the bin, surrounded by two hills. Add the well to one of the hills so that the bottom of the well stays above the clay.
   a. Draw a second diagram to show the changes you have made.
   b. Label the *confined aquifer* on your new diagram.
5. Pour the rest of the water into the gravel.
6. Fill the measuring cup with clear water.
7. Add “fertilizer” to your model as instructed by your facilitator.
8. Simulate “rain” over the newly fertilized ground by slowly pouring water over the area until the water table almost reaches the top of the hill. Observe what happens for two minutes and add this to your diagram.
9. Start pumping the well.
10. Observe changes in the water table. Pay special attention to the water under the clay to see if it moves.
    a. Observe any changes in the movement of the fertilizer. Stop pumping the well once there is evidence that the water in the well has been contaminated.
    b. Make observations of the water under to clay to check for contamination.
11. Remove the well, then pump it until it is empty. If necessary, insert the well into a cup of clean water to rinse out the well. Make sure the well is as empty as possible before moving to the next step.
12. Replace the well in the same general area you had it before but insert it far enough to penetrate the layer of clay.
13. Start pumping. Make observations of what happens.

Consider

1. Use evidence from your model to describe how water moves.
   a. Describe how the level of the water table relates to the level of water in the lake or river.
   b. Describe how pumping water out of the ground affected both the water table and the body of water.
   c. Did the type of substrate (gravel vs. sand) affect the water table, rate of infiltration, or rate of water movement through the ground? Describe your observations.
2. The image below shows diffusion. The red dots can represent a substance that can dissolve in water (solute), such as salt or sugar. The arrow represents the passage of time, even if the container of water and solute is not disturbed or stirred.
3. Describe what is happening to the solute in the water, then relate this to the movement of the pollutant through the model you used in this Investigation.



Credit: Creative Commons, https://commons.wikimedia.org/wiki/File:Diffusion.svg, https://creativecommons.org/licenses/by/3.0/deed.en

   a. Describe the effect of pumping water on the spread of pollution.

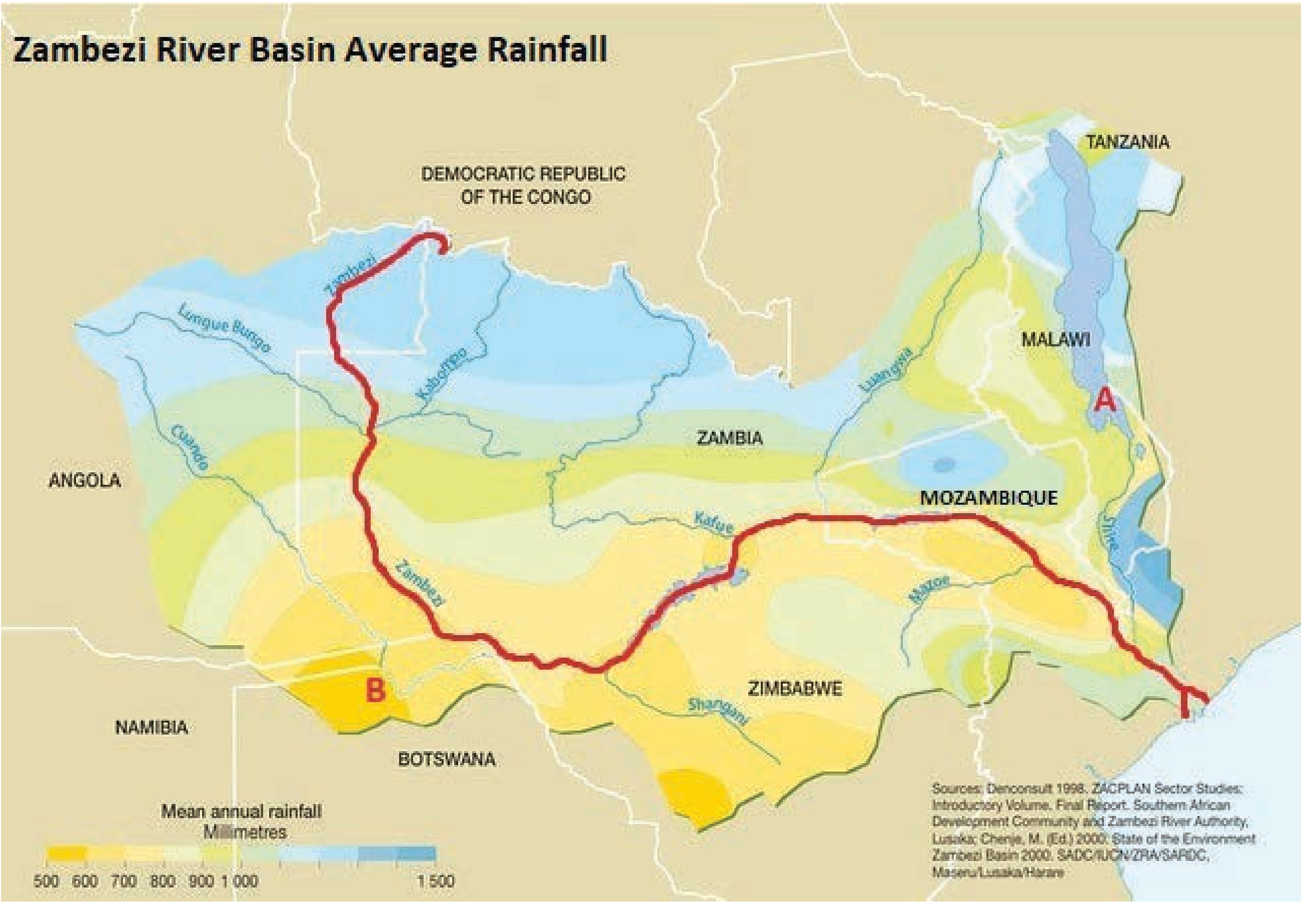
4. When you added the clay, the water under it is called a confined aquifer. Why do you think it is called this? Use evidence from the movement of the pollution to describe your answer.

5. Are water pollutants and contaminants always visible, like the one you used in your model? If not, what are some ways that we can tell water is contaminated if we cannot see it?

Extensions

1. **Testing Variables:** Consider other variables you can test that might affect the movement of pollutants through ground water. For example, test the effect of different substrates (larger gravel, local soil, or others), well depth or having multiple wells. Plan your procedure, make predictions about the effects, and then test them, if possible.

2. **Analyzing Data:** The map, “Zambezi River Basin Average Rainfall,” shows the path of the Zambezi River through eastern Africa and the other rivers that feed into it. It also shows the average annual rainfall (mm) in different areas of the watershed.



Credit: Modified from Denconsult 1998. ZAPCLAN Sector Studies: Introductory Volume. Final Report. Southern African Development Community and Zambezi River Authority, Lusaka; Chenje, M. (Ed.) 2000, Creative Commons.

a. On the map, circle where the Zambezi River outlets into the Mozambique Channel. How can you tell this is the outlet?

b. How many rivers feed into the Zambezi River? Do you think more water enters the Zambezi River from the north or south? Give evidence to support your answer.

c. Point source pollution occurs when contaminants come from one specific location, such as a farm. If there was a farm at point A, indicate the waterways that would be affected by point source pollution if excessive fertilizer was used on this farm.

d. If there was a farm at point B that used the same amount of fertilizer, indicate the waterways that would be affected by point source pollution. Describe how this differs from the farm at point A in terms of: effect of rainfall amounts on the spread of pollution, the number of waterways affected, and how much area would be affected.

e. What else would you want to know about points A and B (or the areas around them) to determine the movement of pollution from these points into the rivers?

INVESTIGATION 4B: WATER QUALITY

Learning Outcome: Test water quality to determine the typical concentrations of substances in water and the concentrations of common water contaminants.

Materials

Per group:

- water test kit
- water samples from different sources (bottled, tap, aquatic environments)
- gloves
- timer
- stalk of celery
- food dye
- beaker of water

What to Do

1. Water quality testing:
   a. Examine the components of your water testing kit. List out each factor you will be testing.
   b. Determine how many different water samples will be tested by your group or by other groups. Make a data table large enough to record observations and data on all the tests for each water sample.
   c. Make observations of each water sample.
   d. Follow the instructions in your specific water testing kit.
   e. Record data as you take it.
   f. Share your results with other groups.
2. Contamination and plants:
   a. Observe the celery that has been sitting in dyed water overnight.
   b. With permission, break or cut the celery.
   c. Describe or draw your observations.

Consider

1. Compare the results of the water tests. Which sample had the best water quality? Which samples would you deem as safe drinking water, if any? Use evidence to support your arguments.

2. If you tested water from the same source as another group, did you get the same results? For what reasons might you get different results?

3. Consider the celery demonstration

   a. Was the food dye able to get into the celery? How do you know?

   b. Do you think contaminants can get into other plants the same way?

   c. Do you think all contaminants are able to get into plants? Why do you think this?

   d. How might pollution affect plants?

   e. How does pollution getting into plants affect animals or the ecosystem?

Extensions

1. **Analyzing Data:** The map, “Water Contamination Around the World,” shows which contaminants are present in freshwater sources, as well as how many people are affected by them. Fluoride and nitrate are non-metals. Manganese, arsenic, and lead are metals. TDS stands for *Total Dissolved Solids*, which is the concentration of any particles dissolved in water, such as salts, metals, and minerals. While TDS is present in every water source, the areas indicated by TDS on the map are areas where the concentration is higher than the accepted concentration for drinking water.

   a. Which freshwater contaminant(s) is/are most common? Give evidence from the map to support your answer.

   b. Research each contaminant to determine their most likely source.

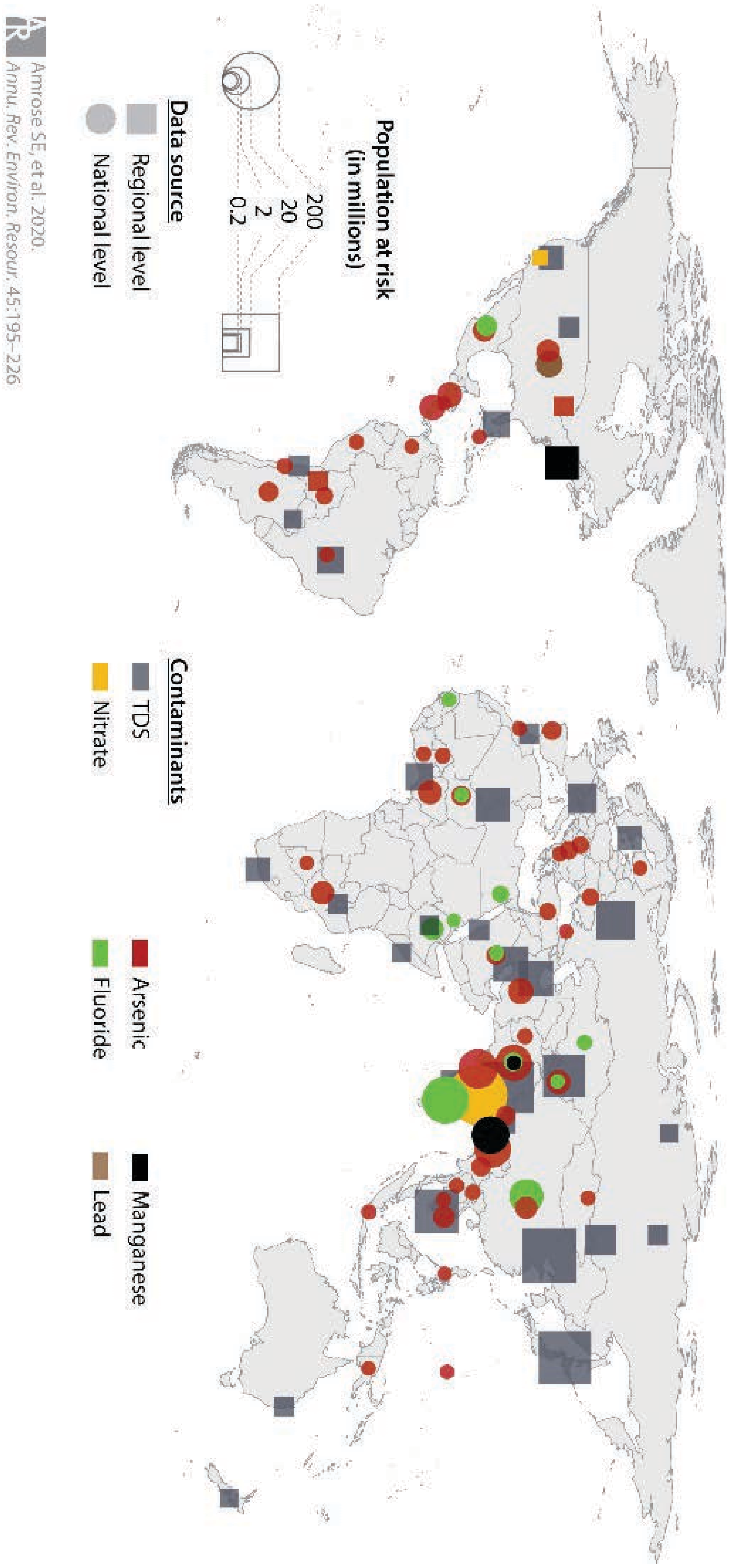
   c. Which are naturally occurring?

   - Which tend to end up in water due to human activity? What human activities lead to these contaminants ending up in the water?

   - If you completed Investigation 4A, use your drawing of the model to describe how these contaminants might end up in the water.

   d. Why do you think some regions have more contaminants than others?

WATER CONTAMINATION AROUND THE WORLD



Credit: Amrose SE *et al.*, Creative Commons, https://commons.wikimedia.org/wiki/File:Chemical_contamination_of_drinking_water.jpg

2. **Analyzing Data:** The map, "Sources of River Pollutants," shows five major pollutants that end up in rivers and where they come from. Nitrogen and phosphorous most commonly come from farming practices. *Cryptosporidium* is a bacterium that comes from humans and other animals and ends up in the water due to untreated sewage or agricultural runoff. Microplastics come from many different sources, mainly man-made products such as tires, personal hygiene products, and road markings. Triclosan is an antifungal chemical put in many soaps, toys, and hospital products to prevent mold growth. The "Indicator" map was made by calculating the impact of each pollutant source to consider the total pollutants entering rivers in each country. Countries in dark blue are considered *hotspots* in terms of river pollution.

    a. How are the legends for each map similar? How are they different?

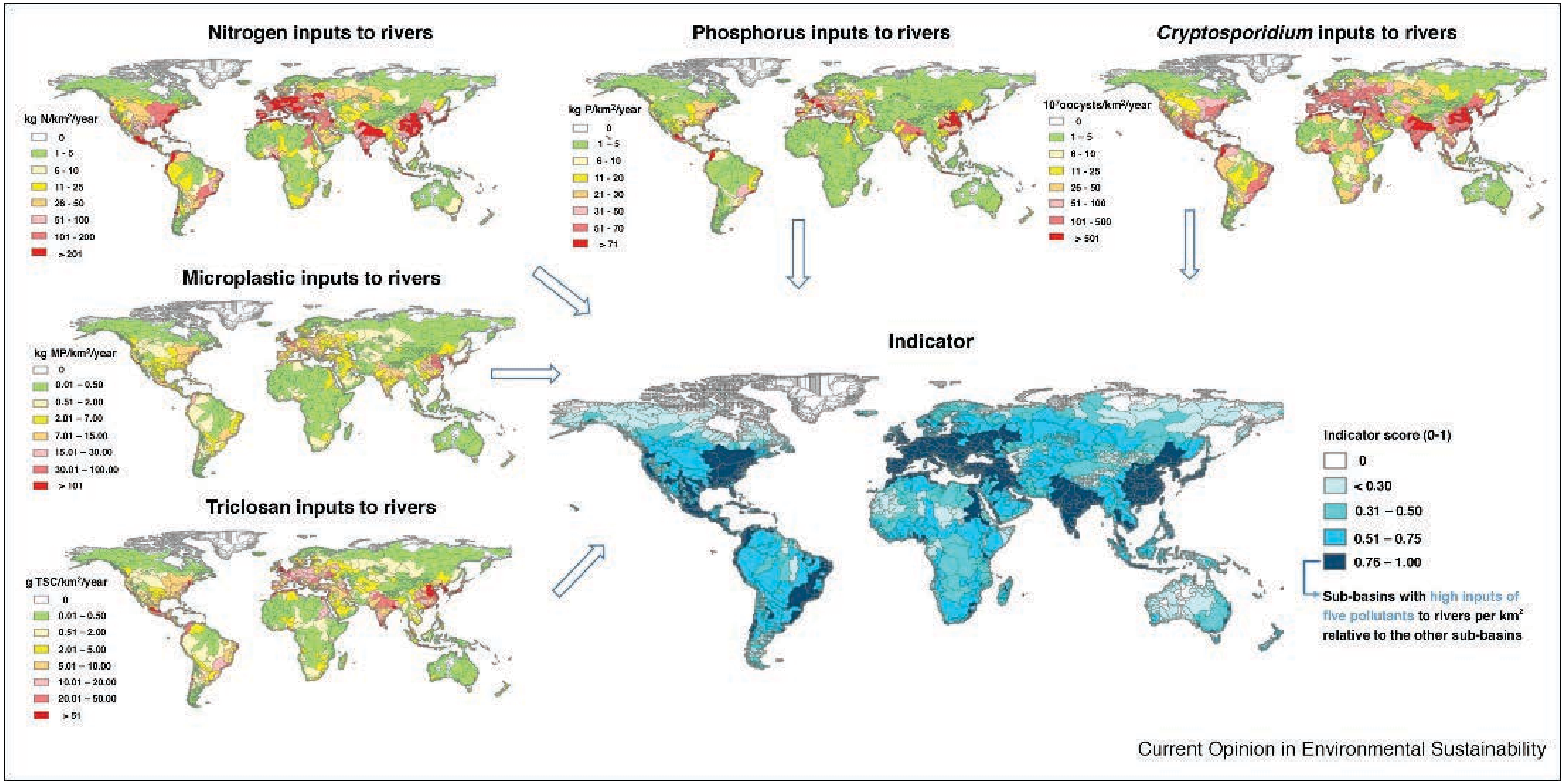
    b. Which countries or regions are the greatest contributors of each pollutant?

    c. Which pollutant is the most widespread in terms of contributing to river contamination? Why do you think this is?

    d. Triclosan was banned by the United States Food and Drug Administration and was limited in its use by the European Union, yet you should notice it is still contributing to river pollution. Why do you think so?

    e. Examine the Indicator map, which compiles information from the five pollutants into a score of 0–1. Does the overall trend match any specific pollutant(s) more than others? Why do you think this may be the case?

SOURCES OF RIVER POLLUTANTS



Credit: M. Strokal et al, Creative Commons, https://www.sciencedirect.com/science/article/pii/S187734351830023X

3. **Analyzing Data:** The graph, "Sources of Pollution in Ireland's Waterways," shows the percent increase in pollutants entering different waterways from various sectors between 2013 and 2018.

    a. Agriculture caused the greatest increase in contaminants in rivers. Did agriculture also cause the greatest increase in contaminants in other waterways? How can you tell?

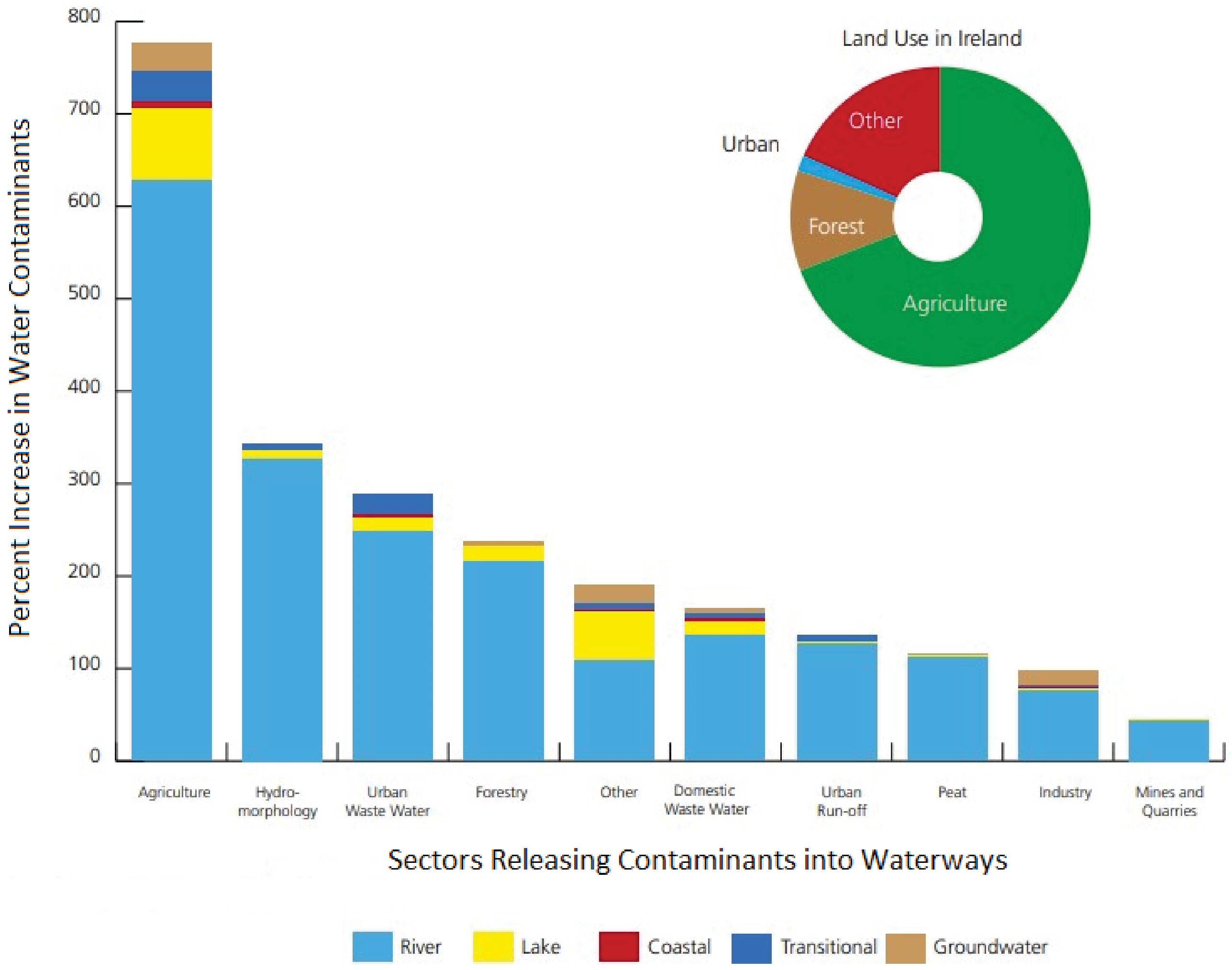
    b. Why do you think agriculture had the greatest input of contaminants to waterways versus the other sectors?

    c. One sector along the x-axis is "Other." Give at least one example of a source of contamination that might fall into this group.

    d. Why do you think pollution increased more in rivers than in any other type of waterway?

    e. Do you think you would see the same trends in other countries? Why or why not? What would you want to know about the country to determine this?

SOURCES OF POLLUTION IN IRELAND'S WATERWAYS



Credit: Modified from Ireland EPA, **https://www.epa.ie/publications/monitoring--assessment/freshwater--marine/Water-Quality-in-Ireland-2013-2018-(web).pdf**, y-axis label added

SUSTAINABLE DEVELOPMENT GOALS

GEOSCIENCE FOR SUSTAINABILITY

Photo ©Shutterstock/Edge of Reason

american geosciences institute
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INVESTIGATION 4C: MEASURING TURBIDITY WITH MICRO:BIT

Learning Outcome: Use a sensor to detect and measure the turbidity of water to observe the process of sedimentation.

Materials

Per group:

- micro:bit (https://microbit.org/)
- LED (white or blue recommended)
- light sensor (photo cell) (https://www.adafruit.com/product/161)
- resistor, 100 to 300 ohms (https://www.allelectronics.com/item/291-120/120-ohm-1/4-watt-resistor/1.html)
- alligator clip cables
- glass jar
- corrugated cardboard box
- low temperature hot glue gun
- packing tape
- opaque cloth (optional)

Credit: Logo Foundation

What to Do

1. Install the LED and the light sensor inside the box on opposite sides. They should be placed so they are centered horizontally and at a height about halfway up the jar above the bottom of the box.

2. Start by putting a mark on one side of the box in that position. Put a mark in the same position on the opposite side of the box.

Credit: Logo Foundation

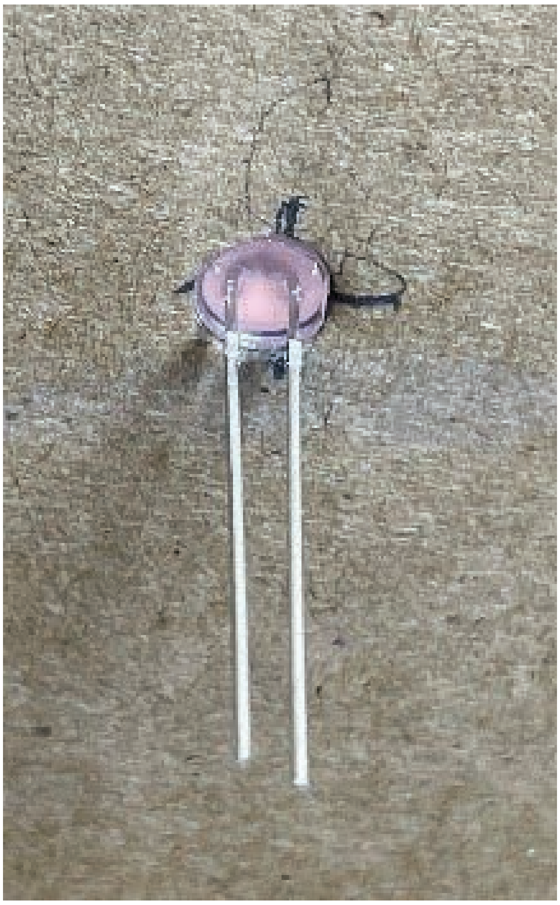
   a. With a pin or needle, make two holes at one of the marks spaced as far apart as the pair of wires attached to the light sensor. Working from inside the box, put the wires through the holes. Put a dab of hot glue behind the sensor. Immediately pull the wires so that the sensor is against the glue. Hold the wires for a few moments until the glue hardens.

Credit: Logo Foundation

Credit: Logo Foundation

3. To Install the LED on the opposite side, make a hole at the mark with a pin or needle. Using a pencil or other tapered pointy stick, widen the hole so that the LED fits into it from the outside. Do this gradually in several steps, widening the hole a little each time until the LED fits tightly. Avoid making the hole too large.

4. The flange at the base of the LED should keep it from pushing all the way into the box. The bulb will stick out on the inside.



Credit: Logo Foundation

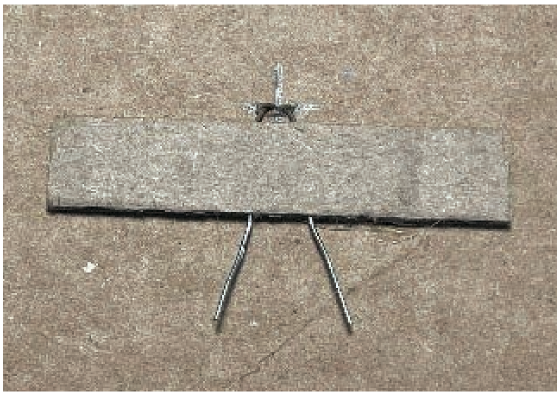
Credit: Logo Foundation

5. Put a bit of hot glue around the base of the LED on the outside of the box.

6. To further secure the LED and light sensor, cut two pieces of corrugated cardboard, each about 5 cm X 1 cm (2 in x .5 in). Cut the strips so that the corrugations are parallel to the short sides.

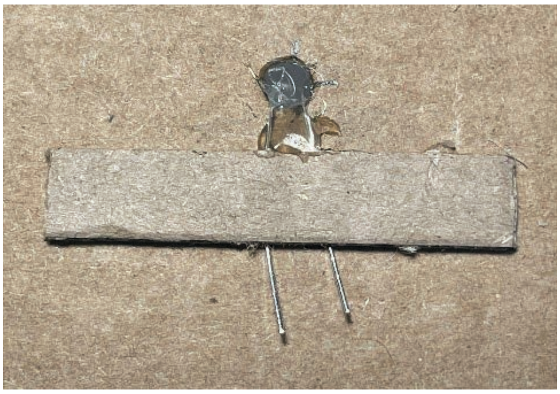
Credit: Logo Foundation

7. Insert the wires of the light sensor through one of the strips. Make sure that the two wires are not in the same channel in the corrugation. The cardboard keeps the wires from touching each other and prevents a short circuit. Gently bending the wires down and glue the cardboard strip to the outside of the box.



Credit: Logo Foundation

8. Do the same on the other side of the box to secure the wires from the LED. To further secure the wires from the LED and light sensor, put some hot glue where the wires enter the cardboard strips.



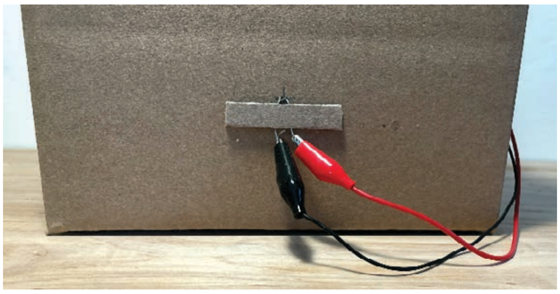
Credit: Logo Foundation

9. Securing the wires is important to avoid movement when you make connections to them. If they move, they could break off and/or cause the LED or light to shift out of position.

10. The finished box will have the LED and light sensor on opposite sides inside the box and the wires to make connections on the outside.

Credit: Logo Foundation

11. The next steps is to connect the micro:bit to the LED and light sensor. Attach an alligator clip wire to each wire of the light sensor.

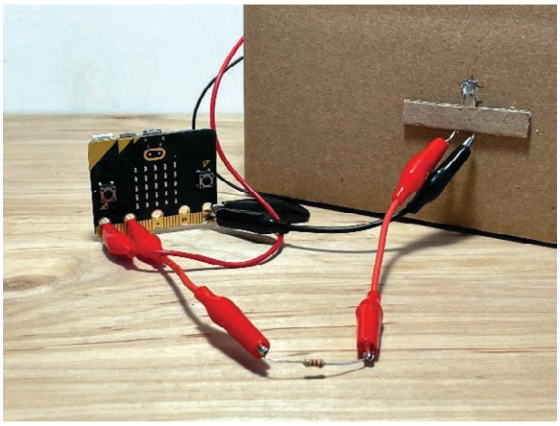


Credit: Logo Foundation

12. Now attach these two wires to the micro:bit. One wire connects to GND on the micro:bit. The other connects to 0. It does not matter which wire connects to each port on the micro:bit, but by convention, a black wire is used for the connection to GND, which is negative. A red wire is typically used to connect to 0 because color-coding helps keep track of the connections.

    a. Connect the wire attached to the 0 on the micro:bit to one end of the light sensor.

    b. Connect the wire attached to the GND of the micro:bit to the other end of the sensor.

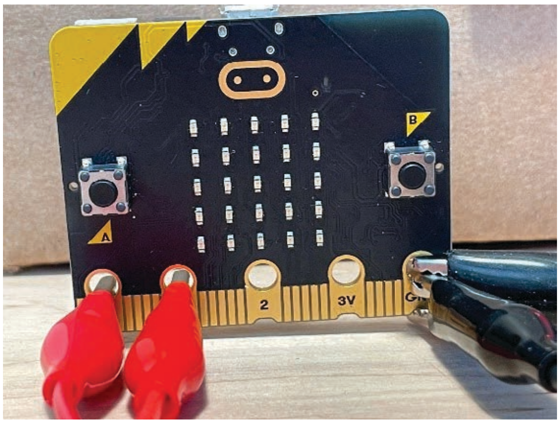


Credit: Logo Foundation

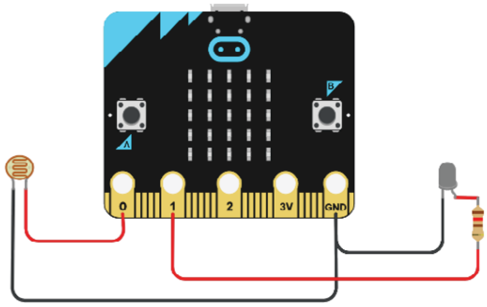
13. Unlike the light sensor, the LED is polarized. This means that electricity passes through it in only one direction.

14. The short wire on the LED is negative and should connect using the wire attached to GND on the micro:bit. There are two alligator clips that need to be connected to GND. One way to do this is to first connect one of them to the micro:bit and then connect the second clip to the first. The circuit diagram has been simplified to show the entire setup without the alligator clips.

  a. Connect the other LED wire to the resistor. Then connect the other wire of the resistor to 1 on the micro:bit.

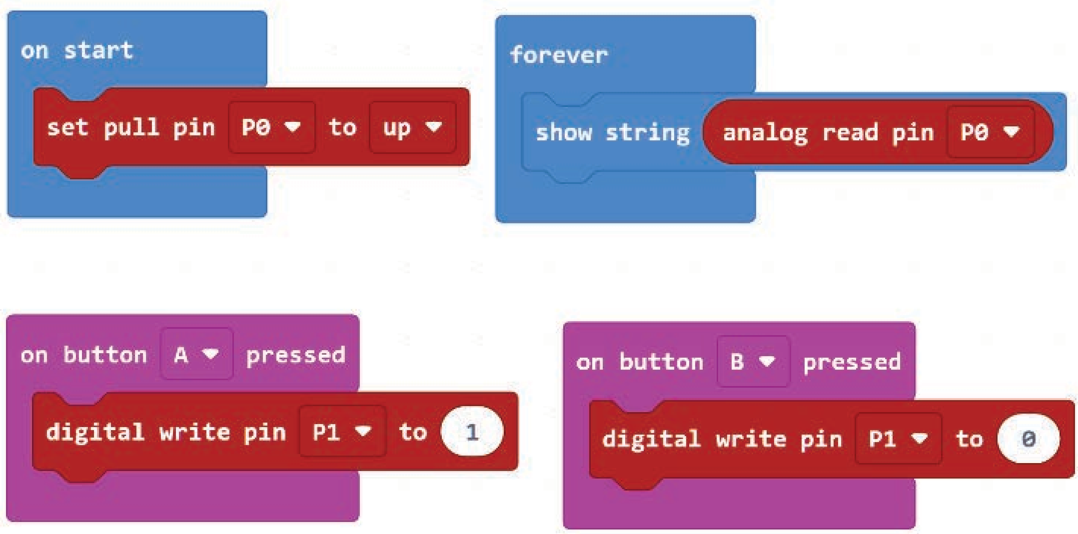


Credit: Logo Foundation



Credit: Logo Foundation

15. The turbidity sensor is now ready to use. To program the micro:bit, go to https://makecode.microbit.org/ and create new project. Enter the code as shown in the next image. (Note that the red blocks are in the Pins section under Advanced).



Credit: Logo Foundation

16. Download the code to the micro:bit. You may leave the micro:bit connected to the computer or connect it to a 3V battery pack or USB charger while in use.

17. Fill the jar with water and place it in the box against the light sensor. Close the box.

Credit: Logo Foundation

18. The value of the light sensor appears scrolling across the micro:bit LED display. The sensor value is in a range of 0 to 1023. The more light the sensor receives, the lower the value. In complete darkness, it should be close to the maximum of 1023. Test this by placing the sensor in the box and close the lid. If the value is low, it is likely that light is getting into the box. Check for possible openings and seal them or cover the box with an opaque cloth while running the turbidity experiment.

19. Press button A to turn the LED on. The sensor value should drop. The exact value depends upon the specific LED and light sensor used and how the box was constructed. Typically, the value with the LED on will be around 700 to 750.

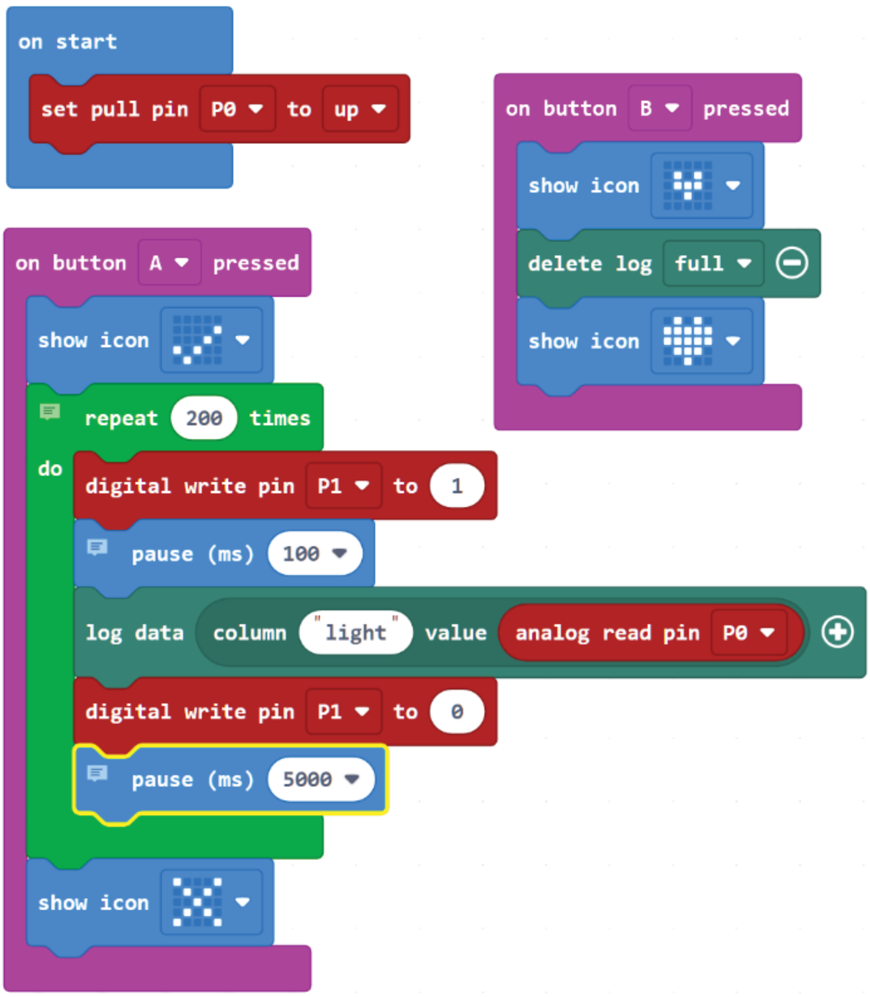
20. Add some soil to the water in the jar. Close the jar and shake it. If the water is still clear enough to see through, add more soil.

Credit: Logo Foundation

21. To log turbidity data, use the code for data logging, at: **https://makecode.microbit.org/_4fiih2TLR2Mt**. Connect the micro:bit to your computer to download this code to the micro:bit. At this point you may leave the micro:bit connected to the computer or disconnect it and connect it to a battery box or USB charger. The program begins to run as soon as it is downloaded. It remains on the micro:bit, even when power is disconnected, until you download another program.

  a. When you first download a program to the micro:bit, or when you reconnect it to a power source, the code in the "on start" block runs. In this case, the "set pull pin P0 to up" stabilizes the sensor value at 1023 when there is nothing connected between pin 0 and GND.

b. Data collection is done within the “repeat” loop. The number of repetitions determines how many data points will be recorded. The “digital write pin P1 to 1” block turns on the LED. The “log data” block reads the light sensor, which is connected to pin 0, and writes its value to the data log. The brief pause – a tenth of a second – before the “log data” block is there to allow the LED to come to full brightness before the light sensor value is read. The “digital write pin P0 to 0” block after the “log data” block turns off the LED.



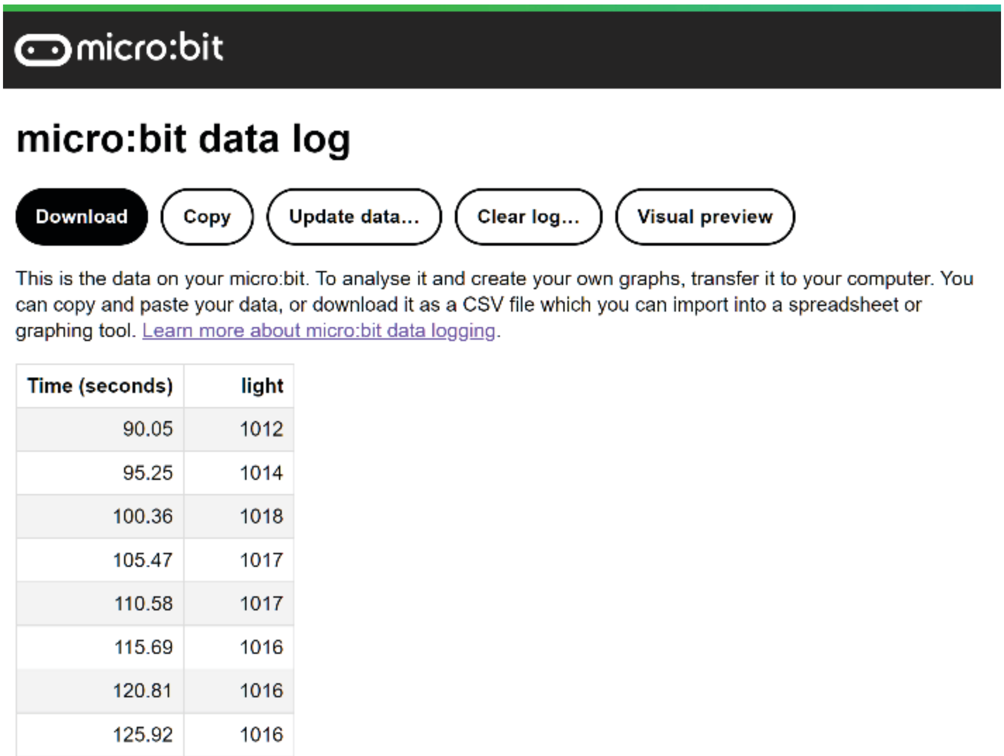
Credit: Logo Foundation

22. Press button “B” to delete any data log that may already be on the micro:bit. A small heart will appear on the micro:bit display to indicate that the deletion is about to start. When the deletion is completed, a large heart will be displayed.

23. Shake the jar again and quickly place it back in the box. Then, close the box lid and cover the box, if needed.

24. With the water sample in place in the box, press Button A to start the logging. A check will appear on the display. When the logging is done, an X will appear.

25. To access your completed data log, connect the micro:bit to the computer via the USB cable. If you left it connected to the computer during the data logging process, disconnect and reconnect it now. The micro:bit appears as if it is a drive on your computer. The data you just logged is in the file MY_DATA.HTM. When you open this file, you will see something like the screen shot to the right.


micro:bit

micro:bit data log

Download | Copy | Update data... | Clear log... | Visual preview

This is the data on your micro:bit. To analyse it and create your own graphs, transfer it to your computer. You can copy and paste your data, or download it as a CSV file which you can import into a spreadsheet or graphing tool. Learn more about micro:bit data logging.

Time (seconds)	light
90.05	1012
95.25	1014
100.36	1018
105.47	1017
110.58	1017
115.69	1016
120.81	1016
125.92	1016

Credit: Logo Foundation

26. Click the Download button to save a .csv file of your data. You can then use this file to graph the data.

Consider

1. Describe the trend of your data. Why do you think this trend occurred?
2. What natural processes would cause there to be sediment in the water?
3. Does sedimentation remove all sediment from the water?
   a. Use your data as evidence for your claim.
   b. What further tests could you run to confirm your claim?

Extensions

1. **Testing Variables:** Determine what other variables you can change in this experiment, then test them to see what effect they have on your data. Explain any changes you observe.

2. **Applying Concepts:** The pause block at the end of the repeat loop determines the time in milliseconds between the recording of data points. In the code used in this Investigation, the pause is 5000 milliseconds, or 5 seconds.

3. Alter the code to change the interval. Predict whether or not this will affect your data. Run the experiment again, then compare your results to your prediction. Did the time interval have an effect? Why or why not?

   a. Take data over a longer period of time. Predict the results, then run a test to see if your data matches your predictions.

4. Using *Scratch*®: The data can also be loaded into *Scratch*®. Here's an example of a *Scratch*® project using the data file we created: **https://scratch.mit.edu/projects/709622155/**.

ESD KIT:
ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 5A1: TREATING WASTEWATER BY FILTRATION

Learning Outcome: Analyze and design different filtration setups to determine their effectiveness in treating contaminated water.

Materials

Per group:

- simulated wastewater, about 1L
- single use bottle with cap
- aluminum sulfate (alum), about 15 g (1 Tablespoon)
- stirring rod or similar
- funnel
- spoon
- cotton ball
- scissors
- 100 mL each of small pebbles or gravel, coarse sand, and fine sand
- 100 mL charcoal or activated charcoal (optional)
- 2 beakers or cups
- water quality test kit (optional, https://amzn.to/38Wgkzk)

What to Do

1. Examine the water sample:

   a. Write down observations of the sample.

   b. Optionally, conduct water quality tests on the sample.

2. Remove the larger solids by allowing them to settle to the bottom and then decant, or pour out, the clearer water on top.

   a. Place 200 mL of the sample in a plastic bottle. Cap the bottle with a lid.

   b. Shake the bottle to aerate the sample for one minute. This removes gases that are trapped in the water.

   c. Pour the sample into a beaker or cup.

   d. Add about 10 grams (1 Tablespoon) of aluminum sulfate (alum) and slowly stir the sample for 3 minutes.

   e. Let the water sit undisturbed for 15 minutes.

   f. Once the water has settled, carefully pour the liquid layer into a clean beaker or cup, while leaving the residue at the bottom of the beaker. This is called decanting.

   g. Write down observations. If water test kits are available for you to use, conduct water quality tests on the treated sample according to the instructions on the water testing kit.

3. Construct a filter:

   a. Cut off the bottom of a single-use bottle.

   b. Use scissors to poke a hole in the cap of the bottle.

   c. Screw the cap back on the bottle and turn the bottle upside down. Place the cotton ball inside and push it down against the cap using a pencil.

   d. Pour the pebbles into the filter. This will be the first filter medium tested.

Credit: L. Brase

4. Clean the filter:

   a. Balance the filter in a beaker.

   b. Slowly pour 100 mL clean tap water through the filter without disturbing the filter medium.

   c. Once water stops dripping out of the filter, move the filter to another clean beaker and discard the tap water.

5. Treat the 200 mL of the water sample by filtration with pebbles as the filter medium.

   a. With the filter set up over a clean beaker, slowly pour about 300 mL of the water sample through the filter.

   b. Write down observations of the water that comes out every 3 minutes or so.

c. Optionally, conduct water quality tests on the treated sample.

6. Treat 200 mL of the original water sample by filtration with coarse sand as the filter medium. Repeat steps 3–5 with coarse sand as the filter medium.

7. Treat 200 mL of the original water sample by filtration with fine sand as the filter medium. Repeat steps 3–5 with fine sand as the filter medium.

8. Treat 200 mL of the original water sample by filtration with activated charcoal as the filter medium. Repeat steps 3–5 with charcoal as the filter medium.

Consider

1. When the alum was added to the water, what did you observe? Why was this step included?

2. If you were to have measured the mass of the sample before and after the water treatments, do you think it would have been equal? Why or why not?

3. How does the original water sample compare to each of the treated samples?

4. How clean would you consider each treated sample? For each treatment method, explain your reasoning using evidence.

- Decanting
- Filtering through pebbles
- Filtering through coarse sand
- Filtering through fine sand
- Filtering through charcoal

5. What are some advantages and limitations of filtration as a treatment method?

Extensions

1. **Testing Variables:** Repeat this procedure using the water samples from Investigation 3B. Was this treatment method effective in cleaning each sample? Why or why not?

2. **Applying Concepts:** Soil can be considered nature's filter. Watch the video provided by Soil Science Society of America (**https://www.youtube.com/watch?v=ZwQeTJEeedk**) to learn why. After watching the video, explain how soils help filter water and the importance of soils.

SUSTAINABLE DEVELOPMENT GOALS

AGI american geosciences institute
connecting earth, science, and people

INVESTIGATION 5A2: DESIGNING A FILTRATION SYSTEM

Learning Outcome: Design a filtration setup, while considering cost, to treat contaminated water.

Materials

Per group:

- simulated wastewater, about 1L
- single use bottle with cap
- aluminum sulfate (alum), about 15 grams (1 Tablespoon)
- stirring rod or similar
- funnel
- spoon
- cotton ball
- scissors
- 100 mL each of small pebbles or gravel, coarse sand, and fine sand
- 100 mL charcoal or activated charcoal (optional)
- 2 beakers or cups
- coffee filter (optional)
- cheese cloth (optional)
- water quality test kit (optional, https://amzn.to/38Wgkzk)

What to Do

1. With your group, design a way to treat a wastewater sample as effectively and as inexpensively as possible with the materials available to you.

   a. If you completed 5A1, consider your results. What processes were helpful? What mediums were most effective to use for filtration?

   b. Examine the handout, “Cost of Materials”, which includes the available materials to build your treatment system. Consider the cost and amount of the materials you would like to use.

   c. With the budget given to you, design a wastewater treatment system. Draw schematics and write notes as necessary. Run your design idea and your budget by your facilitator.

2. Once your design has been approved by your facilitator, construct the water treatment system you designed. If you make modifications to your design as you construct your system, be sure to make modifications to your schematic also.

3. Test out your system by treating 100–200 mL of wastewater.

4. Conduct water quality tests on the treated water.

5. Revise your design schematic and notes based on the first test.

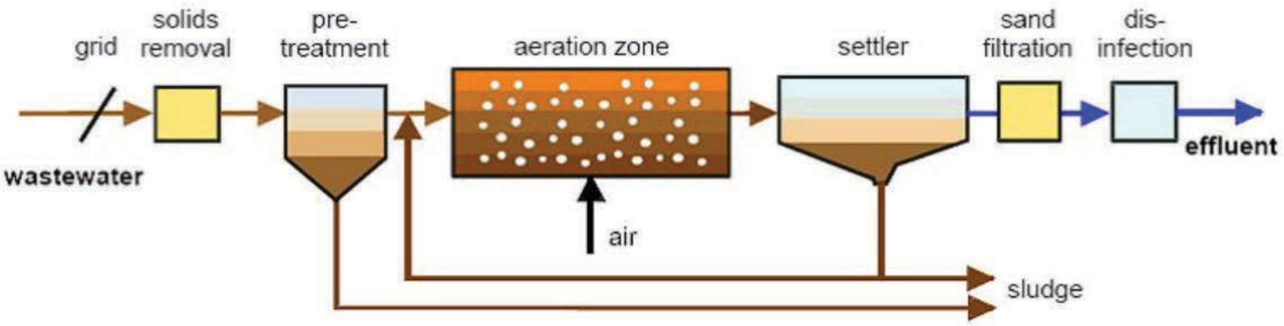
6. Be prepared to share your results with other groups.

Consider

1. How clean would you consider the treated water from your treatment systems and others? Explain your reasoning using evidence.

2. How would you further revise your water treatment system to be more effective? What other materials might you use that weren't available to you?

3. How does your system compare to typical treatment systems, like the image below?



Credit: Creative Commons, https://en.wikipedia.org/wiki/File:MBRvsASP_Schematic.jpg

4. How do you think the percentage of treated wastewater relates to the wealth of a community or nation? What impacts might this have on the community or nation?

Extensions

1. **Testing Variables:** There are a variety of handheld water treatment options available for use by people who travel where treated water is not available (e.g., in wilderness locations). Choose one and explain how it works. If possible, use this treatment method and treat puddle or lake water and conduct water quality tests on the treated water. Would you consider the water clean? What other tests would you want to conduct to prove this water is clean? Use evidence to back up your answer.

Safety Note: *Because it can't be guaranteed this method is 100% effective, the water should not be consumed.*

2. **Applying Concepts:** Learn about the water treatment plant in your community or a nearby community. What processes does the water go through while in the plant? Is there any testing or monitoring of the water quality before it leaves the treatment plant? How was the system you designed similar and different from the treatment plant near you?

3. **Applying Concepts:** Botswana is faced with water shortages and is promoting wastewater treatment and re-use as a solution. Read more about how Botswana is working to improve clean water and sanitation access by treating wastewater, at **https://bit.ly/3G6JNTp**. Why is Botswana faced with water shortages? How is the wastewater being treated? How is the treatment plan going so far? What are some of the challenges and lessons learned from implementing this treatment system? In what ways can Botswana's situation relate to other communities, including yours?

4. **Data Analysis:** Go to this website: **https://data.oecd.org/water/waste-water-treatment.htm**. Look at the graph, "Wastewater Treatment," which shows the percentage of three national populations connected to a public wastewater treatment plant (the y-axis) between 2000 and 2020 (the x-axis). Each line represents data from a different cou ntry. Hover over the lines to display the country names. Go to the drop-down menu titled "Featured Countries" and choose Sweden, Poland, and Mexico. This data does not take into account independent private facilities that treat wastewater.

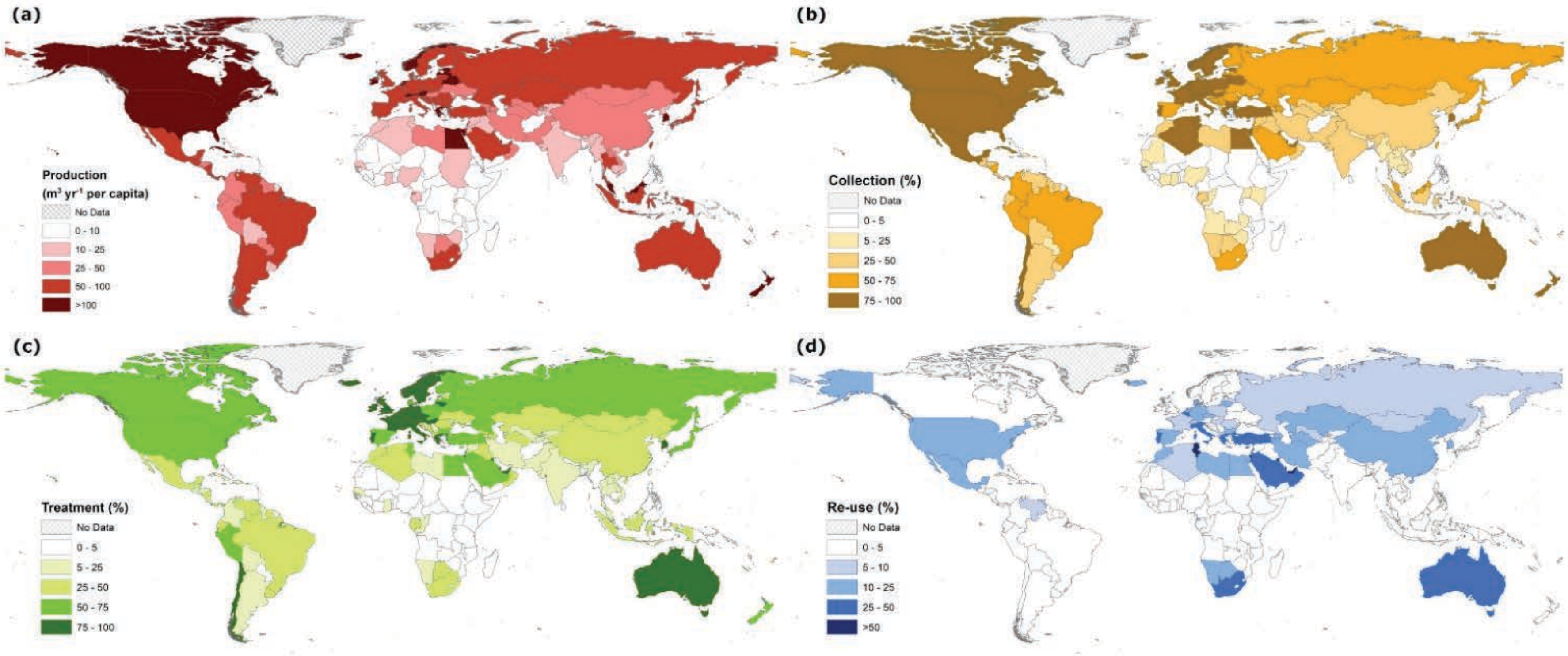
   a. Do you notice any trends in the data for the three countries? What might explain this/these trends?

   b. How do these three countries compare to other countries (shown in grey on the graph) in terms of the percentage of the population connected to public wastewater facilities?

   c. Find the data for your country. Go to **https://data.oecd.org/water/waste-water-treatment.htm** and select your country. How does the percentage of the population that is connected to a public wastewater treatment plant compare to these three countries? How does it compare to the rest of the world's data on this graph?

5. **Analyzing Data:** Examine the maps, Global Wastewater, which display a) wastewater production, b) collection, c) treatment, and d) re-use at the national scale. The data is displayed in proportional terms to facilitate direct comparisons between countries.

GLOBAL WASTEWATER



Credit: Jones et al. 2020, Creative Commons Attribution 4.0

a. What do you notice about the amount of wastewater produced versus treated, collected, or re-used?

b. Where do you see large differences in the data? What might explain why these differences exist?

c. If you can clearly see your country's data, what do you notice about your country's wastewater production, collection, treatment, and re-use? How does it compare to other countries? If you cannot clearly see your country, use your general region.

Cost of Materials

Budget: ________________________________ $100

2L bottle ________________________________ $10
Single serve bottle ________________________ $8
cotton ball _______________________________ $1
coffee filter ______________________________ $5
cheese cloth ___________________________ $2/$cm^2$
gravel _________________________________ $20/kg
small pebbles ___________________________ $25/kg
coarse sand _____________________________ $30/kg
fine sand _______________________________ $40/kg
charcoal _______________________________ $90/kg
activated charcoal ______________________ $100/kg
aluminum sulfate (alum) _________________ $50/kg

Total Spent: $ ______________________________

SUSTAINABLE DEVELOPMENT GOALS

GEOSCIENCE FOR SUSTAINABILITY

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INVESTIGATION 5B: TREATING WASTEWATER USING HEAT AND LIGHT

Learning Outcome: Distill a sample of contaminated water to determine the effectiveness of distillation as a water treatment method.

Materials

Per group:

- simulated wastewater, about 300 mL
- hot plate or Bunsen burner
- large beaker, or large heat resistant container
- small glass bowl that fits inside the beaker (https://amzn.to/3xrWvcE)
- Aluminum foil
- heat resistant gloves or oven mitts
- tongs (optional)
- ice (optional)
- water quality test kit (optional, https://amzn.to/38Wgkzk)

What to Do

1. Examine the wastewater sample.
   a. Write down observations of the sample.
   b. Optionally, conduct water quality tests on the sample.
2. Pour the sample into the large beaker and put it on the hot plate.
3. Place the small glass bowl in the beaker so it floats on the water sample. This is where the distilled water will collect.

Credit: L. Brase

4. Place a piece of aluminum foil over the beaker and press it down slightly in the middle so it dips inward towards the small collection bowl.

Credit: L. Brase

5. Carefully place the beaker on a hot plate and turn it on.

6. Optionally, place some ice cubes in the depression in the foil to enhance condensation.

Credit: L. Brase

7. Once the water is boiling, let the distillation process run for 10 minutes.

8. After 10 minutes, turn the hot plate off. Use heat resistant gloves to remove the aluminum foil.

9. Use the heat resistant gloves and tongs to carefully remove the interior small bowl that collected the distilled water.

Safety Note: *all materials will be extremely hot. Use heat resistant gloves and tongs to move materials around carefully. Follow additional safety instructions given by your facilitator.*

10. Examine the treated water in the small bowl.
    a. Write down observations of the treated sample.
    b. Optionally, conduct tests on the treated water sample, like the ones used in Investigation 3B.

Consider

1. Explain and draw a diagram of how the water moved from the large beaker on the hot plate to the collection bowl inside of it. When did the distillation begin working?

2. If you were to have measured the mass of the water sample before and after distillation, would it have been equal? Why do you think this?

3. Would you consider the sample clean after distilling it? Explain why or why not using evidence.

4. What are some advantages and limitations of using distillation as a water treatment method?

Extensions

1. **Testing Variables:** Another treatment method that utilizes heat is to boil water for a couple minutes. Conduct water tests on a sample of puddle or lake water near you. Then, with adult supervision, treat the water via boiling for 2 minutes and test the treated water. Would you consider this water clean? Why or why not? If not, what else could you do to make the water cleaner?

2. **Applying Concepts:** Repeat this procedure using the filtered water samples from Investigation 5A. Would you consider each sample 'clean'? Was this treatment method effective in cleaning each sample? Why or why not?

3. **Testing Variables:** Utilize the power of the sun instead of a hot plate. Design, construct, and test out a solar distillation setup.

INVESTIGATION 5C: OSMOSIS

Learning Outcome: Conduct diffusion and osmosis experiments to understand how water and other particles move.

Materials

Per group:

- clear cups, x3
- water (room temperature, hot, and cold)
- graduated cylinder
- stir rod or spoon
- food coloring
- 3 plastic bags
- scissors
- pencil
- pin, or similar sharp, small tipped object
- salt
- slices of air-dried potato (about 2.5 cm x 5 cm x 1 cm (1" x 2" x 0.5"), or small enough to fit in the cup), x3
- scale (grams)

What to Do

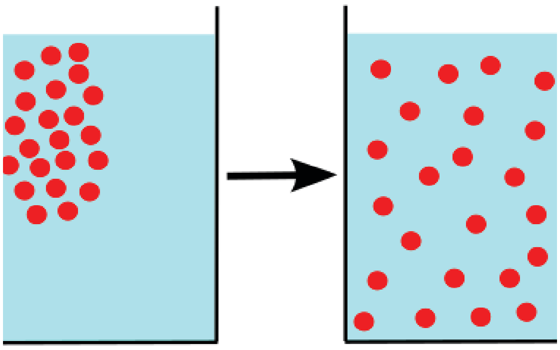
1. Think about how things mix.
   a. What would happen if you placed a drop of food coloring in water and stirred it? Explain why you think so.
   b. What would happen if you placed a drop of food coloring water and let it sit? Explain why you think so.
2. Experiment with how things mix.
   a. Pour 100 mL room temperature water in two cups.
   b. In the first cup, place a drop of food coloring in the water and stir for 10 seconds. Write down observations after stirring and again after a minute has passed.
   c. In the second cup, place a drop of food coloring in the water. Write down your observations after 10 seconds and again a minute.
   d. Pour out the water and rinse the cups.

e. Put 100 mL of room temperature water in the first cup, 100 mL hot water in the second cup, and 100 mL cold water in the third cup.

f. Place a drop of food coloring in all three cups around the same time.

g. Write down your observations after 10 seconds, 30 seconds, and 1 minute.

h. Pour out the contents of the cups and rinse them.



Credit: creative commons, author JrPol, https://commons.wikimedia.org/wiki/File:Diffusion.svg

3. Make a hypothesis: What do you think would happen if there was a barrier set up in the middle of the cup before the dye was added? How do you think this would affect movement of the water and the food dye?

4. Test the effect of different barriers on the movement of the dye:

   a. Add water to each of the three cups so they are three quarters full.

   b. Place the first plastic bag over one cup and add 100 mL water into the bag.

   c. Poke 5–8 holes using a pencil near one of the bottom corners of the second plastic bag.

   d. Place that bag over the second cup, with the corner that has the holes in the water.

   e. Add 100 mL water inside the bag.

   f. Poke 5–8 hole using a pin near one of the bottom corners of the third plastic bag.

   g. Place that bag over the third cup, with the corner that has the holes in the water.

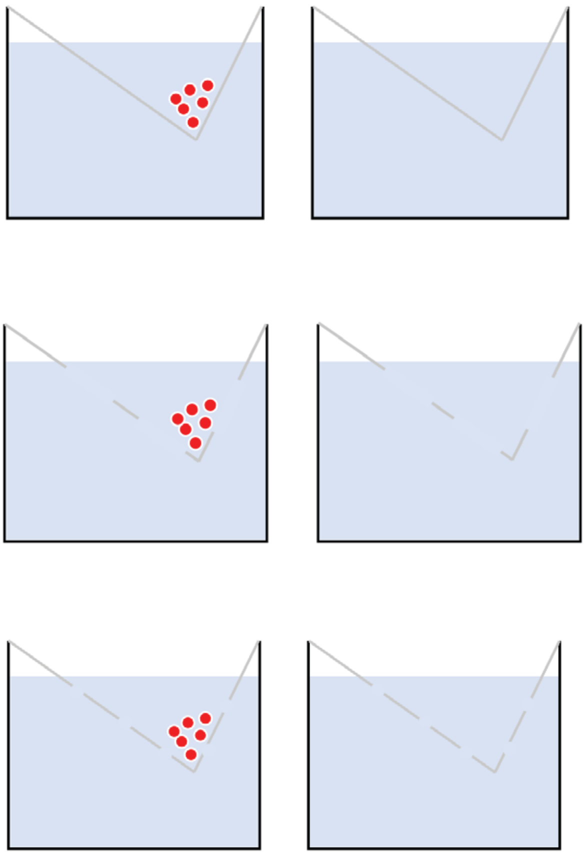
   h. Add 100 mL water inside the bag.

   i. Add 3 drops of food coloring inside each of the bags and stir.

   j. Write down your observations after 10 seconds, 30 seconds, and one minute.

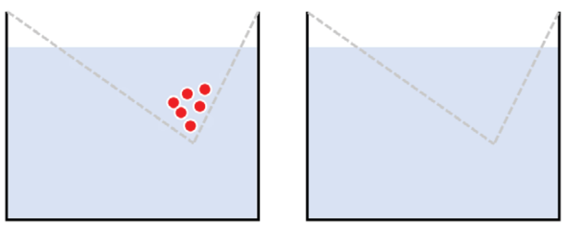
   k. Pour out the contents of the cups and baggies. Discard the bags and rinse the cups.

5. Examine the particle diagrams of the experimental setups. The red particles represent relatively large substances, such as sugar. The blue represents water that is made up of much smaller molecules in comparison to the red. Draw arrows for any movement that occurred, and then draw particle diagrams that you think represent the final results.



Credits: L.Brase

6. Plastic bags have microscopic pores (holes) that you can't see. How do you think that impacts the movement of molecules? Explain your prediction by drawing a particle diagram and use words.



Credit: L.Brase

7. The previous image describes a process called osmosis, which is when water molecules can pass through a membrane, but other particles cannot. Since the membrane allows some molecules through but not others, it is called semipermeable. Water molecules can flow both ways across the membrane, but the overall movement of water occurs from an area of higher water concentration to an area of lower water concentration. You will experiment with how osmosis works using potatoes:

   a. Label the three cups as "air," "water," and "water and salt."

   b. Pour 200 mL into the cups labeled "water" and "water and salt."

   c. In the cup labeled "water and salt," add 15 g (about 1 Tablespoon) of salt and stir.

   d. Obtain three potato slices. Take the mass of each slice.

   e. Place one potato slice in each cup. Keep track of which slice you put in each cup.

   f. After 15 minutes, remove the potatoes from their cups. Write down observations of all three potatoes.

   g. Take the mass of each potato slice.

   h. Calculate the percent change in mass using the equation below:

$$\% \; change \; in \; mass = \frac{final \; mass - initial \; mass}{initial \; mass} * 100$$

8. On the activity handout, “Practicing with Particle Diagrams and Osmosis,” examine the initial particle diagrams. The red particles represent relatively large substances, such as sugar. The blue represents water that is made up of much smaller molecules in comparison to the red. Determine if there will be any movement of particles or water. Draw arrows if you think there would be movement, and then draw what you predict the particle diagram would look like after some time passes.

9. Reverse osmosis is a water treatment method that uses the concept of osmosis in that a semipermeable membrane blocks, or filters, larger molecules but allows water to pass. Reverse osmosis uses pressure to push water in the opposite direction than it would naturally tend to go. Make some predictions for how water would move in reverse osmosis on the activity page, “Practicing with Particle Diagrams.”

Consider

1. How did the three potatoes differ after the 15 minutes? Why do you think these changes took place? Explain with words and diagrams.

2. Imagine sandy water being poured through a coffee filter. How do you think this model is similar to and how is it different from reverse osmosis?

3. Consider the process of diffusion:

   a. What may happen when a contaminant enters a lake or river?

   b. How does diffusion of a contaminant affect its toxicity or the likelihood of it causing harm?

Extensions

1. **Testing Variables:** Test osmosis in egg cells. Place 5 fish eggs next to a ruler to measure the total length of all 5 eggs. Place these eggs in a cup or beaker that contains 100 mL fresh water (preferably bottled, filtered, or distilled). Repeat this with another 5 eggs but place them in a cup or beaker containing 100 mL salt water. Repeat this with another 5 eggs but place them in a cup or beaker containing 100 mL sugar water. Label the cups or beakers and let the fish eggs sit in the solutions for at least 30 minutes. Remove each set of eggs and measure their combined lengths, as done at the beginning of the experiment. What do you notice? How have the eggs changed, if at all? Explain what happened using words and pictures.

2. **Applying Concepts:** Learn about the types of water treatment methods you have in your home or community. Is reverse osmosis used? If so, is it used alone or in combination with other treatment methods?

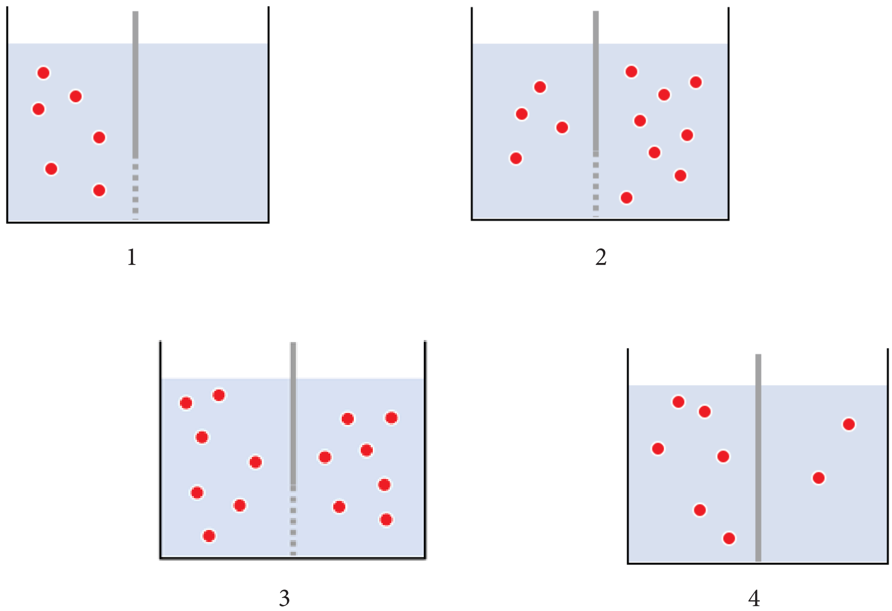
3. Using *Scratch*®: Create a *Scratch*® project or remix an existing project to explore diffusion, osmosis, and reverse osmosis. Here are three projects to look at and possibly remix:

   - Diffusion: **https://scratch.mit.edu/projects/701068790/**
   - Osmosis: **https://scratch.mit.edu/projects/701148785/**
   - Reverse Osmosis: **https://scratch.mit.edu/projects/701665732/**

Practicing with Particle Diagrams

Osmosis

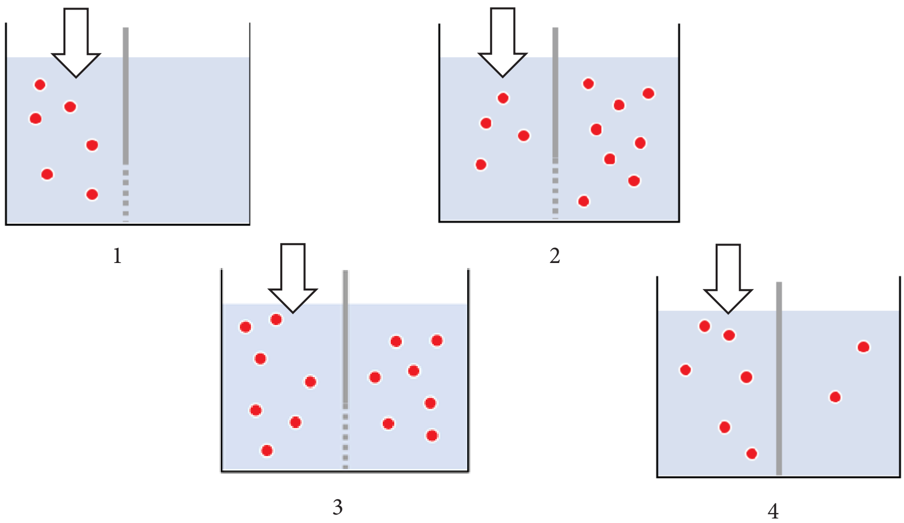
On each particle diagram, determine if there is a side that has a higher or lower concentration of particles. By osmosis, water would move from the lower to the higher concentration through a permeable membrane. Draw an arrow showing overall how you predict the water would move.



Credit: L Brase

Reverse Osmosis

For reverse osmosis to take place, pressure needs to be applied to push the water molecules through the semipermeable membrane. On each diagram, identify how the water would move.



Credit: L. Brase

ESD KIT:
ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 6A: ASSESSING YOUR WATER FOOTPRINT

Learning Outcome: Conduct and assess a personal water footprint analysis to learn how water is used directly and indirectly in daily life.

Materials

Per learner:

- "Assessing Your Water Footprint" handout

What to Do

1. Think about all the ways you use water and how water is used in your house or at your school.
2. Water use can be categorized as household (direct) water use and virtual (indirect) water use.
   a. Household water use includes taking a bath or shower or washing a car. What other water uses could be classified as household water use?
   b. Virtual water use includes the water that goes into making the things you buy or the energy you use. What are other items you use or things that you do that could use virtual water?
3. The ways in which you use water directly and indirectly can be analyzed to calculate your water footprint. Answer the questions on the handout, "Assessing Your Water Footprint" as a starting point to analyzing your household and virtual water use.
4. Add up your score in each category. Column one (furthest to the left) is worth one point, column two is worth two points, column three is worth three points, and column four (furthest to the right) is worth four points.

a. How many points did you calculate for the household, indoor category? What is your water use in the household, indoor category: low (11–22 points), medium (23–33 points), or high (34–44 points)?

b. How many points did you calculate for the household, outdoor category? What is your water use in the household, outdoor category: low (6–12 points), medium (13–18 points), or high (19–24 points)?

c. How many points did you calculate for the virtual water use category? What is your water use in the virtual water category: low (9–18 points), medium (19–27 points), or high (28–36 points)?

5. Discuss some ideas about how to reduce your water footprint with your group members. Remember, little changes can make a big difference.

Assessing Your Water Footprint

Household Water Use, Indoor				
How many people are in your household?	< 4	4 or 5	5 or 6	> 6
How long is the average shower in your household?	< 5 min	5–10 min	11–15 min	>15 min
How often is a bath drawn in your house?	Never	~1–4 baths per week	~ 1 bath per day	>1 bath per day
How long are the bathroom faucets running each day?	< 5 min	5–10 min	11–30 min	> 30 min
Do you have low-flow shower heads, faucets, or toilets?	Yes, all	Yes, most	Yes, a few	No
Do you always flush the toilet?	No, flushing occurs after many uses	Not always, flushing occurs after a few uses	Most of the time	Yes, always
How long is the kitchen faucet running each day?	< 5 min	5–10 min	11–30 min	> 30 min
How are dishes washed?	Thrown away, so no dishes are washed	Water/energy efficient dishwasher	By hand	Older dishwasher
How is laundry done?	Water/energy efficient washing machine	By hand	Older washing machine	At a laundromat
Are pipes and faucets checked for leaks?	Yes, often and they are fixed immediately	Yes, and they are fixed eventually	Rarely	Never
Are there any indoor plants that need to be watered?	No	Yes, a few plants that don't need a lot of water (for example succulents)	Yes, a few plants with normal to high water needs	Yes, many plants

Household Water Use, Outdoor				
Do you have a rain barrel or greywater system installed in your home?	Yes	No		
If you have a lawn or garden that is watered, how large is it?	No	Yes, it is < 50 sq meters (540 sq ft)	Yes, it is 50 sq meters (540 sq ft) to an acre	Yes, it is larger than 1 acre
If you have a lawn or garden that is watered, how often is it watered?	I don't a lawn or garden to water	Less than or about once a week	1–5 times a week	Daily
Do you have a swimming pool? If so, how often is it covered?	No	Yes, >8 months	Yes, 1–8 months	Yes, it does not get covered
How many cars does your family own?	None	1	2	3 or more
How often is the car or are the cars washed?	Never	Rarely, < 2 times a year	Sometimes, 3–5 times a year	Often, > 5 times a year

Virtual Water Use				
How many miles does your family drive per week?	None	0–50 miles	50–100 miles	>100 miles
Does your home have electricity? Where does your electricity come from?	No	Yes, all to most generated at home	Yes, some generated at home or we are involved in green power programs	Yes, all generated through electric utilities
How often does your family grocery shop?	Less than once per week	Once per week	2–4 times per week	Daily
How often does your family shop for other items besides food?	We only shops for basics	We shop occasionally	We shop often	We shop daily
Do you recycle paper, plastic, bottles, cans?	Yes, all of those items all of the time	Yes, most of those items most of the time	Yes, some of those items some of the time	No, none or only one of those items infrequently
Do you donate or re-use old clothing or linens?	Always	Sometimes	Rarely	No
What is your diet?	Vegan	Vegetarian	Occasionally eat meat	Regularly eat meat
Do you have a pet such as a cat or dog? How many cups of pet food is given each day?	No	Yes, about 1–2 cups	Yes, 2–6 cups	Yes, > 6 cups
How many disposable versus reusable items are in your house?	Most items are reusable	A mix of both, but more reusable	A mix of both, but more disposable	Most items are disposable

Consider

1. Did any questions or topics in the "Assessing Your Water Footprint" questionnaire surprise you? What uses of water had you not considered prior to the assessment?

2. Consider how much water you directly use when you are outside the home. How might this effect your water footprint?

3. When disposable plates or cookware are used then discarded, no water is needed to clean up, resulting in a lower water footprint compared with cleaning reusable dishes.

   a. Does this mean that disposable items are better in terms of sustainability? Why do you think so?

   b. Consider how much virtual water it takes to create disposable plates and reusable plates. How might this impact your argument above?

4. Think about the building you are in and what it is mostly used for.

   a. What features of the building do you think contribute most to its water footprint?

   b. How could users of the building help lower the building's water footprint? What steps could you as an individual do to help lower its water footprint?

5. How do the types of water quality vary for each of the uses mentioned? Which uses need safe drinking water? Which could be sufficient with untreated surface water? Given your answers, how important is access to safe drinking water?

Extensions

1. **Applying Concepts:** With an adult from your household, calculate your water footprint by answering similar questions at **https://www.watercalculator.org/wfc2/q/household/**. You will receive an actual value for your water footprint, and how your footprint compares to others. What was your total footprint? Where do you rank compared to others? Were there any questions that surprised you or facts that you learned? Discuss the quiz and your results.

2. **Applying Concepts:** Conduct a water audit at home.

   a. Time how long it takes you and others to wash hands, shower, and so on. Then, collect the water from the same faucet or showerhead for one minute and measure the volume of water. This is the amount of water released per minute. Calculate the volume of water used for the tasks you audited.

   b. What are some ways in which water use could be reduced for the tasks you audited? Which ways can you implement on your own and which do you need help from an adult to implement?

3. **Applying Concepts:** One way to reduce your water footprint is to use rainwater collected in a rain barrel for watering lawns and other plants, washing cars, and so on. You can create a rain barrel by just collecting rain in a bucket, by placing the bucket beneath a drain spout if you have one, or you can design and build a larger rainwater system with a downspout. Create a design, build it, and start collecting water. When it rains, how successful is your rain barrel at collecting the rain? What sorts of ways do you plan to use the collected rainwater? What are the drawbacks of collecting rain in an open container versus designing or using a rain barrel?

4. **Applying Concepts:** Learn more about the virtual water that is used to make something you consume or buy often.

    a. How much water is used to create or grow the item? How much water is used to process the materials that make the item? How much water is used to transport the item? Write down all the ways water use could be related to your item. What alternatives might you use for this item that require less water use?

    b. The Water Footprint Network compiled data about the water footprint of various products, such as an apple, cheese, and leather. Visit **https://waterfootprint.org/en/resources/interactive-tools/product-gallery/** and check out the average water footprint for five objects you use often.

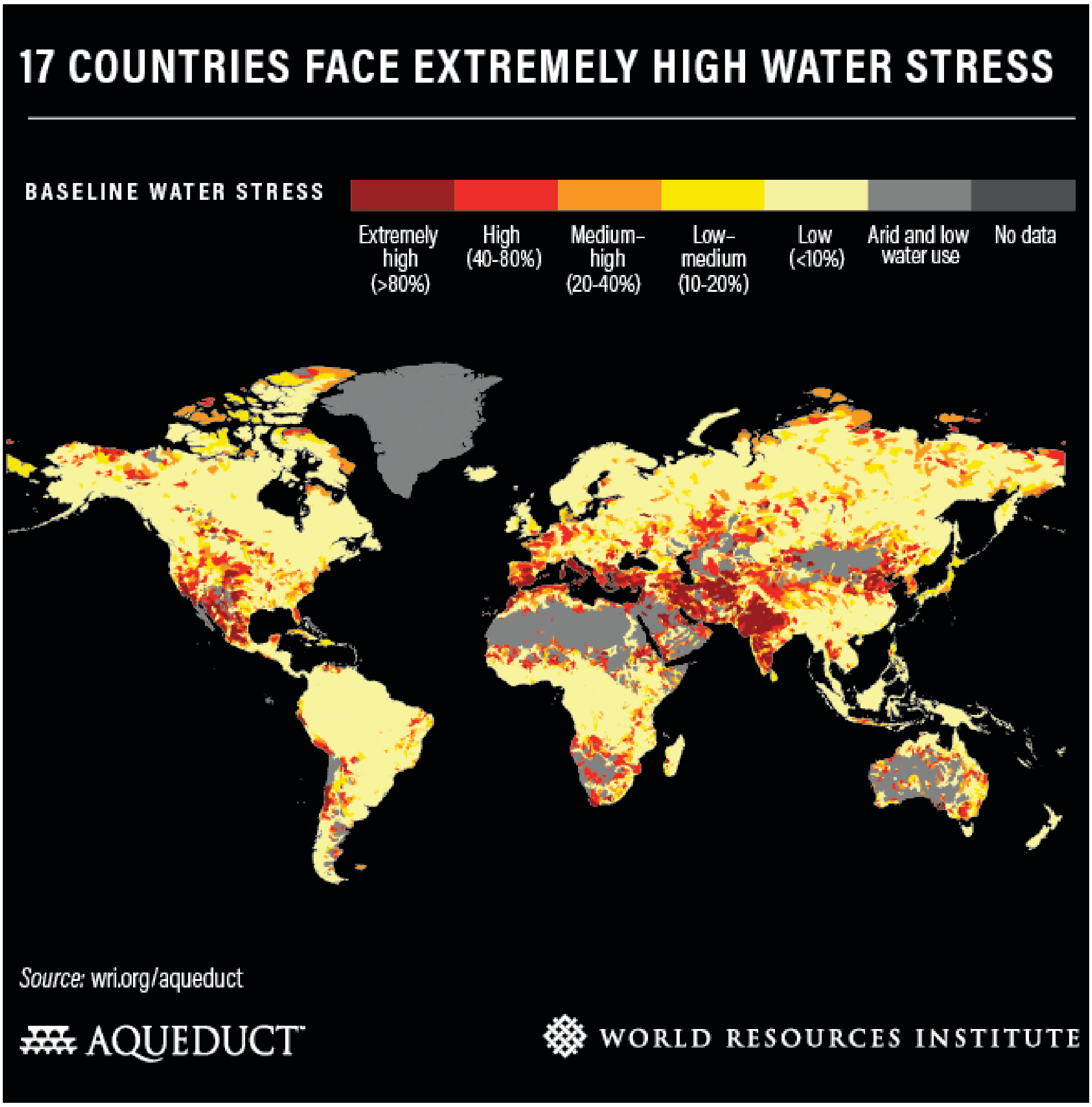
5. **Analyzing Data:** Analyze the map, "Water Stress Around the World", which displays areas according to their baseline water stress.

    a. What areas are experiencing high or extremely high water stress? Is there a trend between or similarities between these locations?

    b. What factors might go into why certain areas have higher water stress than others?

    c. Find your country on the map. According to the map, how does your area classify in terms of water stress? Does this classification also apply for your community? Why do you think so, or why do you think it differs?

WATER STRESS AROUND THE WORLD



Credit: World Resources Institute, https://www.wri.org/insights/17-countries-home-one-quarter-worlds-population-face-extremely-high-water-stress

6. **Analyzing Data:** The Water Footprint Network displays an interactive map which shows nation's water footprints at https://www.waterfootprintassessmenttool.org/national-explorer/. Locate your country and learn about the water footprint. How does it compare to other nearby countries? Examine the map in Extension Question 5. How does the water footprint map compare to the water stress map in question 5?

7. Using *Scratch*®: Remix *Scratch*® projects to look more at your water footprint.

   a. This project looks at water use in the bathroom: https://scratch.mit.edu/projects/735014212/. What is your bathroom water footprint? How does it compare to others? Make a similar *Scratch*® project for other rooms in your house.

b. This project looks at the water footprint of different foods: **https://scratch.mit.edu/projects/735014569/**

c. Which foods require the most water to produce or grow? Why do you think this is? Remix the project by adding more foods. This site provides information on the water footprint of various foods: **https://www.watercalculator.org/water-footprint-of-food-guide/**

d. Find another *Scratch*® project on water footprints at: **https://scratch.mit.edu/search/projects?q=water%20footprint**

INVESTIGATION 6B: WATER USE AROUND THE GLOBE*

*Modified with permission from The Water Project, **https://thewaterproject.org/resources/lesson-plans/water-water-anywhere**

INVESTIGATION 6B1: WATER AVAILABILITY SCENARIOS

GROUP 1: WATER ABUNDANCE

Learning Outcome: Analyze a scenario to explore how access to water is balanced with the needs of a population.

Materials

Per group:

- 10 cups
- gallon container labeled “Resources”
- 700–800 mL (24–27 oz.) water bottle, preferably clear
- 1 large bowl labeled “Water Abundant”
- towel

What to Do

Scenario: You are in an area of water abundance. Water conservation is something you know about but does not seem relevant since where you live there is always access to freshwater and advanced technologies to treat the water. Even though it is abundant, water is distributed unevenly between agricultural, industrial, and human needs. In this simulation, you will be the one distributing water to each of these needs. You may not have enough time to fill all of your population’s needs, so choose which cups are most important to fill first. Use what is left of your five minutes to provide water for this population.

Safety Note: *Clean up any spills immediately to prevent slipping.*

1. Fill your “Needs” cups from your “Resources” container. Have one person at a time choose a cup to fill and pour the water into the cup as full as they would like.
2. Note how full the cup is in the table then transfer the water into the “Population” bottle.
3. Take turns repeating steps 1 and 2. Repeat until all ten cups have been used, you run out of time, or run out of water.

4. When the five minutes are up, transfer all the water back into the “Resources” container and wipe up any spills with the towel.

DATA COLLECTION FOR WATER ABUNDANCE STATION

	1	2	3	4	5	6	7	8	9	10
Need	Agricultural							Industrial		Human
How full?										

Consider

1. Did your population have enough water to fill the water bottle?
2. How did you decide to fill the cups?
3. Did any cups not get filled at all? What impact may that have?
4. How did you feel about the work you had to do to get the water?
5. How did you feel about the quality of water the population had access to?
6. If you were to repeat this, would you change anything about the order in which you filled the cups? What about how much you filled each cup? Why or why not?

GROUP 2: PHYSICAL WATER SCARCITY

Learning Outcome: Analyze a scenario to explore how access to water is balanced with the needs of a population.

Materials

Per group:

- 10 cups
- small container (about 0.7 L [3 cups]) labeled "Resources"
- 700–800 mL (24–27 oz.) water bottle, preferably clear
- 1 large bowl labeled "Physical Scarcity"
- towel

What to Do

Scenario: You are in an area that has physical water scarcity. You may be located near a desert, or your population may have grown large enough to put a strain on your water resources. You may not have enough time to fill all of your population's needs, so choose which cups are most important to fill first. Use what is left of your five minutes to provide water for this population.

Safety Note: *Clean up any spills immediately to prevent slipping.*

1. Fill your "Needs" cups from your "Resources" container. One person at a time should choose a cup to fill and pour water from the "Resources" container into the cup as full as they would like.
2. Note how full the cup is in the table then transfer the water into the "Population" bottle.
3. Take turns repeating steps 1 and 2. Repeat until all ten cups have been used, you run out of time, or run out of water.
4. When the five minutes are up, transfer all the water back into the "Resources" container and wipe up any spills with the towel.

DATA COLLECTION FOR PHYSICAL WATER SCARCITY STATION

	1	2	3	4	5	6	7	8	9	10
Need	Agricultural							Industrial		Human
How full?										

Consider

1. Did your population have enough water to fill the water bottle?
2. How did you decide to fill the cups?
3. Did any cups not get filled at all? What impact may that have?
4. How did you feel about the work you had to do to get the water?
5. How did you feel about the quality of water the population had access to?
6. If you were to repeat this, would you change anything about the order in which you filled the cups? What about how much you filled each cup? Why or why not?

GROUP 3: ECONOMIC WATER SCARCITY

Learning Outcome: Analyze a scenario to explore how access to water is balanced with the needs of a population.

Materials

Per group:

- 10 cups
- opaque pitcher or container, labeled “Resources”
- gallon container, labeled “Potential”
- baster
- 700–800 mL (24–27 oz.) water bottle, preferably clear
- 1 large bowl labeled “Economic Scarcity”
- towel

What to Do

Scenario: You are in an area that has economic water scarcity. There is a nearby source of good source of water, but you are not allowed access to it. This might be due to political unrest, a conflict, private ownership of the land where the water is located, or a lack of money. Instead, you use a water source that is not as close and not as clean. You may not have enough time to fill all your population’s needs, so choose which cups are most important to fill first. Use what is left of your five minutes to provide water for this population.

Safety Note: *Clean up any spills immediately to prevent slipping.*

1. Fill your “Needs” cups from your “Resources” container (opaque pitcher) which is located across the room. One person at a time should use the baster to fill the cup as full as they would like.
2. Note how full the cup is in the table then transfer the water into the “Population” bottle.
3. Take turns repeating steps 1 and 2. Repeat until all ten cups have been used, you run out of time, or run out of water.

4. When the five minutes are up, transfer all the water back into the “Resources” container and wipe up any spills with the towel.

DATA COLLECTION FOR ECONOMIC WATER SCARCITY STATION

	1	2	3	4	5	6	7	8	9	10
Need	Agricultural							Industrial		Human
How full?										

Consider

1. Did your population have enough water to fill the water bottle?
2. How did you decide to fill the cups?
3. Did any cups not get filled at all? What impact may that have?
4. How did you feel about the work you had to do to get the water?
5. How did you feel about the quality of water the population had access to?
6. If you were to repeat this, would you change anything about the order in which you filled the cups? What about how much you filled each cup? Why or why not?

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 6B2: ANALYZING WATER USE (DATA-DRIVEN INVESTIGATION)

Learning Outcome: Analyze data to explore how access to water is balanced with the needs of a population.

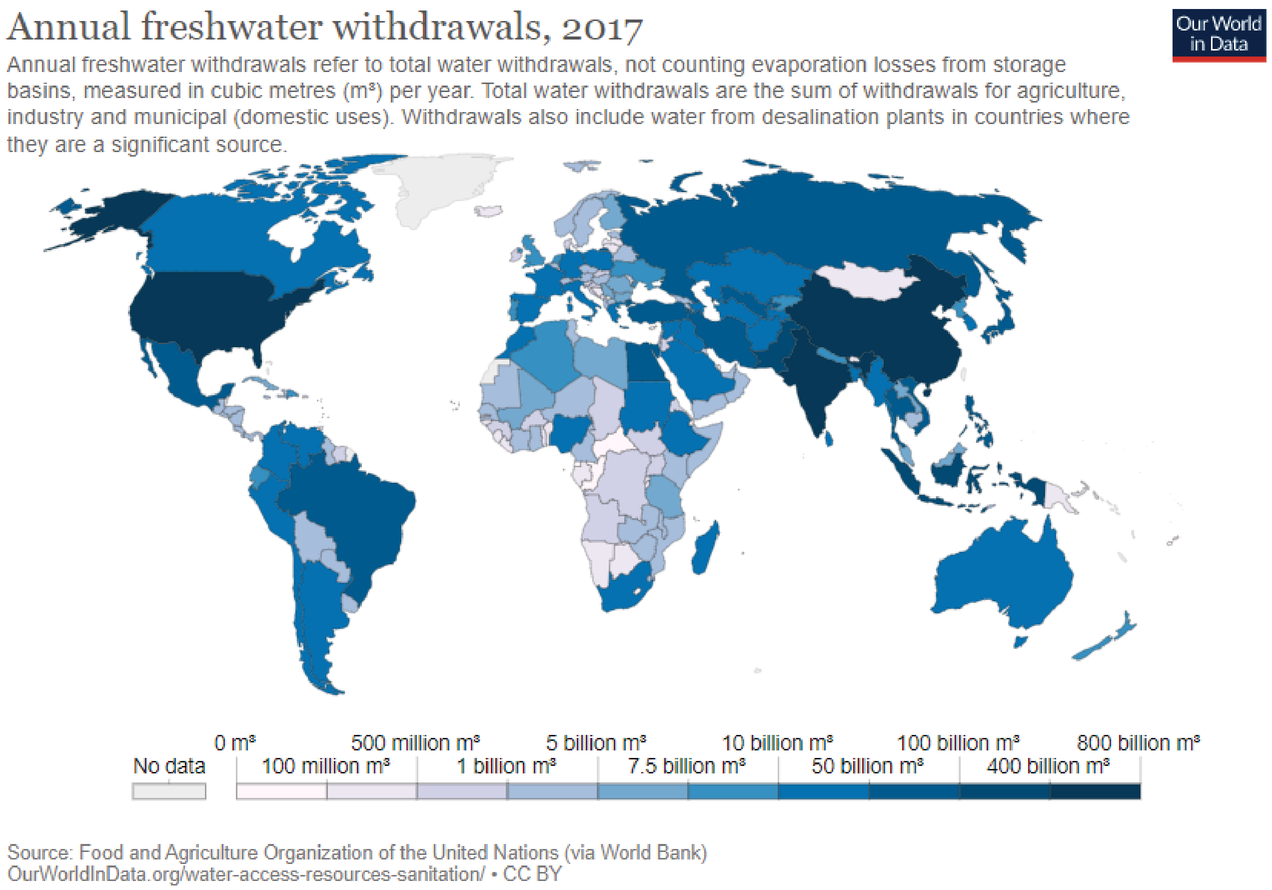
Materials

Per learner:

- copy of maps within Investigation

What to Do

1. Investigation 6B1 examined how access to clean water can vary. For example, it could depend on physical abundance, economics, or both. When there is limited access to clean water, there are decisions to make as to how the water will be used. Examine the map, “Annual freshwater withdrawals, 2017” and read the map description.



Credit: Our World in Data, Food and Agriculture Organization of the United Nations (via World Bank)

a. Which areas have the highest freshwater withdrawal? Why might this be?

b. Which areas have the lowest amount of freshwater withdrawal? Why might this be?

c. Locate your country on the map. Describe your country's annual freshwater withdrawal and how it compares to other nearby countries.

d. If you are able to examine the data online, visit **https://ourworldindata.org/water-use-stress** and examine the graph, "Renewable freshwater resources per capita."

e. Observe the time lapse of the graph. How has water withdrawal changed since 1965?

- In the drop-down menu on the right of each graph, select the continent where you are located to zoom in on the data near you. How do the countries on your continent compare to each other in 2017?

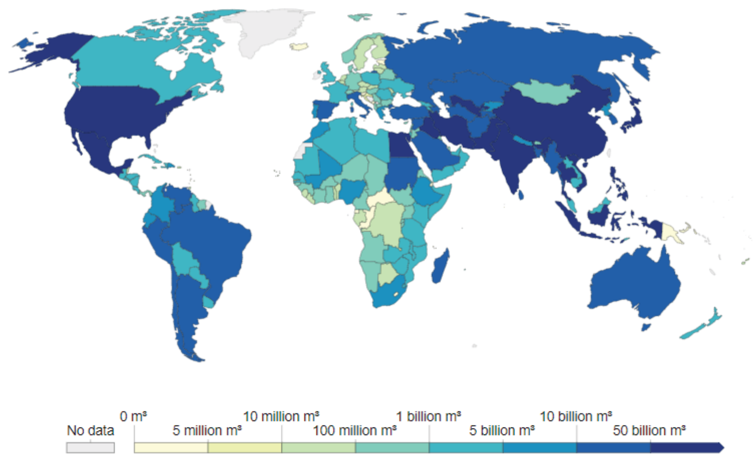
- Click on the "Chart" tab below the map. Add your country to the displayed data by selecting "Add country" in the top left. How do the countries compare to each other? How does the data change over time?

2. Examine the maps and read the map descriptions of three sectors of water use "Agricultural water withdrawals, 2015, "Industrial water withdrawals, 2015," and "Municipal water withdrawals, 2015."

Agricultural water withdrawals, 2015

Our World in Data

Total agricultural withdrawals, measured in m³ per year. Agricultural water is defined as the annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes.

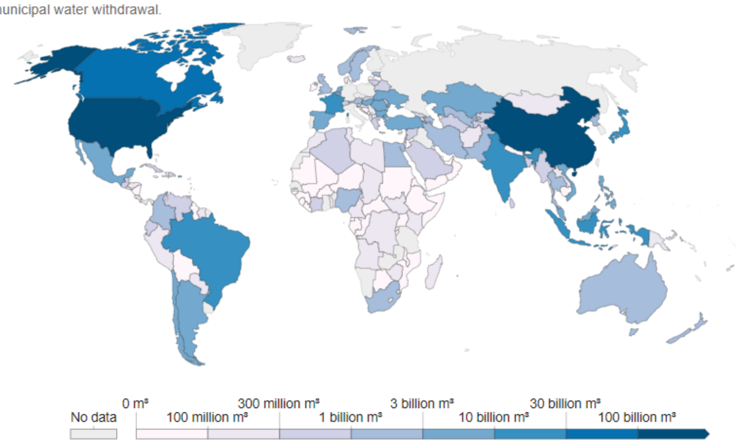


Source: UN Food and Agricultural Organization (FAO) AQUASTAT   OurWorldInData.org/water-access-resources-sanitation/ • CC BY

Industrial water withdrawal, 2015

Our World in Data

This measures the annual quantity of self-supplied water withdrawn for industrial uses, in cubic metres (m³) per year. It includes water for the cooling of thermoelectric and nuclear power plants, but it does not include hydropower. Water withdrawn by industries that are connected to the public supply network is generally included in municipal water withdrawal.

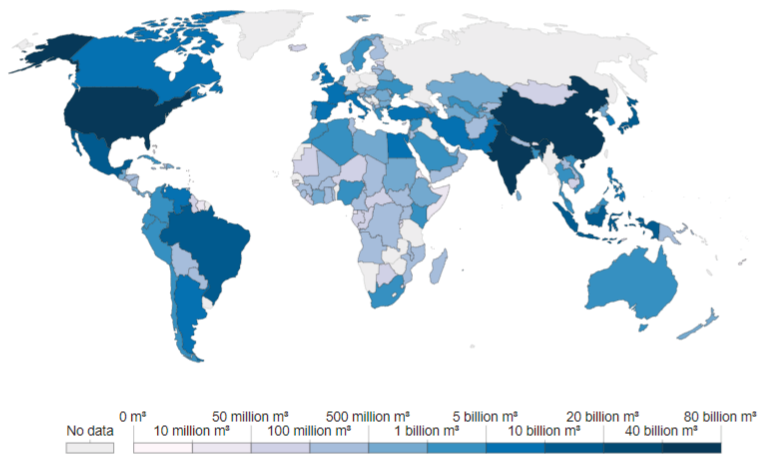


Source: UN Food and Agricultural Organization (FAO) AQUASTAT   OurWorldInData.org/water-access-resources-sanitation/ • CC BY

Municipal water withdrawal, 2015

Our World in Data

Total water withdrawal for municipal (domestic) purposes, measured in cubic metres (m³) per year. Municipal water is the annual quantity of water withdrawn primarily for the direct use by the population.



Source: UN Food and Agricultural Organization (FAO) AQUASTAT   CC BY

Maps credit: Our World in Data, UN Food and Agricultural Organization (FAO) AQUASTAT

a. How is most water used around the world? Why do you think this is?

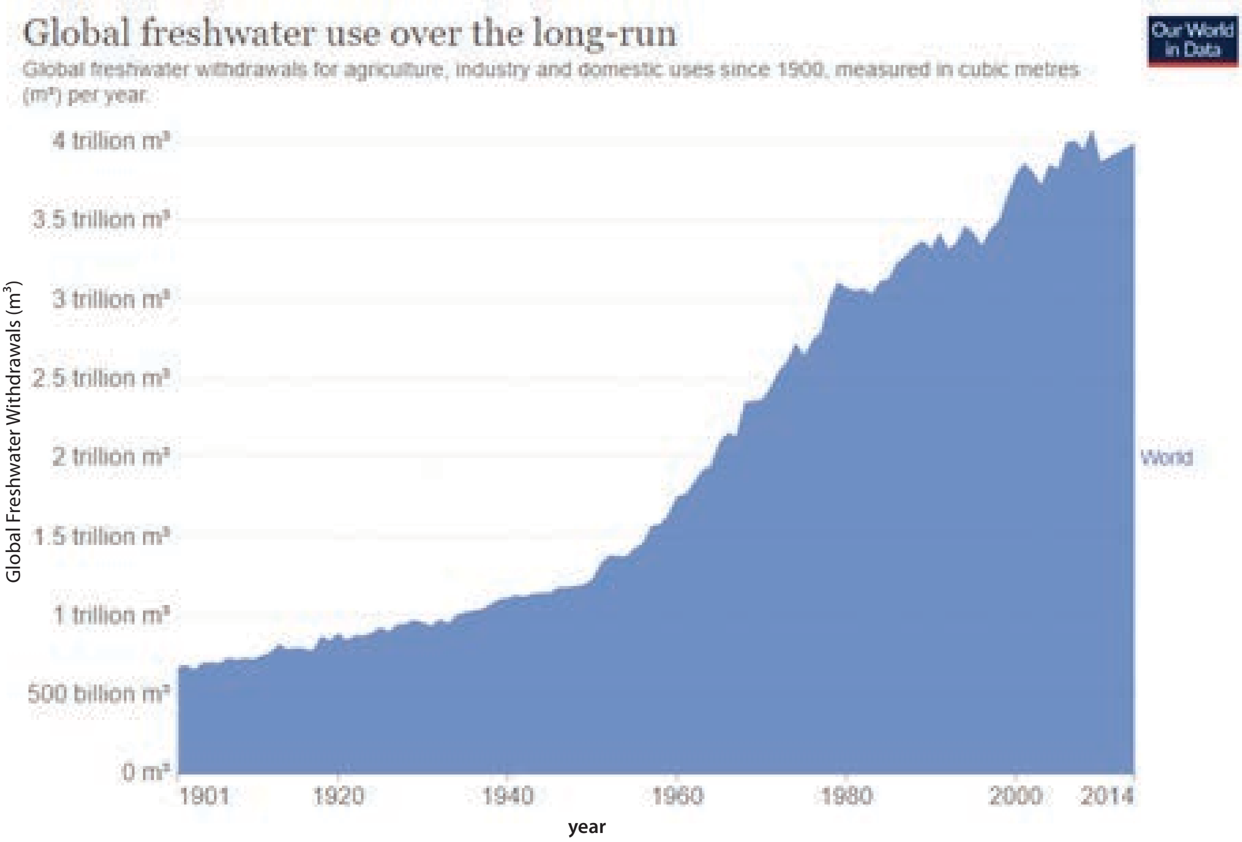
b. How does water withdrawal vary for most countries between the three sectors? Are the withdrawals similar or different? Is one sector always higher or lower? Why do you think so?

c. Locate your country on the maps. Describe your country's agricultural, industrial, and municipal water footprints and how they compare to other countries nearby. Why do you think your country's footprint is higher or lower than other countries?

d. If you are able to examine the data online, visit **https://ourworldindata.org/water-use-stress** and examine the graphs.

- Observe the time lapses of each graph. How has water withdrawal in each of the three sectors changed since 1965?
- In the drop-down menu on the right of each graph, select the continent where you are located to zoom in on the data near you. How do the countries on your continent compare to each other in the most recent data?
- Click on the "Chart" tab below the map. Add your country to the displayed data by selecting "Add country" in the top left. How do the countries compare to each other for each chart? How does the data change over time for each chart?

3. Examine the graph, "Global freshwater use over the long-run." What do you notice about this graph? What might explain the trend(s) you see?



Credit: Our World in Data.org/water-access-resources-sanitation, Global International Geosphere-Biosphere Programme (IGB)

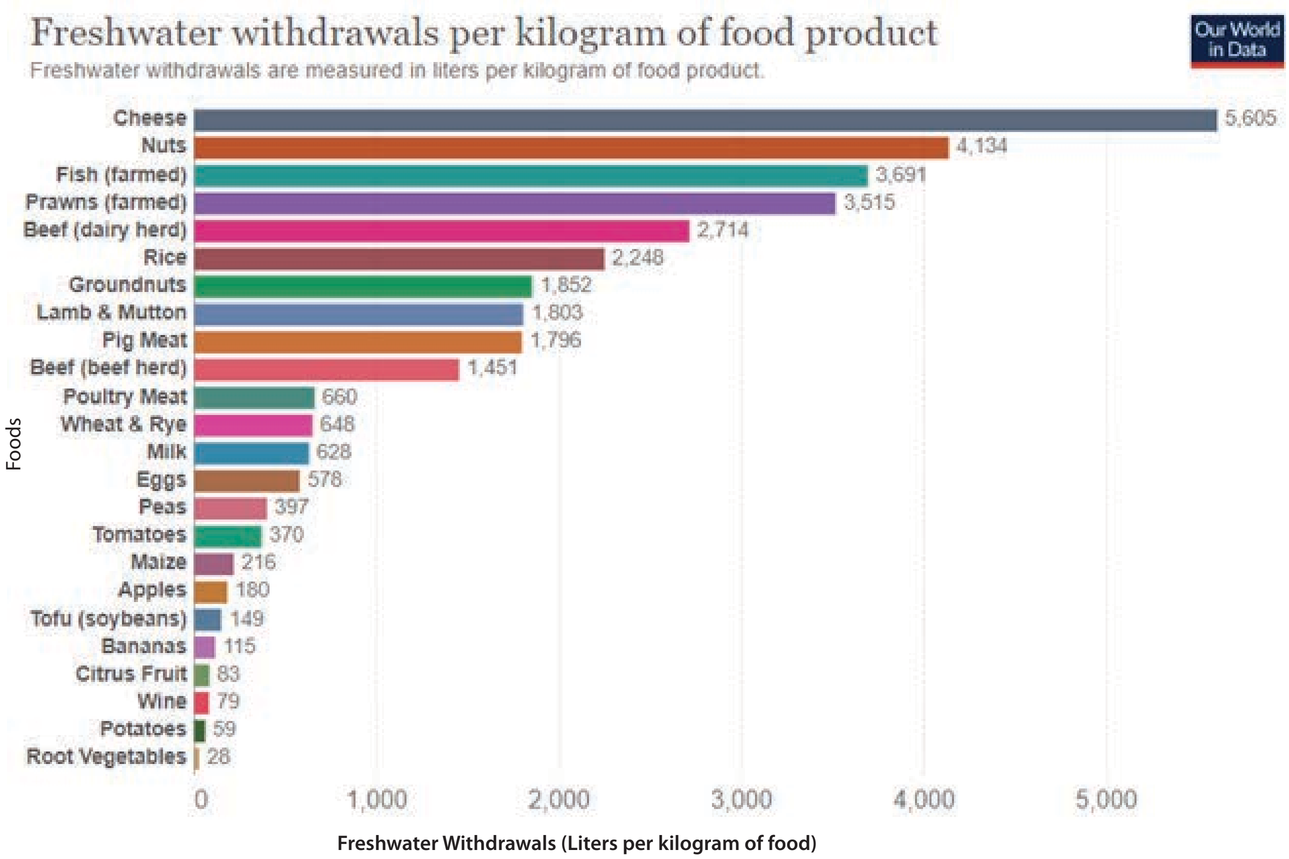
4. While a lot of water is withdrawn for agriculture in general, water requirements vary depending on the product. Examine the graph, "Freshwater withdrawals per kilogram of food product."

a. What trends, if any, do you notice any trends in the data?

b. What, if anything, surprised you about the data?

c. Circle the items you typically eat and examine the amount of water withdrawal for each product.

d. How might you adjust your diet to help lower your contribution of water use?



Credit: Poore, J. & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Our World in Data.

Consider

1. How has examining the data about water withdrawal impacted your perception of global water issues?

2. What new information resonated with you?

3. What actions could politicians and/or city officials take to help with water scarcity issues?

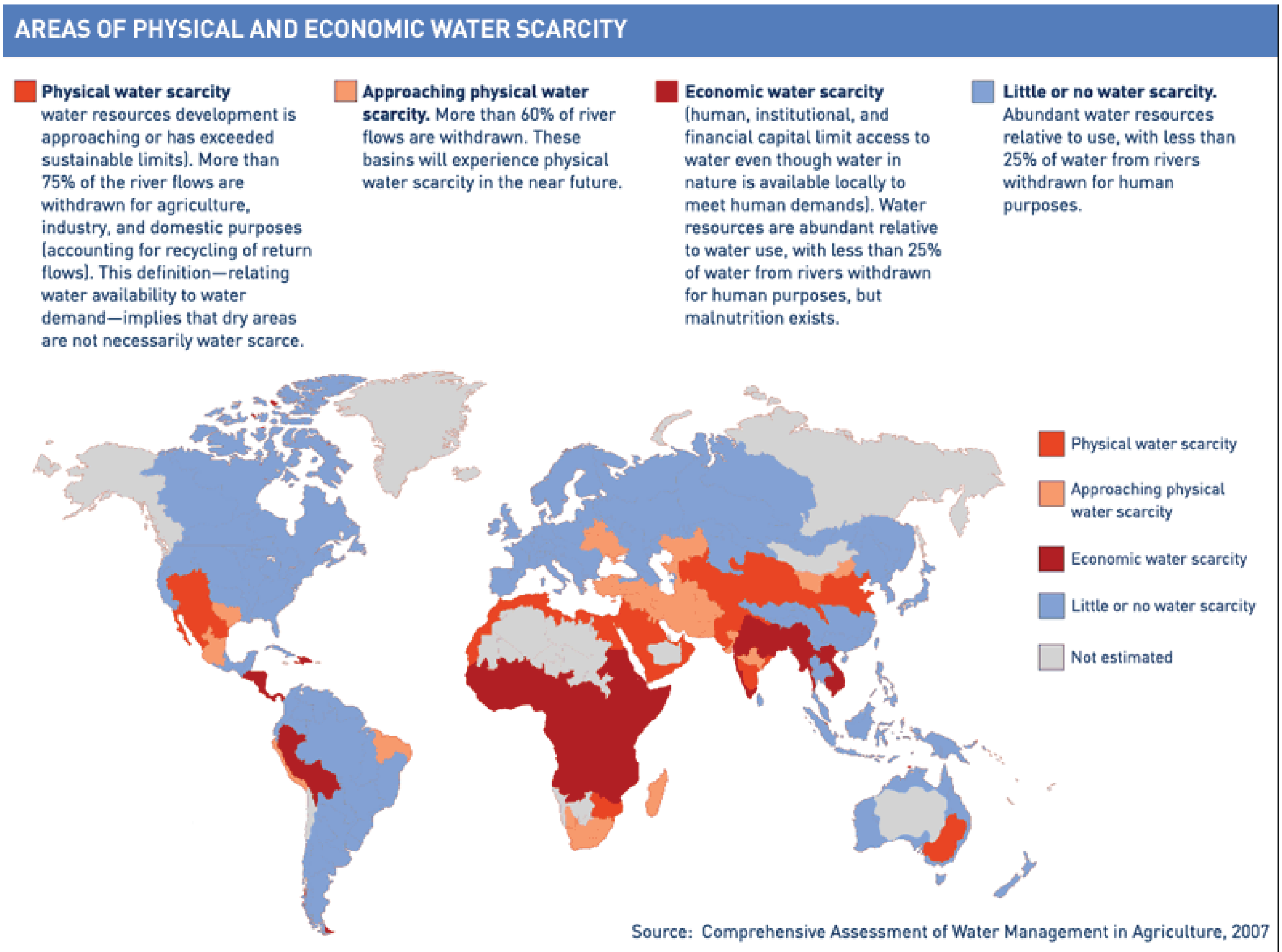
Extensions

1. **Applying Concepts:** Watch the short film about a girl collecting water three times a day, by Water is Basic (**https://bit.ly/waterisbasic_shortfilm**). The filmmakers pose the question, "How can one little girl's life be changed if she is given easy access to clean water?" What are your thoughts?

2. **Testing Variables:** Think about how physical and economic scarcity were modeled in the Investigation 6B1 scenarios. How else could the procedures have been written to represent physical water scarcity and economic water scarcity? If possible, test out the new procedures and see how those changes impact the results.

3. **Analyzing Data:** Go online to examine and analyze other data related to water use stress (**https://ourworldindata.org/water-use-stress**). Scroll through the different maps and graphs. Hover your cursor over a country for more information. Investigate more details about your country and how it compares with others nearby and with the world.

4. **Analyzing Data:** Examine the map, "Areas of physical and economic water scarcity" from 2007 and the corresponding information. Locate your country on the map. How is your area classified? Do you agree or disagree with the map classification? If you perceive your area's water scarcity differently than what the map shows, why might this be?



Credit: Food and Agriculture Organization of the United Nations, Comprehensive Assessment of Water Management in Agriculture, 2007.

ESD KIT: ACCESS TO CLEAN WATER

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 7: WATER USE AND HYGIENE

Learning Outcome: Test different hand washing methods to remove a germ simulant in order to realize the importance of good hygiene practices.

Materials

Per learner:

- "Handwashing Techniques" handout

Per group:

- Glo Germs (**https://amzn.to/3sFYJSX**, or similar)
- UV light (**https://amzn.to/39tPNZY**, or similar)
- sink with running water or empty container with a nozzle and a bucket
- hand soap
- timer
- towels
- large bowl
- ground pepper

What to Do

Safety Note: *This Investigation uses running water and there is potential for the floor to become slippery. Clean up spills immediately.*

1. Think about sanitation and hygiene. Talk with your group about the following questions:

a. What do the terms sanitation and hygiene mean to you?

b. What are some ways you keep yourself and areas around you clean?

c. What are some materials or equipment you use to keep clean?

d. Why do you think it is important to practice good hygiene?

2. Think about how and when you might wash your hands. Write a short procedure for your typical handwashing technique.

3. Examine the handout, “Handwashing Techniques,” which has some descriptions of how people may wash their hands. How does your procedure compare to these? Identify which procedure most closely resembles your handwashing technique.

4. With your group, analyze how effective these hand washing procedures are. Each member of your group should choose a set of procedures to test. Depending on the size of your group, some people may need to test more than one set.

5. Each person will record their results on an outline of both the front and back of their hand. For each procedure you are testing, trace your hand twice. Label one tracing “front” and the other “back.” So, if you are testing Set A, you should have four outlines of your hand (a front and back outline for A1 results and a front and back outline for A2 results).

6. Follow the hand washing procedures and record the results.

   a. Apply a dollop of Glo Germs in your palm. Each member of your group should apply the same amount.

Credit: L. Brase

   b. Rub your hands together to spread the Glo Germs all over the fronts and backs of your hands. Be sure your hands are entirely covered with a thin coat.

   c. Let your hands dry, and then observe your hands under the UV light to ensure they are covered with Glo Germs. If necessary, repeat steps b and c.

   d. Take turns with your group members to follow your parts of the procedure from the “Handwashing Techniques” handout.

   e. After completing your procedure, shake dry your hands for 5 seconds, then immediately look at your hands under the UV light.

   f. Where is the Glo Germ still located? Record the results by shading in your hand tracings to show where the Glo Germ is still on your hands.

   g. Dry your hands.

   h. Repeat steps a-g for each procedure you are testing.

7. When you have finished testing your procedures, wash your hands thoroughly with soap to remove all Glo Germs.

8. Share the results of your experiments with your group and observe and listen to their results. Take notes in the table on the handout, "Handwashing Techniques."

9. Share your group's results with the whole class.

10. Think about soap.

    a. How do you think soap works to help clean things?

    b. What types of soap can you think of? Do you know any differences between types of soap?

11. With your group, conduct an experiment. to examine properties of water and soap.

    a. Fill the large bowl about halfway with water.

    b. Sprinkle some pepper on top of the water. The pepper flakes represent germs.

Credit: L. Brase

    c. Have one member of your group place their finger straight down into the middle of the bowl for 5 seconds and then remove it.

    d. Write down observations of what happened in the bowl and to their finger.

    e. Have a second member of your group place a small amount of liquid soap on their finger and gently touch the layer of pepper on the surface of the water for 5 seconds, then remove their finger.

    f. Write down observations of what happened in the bowl and to their finger.

Safety Note: *Be sure to wash your hands thoroughly after these experiments, especially before eating food or touching your face.*

Consider

1. Examine the procedure you initially wrote about your handwashing technique. After completing this Investigation, how might you modify your procedure to be more effective in removing dirt and bacteria?

2. What do you think some of the consequences of poor handwashing could be on an individual level? How might poor handwashing affect a community?

3. Access to clean water is a global concern.

    a. What are the many ways clean water is used?

    b. Which of those that you listed would you consider top priorities? Why do you think this? Where does hygiene fall on your list?

    c. Since there are many ways clean water is needed and access to it may be low, water should be conserved as much as possible. Revisit the various handwashing procedures. Which used the most water? Which conserved water? Can handwashing be effective while conserving water?

d. Even when access to clean water is limited, good hygiene practices are still important. What are some ways good hygiene can be implemented when there are limited resources?

Extensions

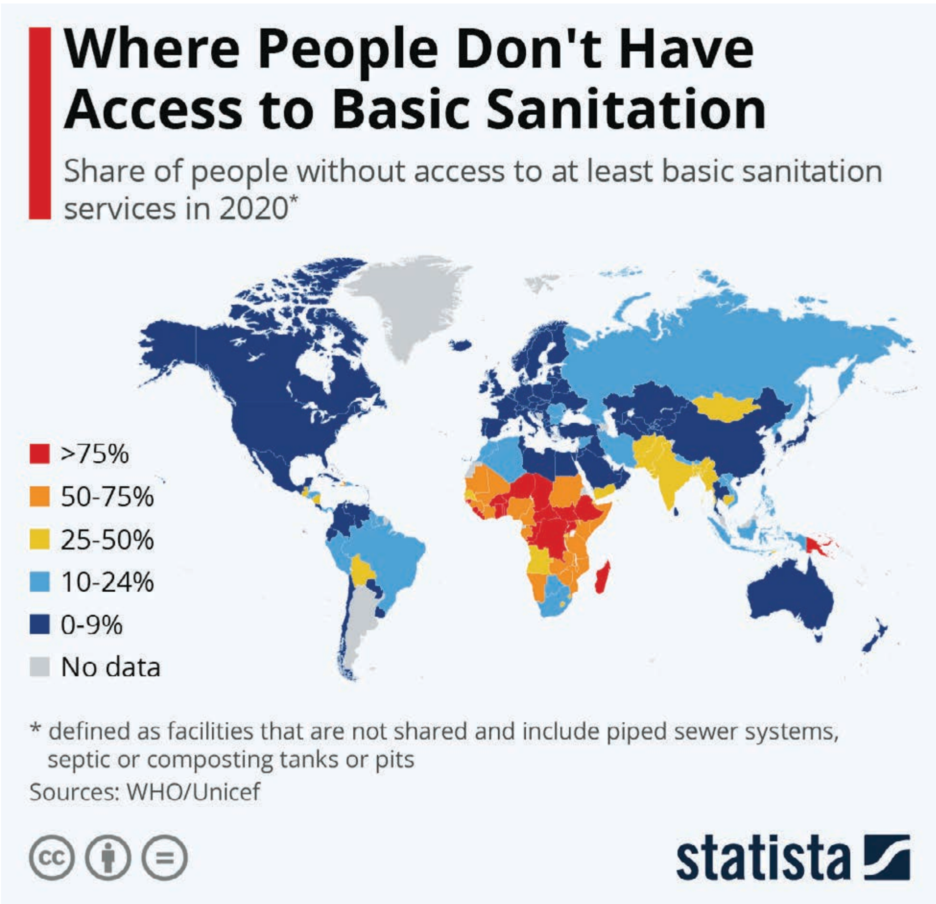
1. **Testing Variables:** How do you think hand sanitizer compares to using soap and water? Does hand sanitizer clean hands as well as washing hands with soap and water? Does the amount of hand sanitizer and the application method matter? Design an experiment using Glo Germs to test out some ideas. Be sure your experiment only tests one variable at a time.

2. **Analyzing Data:** Examine the map, "Where People Don't Have Access to Basic Sanitation," which displays the percentage of the populations from countries that do not have access to sanitation facilities with running water that are not shared.

   a. What areas have a low (<50) amount of best hygiene services? Why do you think this is?

   b. What might you infer about diseases and illnesses around the world after viewing this map? Why do you think this? Use evidence to back up your inferences.

BASIC HYGIENE SERVICES BY COUNTRY



Credit: WHO/UNICEF, Statista, https://www.statista.com/chart/23557/access-to-basic-sanitation/

3. **Analyzing Data:** Examine the map, "Safely Managed Sanitation" which displays the proportion of the population using safely managed sanitation services in 2020. Best case, safely managed sanitation services include bodily waste is safety disposed of and treated and households have their own individual facilities. Unsafe sanitation services consist of hanging or bucket latrines and worst-case sanitation services include open disposal of human waste.

   a. What areas have low (<51) amounts of safely managed sanitation services? Why do you think this is?

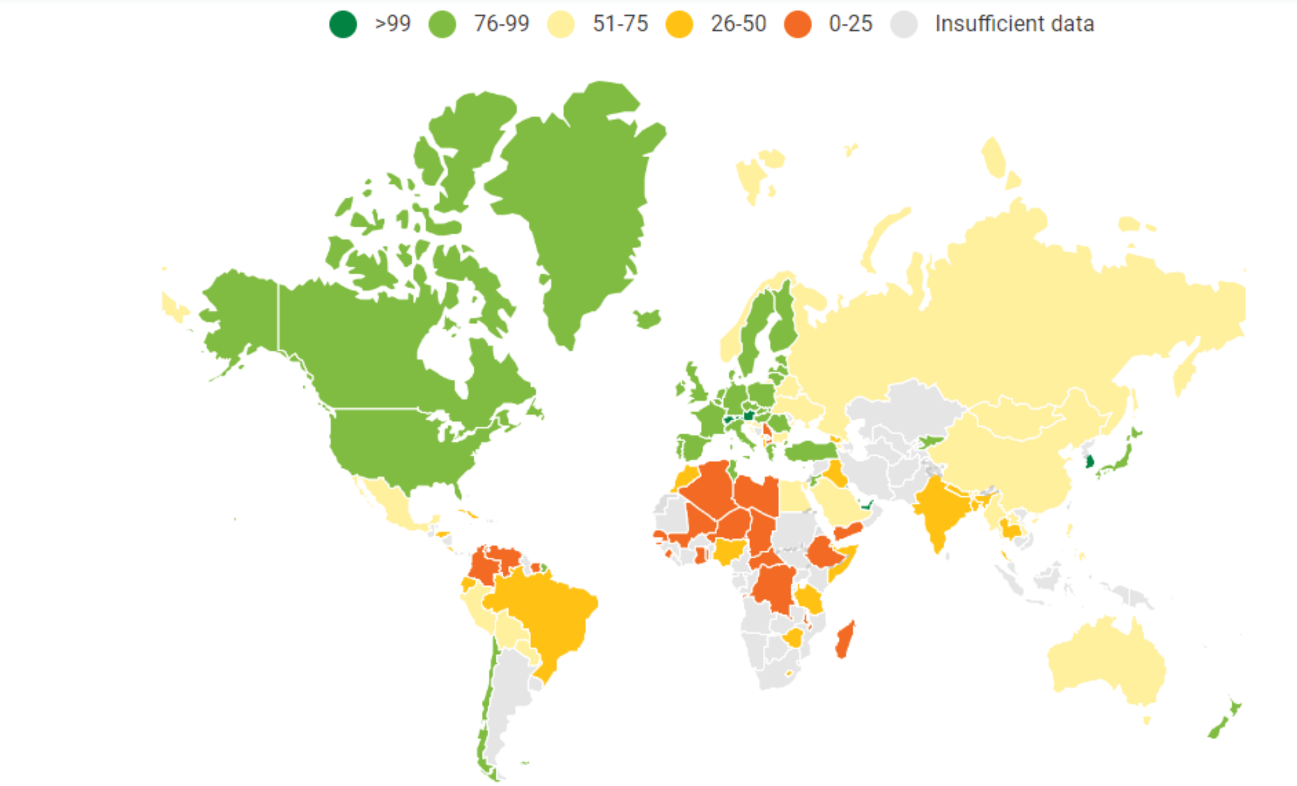
   b. What areas have high (>50) amounts of safely managed sanitation services? Why do you think this is?

   c. Locate your country on the map. What data was reported in 2020? What might you infer from the data about your country, and why?

   d. What might this information allow you to infer about water-borne diseases and illnesses around the world? Why do you think this? Use evidence to back up your inferences.

   e. Compare this map to that shown in extension question 2. Does there seem to be a relationship between countries with fewer sanitation services and those with less access to basic hygiene services? Explain your reasoning.

SAFELY MANAGED SANITATION



This map does not reflect a position by UNICEF on the legal status of any country or territory or the delimitation of any frontiers.

Source: WHO/UNICEF JMP (2021), Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs

Credit: UNICEF

Handwashing Techniques

Set A

- Rinse under water for 5 seconds (no scrubbing).
- Rinse under water for 20 seconds (no scrubbing).

Set B

- Rinse under water for 5 seconds, with scrubbing.
- Rinse under water for 20 seconds, with scrubbing.

Set C

- Rinse with water, then scrub with soap under water for 5 seconds.
- Rinse with water, then scrub with soap under water for 20 seconds.

Set D

- Rinse with water, apply soap, then scrub for a total of 5 seconds, then rinse with water.
- Rinse with water, apply soap, then scrub for a total of 20 seconds, then rinse with water.

RESULTS:

Procedure	5 seconds	20 seconds
Rinsing in running water, no scrubbing		
Rinsing in running water with scrubbing		
Rinse with water, scrub with soap in running water		
Rinse with water, scrub with soap, rinse with water		

ESD KIT: ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 8A: CONSTRUCTING A WETLAND

Learning Outcome: TKTKT

Materials

Per group:

- large, shallow pan (aluminum pan, casserole dish, or clear plastic bins)
- modeling clay or playdough
- sponges (enough to cover the width of the pan)
- approximately 60 mL (¼ cup) of soil
- spray bottle
- colored powder or sprinkles
- water
- bucket or large bowl for wastewater
- baster (optional)

What to Do

1. An ecosystem is where communities of organisms depend on each other and their surroundings. There can be ecosystems that are land-based (terrestrial) or water-based (aquatic). Discuss the following questions about aquatic ecosystems with your group members.

   a. What types of aquatic ecosystems can you name or describe?

   b. Do you think there are any aquatic ecosystems in your community?

   c. What do you think are some important components of an aquatic ecosystem?

   d. How do you think aquatic ecosystems could be disturbed or ruined? Are these impacts positive or negative?

2. A wetland is a type of aquatic ecosystem. Draw on prior knowledge or make predictions with your group to answer the following questions:

    a. What do you think a wetland is? How might you describe a wetland?

    b. What might you find in a wetland ecosystem?

    c. Where do you think wetlands are usually found?

3. Create a model landscape that includes a wetland.

    a. Use modeling clay to create the land portion of the model on one third of the pan. Pack the clay against the bottom and sides of the container. Create mini hills and sculpt in rivers.

Credit: L. Brase

    b. Place the sponges in a line across the width of the pan against the modeling clay to represent the wetlands. They separate the land (modeling clay) from another water source river (empty section of the pan).

Credit: L. Brase

    c. Place a thin and even layer of dirt over the land to represent developed land with less vegetation holding the soil together.

    d. Place some colored powder or sprinkles over the land to represent fertilizer, a common pollutant.

4. Investigate the role of a wetland in how the water moves in the model. Use the spray bottle to simulate rain over the model landscape and make observations of what happens.

    a. What changes occur during and after the rain?

    b. Where does the water end up? What does it look like? How fast does it travel there?

    c. Where does the dirt and fertilizer end up?

5. Modify the model landscape so it does not include a wetland.

    a. Remove the sponges from your earlier model.

    b. Use the baster to remove the water or dump out the water into the waste bucket.

    c. Wipe out the empty part of the pan (the river) with a towel to remove fertilizer or dirt.

   d. Place a new layer of dirt and colored powder or sprinkles over the modeling clay.

6. Investigate how the water moves on the model in the absence of the wetland. Use the spray bottle to simulate rain over the model landscape and make observations of what happens.

   a. What changes occur during and after the rain?

   b. Where does the water end up? What does it look like? How fast does it travel there?

   c. Where does the dirt and fertilizer end up?

Consider

1. Even if there was no pollution present (colored powder or sprinkles), what benefits would wetlands provide to the environment?

2. Many wetlands are being destroyed due to urbanization and other human activities. Explain what effects this may have on the wetland environment, plants, and animals where the wetland was destroyed, and on other nearby areas. Use prior knowledge and evidence from this Investigation to support your answer.

3. One type of pollutant examined in this Investigation was fertilizer. What other types of pollution can you think of that could be transported by rain and in rivers? Do you think wetlands can filter out all of these pollutants? Why or why not?

4. Protecting and restoring wetlands will improve aquatic ecosystems.

   a. How do you think someone like you could help protect or restore aquatic ecosystems?

   b. How do you think an adult or community leader could help protect or restore aquatic ecosystems?

Extensions

1. **Applying Concepts:** Where are wetlands located in your community or country? Examine maps and conduct research to locate wetlands and hypothesize some of the benefits they provide. If your community or country doesn't have wetlands, where may they have been located prior to urbanization? Or what is it about your region that makes conditions unlikely to support a wetland? Where could your community or country create wetlands? Why do you think it would be successful in this location?

2. **Applying Concepts:** The amount and types of life in an aquatic ecosystem can give clues to the cleanliness of the water. *Benthic macroinvertebrates* ("bottom dwellers") are small aquatic animals that live at the bottom of rivers, lakes, and oceans. Some examples include slugs, snails, worms, crustaceans, and aquatic insects. Many "bottom dwellers" are often found attached to rocks, vegetation, logs, sticks, or burrowed into the bottom of the stream. Because they move slowly (unlike fish) they are good indicators of the cleanliness of the water. An area that has many types and an abundance of "bottom dwellers" usually is an indicator of clean water. An area that has few of these organisms, or that has types that are tolerant to pollution, usually indicate areas of lower water quality.
Go with an adult to a local stream, river, or aquatic ecosystem and examine the biodiversity. Make a list or take pictures of all the bottom dwellers that you see. Use your evidence to make a claim about the cleanliness of the water.

3. **Testing Variables:** In addition to acting as filtration systems and buffer zones, wetlands are home to many types of life. Wetlands can vary in how much water they hold and in what forms (in a body of water, within the soil, or as humidity), which will determine the types of plants that grow and the animals that live there. Build two models of wetlands, one that drains constantly and one that maintains a well-saturated soil. Add soil, plants, and water. Add the same amount of water to both containers occasionally and monitor the ecosystems for a couple weeks.
American Geosciences Institute gives more detailed directions at https://www.earthsciweek.org/classroom-activities/dynamic-wetlands.

4. **Analyzing Data:** Go to the Global Wetlands website to learn what wetlands are in your country: https://www2.cifor.org/global-wetlands/. What are the most predominant types? Where are they located? How does the amount and types of wetlands in your country compare to nearby countries? What might account for these differences?

SUSTAINABLE DEVELOPMENT GOALS

GEOSCIENCE FOR SUSTAINABILITY

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INVESTIGATION 8B: RESTORING HABITATS

Learning Outcome: TKTKT

Materials

Per group:

- 2 small bowls
- water
- vegetable oil mixed with oil-based food coloring
- pipettes
- spoons
- graduated cylinder (preferably 25 mL)
- thin plastic tubing or flexible straws
- tape
- cotton balls
- feathers
- soap
- rock
- sand
- 22 cm x 33 cm (9" x 13") baking pan or shallow plastic bin
- toothbrush
- timer
- "Oil Spill Cleanup Guide" handout
- washcloth
- data sheet
- soap (optional)

What to Do

1. Testing oil clean-up methods:

    a. Label one small bowl as "waste."

    b. Fill a small bowl three quarters of the way full with water. Measure 20 mL of dyed oil and pour it into the water. Make observations of what happens.

    c. Use a spoon and a pipette as skimmer to try to remove as much oil from the water's surface as possible.

    - Put the oil into the graduated cylinder as it is collected.
    - Once you have recovered as much oil as you can, let the graduated cylinder sit for a minute so any water you collected settles to the bottom of the cylinder.

    - Record how much oil you were able recover.
    - Record how much water was also collected.

2. Rinse out the bowl and wipe it out with a washcloth. Make sure there is no oil residue on the sides of the bowl. Use soap if necessary.
3. Fill the bowl three quarters of the way full with water. Measure 20 mL of dyed oil and pour it into the water.
4. Use cotton balls or other absorbent materials (sorbents) to remove the oil.
    a. If possible, squeeze the oil out of these materials and into the graduated cylinder.
    b. Make sure only the oil and water, but none of the material, goes into the cylinder.
    c. Place any used sorbents or absorbent materials into the waste bowl to keep track of how much or how many were used.
    d. Once you have recovered as much oil as you can, let the graduated cylinder sit for a minute so any water you collected settles to the bottom of the cylinder.
    e. Record how much oil you were able recover.
    f. Record how much water was also collected.
5. Rinse out the bowl and wipe it out with a washcloth. Make sure there is no oil residue on the sides of the bowl. Use soap if necessary.
6. Fill the bowl three quarters of the way full with water. Measure 20 mL of dyed oil and pour it into the water.
7. Add 5 drops of soap and observe what happens.
8. Observe oil on natural materials:
    a. Dip a rock in water and make observations of if the water adheres to the rock or not. Repeat with oil.
    b. Using water and a toothbrush, try to clean the oil off the rock. If not successful, add soap.
    c. Dip a feather in water and make observations of if the water adheres to the feather or not. Repeat with oil.
    d. Using water and a toothbrush, try to clean the oil off the feather. If not successful, add soap.
9. 3. Cleaning an oil spill:
    a. At one end of a shallow baking pan or plastic bin, use sand to build a small beach area.
    b. Add water so it is three quarters of the way up the beach.
    c. Add 50 mL of dyed oil to the middle of the water.
    d. Review the “Oil Spill Cleanup Guide” sheet to consider the cost of each oil removal method.
    e. Use the provided tools to clean up the spill. Record how many tools you use and for how much time on the “Oil Spill Cleanup Guide.”
    f. Use the information on the “Oil Spill Cleanup Guide” to calculate how much it cost to clean the oil spill.

Consider

1. Which skimmer did you find more effective, the spoon or the pipette? Why do you think this tool is more effective at removing an oil slick?

2. Describe what happened to the oil when you added soap to the water-oil mixture. Why do you think the materials reacted like this?

3. Consider the effectiveness of each method in step 1:

   a. How much oil were you able to recover using each method?

   b. Compare your results to other groups. Why might there be variation in the success of some of the methods used to clean up oil?

   c. Was any group able to collect all of the oil with one of the cleaning methods? If so, which technique did they use? If not, why was it not possible to clean all the oil?

   d. Based on this data, rank the methods from least to most effective. Also, take into account if water was collected. Why is an oil-cleaning method that collects water considered less effective than one that does not?

4. Was oil easiest to remove from the water, the rock, or the feather? Which was the hardest? Why do you think this is? How does this demonstration show the importance of keeping oil spills away from land and animals?

5. Consider how effective and efficient your group was in cleaning up the large oil spill in step 3:

   a. How did you use the information from step 1 to make your plan for cleaning up the larger oil spill?

   b. Compare how much money and time you spent versus other groups when it came to cleaning up the large oil spill. How did your use of the provided tools differ from the other groups?

   c. Were you more or less successful at cleaning the spill and saving money than other groups? Why do you think so?

   d. For the group that collected the most oil, did they also collect the least water? Did they have the lowest total cost? How do these factors affect your thoughts on how successful a group was at cleaning the oil spill?

6. What other pollutants are frequently found in oceans? How do you think they could be cleaned up?

Extensions

1. **Testing Variables:** Consider other factors that could naturally affect the movement of an oil spill through water. What other variables could be tested in this experiment? If possible, gather the materials and test these variables. Ensure you are only testing one variable at a time.

2. **Applying Concepts:** Another major pollutant in ecosystems is microplastics. Microplastics are commonly found in aquatic ecosystems but are also frequently found in soils. Research microplastic pollution to learn more about how they get into and spread within the environment. Create a diagram of the "life cycle of microplastics" including information on why they are hazardous, as well as the difficulty in removing them from the environment.

Oil Spill Cleanup Guide

Your main objective is to remove as much oil from the water as possible without also collecting water. Use this table to keep track of how long or how many of each type of oil removal method you use. While you are not limited to a budget, keeping costs down is also part of your objectives.

Oil Removal Method	Cost per Unit	Quantity or Time Used	Total Cost for this Method
Skimmer, pipette	$75 per pipette per minute	# = Total time =	
Skimmer, spoon	$125 per spoon per minute	# = Total time =	
Boom, plastic tubing (or flexible straws)	$25 per 5 cm (2”)	# of 5 cm segments =	
Sorbent, cotton ball	$20 per cotton ball	# =	
Disposal Costs	$1000 flat fee for disposal of sorbents	# =	
Filtration of wastewater collected	$1000 per 25 mL	mL =	
Labor	$500 per person per minute	# of people = Total time =	
		Total Cost:	

ESD KIT: ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

ESD KIT PROJECT: DESIGNING A NET-ZERO WATER COMMUNITY

Clean water is imperative to human life. The more the human population grows, the more water we use, and so conservation is more important than ever. Many areas of the world are facing water scarcity issues and so we are becoming more aware of the need to preserve water and not deplete water sources. By balancing water availability and demand, communities can become more resilient and conserve this valuable natural resource.

Net-zero water-use means using the water you have access to, limiting its consumption, and returning it back to the same watershed so the water source is not depleted. Implementing net-zero water strategies means living within the limits of available water that your area can provide and treat so the water is usable. In this project, you will consider how your community currently *uses* and *interacts* with water, and then strategize how to manage water in a community so that the community can be considered net zero in its water use.

Part 1: Success Stories

Research and read about buildings, companies, and other parts of a community that have designed or successfully implemented a net-zero water strategy. Think about the following questions as you do the research:

- Where does the water come from?
- How is water transported?
- How is water treated?
- How is water used?
- How is used water disposed of safely?

Part 2: Assess Your Community

Think about your community and what you learned in the Investigations. You will take ideas generated by these questions into consideration while designing a net-zero water town.

Investigation 1 -3: Water Availability

- Where is there natural water in your community? Is it saltwater or freshwater? What are potential impacts of water withdrawal from these location(s)?
- Identify parts of the water cycle where water is stored.
- Identify in what watershed(s) your community is located.
- Where does the water within your watershed come from? Where does it travel to?
- From where in your watershed does your community collect water?
- What may be sources of pollution for your community?
- Where in your watershed would you expect to find the most contaminants in the water? Why?
- How does your community monitor and manage water pollution?

Investigations 4 and 5: Water Quality and Treatment

- Is water tested, treated, and distributed communally, or are individual families/ businesses responsible for their own water?
- Is water currently tested and treated in your area? If so, how?
- If water is treated communally, do community members use additional water treatment methods in homes? If so, what types?
- What could be a more ideal way for water to be treated, in terms of sustainability?

Investigations 6 and 7: Access to Clean Water

- How would you describe your community's water footprint? What steps could be taken to reduce this footprint?
- How is water use measured in your community or at individual locations?
- How would you describe your community's access to sanitation facilities (areas where human waste and garbage are safely disposed)?
- How would you describe your community's access to hygiene facilities which have soap and water available?
- How could access to sanitation and hygiene facilities be improved in your community?
- How is water used and distributed in your community? How does the amount of water use compare between agricultural, industrial, and municipal sectors?
- What are some businesses or other places in your community that you think use the most water?

Investigation 8: Water in Ecosystems

- In what type of biome or ecosystem was your community built? Is there evidence of this biome or ecosystem still in your community or do you have to leave your community to see the natural landscape?
- How did the formation or expansion of your community likely change the natural water movement in the area?
- How would water withdrawal impact these ecosystems?
- Does your community play an active role in ecosystem restoration or protection? If so, how? If not, how could your community improve or protect these ecosystems?

Part 3: Design an Ideal Net Zero Water Strategy

Brainstorm aspects of the town you would want to design. Discuss your plans with a partner or your facilitator. Be sure your plans address concepts above, including where the water is coming from, how it will be made safe for consumption/use, the different uses of water in the town, and how it will be safely returned to the watershed.

After discussing your ideas, draw out a map of your town that displays your ideas or share your strategy another way.

Present Your Net Zero Water Strategy

- a written report
- a slide show
- an animated *Scratch*® presentation
- an oral presentation with visuals or a model, which may also be video recorded.

ESD KIT:
ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

APPENDIX 1: USING *SCRATCH*® WITH THE ESD KIT INVESTIGATIONS: TIPS AND TECHNIQUES

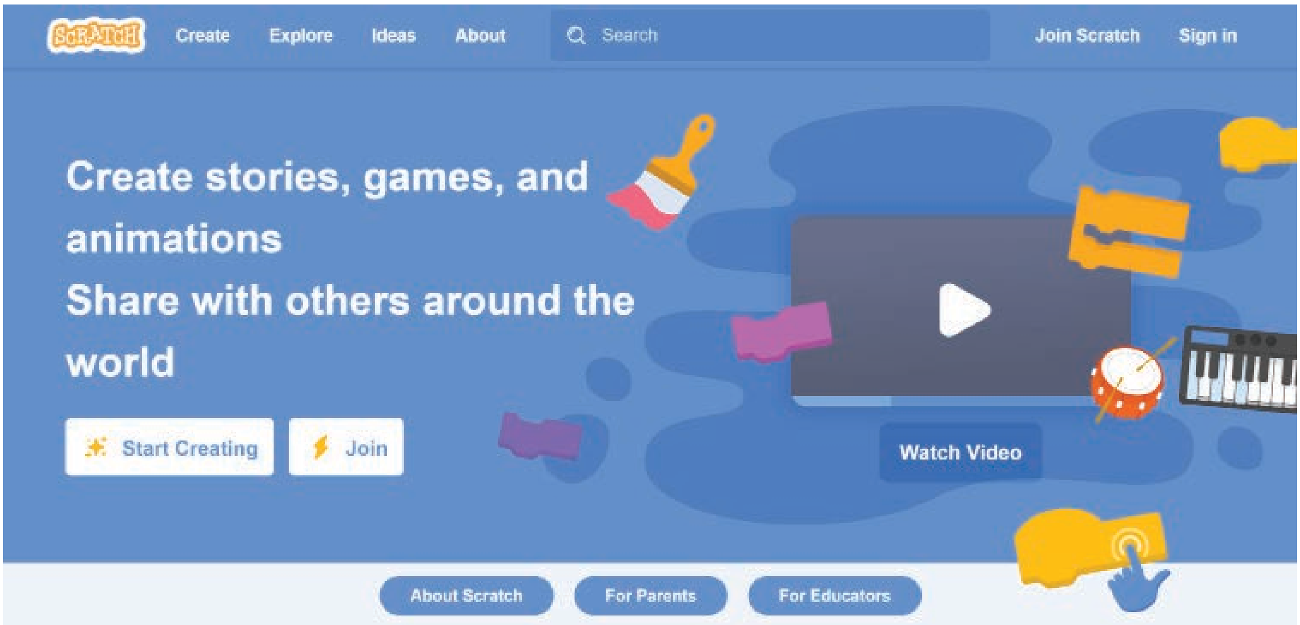
An important aspect of your work with ESD Kits is reporting and presenting the results of the Investigations and ESD Kit Project. This can be done in a variety of ways: written reports, slide shows, videos, and oral presentations. *Scratch*® is a highly recommended platform to report and present findings or designs for projects. *Scratch*® is a programmable learning environment that enables you to design and build your own interactive stories, games, and animations — and to share your creations with others in the online community. *Scratch*® is also a good vehicle for creative and interesting ways to visualize data. In the process, you will also learn how to code.

If you are not already familiar with the basics of *Scratch*®, first look at *Getting Started with Scratch*, which tells you how to set up an account on the *Scratch*® website and where to find introductory tutorials and guides. If you are familiar with *Scratch*®, skip ahead to *Tips and Techniques for Scratch* for how to work with *Scratch*® to share what you learn while working through the ESD Kit Investigations.

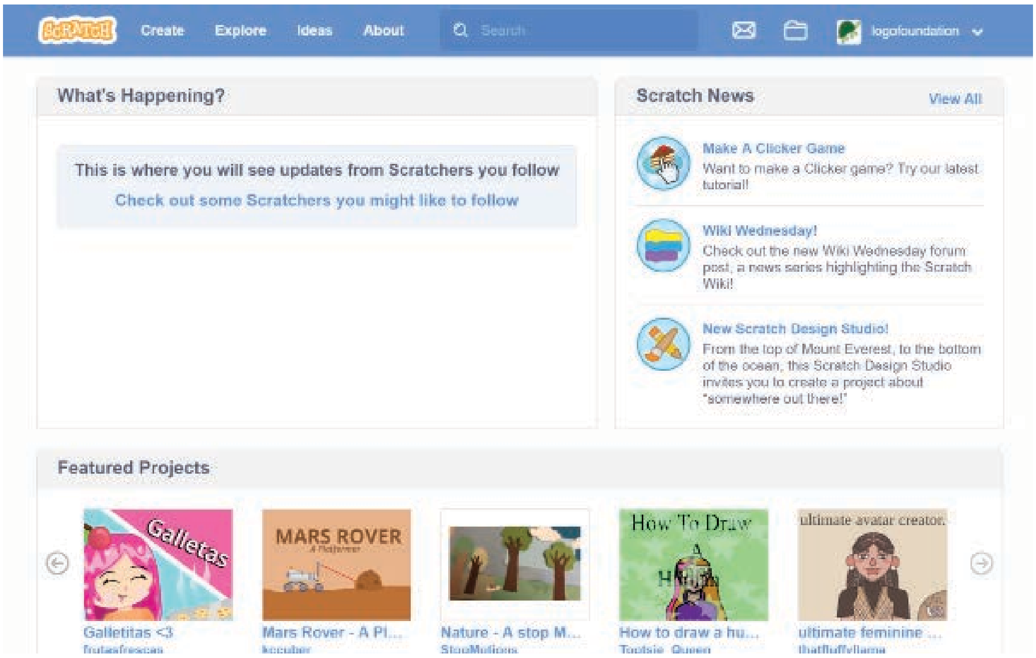
Getting Started with *Scratch*®

Scratch® works in your Web browser. There is no need to download and install an application. Your projects are saved automatically in the cloud. You can sign into your account from any computer and have access to everything you have created.

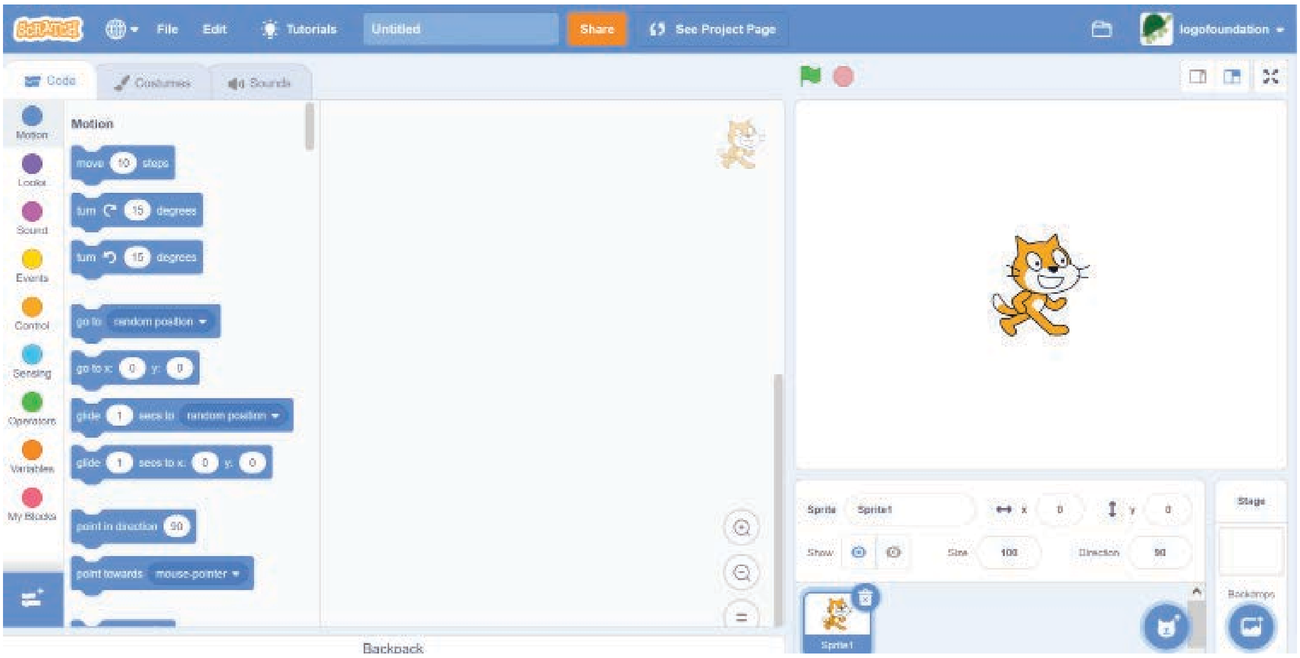
To get started, go to the *Scratch*® website: https://scratch.mit.edu/ This is what you'll see:



You should first create your own account on *Scratch*® so that you can save your work and share and communicate with other Scratchers. Click the **Join** button at the lower left or **Join Scratch** at the upper right. Follow the steps to set up your account. Once you are signed in, the *Scratch*® homepage will look something like this:

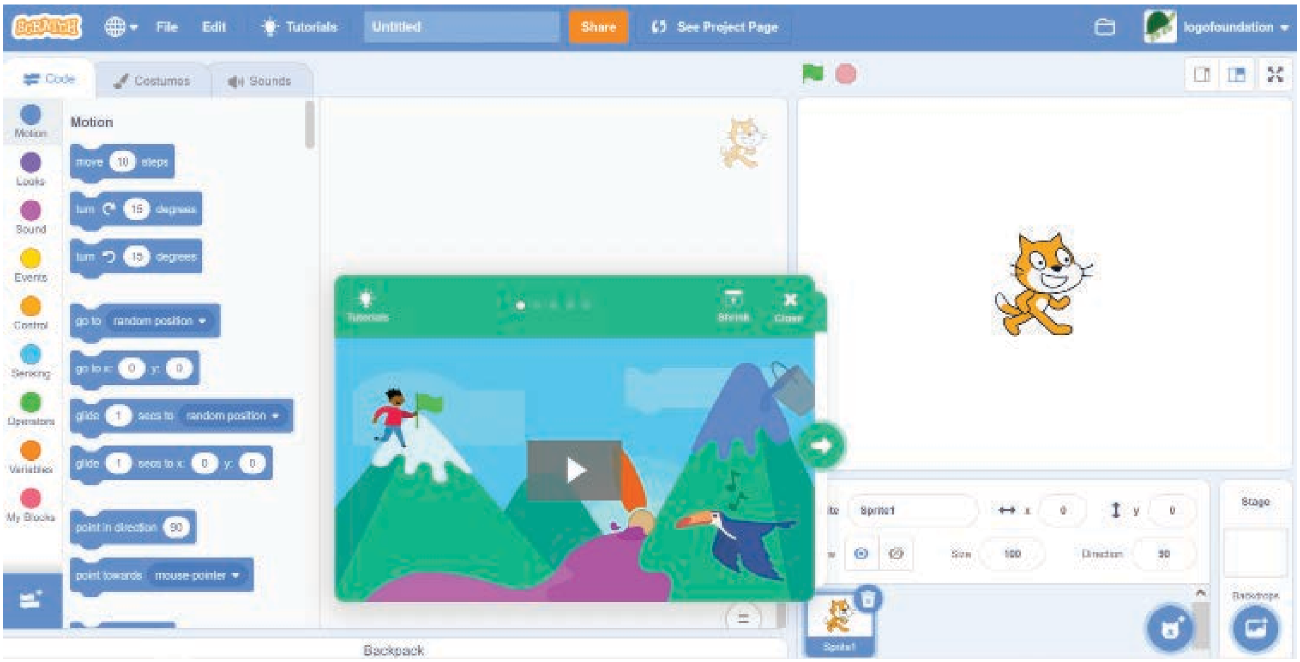


Your username appears at the upper right. You can browse the **Featured Projects** and other projects that appear as you scroll down the page. To get started yourself, click on **Create** at the upper left. This will take you to the *Scratch*® Editor. Your screen will look like this:



You can watch a brief video that shows some of the many things you can do with *Scratch*®. You can also jump right in by clicking on **Create** at the upper left or **Start Creating** at the lower left. This will bring you into the *Scratch*® Editor with an introductory tutorial running.

Click on **Tutorials** at the top of the page to go to a page with links to more than two dozen tutorials that will get you started with *Scratch*®. Each one appears in a window over the Editor.



You can stop and start, and back up as you need to. As you follow the tutorial, you will create your version of the project in the *Scratch*® Editor. Initially it will be called Untitled. You can click on the name and change it. It will automatically be saved in your *Scratch*® account.

More Resources

In addition to the resources on the *Scratch*® website, the *Scratch*® Wiki **https://en.scratch-wiki.info/** has a great deal of information about *Scratch*®.

The *Scratch*®ED website at **https://scratched.gse.harvard.edu** is an archive of documents and projects created by *Scratch*® Educators.

For very young children there is *Scratch*® *Jr*, which you will find at **http://www.scratchjr.org/**. You may download and install it on your iPad or Android tablet. There is also a version for Chromebooks.

Scratch® Tips and Techniques

Putting on a Show

You can think of your *Scratch*® program as a theater. Your screen is the stage, and the backdrops are the scenery. The actors in your show are called sprites. They can wear a variety of costumes, move around, talk, sing, and interact with each other. Your show can have several scenes. To change from one scene to another, you can write the program to change the backdrop, hide characters that won't appear in the next scene, and get new characters to appear.

Working with Images

There are dozens of backdrops for the stage and costumes for the sprites that are built into *Scratch*®. You can choose which ones you want to use. You can also import images into *Scratch*®. These can be your own photos or images produced using other applications or downloaded from the internet. There is also a Paint Editor that you can use to draw backdrops and costumes or to alter existing images.

Visit this page for more information about using images in *Scratch*®: **https://digitalmaestro.org/articles/prepare-images-for-use-in-scratch-code-projects**

Displaying Text

One way to include text in your project is to use the paint program to create or modify a backdrop for the stage, or a costume for a sprite. Click on the letter T and then click where you want to begin your text. This creates a text box where you can type your text. You can also paste text that you have copied from another application. Once you have written some text, you can select the text box with the pointer icon to resize, move, or rotate it. If your text is on a sprite costume, you can make it move around by programming the sprite to move. Text on backgrounds or costumes will remain on the screen until the scene or costume changes.

Another way to use text is to use the **say** or **think** blocks. These can be found in the “Looks” tab to the left of the *Scratch*® program. These will display comic book style balloons with text in them next to your sprite. You can also choose how long these balloons appear, and you can program as many as you want to use in a scene.

Sounds

Using the Text to Speech extension, a sprite can say what you type into the **speak** block.

Scratch® can also play recorded sounds. These can be music, sound effects, and spoken words. You can record music or your own voice in *Scratch*® and then play it as part of your project. To do this, click on the Sounds tab, then on Choose a Sound, then on the microphone icon.

In addition to recorded music, there is a music extension that you can use to create melodies note by note, to be played by a variety of online instruments.

Working with Data

When trying to understand the significance of some data, it is helpful to have a visual representation rather than just a list of numbers. We often see line and bar graphs, pie charts, and other diagrams used for this purpose. For example, look at *Investigation 4: Understanding Our National Energy Mix* and *Investigation 7B: Logging Temperature Automatically Using a micro:bit* where data is used to create graphs. *Scratch*® can be used to draw graphs, but it also adds the ability to create a wider range of visual representations of data that can also be dynamic and interactive.

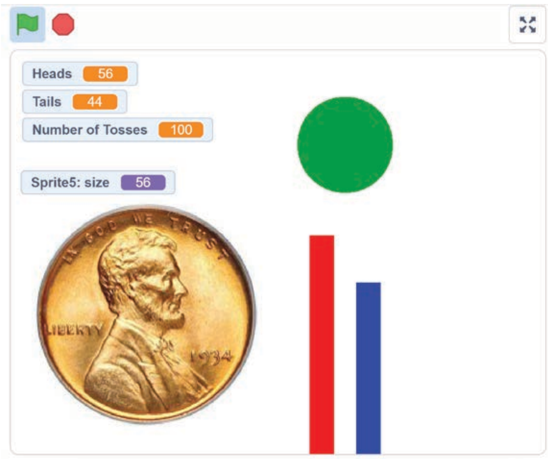
For example, look at the *Scratch*® project Coin Toss: https://scratch.mit.edu/projects/486312136/

It uses the **pick random** block to simulate tossing a coin 460 times. It creates a graph showing the percentage of heads as the tossing progresses. The graph looks different each time the program is run, but the following image is typical. In *Scratch*®, you can watch this emerge as the graph is drawn in real time.

Another coin tossing project is Coin Toss Visualization: https://scratch.mit.edu/projects/2207857/

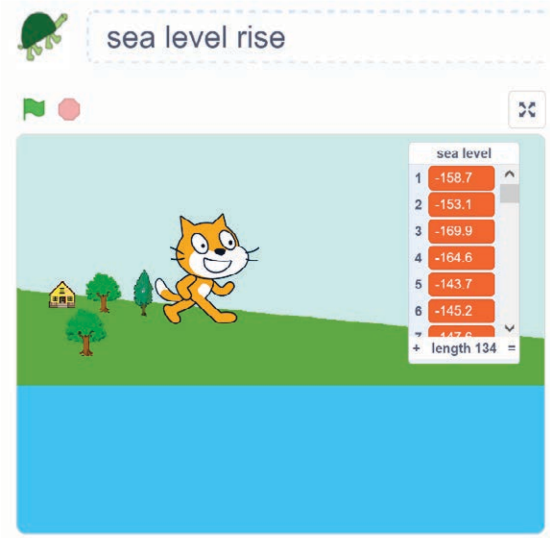
The coin is flipped 100 times and the visual representations of the proportions of heads and tails emerge dynamically. In addition to a bar chart, the size of the green circle increases and decreases based on the percentage of heads up to that point.

In addition to visualization, there is sonification. The pitch of a note played on a virtual piano reflects the percentage of heads.

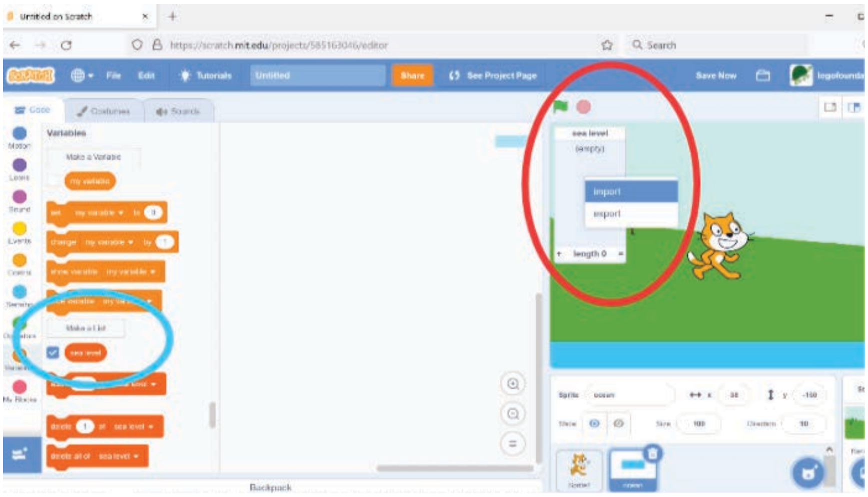


In the coin tossing projects, the program generates the data for the visualizations. You can also bring outside data into a *Scratch*® project.

The sea level rise project at https://scratch.mit.edu/projects/585163046/ uses global mean sea level data for the years 1880 to 2014 from the Climate.gov website. To bring this data into *Scratch*®, we first download it from Climate.gov as a .csv file (Microsoft Excel). We then create a list named "sea level" and imported the data into it. Here is how to do that:



Go to the variable section of the code tab and click on Make a List. Give the list a name. The list appears on the stage. (You can make it invisible by unchecking the blue box next to the name.) Now right-click on the list and you will see the option to import or export data. Click input and then select the .csv file you want to import. You can only import one column of a .csv file into the list. If there are more columns in the file, *Scratch*® will ask you which one you want to import. The sea level data file from Climate.gov has three columns. The second column has the data we need on sea level.



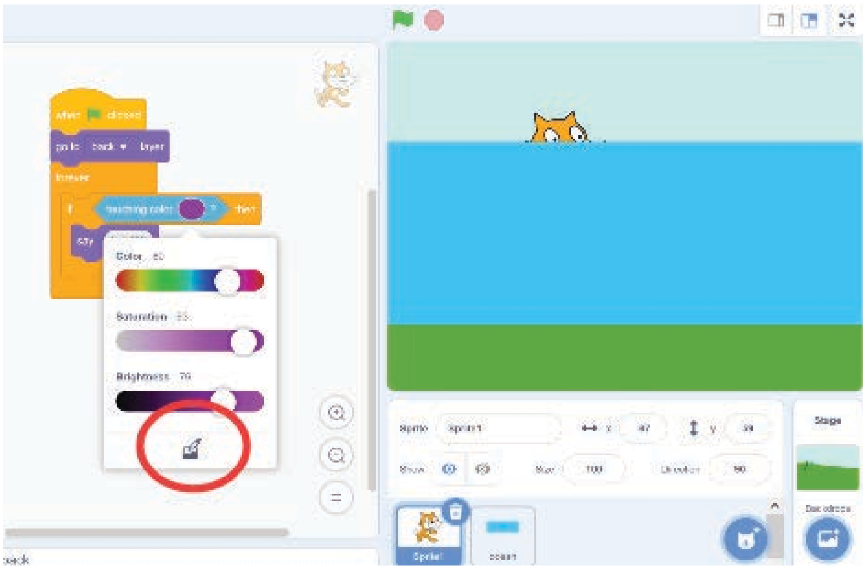
Once the data is imported, you may have to do some touching up. Often a .csv file will have a label in the first row of each column. This label will be imported into the *Scratch*® list along with the data below it. To remove this label and leave only data in the list, click on that first item. An X will appear in it. Click the X to remove the item.

Now the list of sea level data is ready to use. Create a variable named "pointer." This is used to step through the list of data one item at a time. The Y coordinate of the ocean sprite is set to each value of the sea level data in turn until the end of the list is reached.

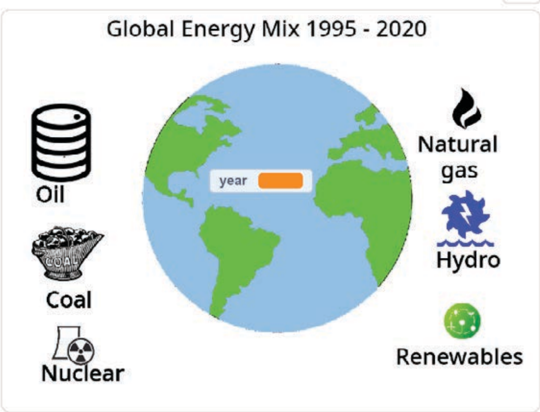
To see more about how the program works, go to the code tab of the ocean sprite, and look at the comments attached to the code for an explanation.

The cat is also programmed to cry out for help as the sea level rises and touches her. The code looks to see if the cat is touching the color blue (the sea) and causes the cat to say "Help!!!" when that happens. Look at the code tab of the cat sprite to see that program.

To get the correct color into the **touching color** block, click on the color oval in the block and then on the color picker icon below the sliders. Then click on the color that you want to pick up. In this case, that's the blue of the ocean sprite.

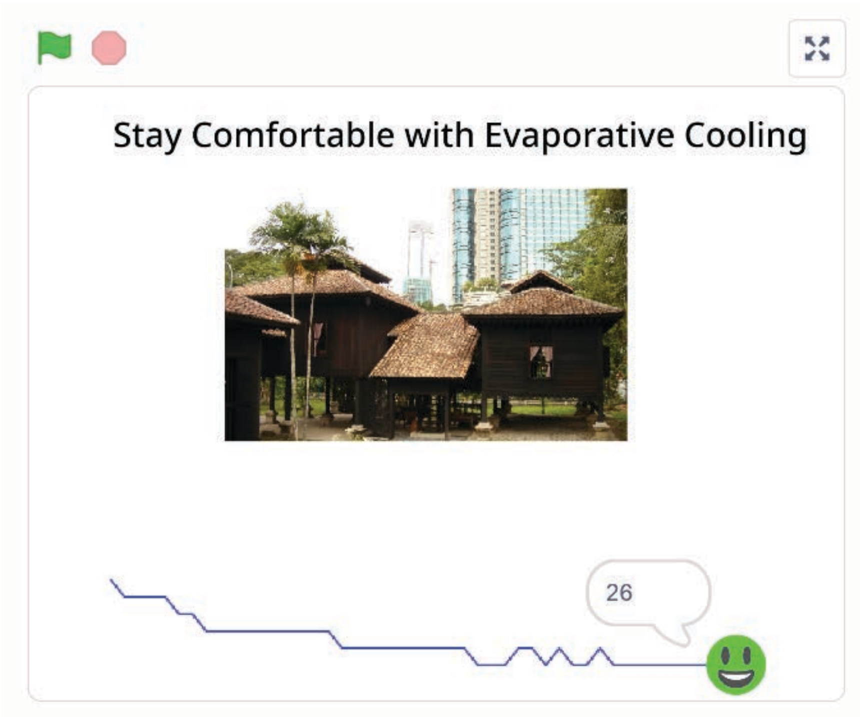


Investigation 4: Understanding Our National Energy Mix looks at the distribution of different energy sources over time. The data are represented by line graphs. The *Scratch*® project *Global Energy Mix* https://scratch.mit.edu/projects/573662932/ visualized that same data by increasing and decreasing the sizes of icons representing each energy source. You can remix it to use your own icons. You could extend the time frame so as to include projections of the energy mix in the future.



In *Investigation 7B*: ***Logging Temperature Automatically Using a micro:bit***, temperature data will be logged using a micro:bit. The data, when downloaded from the micro:bit as a .csv file can be used to make a graph or *Scratch*® program. Using Excel, we can create a line graph in the .csv file, showing the change in temperature under a damp clay flowerpot over a period of 47 minutes.

The *Scratch*® project *Evaporative Cooling* (https://scratch.mit.edu/projects/574196032/) uses that data to draw a line graph in a somewhat different way.

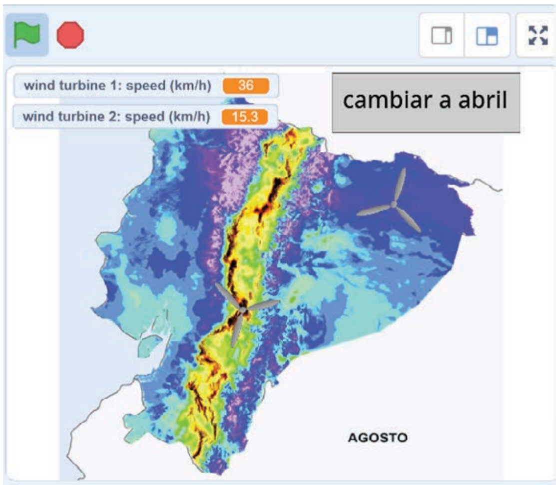


Making Your *Scratch*® Project Interactive

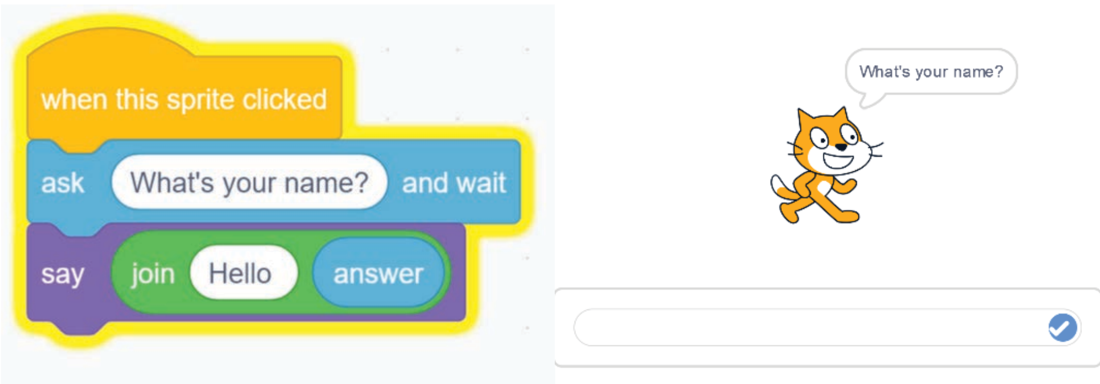
Anyone who uses an interactive *Scratch*® program can affect the course of action, what appears, and the sounds, voices, and music that are heard. Here are some examples:

Exploration 3B1: Locating Wind Energy shows how the potential for wind power in Ecuador varies from one location to another. In the *Scratch*® project Ecuador Wind Power (**https://scratch.mit.edu/projects/579828042**), the colors on the map indicate average monthly wind speeds. There are two sprites in the shape of wind turbines that can be dragged around the map. They are programmed to detect the color they are touching and set the wind speed accordingly. These values appear at the top of the screen. To actively visualize the data, the wind speed variables determine how rapidly each wind turbine spins.

Sprites can be programmed to detect color or other sprites. They can respond to a mouse click. They can be dragged with the mouse or by using specific keyboard keys. Other keypresses could be programmed to trigger other actions.



The **ask** and **answer** blocks allow you to prompt the user for a response and take action based on what they type into the dialog box that appears.



Here, the cat asks, “What’s your name?” When you type in your name and click the check box, the cat replies with “Hello” followed by your name.

You can use this feature to determine the flow of your program. For example, you could create a project where you ask whether the user wants to learn more about Coal or Gas. The response could trigger a switch to an appropriate backdrop and start a flow of information and actions on the chosen topic.

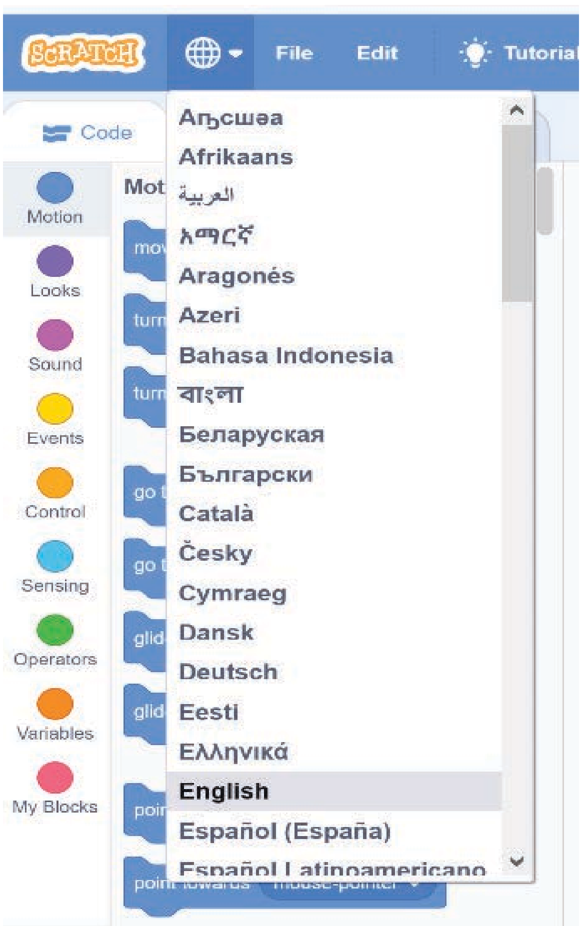
Look at the Sensing section of the Blocks Palette for some additional ways to make your *Scratch*® project interactive.

Changing Language

Scratch® supports many languages. Click on the globe icon in the upper left corner and you will see a list of the available languages. When you select one, the text on the code blocks, the menu items, and other text elements of the *Scratch*® user interface change to that language.

This makes it possible for Scratchers worldwide to work in their own language. It is also useful when looking at a project that someone has created with *Scratch*® set to a language other than your own. You can switch to your language and the code blocks will change so that you can better understand the project.

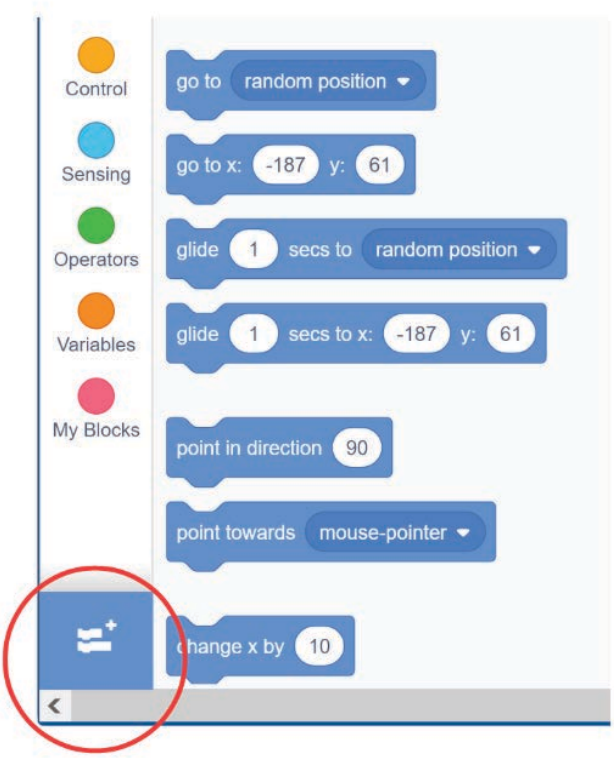
This feature does not change the text that the user has written on backdrops or sprite costumes, or text written into the **ask**, **say**, or **think** blocks. There is a separate translation extension to change these features.



Scratch® Extensions

A *Scratch*® Extension is a collection of code blocks for a specific purpose. The Pen extension enables Sprites to draw lines as they move. This is used to draw line graphs in the Evaporative Cooling and Coin Toss projects shown above. The Coin Toss Visualization project uses the Pen extension along with the music extension.

To use an extension, click the icon at the lower left of the *Scratch*® Screen. This brings you to a page where you can select the extension you want to load.



There is an extension for micro:bit which allows *Scratch*® to respond to various movements of the micro:bit as well as the pressing of the buttons on the board.

With Video Sensing, *Scratch*® responds to movements picked up by the computer's camera.

Text to Speech produces audible speech of the written words you type into the speak block. Translate take the text you type into the translate block and reports it translated into the language you specify. It's interesting to use these two extensions together. With the code at the right, you will hear *Scratch*® say "Hola."

Sharing and Remixing *Scratch*® Projects

There are millions of projects shared on the *Scratch*® website. Examining these projects is an effective way to learn more about *Scratch*® programming and project building, as well as about the content conveyed in the projects.

When you first create a *Scratch*® project, it is private so that only you can see it. You can share it so that everyone else who visits the *Scratch*® website can also view it. In either case, only you can make changes to it. But *Scratch*® also allows you to remix someone else's project, making a copy of it for yourself. Here is how that works:

Sign into your *Scratch*® account and go to a project you are interested in. You will see a green "Remix" button at the top of the Projects Page. When you click this, a copy of the project will be saved in your account. It will have the same name as the original project with the word "remix" added at the end. There will be a message at the top of the Projects Page crediting the author of the original.

You are now free to alter it, add to it, use parts of it in another project of yours. You can share your resulting project. For more information about remixing, look at: **https://en.scratch-wiki.info/wiki/Remix**

Additional *Scratch*® Projects Related to the ESD Kits

Here are some examples of Projects created by *Scratch*® users and shared on the *Scratch*® website that relate to the themes of the ESD Kits. You can search on the *Scratch*® website using terms such as "wind power," "water quality," or "renewable energy" and you will find many more.

You can search for Projects or Studios. A *Scratch*® Studio is a collection of Projects that are related to each other in some way. Any *Scratch*® user can set up a Studio. If you search for "renewable energy" you will see Projects related to that theme. If you click the Studios tab, you will see Studios with collections of Projects on that theme. If you click on one of them, you will see the Projects in that Studio.

Wind Power

https://scratch.mit.edu/projects/15858581/
This is an interactive report on wind power and other sources of energy used to produce electricity.

Wind Power Grids

https://scratch.mit.edu/projects/718595
An overview of US Wind Power electric power grids.

The Story of Energy

https://scratch.mit.edu/projects/1021089
This interactive story of energy includes four games focused on using renewable energy sources and reducing energy consumption.

Solar Panel

https://scratch.mit.edu/projects/11732/

This *Scratch*® project presents the case for increased use of solar panels to generate electricity.

Protect our water quality!

https://scratch.mit.edu/projects/437778501/

This animated tutorial on water quality is followed by a brief quiz.

Water Quality

https://scratch.mit.edu/projects/299820109/

This is an interactive presentation about water quality with a quiz at the end.

ESD KIT:
ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

APPENDIX 2: ABOUT MICRO:BIT

The micro:bit is a microcontroller that connects with a wide range of sensors and output devices and is programmed by connecting it to a laptop, tablet, or smartphone. It is designed for use in education and is widely available in many countries. Visit the micro:bit Foundation website at **https://microbit.org/** for all the information you need to get started. Click the Get Started tab on the homepage for tutorials on how to set up and program the micro:bit. To obtain a micro:bit, click the Buy tab on the homepage to locate a distributor in your country.

For activities that include data logging, you will need a micro:bt V2, which is the current version. To become familiar with how data logging works, go to **https://microbit.org/get-started/user-guide/data-logging/.**

The micro: bit is a good choice for ESD Kit Investigations and projects for several reasons. It is

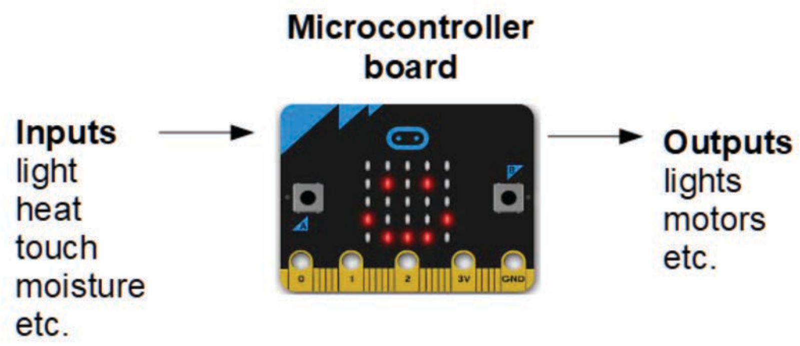
1. designed for education and has extensive support for teachers and students,
2. relatively low cost, and
3. widely available around the world.

Also, micro:bit has sensors built into the board itself, including temperature and light. Additional external sensors may be connected to it. The current version (V2) can be used for data logging.

An alternative to micro:bit is Arduino **https://www.arduino.cc/**, a family of similar microcontrollers. They are also widely available and well-supported.

More About Microcontrollers

A microcontroller is a device that takes inputs from sensors and acts upon them to control various devices. They are found in many appliances including microwave ovens, heating and cooling units, and automobiles.



Credit: Logo Foundation

Here are some examples of how a microcontroller can be used with sensors and output devices:

Light sensor ► turn lights on at night, off during the day

Temperature sensor ► turn a fan on when it's hot, off when it's cool

Moisture sensor ► turn irrigation water on when the ground is dry; off when moist

Microcontrollers can also be used to record sensor data over time. For example, you could record temperature at one-minute intervals over a period of 24 hours and then use the data in a graph or other visual representation.