SUSTAINABLE DEVELOPMENT GOALS

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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

Facilitator Guide

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Facilitator Guide

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ESD KIT: ACCESS TO CLEAN WATER

Sustainable Development Goal 6: Clean Water and Sanitation

INTRODUCTION

ESD Kit Strategy

Young learners can be inspired to take an active role in promoting sustainable development in their communities. The Next Generation (NextGen) ESD Kits will help learners build knowledge about important topics that affect all communities and individuals. Unlike past versions of ESD Kits, which were developed as stand-alone activities, ESD Kits are designed to promote sustained attention to a topic and the development of multi-faceted understanding.

Each kit consists of Investigations that are presented in a variety of engaging formats. The focus topics addressed in the ESD Kit Investigations are closely aligned with the United Nations Sustainable Development Goals (SDGs) on which each kit is based. The knowledge that learners develop about the SDGs will bring light to local issues and will prepare them for community awareness and engagement.

The first four ESD Kits are currently in development. Each focuses on one SDG:

SDG 6: Clean Water and Sanitation

SDG 7: Affordable and Clean Energy

SDG 12: Responsible Consumption and Production

SDG 13: Climate Action

Learning outcomes for the kits address ideas in the SDG targets, as well as the relevant UNESCO **Education for Sustainable Development Goals: Learning Objectives**.

Learning Progression

Each ESD Kit provides multiple opportunities for learner engagement across a range of learning styles, interests, and skill levels. Each kit starts with an Investigation in which learners reflect on their own relationship with the topic of the SDG — such as their energy use or how they may be affected by climate change. In the remaining Investigations learners will explore different aspects of the topic. The activities in the ESD Kits may make use of one or more active learning approaches, including:

- Hands-on learning
- Data-focused analysis
- Computer coding by designing or repurposing projects in *Scratch*®
- Applications of microprocessors for sensing and control, and for data logging
- Strategies for communicating with others about ideas, problems, and solutions

Across these approaches, learners have opportunities to practice 21st Century Skills such as critical thinking, communication, and information literacy. Each ESD Kit includes a project that allows students to synthesize ideas, relate them to their community, and share them with peers.

Materials

The ESD Kits are designed to be implemented across the world, using materials that are expected to be readily accessible in different international contexts. The material lists in the facilitator guides include specific details about the items to be used. Whenever possible, Investigations use materials and supplies that are familiar and easy to acquire locally. Investigations using more technical items, such as microprocessors, also provide less technical options that address the same concepts.

Uses of *Scratch*® and Microcontrollers

The ESD Kits incorporate the use of *Scratch*®, a widely available, free programming environment that is implemented in dozens of languages and has user support documentation available in many of them. In the ESD Kits, coding is also used with microprocessors (e.g., micro:bit) to support two broad focus areas — technological literacy and creative self-expression.

Computer-based technologies affect every person and society in ways that are direct and other ways that are indirect. Citizens of the future need to understand basic computer processes such as coding to control and automate systems. This understanding is an important aspect of technological literacy and is a foundation for further learning in computer science and other technologically sophisticated fields.

As well, *Scratch*® provides an open-ended but well-supported set of tools for learners to model, explore, and present their ideas about the topics they are learning about in the ESD Kits in creative and technologically advanced ways. Included are many examples of *Scratch*® projects that can inspire learners and/or be the basis of their own work. Presentations provide a way for the learners' ideas to be clarified, validated, and appreciated by a range of audiences, including their peers, their parents, and other community members.

Extensions

Each Investigation has at least two Extension activities that build on or supplement the concepts covered as learners complete the procedure and analysis questions. There are four categories of Extension activities. *Testing Variables* allows learners to explore additional variables that could be tested within the procedure or a related experiment. *Analyzing Data* has learners describe and explain trends in graphs, maps, and data tables. *Applying Concepts* asks learners to use the main concepts covered in the Investigation to make sense of other phenomena, technologies, or issues. Lastly, *Using Scratch* gives learners ideas for how to make interactive computer-based presentations, stories, and games related to the Investigations. The Extensions are meant to give learners a more complete understanding of the concepts covered. Although they are optional, they are highly recommended.

Facilitator Support

The ESD Kits have been developed by experienced educators and curriculum designers to provide the support needed for facilitators to be successful. At the same time, the guidance in the kit is flexible enough to allow facilitators to respond to their learners and communities by adapting Investigations — such as by accessing locally relevant data, applying ideas to examples that are known to the children, and providing opportunities for learners to creatively express their own ideas in multiple formats, including through *Scratch*® programming.

The facilitator support includes such key elements as:

- An overview that briefly presents key concepts and descriptions of each Investigation.
- A master list of materials, organized by Investigation.
- Detailed step-by-step guidance for facilitating learner participation in each Investigation.
- Photographs of key stages within Investigations.
- Conceptual background needed to guide learners.
- A pacing guide to help facilitators estimate the time each Investigation may take.
- Extension opportunities, guidance connecting each Investigation to the project.
- Questions to consider with learners--and possible responses.
- "Notes for the Facilitator" that point out instructional options and fine points.
- Guidance on the use of microprocessors and *Scratch®.*

With these support features, facilitators will find the ESD Kits useful to inspire the next generation of community problem solvers, whether or not they've worked in education and outreach before.

Partnership Model

ESD Kits will be implemented by Schlumberger employees working in collaboration with partners in their locations. These partners may come from a variety of areas of expertise and may play any of several roles in the implementation. Examples of partnerships include:

- Educators in the community facilitating specific ESD Kit Investigations, or whole kits.
- Specialists working in areas of the community related to the ESD Kit, such as managers of local water facilities (SDG 6), power plants (SDG 7), retail shops (SDG 12), architectural design firms (SDG 13), to offer learners a real-world perspective on the dynamics of the topics as they affect the learner's community.
- Community members/organizations working on projects that make positive changes in the community that relate to one or more of the SDGs (e.g., recycling).

Inspiring Action

Overall, the intent of the ESD Kits is to inspire and enable young people to take action in their homes and communities. Through active learning, effective facilitation, and strong community partnerships, the ESD Kits can play a role in building a positive and sustainable future for all.

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ESD KIT: ACCESS TO CLEAN WATER

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OVERVIEW FOR THE FACILITATOR

In this ESD Kit, learners will explore sources and properties of water to understand its vital role in maintaining the health of the Earth and its many environments. This ESD Kit focuses on the Key Concepts of the *Targets and Indicators* within **Sustainable Development Goal (SDG) 6:** Ensure availability and sustainable management of water and sanitation for all.

This ESD Kit is designed using a "**systems thinking**" approach. Water is described in terms of its importance to the global ecological system as well as how human impacts affect water quality around the world. Most of the attention in the ESD Kit is on sources of water and the treatment of these sources when water becomes contaminated.

Data-focused Investigations are used to call attention to global trends of water quality and how this affects access to safe drinking water. Hands-on Investigations are used to learn about water movement through the environment as well as methods for treating contaminated water. Some Investigations also include opportunities to use technologies for sensing and coding, using the coding language *Scratch*®.

ESD Kit Project: Design a Net-Zero Water Community

Learners will complete Investigations to learn about water. They will then complete a culminating ESD Kit project in which they will use what they have learned to design a community or building that has specific features that reduce water use. Learners will prepare a presentation that outlines the decisions they made about design features of the community, and the water-related rationales for those decisions. Their presentation will relate the features of their community or building to Key Concepts of SDG 6.

Key Concepts

Several Key Concepts for this ESD Kit have been summarized from the SDG 6 Targets and Indicators. Added to those are other Key Concepts that students will need to know to understand fundamental ideas about water. The Key Concepts for this ESD Kit are: *desalination, freshwater, hygiene, safe drinking water, sanitation, wastewater, water cycle, water footprint, water management, water pollution, water quality, water-related ecosystems, water scarcity, water treatment, water-use efficiency, water withdrawals*

Investigation Descriptions

Key concepts are in italics.

1. **Water Around Us.** Key Concepts: *freshwater, safe drinking water*

   Learners consider what they know about water, such as types (*e.g., freshwater* vs. saltwater) and where water is found. A demonstration allows learners to visualize the relative amount of water in different types of bodies of water. Learners then consider where and how water is found and accessed in their own communities. The United Nations' Sustainable Development Goal 6 is introduced as an overarching theme of the ESD Kit, which looks at how people can work toward improving the quality of water sources and access to *safe drinking water* around the world.

2. **Water Movement Through the Environment.** Key Concepts: *freshwater, water cycle, water quality, water withdrawals*

   Learners experiment with how the availability of *freshwater* impacts the mass of plants. The results of the experiment are then related to the *water cycle*. Learners then play a game where they act as a water molecule moving through the water cycle to better understand processes that affect the distribution and movement of water through the environment. Learners are asked to consider in what stages of the water cycle *water withdrawals are* made by people, as well as how contaminants can enter the water cycle and decrease *water quality*.

3. **Building a Model Watershed.** Key Concepts: *freshwater, water pollution*

   Learners use a model to examine how *freshwater* moves in a watershed. Contaminants can be added to the model to show how *water pollution* can spread through the environment. Learners then analyze topographic maps and apply what they learned about how water moved on their models, and then assess their local watershed.

4. **Groundwater Movement and Pollution.** Key Concepts: *safe drinking water, water pollution, water quality, water withdrawals*

   Learners model how groundwater moves to and around a body of water. The model is modified to show confined aquifers and how *water pollution* can be spread by groundwater and affect bodies of water. A model well is added to demonstrate one method of *water withdrawal.* Learners will also test *water quality* to investigate possible contaminants entering the well and affecting access to *safe drinking water*. Through data analysis, learners will look at how contaminants enter bodies of water around the world. There is also an opportunity to use a micro:bit to assess water clarity (turbidity) and how it relates to making water potable.

5. **Treating Wastewater.** Key Concepts: *desalination, freshwater, safe drinking water, wastewater, water quality, water treatment*

   Learners use simulated *wastewater and experiment with different water treatment processes* to understand how *safe drinking water can be produced*. Learners first test common filters, and then design their own. Optionally, *water quality* tests can be done to assess the water samples and determine if further treatment is necessary. Learners then experiment with *desalination* by distilling the simulated wastewater. A facilitator demonstration explores how light can be used to improve water quality. Learners then run and analyze osmosis experiments to understand how it works and consider how reverse osmosis can improve water quality. Learners will consider which water treatment processes *are able to produce freshwater from saltwater*.

6. **Assessing Your Water Footprint.** Key Concepts: *water footprint, water management, water scarcity, water-use efficiency, water withdrawals*

   Learners assess their *water footprint* to generate ideas about how to reduce their water use. Using a hands-on simulation, learners consider factors that affect or cause *water scarcity* and how different populations can use *water management* strategies to address this problem. Data analysis has learners consider water use in different countries. An understanding of *water withdrawals* at the individual, population, national, and world scales can facilitate a discussion of how to improve *water-use efficiency.*

7. **Water Use and Hygiene.** Key Concepts: *hygiene, sanitation*

   Learners test various methods of handwashing to determine their effectiveness and amounts of water used. Some properties of water are tested to initiate discussion of how soap works. Learners use what they observe to discuss the need for good *hygiene* practices, access to clean water, and the need to conserve water. Data analysis has learners consider the difference between hygiene and *sanitation* and analyze the global trends of each.

8. **Restoring Habitats.** Key Concepts: *freshwater, water quality, water pollution, water-related ecosystems, water treatment*

   Learners create a model landscape to test the effects of *water-related ecosystems,* specifically *freshwater* wetlands, on the movement of water and *water pollution*. Learners then simulate an oil-spill to investigate how it can affect *water quality* and other components of the environment. Common methods for cleaning oil spills are tested to compare them in terms of cost- and overall-effectiveness. Learners then consider the need for *water treatment* procedures to restore water quality.

ESD KIT: ACCESS TO CLEAN WATER

Sustainable Development Goal 6: Clean Water and Sanitation

MASTER LIST OF MATERIALS

Investigations are intended to be completed in small groups. Materials used in multiple Investigations are marked with asterisks.

Materials by Investigation:

Investigation 1: Water Around Us

Per group:

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

*Also used in Investigation 8B

Investigation 2: Water Movement Through the Environment

For Facilitator Demonstration:

- 4 small potted plants (preferably begonias)
- large, clear plastic bag
- plastic wrap
- *4 small plastic cups
- small fan
- desk lamp
- scale

- tape
- marker
- **spray bottle
- water
- poster paper (optional, for displaying data table)

For Learner Investigation:

Per learner:

- 6-sided die
- unlabeled "Water Cycle Diagram" handout

Per group:

- station instruction sheet

*Also used in Investigations 4A and 6B1
**Also used in Investigations 3A and 8A

Investigation 3A: Building a Model Watershed

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)

*Also used in Investigations 2 and 8A
**Also used in Investigation 4A, 4B, and 8A
†Also used in Investigations 8A

Investigation 3B1: Using Topographic Maps

Per learner:

- "Topographic Maps" handout
- pencil

Investigation 3B2: Identifying Your Watershed

Per learner:

- copy of local watershed map
- pencil
- colored pencils

Investigation 4A: Groundwater Movement and Pollution

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)

*Also used in Investigations 2 and 6B1
**Also used in Investigation 3A, 4B, and 8A
†Also used in Investigations 5A1 and 5A2
‡Also used in Investigation 6B1, 7, and 8A

Investigation 4B: Water Quality

Per group:

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

*Also used in Investigations 5A1, 5A2, and 5B
**Also used in Investigations 7 and 8B
†Also used in Investigations 3A and 4A

Investigation 5A1: Treating Wastewater by Filtration

†Simulated Wastewater, per group:

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- granular, liquid, or tablet fertilizer , 10 grams,
- small plastic beads, 3 grams, such as PH Purple Seed Beads (https://amzn.to/3SRrkQB)

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**)

*Also used in Investigations 4A and 5A2
**Also used in Investigations 4B, 5A2, and 5B
†Also used in Investigations 5A2 and 5B
‡Also used in Investigation 5A2
§Also used in Investigations 5A2 and 8B

Investigation 5A2: Designing a Filtration System

†Simulated Wastewater, per group:

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- granular, liquid, or tablet fertilizer, 10 grams,
- small plastic beads, 3 grams, such as PH Purple Seed Beads (**https://amzn.to/3SRrkQB**)

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**)

*Also used in Investigations 4A and 5A1
**Also used in Investigations 4B, 5A1, and 5B
†Also used in Investigations 5A1 and 5B
‡Also used in Investigation 5A1
§Also used in Investigations 5A1 and 8B

Investigation 5B: Treating Wastewater Using Heat and Light

**Simulated wastewater, per group:

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- fertilizer, 10 grams
- small plastic beads, 3 grams, such as PH Purple Seed Beads (https://amzn.to/3SRrkQB)

For Facilitator Demonstration:

- simulated wastewater, about 300 mL
- clear glass or plastic bottle or jar with lid
- sunny area or UV lamp
- camera or phone with camera (optional)

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)

*Also used in Investigations 4B, 5A1, and 5A2

**Also used in Investigations 5A1 and 5A2

Investigation 6A: Assessing Your Water Footprint

Per group:

- "Assessing Your Water Footprint" handout

Investigation 6B1: Water Availability Scenarios

Per group:

- *10 cups
- 700-800 mL (24-27 oz.) water bottle, preferably clear
- †1 large bowl
- **towel

Group 1:

- gallon container labeled "Resources"

Group 2:

- small container (about 0.7 L [3 cups]) labeled "Resources"

Group 3:

- opaque pitcher or container, labeled "Resources"
- gallon container, labeled "Potential"
- ‡baster

*Also used in Investigations 2 and 4A
**Also used in Investigation 7
†Also used in Investigations 4A, 7, and 8A
‡Also used in Investigation 8A

Investigation 6B2: Analyzing Water Use

Per group:

- copy of maps within Investigation

Investigation 7: Water Use and Hygiene

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

*Also used in Investigations 4B and 8B
**Also used in Investigation 6B
†Also used in Investigations 4A, 6B1, and 8A
‡Also used in Investigation 8B

Investigation 8A: Constructing a Wetland

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)

*Also used in Investigation 2 and 3A
**Also used in Investigations 4A, 6B1, and 7
†Also used in Investigations 3A, 4A, and 4B
‡Also used in Investigation 6B1

Investigation 8B: Restoring Habitats

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

*Also used in Investigation 1
**Also used in Investigation 3A
†Also used in Investigations 4B and 7
‡Also used in Investigation 5A1 and 5A2
§Also used in Investigations 7

ESD KIT:
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Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 1: WATER AROUND US

Facilitator Background

Connection to SDG 6: The goal of SDG 6 is to "ensure availability and sustainable management of water and sanitation for all" (https://sdgs.un.org/goals/goal6). To understand the availability of water for all, it is important to know how much usable water there is on Earth. Water covers most of the Earth's surface and may seem like an abundant resource, but most of Earth's water is salt water and most of the *fresh water* is tied up in ice or is underground. In this introductory Investigation, learners will model the relative amounts from water in various sources and consider the water sources in their community as well as their access to *safe drinking water*.

Key Concepts: *fresh water, safe drinking water*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider ideal locations for their net-zero town.

Notes for the Facilitator: If planning to complete the ESD Kit Project, it is a good idea to introduce it to learners during this Investigation. The ESD Kit Project revisits the major concepts in the Investigations that can be incorporated into their net-zero town design. Introducing the ESD Kit Project now would allow learners to think about their designs in advance of starting the project.

PACING GUIDE

PREPARATION
10 minutes reading the facilitator notes and researching community-specific answers to Step 3
10 minutes setting up supplies for learners

WHAT TO DO
30 minutes for the Investigation
10 minutes to discuss the ESD Kit Project (optional)

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?

Notes for the Facilitator: Have a class discussion about these three questions. Answers could include freshwater, saltwater, water as a liquid, water as a gas, water as a solid for 1a. Oceans, glaciers and other frozen water, groundwater and soil moisture, lakes, wetlands, atmosphere, and rivers are answers for 1b. Freshwater sources including groundwater, lakes, atmosphere (e.g., clouds, humidity, rain), and rivers are answers for 1c. Students may bring up that water should be treated before consumption.

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:

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

Notes for the Facilitator: Discuss student predictions, then share the correct percentages and volumes with them. You can also measure the correct volume of water for each water source into a set of labeled cups to create a more accurate display.

Water Source	% Total	Volume
Oceans	96.50%	483 mL
Glaciers and Other Frozen Water	1.80%	9 mL
Groundwater and Soil Moisture	1.70%	8 mL
Lakes	0.01%	1 drop
Wetlands	<0.01%	1.1 drops
Atmosphere	<0.01%	0.1 drops
Rivers	<0.01%	0.02 drops
Total	**100%**	**500**

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?

Notes for the Facilitator: Have a whole group discussion about water in your community. Discuss answers to these questions, which will vary depending on your location. Some potential answers to 3a include drinking water, watering plants, water for animals, water for toilets and bathing, cleaning and appliances, and so on. Within this discussion, compare your community with what others may experience, such as water scarcity or contamination. End the discussion by introducing learners to the United Nation's Sustainable Development Goals and specifically SDG 6 on Clean Water and Sanitation (**https://sdgs.un.org/goals/goal6**).

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?

Notes for the Facilitator: After introducing SDG 6 to learners and discussing the questions above, discuss the Targets and Indicators within SDG 6 and their importance in terms of access to clean water. If possible, have learners read through the SDG Targets and discuss which the learners consider most important and why.

Consider

1. How did your predictions compare to the actual amounts from each water source? Why might your prediction have been off?

Notes for the Facilitator: Answers will vary. Learners may believe fresh water is more abundant than it is. Living by freshwater sources may also cause learners to perceive more fresh water on Earth than a learner who lives near an ocean.

2. What do you notice about the distribution of the world's water among the different sources? Did anything surprise you?

Notes for the Facilitator: Answers will vary.

3. Which of the water sources is considered freshwater? How much of the world's water is freshwater and how much is salt water?

Notes for the Facilitator: Fresh water is located in glaciers and other frozen water, as well as lakes, wetlands, atmosphere, rivers, groundwater, and soil moisture. Salt water is located in oceans and seas, and a even a significant percentage of groundwater is considered brine, particularly deeper ground water sources. About 97% of the water on Earth is saltwater, while about 3% is freshwater.

4. What are some common uses of fresh water?

Note for the Facilitator: Answers will vary but could include drinking water, bathing, cleaning, food production, power generation, manufacturing, sanitation, and recreation.

5. What are some ways you know of or ways you think saltwater could be used?

Notes for the Facilitator: Answers will vary but could include industrial purposes, mining, and power-plant cooling or for personal health reasons like treating skin conditions. Saltwater can also become freshwater through desalination, although it is expensive.

6. How might the distribution between freshwater and saltwater change as the Earth's temperature increases?

Notes for the Facilitator: The distribution of freshwater is predicted to change. With rising temperatures, sea levels will rise causing the saltwater to intrude into freshwater sources near the coast. This will reduce the amount of available freshwater compared to saltwater in those locations. Also, as temperatures increase, glaciers and icebergs will melt, which can threaten freshwater sources for communities that rely on those sources. Overall, as temperatures warm, there will be more evaporation and the atmosphere could hold more moisture, so the amount of precipitation is expected to increase globally, but the distribution of rainfall will change. It is expected that there will be increased drought in subtropical regions but more rain elsewhere.

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).s

ESD KIT:
ACCESS TO CLEAN WATER

6 CLEAN WATER AND SANITATION

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 2:
WATER MOVEMENT THROUGH THE ENVIRONMENT

Facilitator Background

Connection to SDG 6: Indicator 6.3.2 sets a goal to increase the "proportion of bodies of water with good ambient *water quality*" (**https://sdgs.un.org/goals/goal6**). Analyzing the *water cycle* allows for an understanding of how water molecules are transferred between Earth's spheres. Within the context of the water cycle, it is important for humans to recognize natural sources of *freshwater* to use, and also to protect and conserve. This Investigation looks at the water cycle and introduces learners to sources of *water withdrawals* utilized by people.

Key Concepts: *freshwater, water cycle, water quality, water withdrawals*

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

Connect to the ESD Kit Project: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners will be able to consider how the water cycle affects their town, as well as how their town might affect the water cycle.

PACING GUIDE

PREPARATION

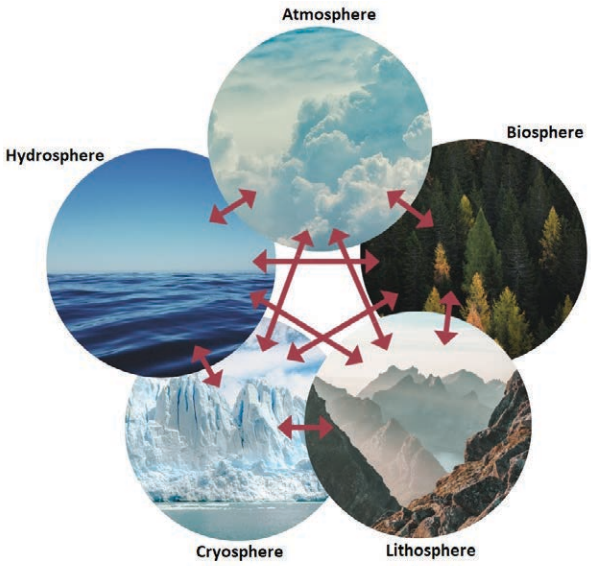
- **10 minutes** setting up plants for the Facilitator Demonstration, 1–3 days in advance
- **5 minutes** making copies of the Water Cycle Diagram
- **15 minutes** setting up materials for groups

WHAT TO DO

- **5 minutes** discussing the introduction material
- **20 minutes** for the Investigation
- **10 minutes** for the Facilitator Demonstration

Introduction

Earth is described as having many systems, which are referred to as spheres, each of which describes a major component of Earth, such as rocks, water, air, and living organisms. "Hydrosphere" is the term used to describe all the water on Earth. Earth's water is not usually pure, nor is it always liquid; regardless of its quality or state, all water on Earth is part of the hydrosphere. For example, the term "cryosphere" is used to describe ice on Earth, but this is still water and is sometimes considered part of the hydrosphere. Water molecules can move between water sources within the hydrosphere, and they can also become part of the other spheres. Taken together, the processes by which water moves are referred to as the water cycle.



Credit: Modified from Unsplash, Creative Commons, https://commons.wikimedia.org/wiki/File:Climate-system.jpg

Notes for the Facilitator: Review each of Earth's spheres as needed so learners can label them on their water cycle diagrams.

Materials

For Facilitator Demonstration:

- 4 small potted plants (preferably begonias)
- large, clear plastic bag
- plastic wrap
- 4 small plastic cups
- small fan
- desk lamp
- scale
- tape
- marker
- spray bottle
- water
- poster paper (optional, for displaying data table)

For Learner Investigation:

Per learner:

- 6-sided die
- unlabeled "Water Cycle Diagram" handout

Per group:

- station instruction sheet

What to Do

Facilitator Demonstration:

At least 24 hours before learners conduct this Investigation, remove four leafy plants of approximately the same size, their attached root balls, and excess soil from pots.

1. Remove ¾ of the root ball from each plant so they are roughly the same size.
2. Place each plant in its own plastic cup. Add enough water so the soil is moist but not overly wet. Add the same amount of water to each plant.
3. Use plastic wrap to cover the cup and prevent water from escaping into the air. Wrap it tightly around the stem of the plant. Alternatively, you could place the plastic cup into a plastic sandwich bag and secure the bag around the stem using a rubber band.

PLANT TRANSPIRATION DEMONSTRATION

Credit: USGS, Public Domain, https://www.usgs.gov/media/images/experiment-shows-result-plant-transpiration

4. Take the mass of each plant and record them on a data table that will be shared with learners. Make columns for recording the final mass and percent change in mass. When adding variables in the next step, be very careful to track which plant is placed in which setup.

5. Place all four plants in the same general area so they are exposed to similar conditions aside from the following:

   a. Place a lamp directly over one plant.

   b. Place one plant in front of a small fan.

   c. Place a large plastic bag around one plant. Use a spray bottle to mist water onto the plant and the inside of the bag. Seal the bag so the entire setup is inside it.

   d. The fourth plant will be a control. Make sure it has the same amount of sunlight as the other setups.

6. Do not move or water the plants during the course of the experiment, which can last from 24–72 hours.

7. On the day of the Investigation, describe the setup to learners and allow them to make observations or inferences about what environmental conditions each setup represents.

Notes for the Facilitator: The plant with the lamp is exposed to more light than the other plants; the light can heat up water and increase evaporation. The plant in the bag is in humid conditions; there is a lot of water in the atmosphere, which decreases evaporation. The plant with the fan is in windy conditions; wind moves air within the atmosphere and increases evaporation.

8. Have learners make predictions about what they expect to have happened to the mass of each setup.

9. Take the mass of each plant in their cup and record it in the data table. For the plant in the plastic bag, remove the bag before massing.

10. Calculate the percent change in mass by:

    a. subtracting the initial mass from the final,

    b. dividing the difference in mass by the initial mass, then

    c. Multiplying by 100.

$$\%\,change\ in\ mass\ = 100 \cdot \frac{(final\ mass - initial\ mass)}{(initial\ mass)}$$

11. Record the percent change in mass on the data table.

Notes for the Facilitator: If the plant lost mass, the percent change in mass will be negative. If the plant gained mass, the percent change in mass will be positive. The percent change in mass takes initial mass into account (which are all different) so that the results from the plants can be compared. Only using the change in mass is misleading because it does not report the loss or gain in mass with respect to the initial mass. Discuss with learners potential sources of error during the experiment, including plants with more leaves, a greater mass, or more roots in their root ball being able to exchange more water with the environment.

Learner Investigation:

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.

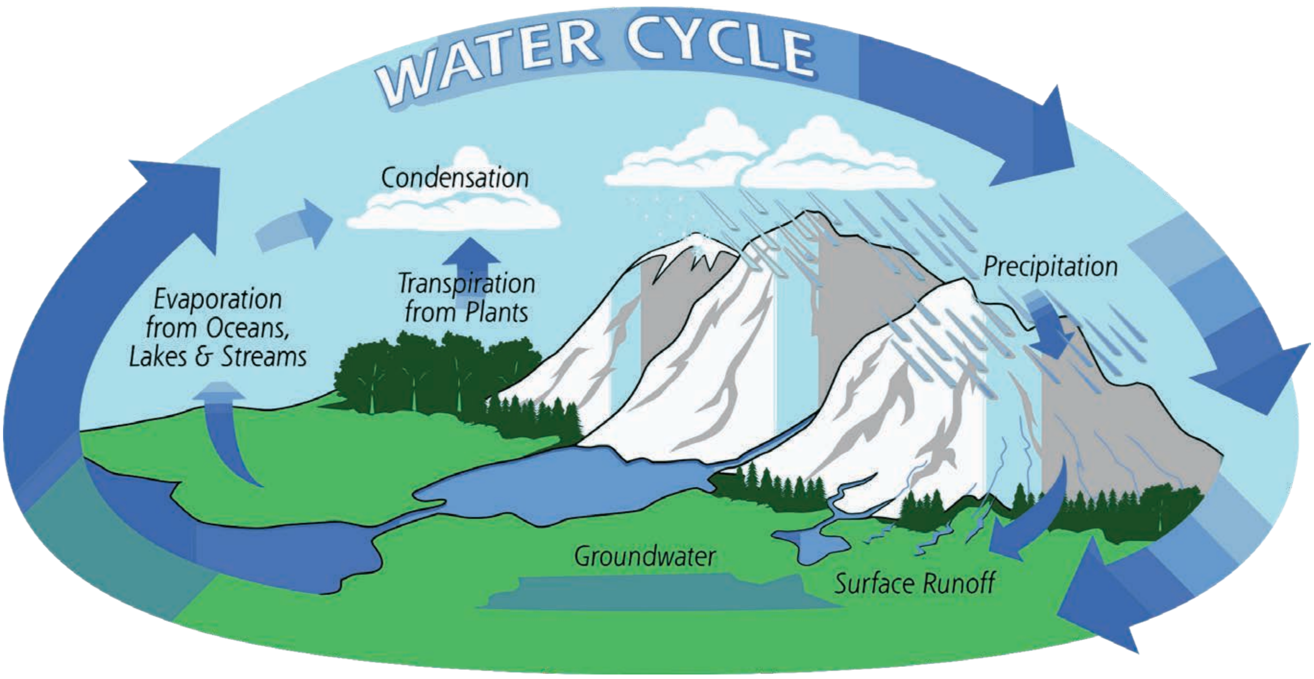
d. Roll again and use the instructions at the station to determine your next location.

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.

Notes for the Facilitator: An example of a completed water cycle has been provided for your reference.

WATER CYCLE DIAGRAM



Credit: NASA

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

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?

Notes for the Facilitator: Learners' predictions will vary, but the results likely show no change (or a slight increase) in mass for the plant in the bag and a decrease in mass of the other three plants; the plants under the light and fan will likely lose more mass than the control plant. The plant in the bag likely gained mass due to taking in water from the soil but not releasing much water, since all the excess atmospheric water around the plant will have decreased water loss from the leaves. Both the light and the fan facilitated water movement away from the plant, which sped up the rate of transpiration, causing a water loss to the atmosphere. Transpiration causes water to move from the soil (lithosphere/geosphere) into plants (biosphere) and then into the atmosphere. It is unlikely that all the water from the soil goes into the plant, and this can likely be seen if some water has accumulated on the plastic wrap covering the cup. Water evaporating from the soil will condense on the plastic wrap, showing that some water is transferred directly from the soil into the atmosphere.

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?

Notes for the Facilitator: The ocean, because about 97% of the world's water is in oceans https://on.doi.gov/3JAnfun, so water in the oceans is likely to stay there. Only water molecules at the surface of the ocean can evaporate or freeze; and the living organisms in the ocean are sparse enough (while the oceans cover 70% of the earth's surface, they contain only 1% of the Earth's total biomass [**https://ourworldindata.org/life-by-environment**]) that the amount of water going directly from the ocean to the biosphere is also low and that water is also is not trapped in the biosphere long. Except for water in deep aquifers or glacial ice caps, water in locations other than an ocean can more easily move to other bodies of water or spheres because these locations are more dynamic (like the atmosphere), smaller, or have a greater surface area-to-volume ratio (or contact with other spheres). Scientists refer to these as reservoirs which have different residence times. Average residence times in the biosphere and atmosphere can be as little as days to a week, a decade for lakes, but 4,000 years for the ocean and up to 10,000 years for groundwater and glaciers (**https://www.khanacademy.org/science/biology/ecology/biogeochemical-cycles/a/the-water-cycle).**

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?

Notes for the Facilitator: Answers will vary as learners will have unique pathways based on where they started and how they rolled throughout the activity. The learners' examples should be similar in that they ended up in every (or most) location(s) within the cycle, and likely spent a good deal of time in the ocean. This is realistic because it is by random chance that a specific molecule of water moves from one location to another.

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

Notes for the Facilitator: Since this is posed as an argument, accept multiple answers based on the learners' reasoning. Lakes and rivers are freshwater sources within the hydrosphere that are directly consumable. The lithosphere/geosphere contains water moving through aquifers, which is where most wells get their water. Humans also consume water from their diet by eating plants and other animals (biosphere).

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.

Notes for the Facilitator: All organisms consume water as well as give it off as a waste product. Plants also use water to conduct photosynthesis and other biologic processes. Microorganisms that live in clouds, such as bacteria and fungi, are involved in the freezing and nucleation of water, which causes precipitation to occur. For more information on microorganisms that live in clouds, visit: https://theworld.org/stories/2017–03–22/bacteria-are-thriving-sky-and-they-influence-weather. Microorganisms that live in permafrost are often involved in helping other organisms thrive and access water in cold environments. For more information on microorganisms that live in ice, visit: **https://link.springer.com/article/10.1007/s00253-019-09631-3**.

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:

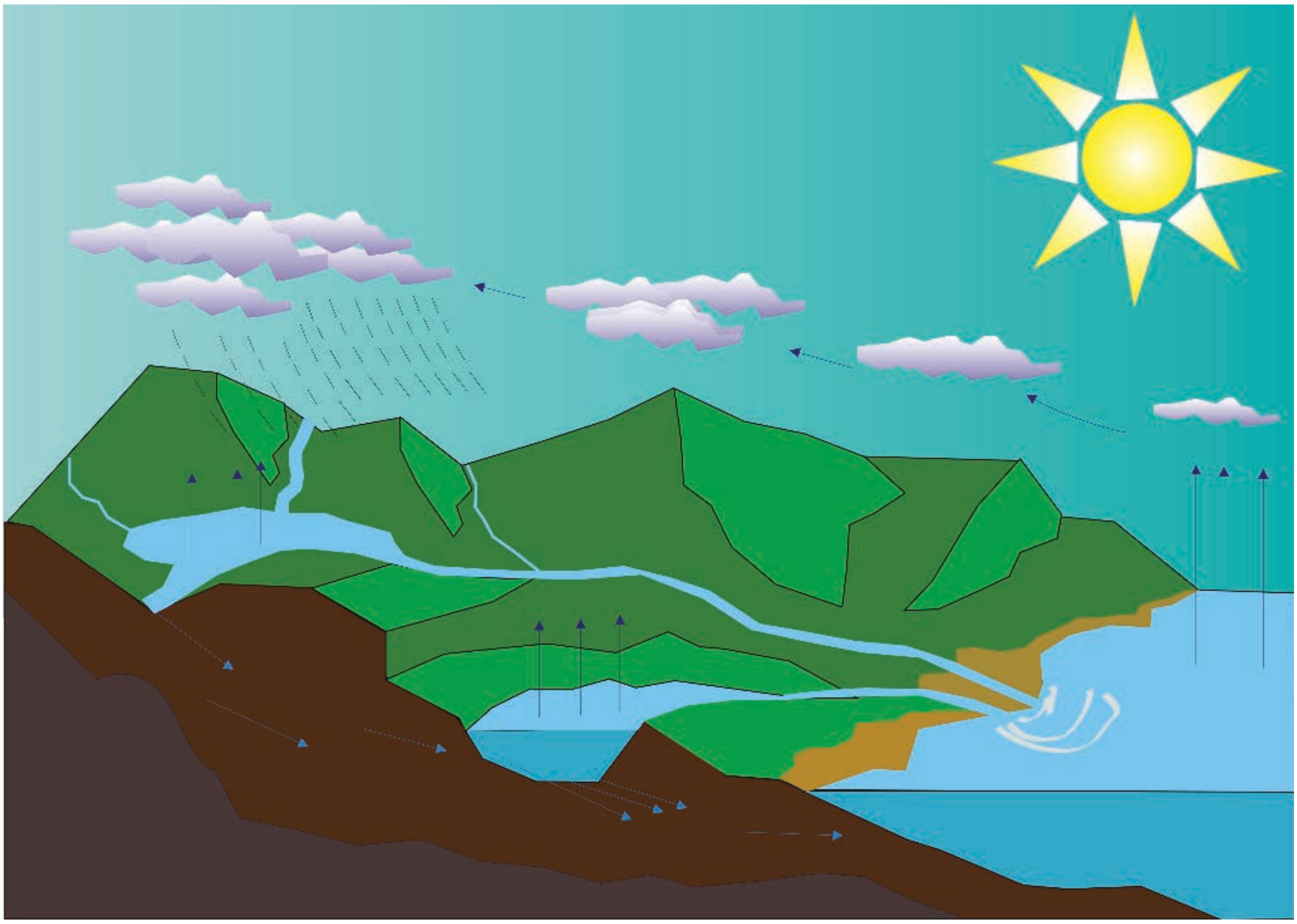
    a. For a simple animation of the water cycle: **https://scratch.mit.edu/projects/735011384/**

    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**

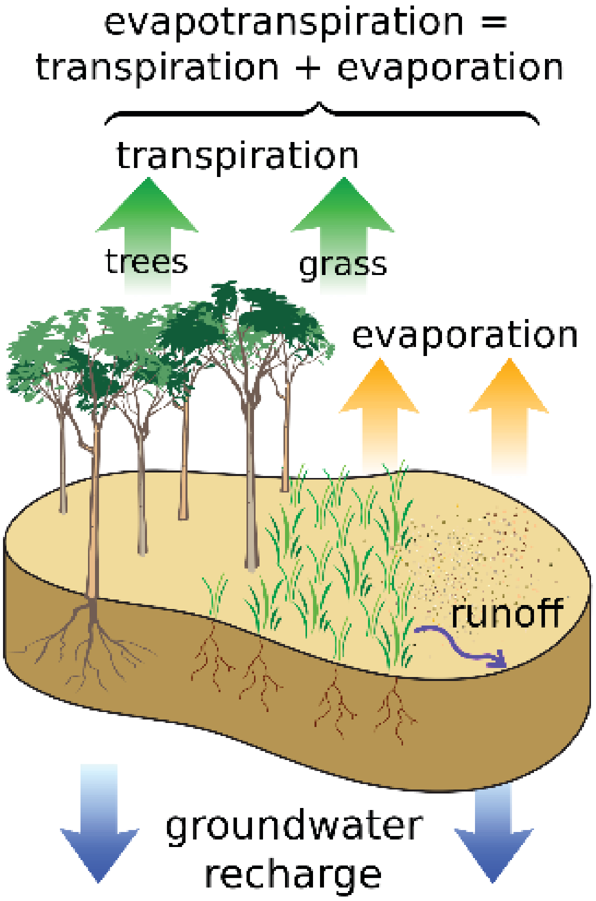
WATER CYCLE DIAGRAM



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

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

ESD KIT:
ACCESS TO CLEAN WATER

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 3A: BUILDING A MODEL WATERSHED

Facilitator Background

Connection to SDG 12: Target 6.1 aims to "achieve universal and equitable access to safe and affordable drinking water for all" (**https://sdgs.un.org/goals/goal6**). Drinking water can come from *freshwater* sources below ground (groundwater) or on the surface from lakes, streams, and rivers. Many different water sources are connected within a watershed, which is an area where all water drains into a common outlet. Since water sources are connected, when *water pollution* occurs, it travels down through the watershed and contamination spreads. In this Investigation, learners will build a landscape model to examine how water moves and how pollution might spread.

Key Concepts: *freshwater, water pollution*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town which uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider the watershed where their town is located and at what general elevations or near what topographic features water is most easily accessible.

PACING GUIDE

PREPARATION
10 minutes setting out materials
10 minutes creating and printing community maps for extension activity (optional)

WHAT TO DO
20 minutes for the Investigation

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)

Notes for the Facilitator: The Awesome Aquifer© Kit (**https://awesomeaquifer.com/**) can also be used to complete this Investigation. The colored powder or sprinkles will be used to represent the addition of fertilizer to the environment; the runoff from this will demonstrate the spread of excess nutrients as one source of pollution. An online search will yield many options for purchasing or making these materials.

To help learners see where the water is moving, it is helpful to add food dye to the water in the spray bottle. If you want learners to create a larger scale version of a watershed, you can use a shower curtain instead of a garbage bag and eliminate the tray. It is recommended to do this Investigation outside if using the shower curtain.

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.

credit:

credit:

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?

Notes for the Facilitator: Lead a whole group discussion of learners' results. Discuss how water moves from high to low elevations, water moves faster when the landscape is steeper, and water settles at low points. Different groups are likely to have different numbers of watersheds and different areas where water collects.

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?

Notes for the Facilitator: Discuss the difference between contamination and pollution. Then discuss results as a whole group and relate to the terms *contaminant* and *pollutant*. The pollution (colored powder) should have moved downstream after the rain, which would impact the humans, animals, and plants downstream from the initial point of pollution.

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?

Notes for the Facilitator: The tallest landmasses in a region separates watersheds and determine which way water flows. This is what learners should have seen in the model and is accurate in real life as topography is the key element affecting how water drains in a landscape. There are some important differences between the model and the real world. For example, in the model water does not continue to flow once it settles in a low point on the garbage bag. In real life, water also moves through the ground, and lakes will have their own outlets, so there are connections between smaller watersheds (subwatersheds) and a large-scale watershed. Also, in real life, erosion and sedimentation occur constantly, which affects watersheds and how water moves.

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?

Notes for the Facilitator: The garbage bag is impervious, so no water can move through it. Instead, all the water moves as surface flow. This accurately reflects impervious surfaces in a watershed such as exposed solid rock and human-made roads and buildings but does not accurately reflect the pervious surfaces such as the soil and grassy areas. A better representation of pervious surfaces could be sponges since they take in water. Using a pervious surface on the model would slow the flow of water and would increase the time for water to collect in low elevations.

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?

Notes for the Facilitator: Surface water features such as streams, rivers, and lakes could have formed on the surface in the model. Others that exist include oceans, wetlands, alpine glaciers, and ice sheets. In the model, groundwater is not represented. In real life, groundwater is everywhere although the depth and speed of movement differs.

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?

Notes for the Facilitator: Areas at lower elevations tend to have more surface water in the forms of lakes, rivers, and wetlands. While areas at higher elevations also have lakes and streams, they tend to be dependent on precipitation (e.g., ephemeral streams that only flow for a short time after rain events) or are seasonal (e.g., intermittent streams that are fed by groundwater but may dry up during certain seasons). Towns at lower elevations may have more access to water compared to towns at higher elevations.

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?

Notes for the Facilitator: A contaminant is the more general term for when a new substance or a substance in excess quantities is present. A pollutant is a specific type of contamination that causes harm. Pollution is always contamination, while a contaminant is not always considered pollution. Pollutants can be very small quantities of a chemical that are unsafe at any level, like arsenic or lead, or it can be a chemical in too high of quantity that it can cause harm, like chlorine or nitrates.

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?

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 3B: ANALYZING WATERSHEDS

Facilitator Background

Connection to SDG 12: Target 6.1 aims to "achieve universal and equitable access to safe and affordable drinking water for all" (**https://sdgs.un.org/goals/goal6**). Drinking water can come from *freshwater* sources below ground (groundwater) or on the surface from lakes, streams, and rivers. How water moves across the surface is determined mostly by the topography of the land. In this Investigation, learners will examine topographic maps to determine differences in how water moves and collects in different types of landscapes. They will also examine a local watershed map to learn how surface water moves near them.

Key Concepts: *freshwater*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider how the topography their town relates to water sources and watersheds.

PACING GUIDE

PREPARATION

10 minutes copying handout

20 minutes finding and copying local watershed maps, for Part 2

WHAT TO DO

30 minutes for Part 1

15 minutes for Part 2

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 3B1: USING TOPOGRAPHIC MAPS

Materials

Per learner:

- "Topographic Maps" handout
- pencil

Notes for the Facilitator: A good global resource for analyzing topography is **https://en-gb.topographic-map.com/**. If you are located in the United States, River Runner is another good resource to show learners or have learners test out: **https://river-runner.samlearner.com/.**

Introduction

A topographic map uses lines to show different elevations. These lines are called contour lines. All points on a contour line are at the same elevation. The horizontal distances between contour lines are determined by the steepness of the landscape. If contour lines are closer together, the landscape is steep. If the contour lines are fairly spread out, the landscape has a gentler slope or is flatter.

Topographic maps are helpful to understand why water moves in certain directions and how watershed boundaries are determined. A watershed can be any size – as small as a lake and as large as millions of square kilometers. Larger watersheds are comprised of subwatersheds (up to thousands of them). All water within related subwatersheds will end up draining to the same location.

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.

Notes for the Facilitator: It would be best to give learners some time to answer questions a-f with their groups, and then to display the maps, if possible, and go through the answers. The United States Department of Agriculture, Natural Resources Conservation Service provides more information about topographic maps at **https://bit.ly/39F4jOW**. If learners completed Investigation 3A, you can relate topographic maps back to their models.

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

Notes for the Facilitator: Answers will vary, and could include there are many lines, some lines are labeled, some lines are bunched closely together while others are spread apart. The lines on a topographic map never cross. Some lines make closed circles; if learners observe this, inform them that if the map was larger (zoomed out), they would see more lines connect and form circles.

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?

Notes for the Facilitator: On Map A, the labeled contour lines are 100 and 50 and there are four lines between them, which means each line represents an elevation change of 10 meters. The highest elevation contour line is 120 meters and the lowest is 40 meters.

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?

Notes for the Facilitator: On Map B, the labeled contour lines are 500, 1000, 1500 and there are four lines between the labeled lines, which means each line represents an elevation change of 100 meters. The highest elevation contour line is 1900 meters and the lowest is 500 meters.

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?

Notes for the Facilitator: Map B displays higher elevations in general and a wider range of elevations compared to Map A. Therefore, Map B likely displays a map of a mountainous area. Map A displays a small range of elevations (40–120 meters) which would be considered a flatter landscape with some hills.

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?

Notes for the Facilitator: The rivers are located where the contour lines form a "V" shape. The lake on Map B formed in a relatively flat, low area.

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.

Notes for the Facilitator: The river flows towards the west on Map A and towards the east on Map B. The arrows are displayed on the Facilitator Answer Key maps.

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"?

Notes for the Facilitator: Water always moves from a higher elevation to an area of lower elevation. On Map A, water would flow downward toward "E." On Map B, water would flow downward to "C." Here, "down" is in reference to elevation; make sure learners do not confuse this for "south."

c. Locate the star on Map A.

d. At what elevation is the star located?

Notes for the Facilitator: On Map A, the star is located at 110 meters. On Map B, the star is located at 1600 meters.

e. Identify the "down" direction, or the lower elevation.

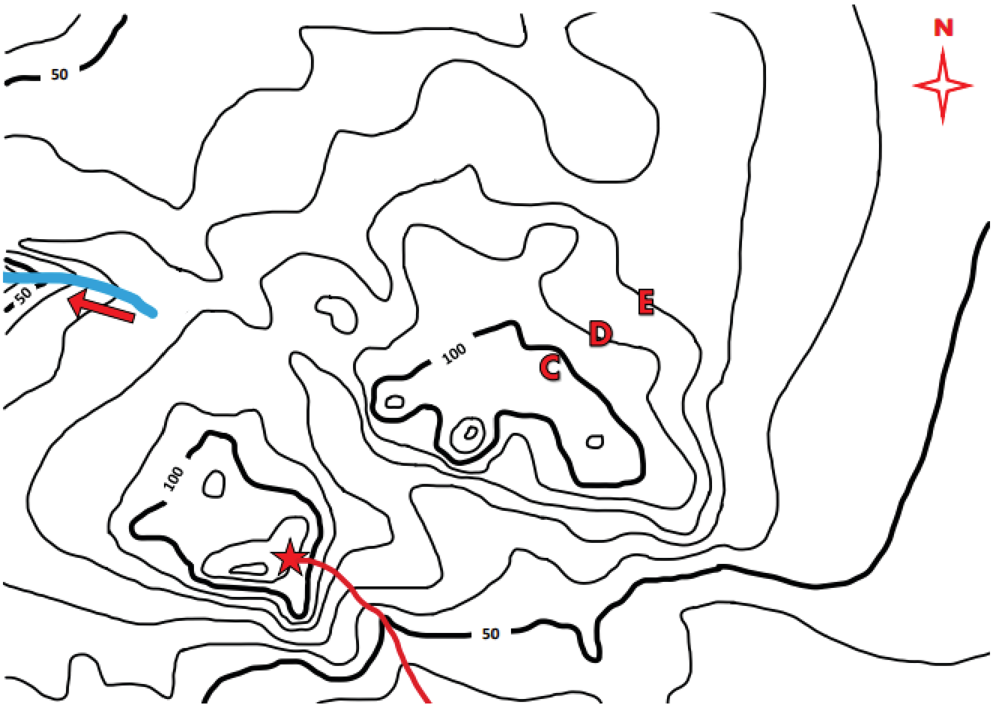
f. Use your finger and predict the path that water would take down the landscape until it ends up at a surface water feature or runs off the map. Remember, water will usually move perpendicular to contour lines.

g. Once your group is satisfied with the prediction, draw the path on the map.

h. Repeat with Map B.

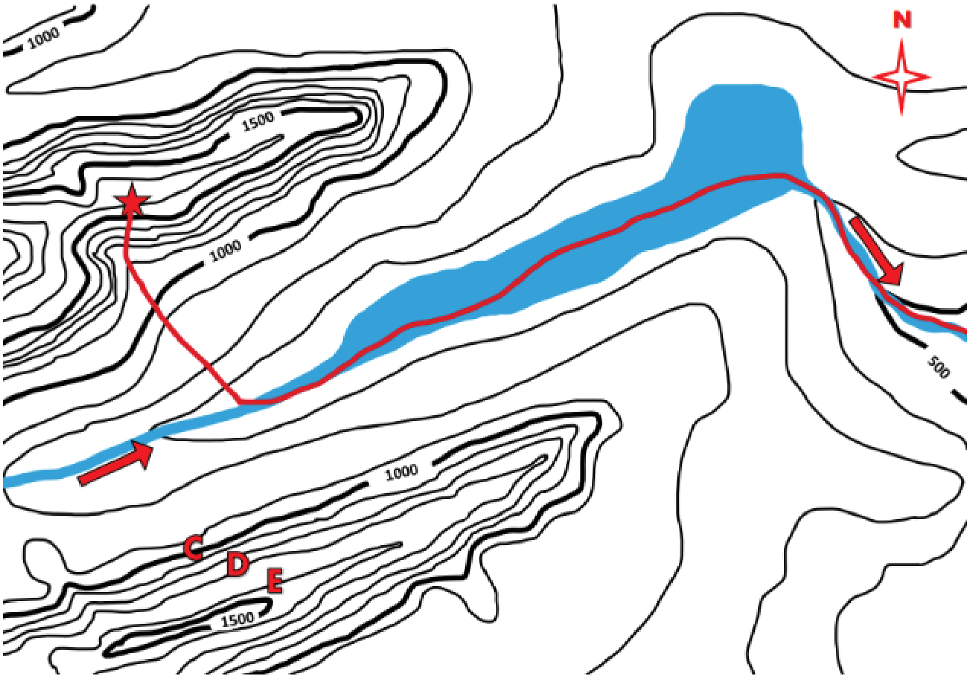
Notes for the Facilitator: Discuss group predictions and any discrepancies between groups. Share an acceptable path for Map A and explain any variations from learners' predictions. If learners did not have the same prediction, give them an opportunity to back up their claim using evidence from the map and discuss the variations in answers. If you have time, allow learners to revise their predictions for Map B before discussing a probable route for water to travel from the star.

MAP A KEY



Credit: L. Brase

MAP B KEY



Credit: L. Brase

Consider

1. Think about topographic maps.

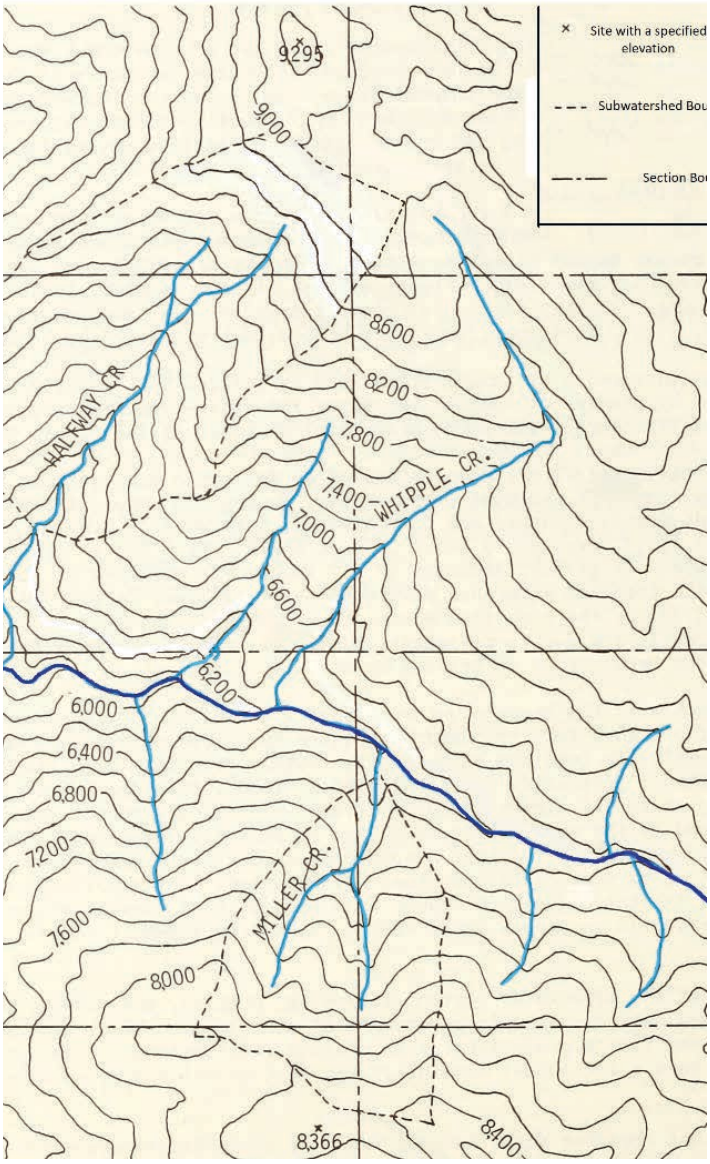
a. If contour lines are close together, how would you describe the landscape?

b. What about if contour lines are far apart?

c. How would water move similarly and differently across these types of landscapes?

Notes for the Facilitator: When contour lines are close together, the landscape is steep such as is often the case in a mountainous area. When contour lines are spread apart, the landscape is flatter or has gentle slopes. In both landscapes, water will move from high elevations to lower elevations. In a mountainous landscape, water will usually form tributaries or streams between peaks in areas that look like a "V" on topographic maps. Water will tend to be narrowly confined and so its locations are often more predictable. Water will also tend to flow in areas that form a "V" on topographic maps for flatter areas, but this is usually less obvious since the landscape is gentler. Water also tends to pool more in flatter areas and does not move over the surface as quickly as it does in mountainous areas.

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?

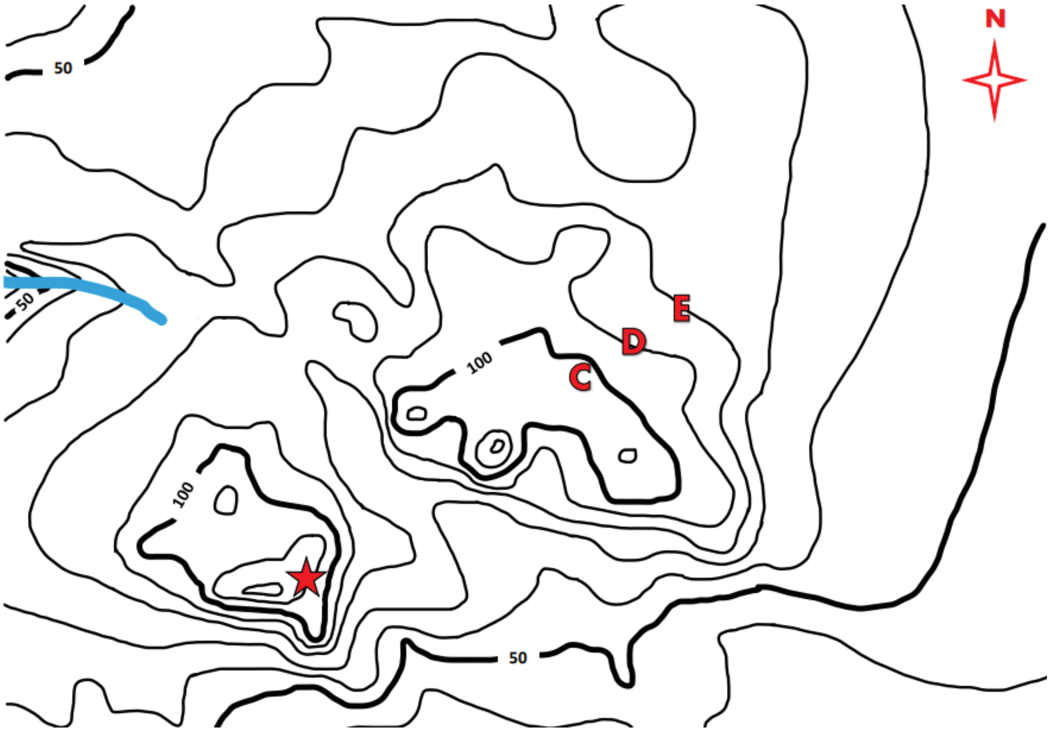


Credit: Modified from R. Doty, Public Domain, **https://www.flickr.com/photos/internetarchivebookimages/20063218073/in/photostream/**

Notes for the Facilitator: Larger rivers tend to be at lower elevations while smaller tributaries and streams tend to be at higher elevations. Smaller tributaries at high elevation may not even be labeled on the map as they may be ephemeral or intermittent. The primary tributaries join and form a stream, which then joins another tributary or stream to form a larger stream or river. This process continues as elevation decreases. The shapes of tributaries and streams at higher elevations usually follows the crevices between higher landforms and their paths are often straighter. Rivers and streams are usually curvier on flatter ground due to slower moving water not being able to cut through the landscape as easily as steeper, faster streams, and also because slower water deposits sediment along the edges of channels.

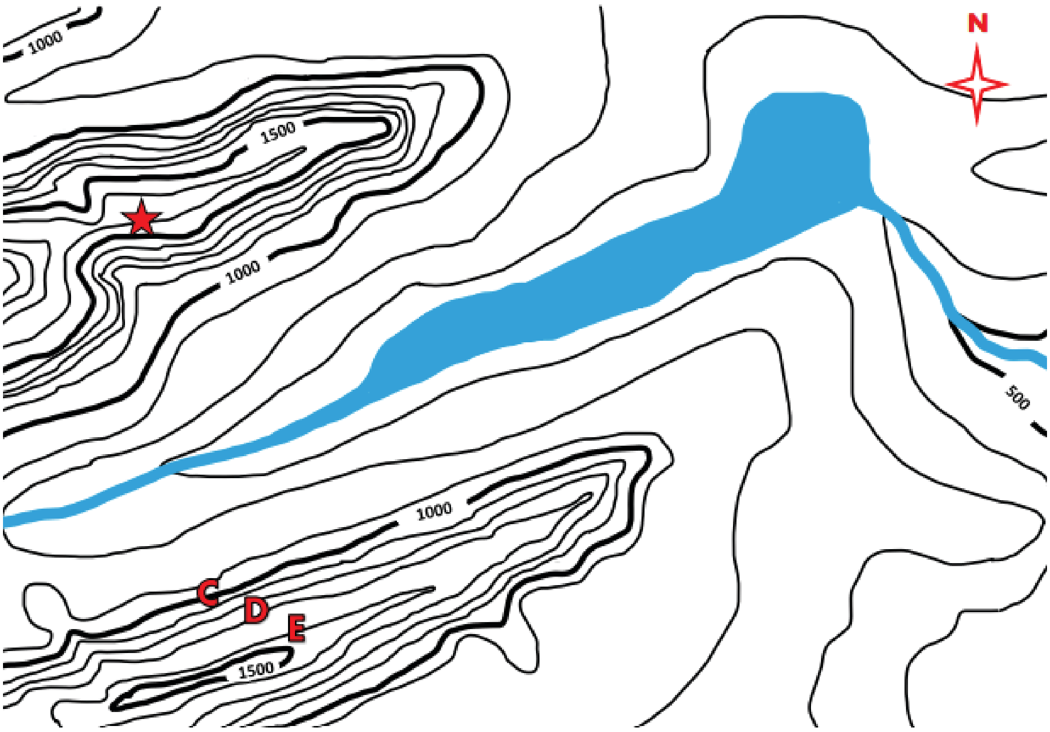
Topographic Maps

MAP A



Credit: L. Brase

MAP B



Credit: L. Brase

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 3B2: IDENTIFYING YOUR WATERSHED

Materials

Per learner:

- copy of local watershed map
- pencil
- colored pencils

Notes for the Facilitator: You can find watershed maps of most locations with an internet search. The Interactive Database of the World's River Basins (**http://riverbasins.wateractionhub.org/**) provides information about larger watersheds but ideally you should find a map more specific to your community or country. If you are located in the United States, you can find local watershed maps at **https://water.usgs.gov/wsc/map_index.html**.

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?

Notes for the Facilitator: Answers will vary. Learners could point out freshwater sources such as rivers and lakes, which would need to be treated, either by the city, community, or the individual if they are used for drinking water. Often, drinking water is pulled from groundwater through wells. This water may or may not need to be treated depending on the location, but water should always be tested prior to consumption and at regular intervals to ensure new contaminants have no entered the system.

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?

Notes for the Facilitator: Materials can include leaves, dirt, trash, fertilizer, salt, and oil. These materials could be deposited anywhere along the water's pathways, may enter the groundwater, or may eventually make their way all the way to the common outlet. Items that are initially located higher in elevation and farther from the common outlet position, that are lighter, or that can be dissolved or easily mixed with water usually have the ability to travel the farthest.

3. How might urbanization affect how water moves into, throughout, and out of a watershed?

Notes for the Facilitator: Towns and cities usually have drainage systems that may not follow topography. Many surfaces may be covered with impervious materials, which causes more water to flow along the surface and less to enter the groundwater. Also, human activity can impact the shape and locations of surface water features which will impact how water moves throughout the watershed and where it might drain. Towns within watersheds that have low input may bring water in from outside their watershed, which will increase the amount of water flowing through and exiting the watershed. Urbanization will also increase the amount of water pulled from natural water sources such as lakes, rivers, groundwater, and so on which could result in water sources not having enough water to supply demand.

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.

ESD KIT: ACCESS TO CLEAN WATER

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 4A: GROUNDWATER MOVEMENT AND POLLUTION

Facilitator Background

Connection to SDG 6: Target 6.3 aims to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials" (**https://sdgs.un.org/goals/goal6**). Pollutants and other contaminants can enter the environment in many ways. Natural sources of *water pollution* can be picked up by water travelling through soil or rocks that contain potentially harmful substances, such as fluorine and arsenic. The source of most water pollution is human activity, especially agricultural runoff. Once pollutants reach waterways, they contaminate nearby areas, and are also spread as water moves. In this Investigation, a model will be used to show how pollutants can be introduced to waterways, how they spread through waterways, and how *water withdrawals* can lead to pollutants being found in drinking water.

Key Concepts: *water pollution, water withdrawals*

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

Connect to the ESD Kit Project: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider how to reduce the pollution moving from their town into the watershed and that water entering their watershed may be contaminated from upstream.

PACING GUIDE

PREPARATION
10 minutes setting up materials for groups

WHAT TO DO
20 minutes to discuss the introduction material
30 minutes for the Investigation

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)

Notes for the Facilitator: The Awesome Aquifer© Kit (https://awesomeaquifer.com/) can also be used to complete this Investigation. The colored powder or color tablets will be used to represent the addition of fertilizer to the environment; the runoff from this will demonstrate the spread of excess nutrients as one source of pollution. An online search will yield many options for purchasing or making these materials. Red or green colors are suggested, since they will be easiest to see in the blue water in the model.

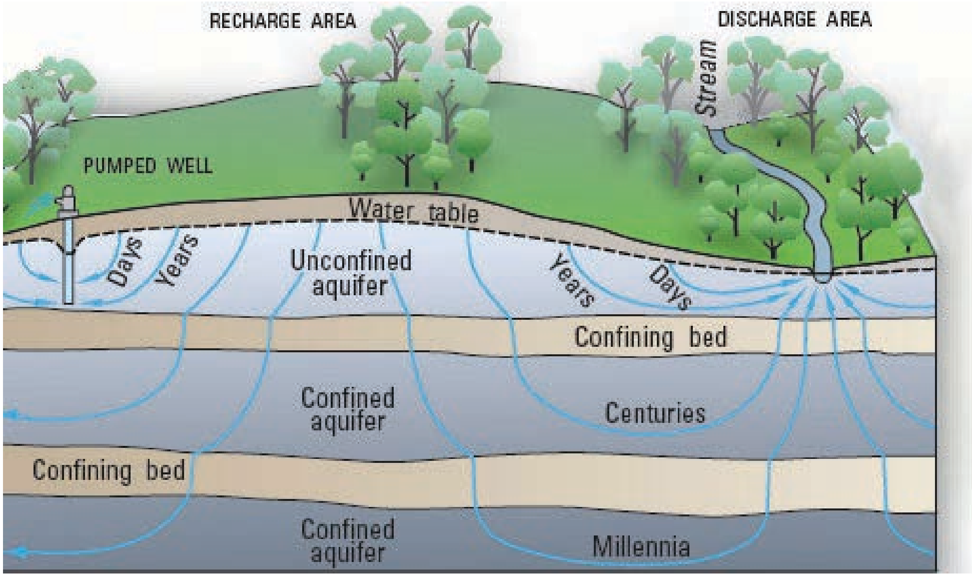
It is recommended to introduce or review the vocabulary in the first paragraph of this Introduction before learners complete the Investigation. After learners have completed steps 1–6, help them apply the vocabulary to their models. The second paragraph and diagram is best discussed after learners complete step 20.

Introduction

A *body of water* is any stream, river, or lake where a lot of water collects. Water enters bodies of water in one of three ways: directly from *precipitation* into the body of water, or by flowing as either *groundwater* or *surface water*. Surface water flow is when water travels along the top of the groundcover and into a body of water. Groundwater is when precipitation goes down through the soil's surface in a process called *infiltration* and then can go deeper in the soil in a process called *percolation*. When precipitation percolates into the ground, it replenishes any groundwater that has been *discharged* by flowing into bodies of water or has been removed by humans. The replenishment of groundwater is called *recharge*. The blue arrows on the diagram "Groundwater Flow" show how groundwater moves into wells and aquifers, as well as how it moves from a recharge area to a discharge area, where it enters a body of water.

An *aquifer* is a rock layer that can hold groundwater. *Unconfined aquifers* are made of and surrounded by sediment or permeable rock types that readily allow for recharge and discharge of groundwater. *Confined aquifers* are permeable and can hold groundwater but are surrounded by *confining beds* made of sediment or rocks that do not allow water to easily flow through them. If water is removed from confined aquifers, it can take much longer to recharge them due to being surrounded by confining beds. Confined aquifers also do not contribute as much to the process of discharge to a body of water as unconfined aquifers do.

GROUNDWATER FLOW



Credit: USGS, Public Doman, https://www.usgs.gov/media/images/conceptual-groundwater-flow-diagram

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

Notes for the Facilitator: Learners could make a round depression to represent a lake or could make more of a channel across the width of the container to represent a river.

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*.

Notes for the Facilitator: Review pertinent vocabulary with learners, as needed, especially as learners are labeling their diagrams. Learners will have been introduced to some of this vocabulary if they completed Investigations 2 and 3.

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.

Credit: L.C.Mossa

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

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.

> **Notes for the Facilitator:** Give specific instructions for adding fertilizer, depending on which you choose (powder, sprinkles, or tablets). Learners should add the fertilizer to the hill opposite where the well is located.

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.

Notes for the Facilitator: The water table in the model lines up with the height of the water in the lake or river. The water table continues underground.

    b. Describe how pumping water out of the ground affected both the water table and the body of water.

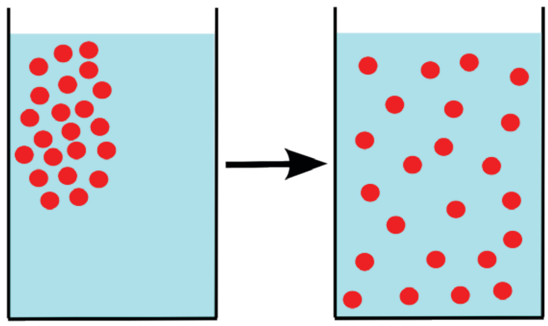
Notes for the Facilitator: Pumping water through the well first lowered the water table, since groundwater was being extracted. Then, the water in the body of water dropped, as some of that water replaced the groundwater that was pumped out. The water table maintained the same height as the body of water.

    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.

Notes for the Facilitator: Water moves faster through a substrate with larger particles. Water should move faster through gravel than sand. As long as the same amount of water was used, the water table should have the same height with either gravel or sand.

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

Notes for the Facilitator: The solute molecules spread out (diffuse) until they are approximately evenly spread throughout the water. The pollution in the model did the same thing, because it could dissolve in water and had time to spread through the water.

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

Notes for the Facilitator: Pumping water caused the pollution to spread faster because as the water was drawn up the pump, it caused the water in the water table and the body of water to move, which then pulled pollutant along with it.

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.

Notes for the Facilitator: The layer of clay separated the confined aquifer from the rest of the groundwater. The pollutant did not enter the confined aquifer because the clay prevented the mixing of the water above and below it.

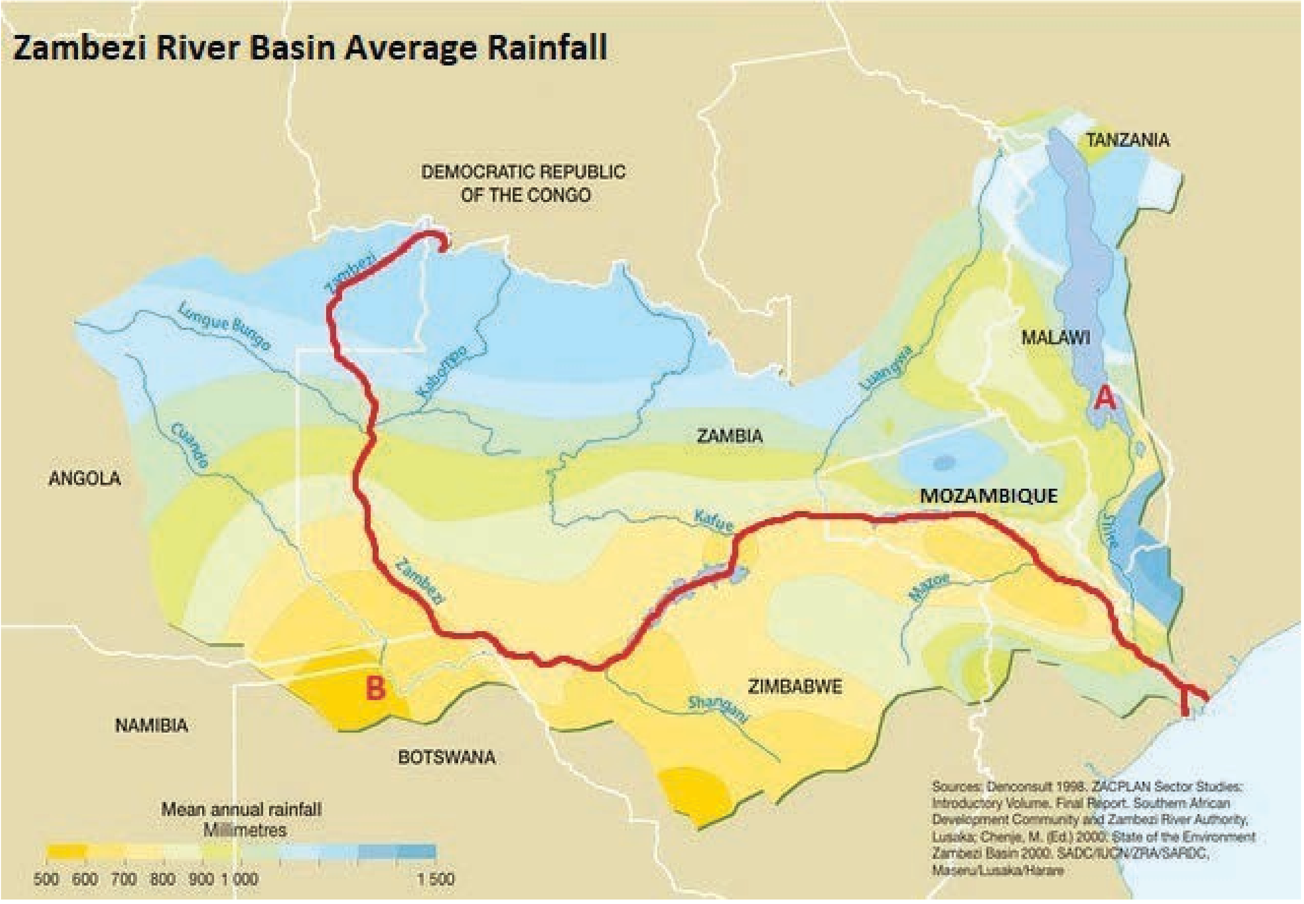
5. Are water pollutants and contaminants always visible, like the one you used in your model? If not, what are some ways that we can tell water is contaminated if we cannot see it?

Notes for the Facilitator: No, many contaminants dissolve in water. Water testing kits allow us to quantify how much of a substance is dissolved in water, such as nitrates and other nutrients, or lead and other metals. Microscopes could allow us to observe bacteria or other microscopic organisms living in the water, some of which may be harmful. Some contaminants cause water to have a distinct odor, such as sulfur.

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.

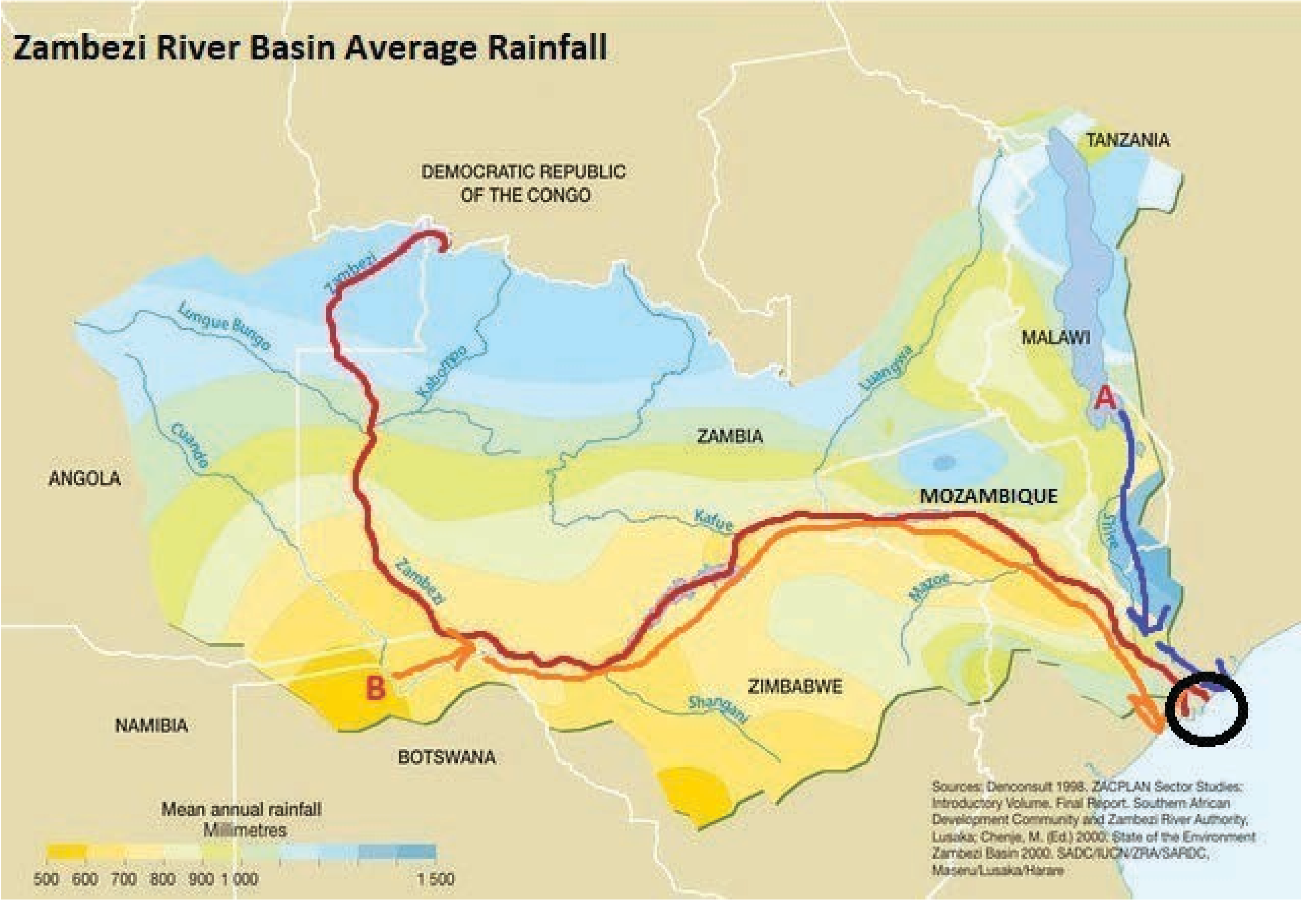
2. **Analyzing Data:** The map, "Zambezi River Basin Average Rainfall," shows the path of the Zambezi River through eastern Africa and the other rivers that feed into it. It also shows the average annual rainfall (mm) in different areas of the watershed.



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?

Notes for the Facilitator: The black circle on the following map shows the outlet of the Zambezi River. This is where the river enters into a larger body of water.



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.

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.

Notes for the Facilitator: 8 rivers flow into the Zambezi River. More water likely enters from the north, since more rivers that enter the Zambezi come from the north and also because there is more rain north of the Zambezi.

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.

Notes for the Facilitator: This information is shown by blue arrows in the map above (with question a). The Shire River and the very end of the Zambezi River would be affected. Then pollution would spread into the Mozambique Channel and beyond. As more water mixes with the fertilizer, the concentration decreases.

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.

Notes for the Facilitator: This information is shown by orange arrows in the map above (with question a). The pollution from farm B would first enter the Cuando River, which merges with the Zambezi River much farther upstream than the Shire River. The pollution from farm B would affect a much larger area than that at point A, because the pollution would travel through over half the length of the Zambezi. The number of waterways affected is the same, but the area affected is much greater for farm B. However, because farm A gets a great deal more rain than farm B, it is likely that more surface runoff comes from farm A, both in quantity and frequency.

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?

Notes for the Facilitator: Answers will vary but may include: elevation, slope, population size, farm size, amount of chemicals used, when chemicals are used in relation to when it rains, and how fast the rivers flow.

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INVESTIGATION 4B: WATER QUALITY

Facilitator Background

Connection to SDG 6: Indicator 6.1.1 aims to increase the "proportion of the population using safely managed drinking water services" (**https://sdgs.un.org/goals/goal6**). For water to be considered *safe drinking water*, it must contain minimal amounts of contaminants. *Water quality* can be measured to assess the types and concentrations of contaminants. Water testing is especially important for contaminants that dissolve in water and are not readily visible. Once contaminants are in the water, they can spread to other water sources or make their way into plants and then into food chains. Pollutants can affect the health of all organisms in the environment. In this Investigation, learners will conduct tests to determine the quality of different water sources.

Key Concepts: *safe drinking water, water quality*

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

Connect to the ESD Kit Project: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider how they will test drinking water or another water source in their town to check if it is contaminated.

PACING GUIDE

PREPARATION

10 minutes setting up materials for groups
20 minutes collecting water samples
10 minutes setting up celery and water tests that take longer than 30 minutes

WHAT TO DO

30 minutes for the Investigation

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

Notes for the Facilitator: Use a water test kit that can at least test for pH, nitrates, pesticides, and bacteria, such as: **https://amzn.to/3wvcCWb**. Collect water samples from the tap, bottled water, puddles, streams, or other local bodies of water. For the celery demonstration, place 10 drops of red food dye in 100 mL of water. Cut the bottom off enough stalks of celery that you have one per group of learners. Place the stalk of celery in the dyed water and let sit for 24–48 hours.

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.

Notes for the Facilitator: Some tests, especially for bacteria, need to be set up in advance, because testing takes hours or days.

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.

Notes for the Facilitator: You can use one stalk of celery for the whole group to view, but it is preferable to have one small stalk per group so they can cut or break it to see the veins (xylem) better.

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.

Notes for the Facilitator: Learners should compare their data to the color chart(s) that come with the water quality tests. The water samples with the most factors in the acceptable range are the ones with the best quality, meaning they are likely potable and otherwise safe for human use. Some may be safe for bathing or washing, but not for drinking, depending on what contaminants they contain and in what quantities.

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?

Notes for the Facilitator: Answers will vary. Groups may get different results from the same water sample due to testing errors or the fact that some substances may vary in concentration within water samples. By random chance, the small sample they tested may not have had the same level of contaminants as other samples from the same water source. This is why it is important to conduct multiple trials and to carefully follow directions on the water testing kit.

3. Consider the celery demonstration

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

Notes for the Facilitator: The food dye will have traveled up the celery stalk through its vessels (xylem).

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

Notes for the Facilitator: Not all plants have these veins; others take in water and other substances through their cell membranes.

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

Notes for the Facilitator: Any contaminant that is water-soluble could enter a plant via veins or cell membranes. Some contaminants that are not water-soluble, like oil, could coat a plant and affect it in different ways, but not all contaminants can enter plants.

d. How might pollution affect plants?

Notes for the Facilitator: Pollutants that enter plants may be toxic to cells and prevent necessary processes. This may lead to death of part or all of a plant.

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

Notes for the Facilitator: Once pollutants are in plants, any animals that consume them are going to ingest the pollution. This causes pollutants to accumulate up the food chain because an animal eats many plants per day, and so are possibly consuming many pollutants. If the pollutants kill plants, this will negatively affect soil health and water quality, since plants help maintain these.

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.

Notes for the Facilitator: Circles on the map indicate contaminants that are a national issue, so regardless of their size, they are more common than those indicated by squares. Arsenic is the most common circle on the map, followed by fluoride. For regional issues (represented by squares on the map), TDS is the most common square and is often larger than the other symbols.

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

   c. Which are naturally occurring?

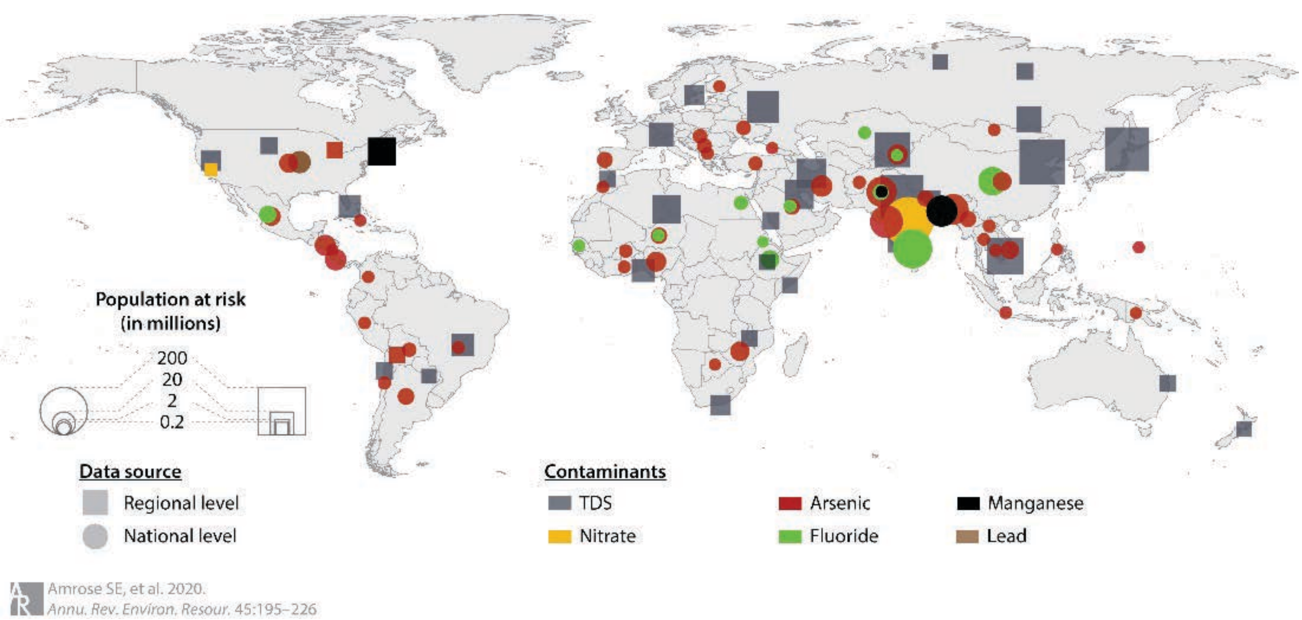
   - Which tend to end up in water due to human activity? What human activities lead to these contaminants ending up in the water?
   - If you completed Investigation 4A, use your drawing of the model to describe how these contaminants might end up in the water.

Notes for the Facilitator: Fluoride can occur naturally in water when it's released by weathered rocks. A few dozen countries fluoridate their drinking water, which then ends up in natural water sources. Nitrate is naturally produced by bacteria in soil and travels via surface runoff. Nitrate pollution occurs when excess nitrate enters the water, which can come from fertilizers used in agriculture, as well as sewage and animal waste. Manganese is naturally occurring in water but can reach unnaturally high levels due to metal working and mining practices. Arsenic can naturally be found in water that runs through rocks containing arsenic. Humans contribute less to arsenic in water but can do so through mining, wood processing, pesticides, and burning fossil fuels. Lead rarely occurs naturally in water and often enters drinking water while it is travelling through old pipes. TDS includes any soil, sand, sediment, minerals, or metals picked up by water as it travels through rocks or bodies of water, within pipes, or across farms and cities.

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

Notes for the Facilitator: Answers will vary but can include: what is manufactured in the region, what laws are in place to prevent water contamination, population size and density, number of water treatment facilities, the rock and soil types in the area, and how people source their water or how water is transported by people.

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?

Notes for the Facilitator: The color schemes are the same with white as 0, then greens and yellows being low, working toward pinks and red being the highest inputs to rivers. The exact values for each color are different depending on the levels of inputs. Nitrogen, phosphorous and microplastics all have the same units, but Triclosan is in grams, and *Cryotpsporidium* is the number of spores (oocysts) times 10 to the seventh power (10^7).

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

Notes for the Facilitator: The greatest inputs to rivers for nitrogen are China, Japan, India, Europe, the Eastern United States and Central America. Phosphorous, *Cryptosporidium*, and Triclosan have the same trend as nitrogen, but with less reds. For microplastics, Japan, China, and England have the only dark reds.

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

Notes for the Facilitator: Nitrogen is the most widespread pollutant because it is very common in fertilizers and animal wastes. All countries have agriculture, which explains why nitrogen inputs to rivers are so common.

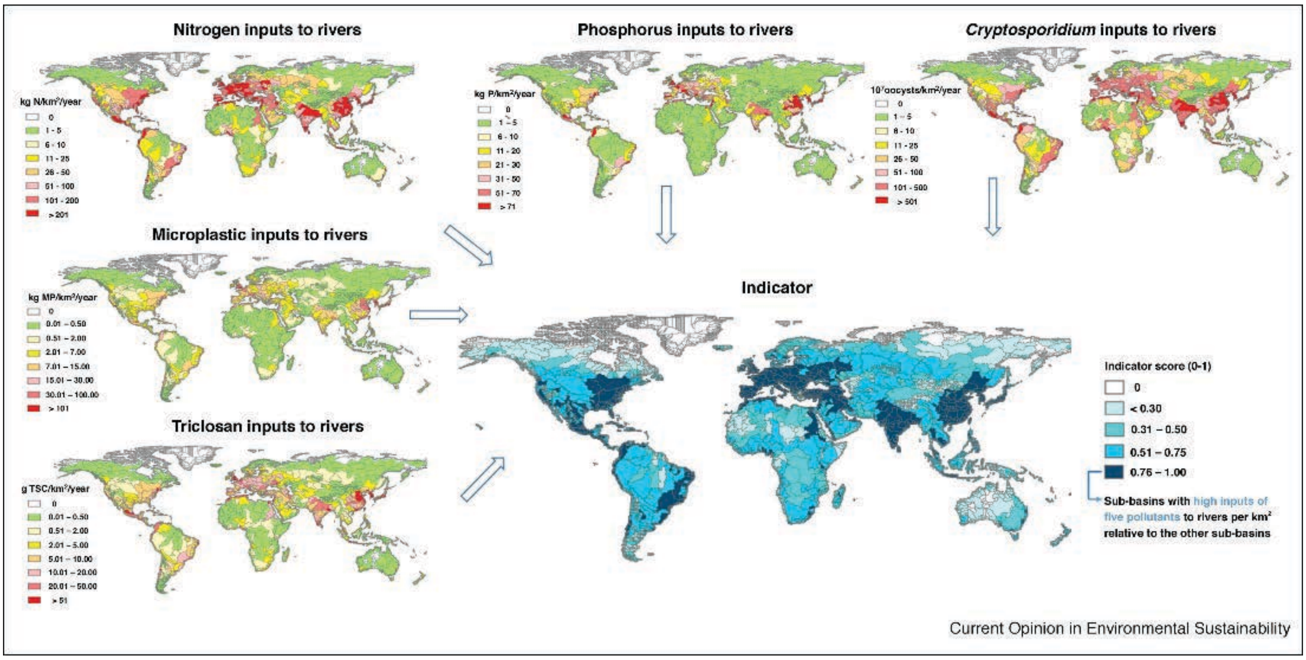
   d. Triclosan was banned by the United States Food and Drug Administration and was limited in its use by the European Union, yet you should notice it is still contributing to river pollution. Why do you think so?

Notes for the Facilitator: Products are no longer being manufactured with Triclosan in it, but there are still products containing Triclosan that exist in homes and landfills. These products can still release Triclosan into the environment. Also, most chemicals do not degrade immediately, so it might take a while for the Triclosan in the environment to break down.

   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?

Notes for the Facilitator: The Indicator Map matches the nitrogen and *Cryptosporidium* inputs to rivers. This makes sense, since these two pollutants have the highest inputs and so would affect the overall score of how much the rivers in these areas are polluted.

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?

Notes for the Facilitator: Yes, the light blue section of each bar represents rivers and is the largest portion of every bar.

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

Notes for the Facilitator: The main land use in Ireland is agricultural, so there are either a lot of farms or there are large farms whose runoff contributes to contaminants entering waterways.

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.

Notes for the Facilitator: Answers will vary but could include Recreational Activities or Travel/Roadways.

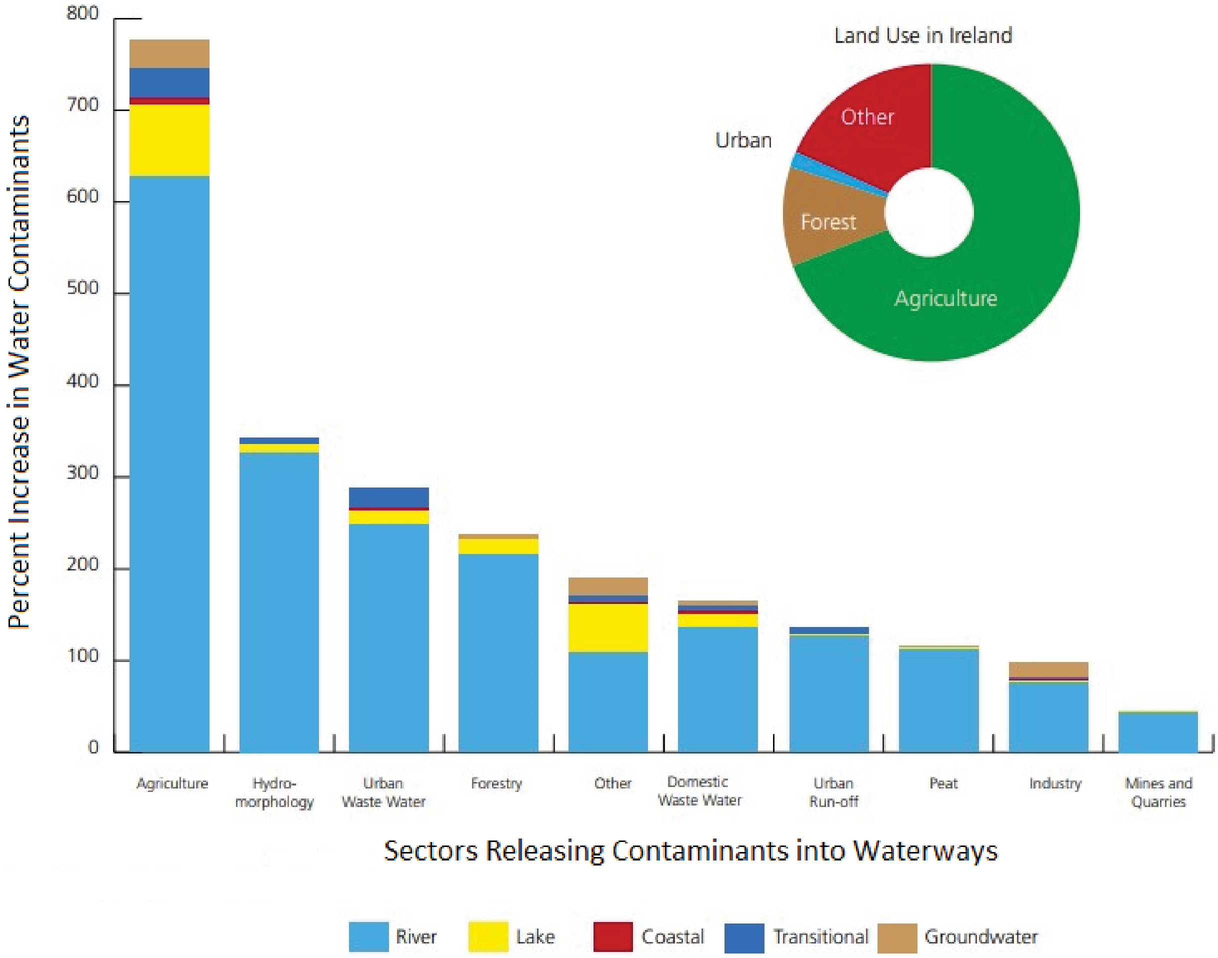
d. Why do you think pollution increased more in rivers than in any other type of waterway?

Notes for the Facilitator: Rivers are likely spread throughout the entire country and cover a much larger area than other waterways. People also commonly build and live near rivers, which would affect the amount of runoff carrying pollution into them.

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?

Notes for the Facilitator: Answers will vary. Learners may need to know the land use, population size, country size, number of waterways, number of cities, and climate to know more about their water contamination.

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

american geosciences institute
connecting earth, science, and people

INVESTIGATION 4C: MEASURING TURBIDITY WITH MICRO:BIT

Facilitator Background

Connection to SDG 6: Target 6.3 aims to “improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials” (**https://sdgs.un.org/goals/goal6**). Water quality is affected by both the type and quantity of materials within the water, including sediments and *water pollution*. In this Investigation, water clarity and the process of sedimentation are observed by using a micro:bit to sense and measure turbidity. This process will be linked to others in future Investigations for learners to gain an understanding of how water is filtered and treated to improve water quality.

Key Concepts: *water pollution*

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

Connect to the ESD Kit Project: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners will see how the turbidity of water can be measured to tell the effectiveness of early steps of water treatment.

PACING GUIDE

PREPARATION
10 minutes setting up materials for groups

WHAT TO DO
5 minutes to discuss the introduction material
30 minutes for the Investigation

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)

Notes for the Facilitator: The exact dimensions of the corrugated cardboard box and the glass jar are not critical, but the jar should fit comfortably inside the box. The box should be able to be closed tightly or covered with an opaque cloth so as not to admit any light from the outside. Seal the bottom with packing tape. Leave the top open. We used a box that was 16 cm X 16 cm X 21 cm and a glass jar that was 11cm tall X 4.5cm in diameter. The setup for Investigation 5D builds on this one, so you may want to read that procedure before completing this Investigation to use a similar setup.

Credit: Logo Foundation

Introduction

Water in lakes and rivers often has particles of organic and inorganic material suspended in it giving it a cloudy appearance. This is called *turbidity*. When a lake or river is used as a source of drinking water, turbidity can be a problem since the material causing the turbidity could potentially cause health problems and makes the water less suitable for human use. For more information about turbidity and water, visit the U.S. Geological Survey website: **https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water.**

In water treatment, suspended particles can be removed by filtering. But before filtering, it is also possible to remove suspended particles by letting them settle. Filtration may still be needed, but there is less of a burden on the filtration system if settling has occurred first.

In order to implement a system that reduces turbidity, it is first necessary to measure turbidity. You can measure turbidity by shining a light through a container of water and sensing how much light passes through the sample. When light passes through turbid water, some of it is scattered by the particles suspended in the water instead of passing directly through the water. The more turbid the water, the more light is scattered, and so less passes through.

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

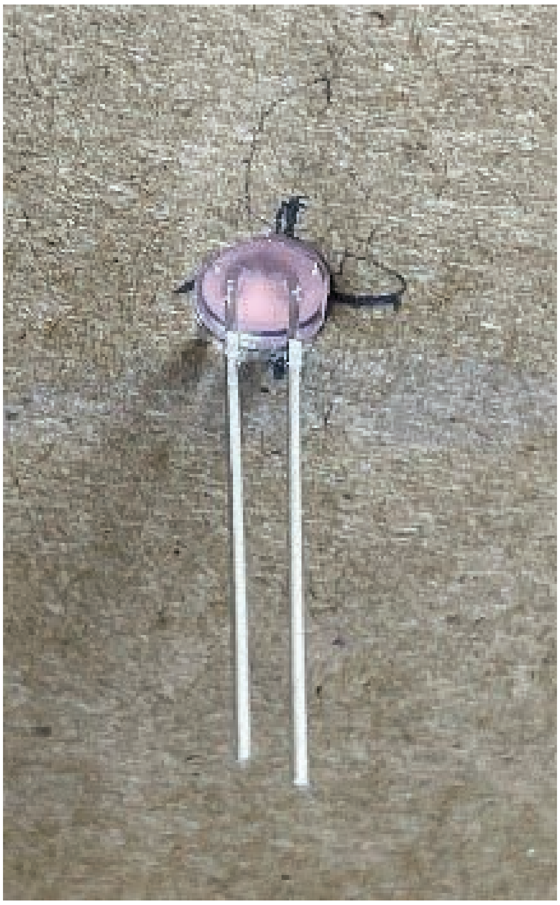
a. With a pin or needle, make two holes at one of the marks spaced as far apart as the pair of wires attached to the light sensor. Working from inside the box, put the wires through the holes. Put a dab of hot glue behind the sensor. Immediately pull the wires so that the sensor is against the glue.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

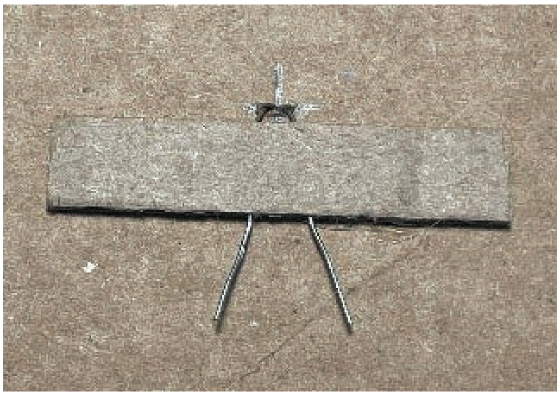
Credit: Logo Foundation

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.

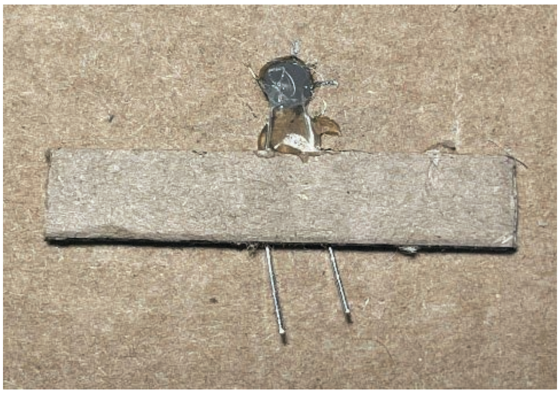
Credit: Logo Foundation

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.



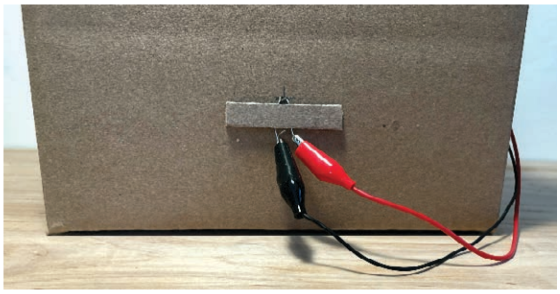
Credit: Logo Foundation

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.

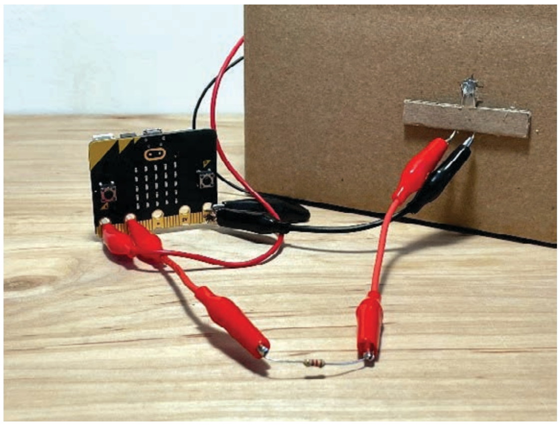


Credit: Logo Foundation

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.

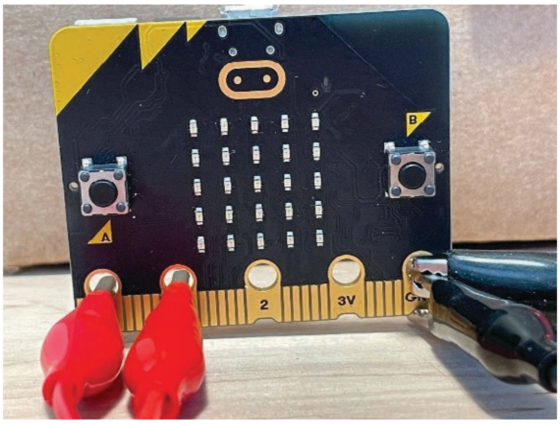


Credit: Logo Foundation

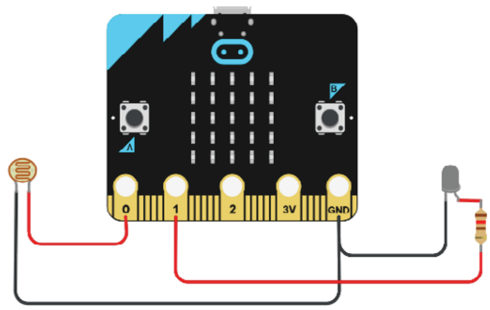
13. Unlike the light sensor, the LED is polarized. This means that electricity passes through it in only one direction.

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.

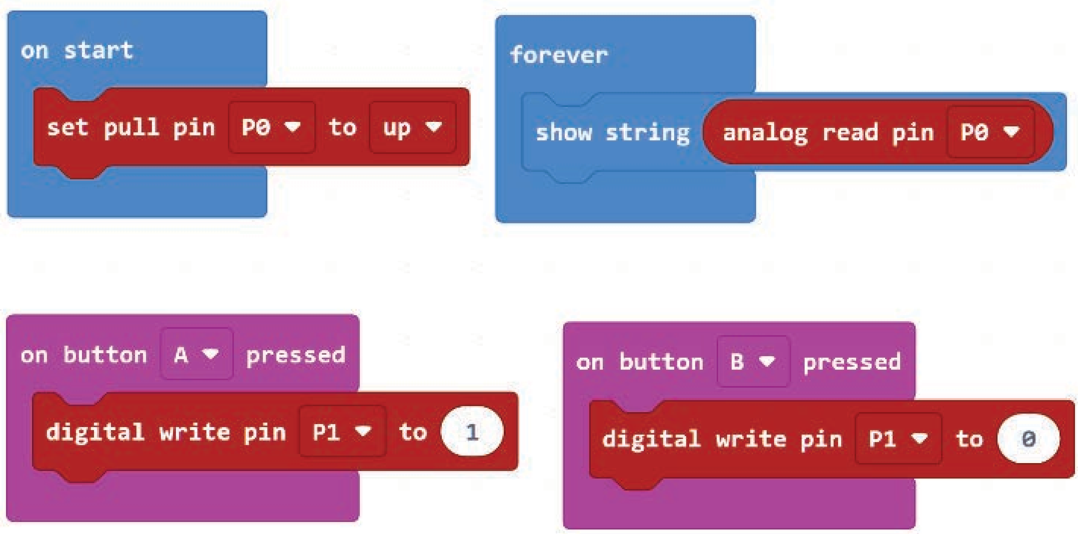


Credit: Logo Foundation



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

Notes for the Facilitator: If learners need help with the code, it is available and ready to use here: https://makecode.microbit.org/_Eff0Jf3Pza6w

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.

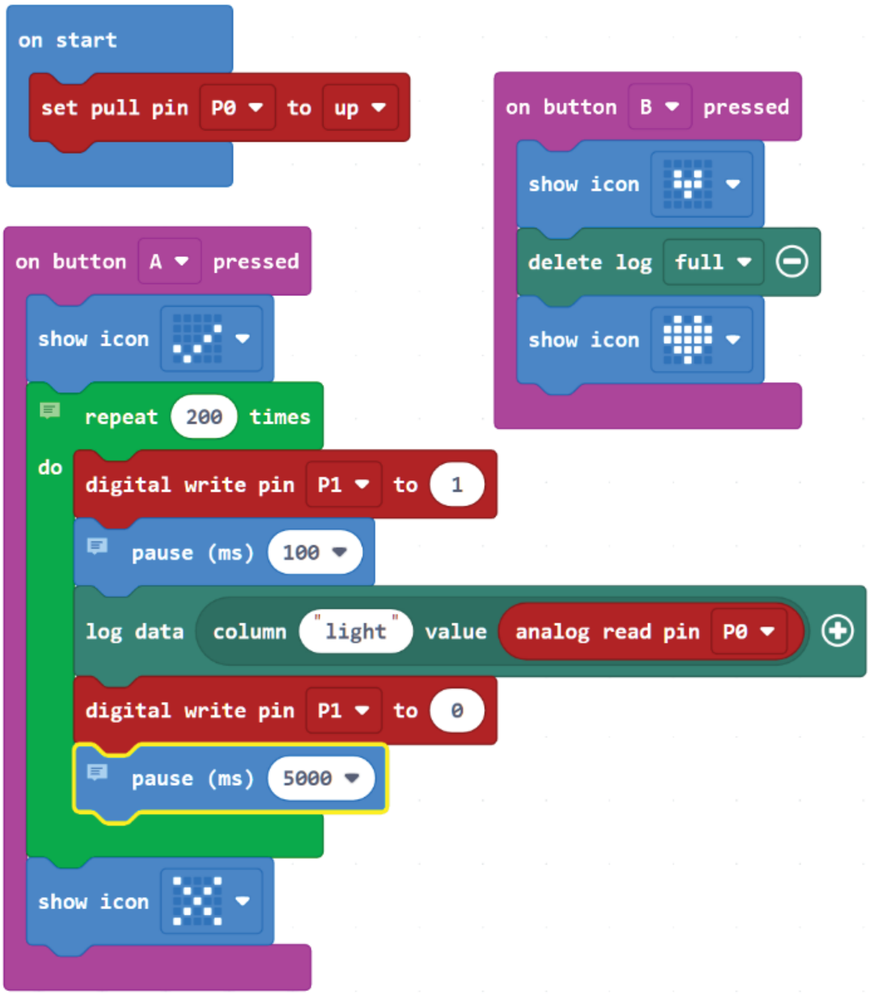
Credit: Logo Foundation

Notes for the Facilitator: The next steps describe how to use the micro:bit to log (record) data over time. Using data logging you can leave the micro:bit running on its own to record data over a period of many minutes, hours, or days. You can also record data points separated by very short time intervals of a few seconds or less. Both of these tasks would be impractical to do by reading the display and writing down the results. Also, the data file will be in a form that can be loaded into a spreadsheet where it can be manipulated and used to generate a graph. The file can also be loaded into a *Scratch*® project. For more information on how the micro:bit records data, visit: **https://microbit.org/get-started/user-guide/data-logging/**.

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

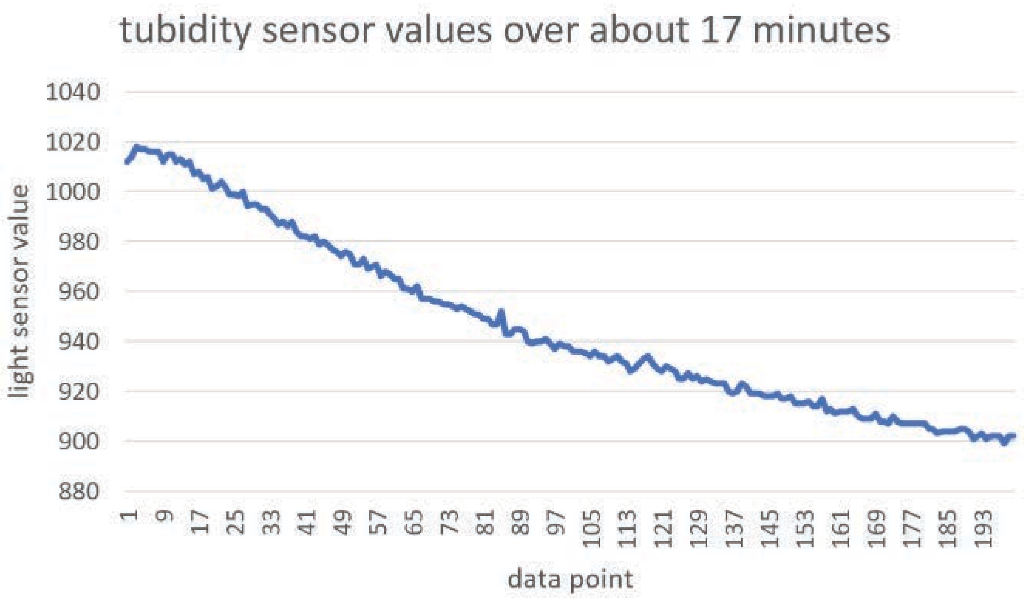
This is the data on your micro:bit. To analyse it and create your own graphs, transfer it to your computer. You can copy and paste your data, or download it as a CSV file which you can import into a spreadsheet or graphing tool. Learn more about micro:bit data logging.

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.

Notes for the Facilitator: The graph shows the expected trend in turbidity data over 17 minutes.



Credit: Logo Foundation

Consider

1. Describe the trend of your data. Why do you think this trend occurred?

Notes for the Facilitator: The turbidity of the water decreased relatively steadily over the course of the experiment. There were higher readings near the beginning of the trial, which gradually decreased over time. The densest particles likely settled first, and then slightly less dense particles settled out. Depending on how long the experiment is run, learners may see the graph level out, showing that sedimentation rates eventually near or reach zero.

2. What natural processes would cause there to be sediment in the water?

Notes for the Facilitator: Water movement or animal activity in an aquatic environment could cause sediment to be suspended 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?

Notes for the Facilitator: Sedimentation will not remove all sediment from the water, as some particles are buoyant and will remain suspended in the water or floating on the water (which are visible, but are not detected by the sensor, since they are above where the sensor is taking data). Learners can see from the data that the reading on the light sensor does not return to the original reading it gave when tested using only water (before the soil was added to the jar). Running the test for a longer period of time could show whether or not all of the sediment eventually settles out of the water.

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.

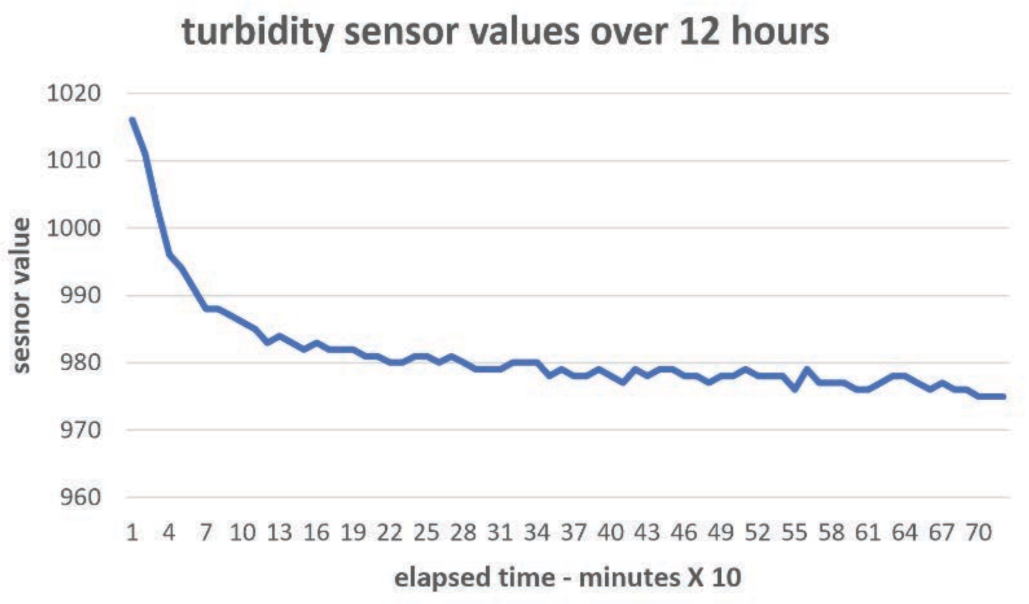
Notes for the Facilitator: Answers may vary but can include the amount of soil in the jar or the dimensions of the jar.

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.

Notes for the Facilitator: Learners should note that the overall trend is the same, with turbidity decreasing over time. If the length of the intervals at which data is taken are shortened, more data points will be collected and will give a more accurate picture of the rate at which sedimentation occurs. Taking data for a longer period of time will not change the overall trend but will allow learners to see that sedimentation slows down over time, as the slope of the graph decreases as data is taken for a longer period (the graph shows data logging over 12 hours).



Credit: Logo Foundation

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 5A: TREATING WASTEWATER BY FILTRATION

Facilitator Background

Connection to SDG 6: Target 6.3 aims to "improve water quality by...halving the proportion of untreated wastewater" (**https://sdgs.un.org/goals/goal6**). Clean water is vital to human life on an individual level, such as for *safe drinking water*, and on an industrial level, such as farming and the generation of electricity. No matter the scale, it is important that *wastewater* and other contaminated sources undergo *water quality* testing and then, if necessary, a form of *water treatment*. A common method to treat contaminated *freshwater* is filtration. In Investigation 5A1, learners will experiment with different filtering media to help understand how filtration works, as well as the limitations of filtration as a water treatment method. Learners will then design and construct their ideal filter with budgeting constraints in Investigation 5A2.

Key Concepts: *safe drinking water, wastewater, water quality, water treatment, freshwater*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider the benefits and drawbacks to using filtration as a water treatment method, and if or how it could be used in the town.

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PACING GUIDE

PREPARATION

10 minutes preparing simulated wastewater

10 minutes setting materials out for groups

WHAT TO DO

60 minutes for 5A1

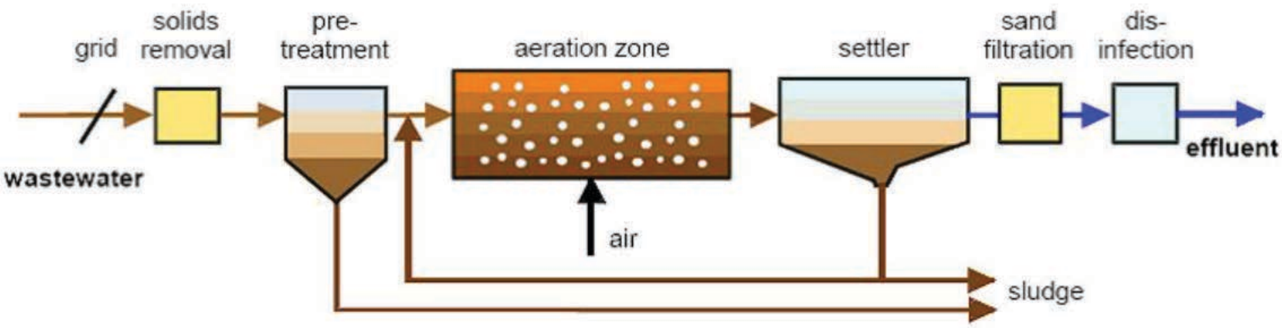
10 minutes for water quality testing (optional) in 5A1 and in 5A2

30 minutes for 5A2

Introduction

Water can be made safe to drink through a variety of treatment methods. It is important to conduct water quality tests to determine the types of contaminants and how to treat the water. Some treatment methods include filtration, boiling, distillation, ultraviolet (UV) radiation, reverse osmosis, and chlorination.

Public drinking water systems usually use a combination of treatment methods that are specific to the local water quality. A general example of a treatment process that uses a combination of methods is below and includes coagulation and flocculation to clump solid particles, sedimentation or settling, filtration, and disinfection. The United States Center for Disease Control and Prevention provides more background information at **https://bit.ly/3Npn07I**.



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

INVESTIGATION 5A1: WATER FILTRATION

Materials

Simulated wastewater, per group:

Notes for the Facilitator: The following list and amounts are recommended, but not necessary. You can create your own simulated wastewater using similar materials you have available. Puddle or lake water is preferred over tap water since these sources are more likely to contain bacteria or viruses. Be sure the water used within these investigations is not consumed.

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- granular, liquid, or tablet fertilizer , 10 grams,
- small plastic beads, 3 grams, such as PH Purple Seed Beads **(https://amzn.to/3SRrkQB)**

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**)

Notes for the Facilitator: Learners can conduct water quality tests on the samples at the beginning and end of the different water treatment processes. Communicate with learners about the procedures associated with the kit you provide.

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.

> **Notes for the Facilitator:** As learners are waiting, they can continue with steps 3–8, and can also work on the Consider questions.

   - **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?

Notes for the Facilitator: When the alum was added, particles (contaminants) began to clump together. By making the particles stick together, they are more easily removed via decanting or filtration.

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?

Notes for the Facilitator: Some mass will be lost during the filtration method. The contaminants and some water particles will remain in the filter and therefore their mass will be lost.

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

Notes for the Facilitator: The decanted and filtered samples should be clearer than the original sample. The clarity should improve as the filter medium becomes smaller (finer textured).

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

Notes for the Facilitator: Learners should describe the clarity of the water as evidence for their reasoning. Learners may also use observations of contaminants left in the filter as evidence. Although most of the treated water appears somewhere between slightly to perfectly clear, it still is not considered clean and safe for consumption. Bacteria and viruses are not removed during the filtering process.

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

Notes for the Facilitator: Some advantages include filtration systems are low cost, easy to install/use, and remove large unwanted contaminants. Some limitations include filtration systems don't remove all contaminants (e.g., dissolved material cannot be filtered) and the filters need to be replaced or maintained to remain effective. Adding alum as a flocculant is inexpensive and widely available, but it creates a lot of sludge to deal with and there is a limit to how effective it is.

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.

INVESTIGATION 5A2: DESIGNING A FILTRATION SYSTEM

Materials

Simulated wastewater, per group:

Notes for the Facilitator: The following list and amounts are recommended, but not necessary. You can create your own simulated wastewater using similar materials you have available. Puddle or lake water is preferred over tap water since these sources are more likely to contain bacteria or viruses. Be sure the water used within these investigations is not consumed.

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- granular, liquid, or tablet fertilizer , 10 grams,
- small plastic beads, 3 grams, such as PH Purple Seed Beads (https://amzn.to/3SRrkQB)

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)

Notes for the Facilitator: Learners can conduct water quality tests on the samples at the beginning and end of the different water treatment processes. Communicate with learners about the procedures associated with the kit you provide. Be sure the water used within these investigations is not consumed.

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?

Notes for the Facilitator: To help inspire design ideas, review the introduction section and a schematic of typical wastewater treatment systems with learners.

   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.

Notes for the Facilitator: Revise the materials list and costs with materials you will be providing, using a currency with which learners are familiar. Also, provide a budget on the handout.

   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.

Notes for the Facilitator: As time and available materials allow, have the learners rebuild their wastewater treatment system and treat a new sample of wastewater.

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

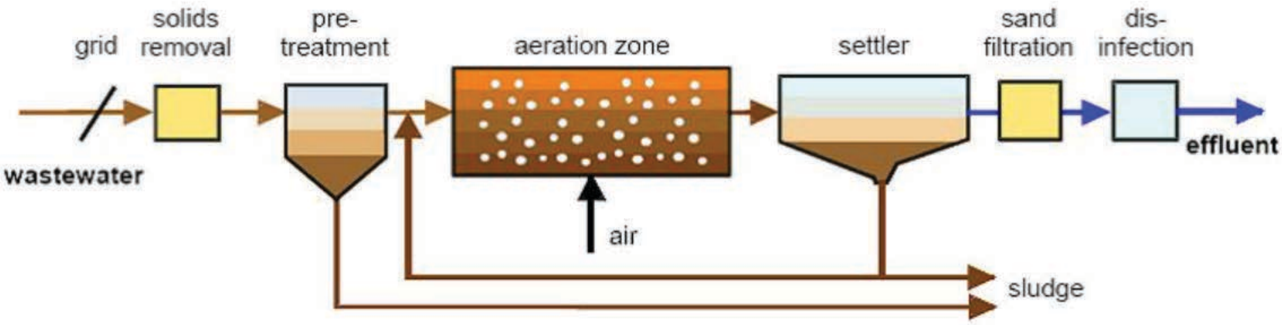
Notes for the Facilitator: Reserve at least ten minutes to discuss designs and results as a whole group. Which designs were most effective? Which were least effective? How did budgeting play into the designs? What additional modifications would the learners make to their designs, given more time, money, or materials?

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?

Notes for the Facilitator: Botswana is faced with water shortages due to its limited water resources, low rainfalls, high evaporation rates, high salinity groundwater, and water waste. The devised treatment method diverts wastewater into a constructed wetland ecosystem to increase water reuse. Solids are removed using septic tanks and liquid waste is transported across reed bed systems. The treatment plan has been successful in treating wastewater for non-potable uses but was not effective in pathogen removal. Some challenges include receiving necessary funding and manpower to keep the system working.

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 country. 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?

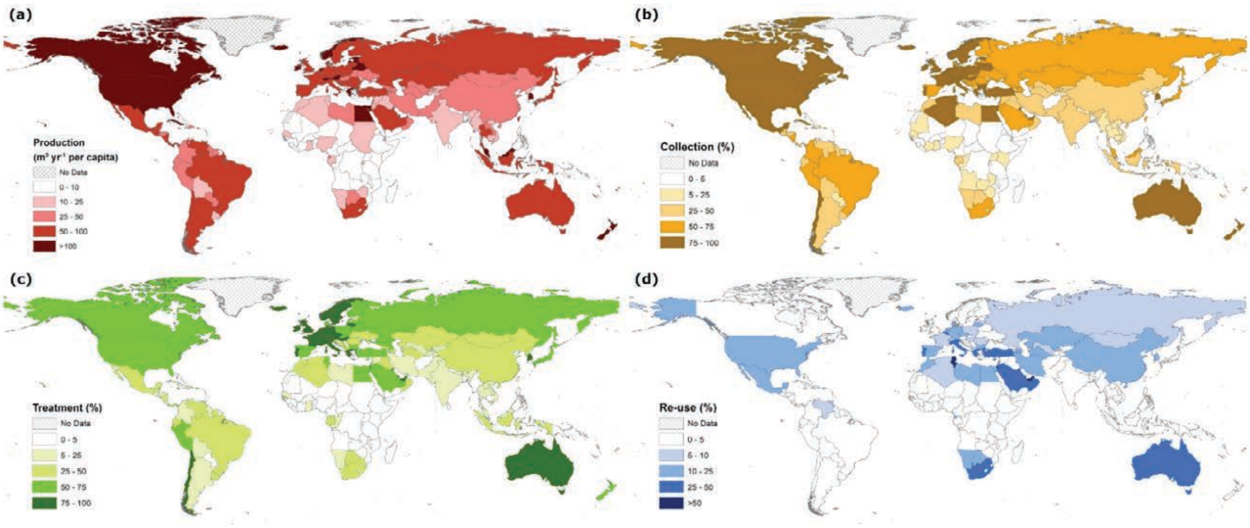
    b. How do these three countries compare to other countries (shown in grey on the graph) in terms of the percentage of the population connected to public wastewater facilities?

    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?

Notes for the Facilitator: Poland and Mexico both have increasing percentages of the population connected to a wastewater treatment plant, while Sweden's percentage has remained at a relatively high and constant level. Countries that had about 80% or more of their populations connected in 2000 remain relatively constant or have slight increases by 2020, similar to Sweden. Countries that began with fewer 80% for the most part increase by 2020, similar to Poland and Mexico, although there are exceptions and variations within those 20 years for some countries. Answers will vary depending on specific countries examined for part c.

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.

Notes for the Facilitator: The percentages get smaller between each graph. The largest differences in the data are between treatment and re-use. Treating wastewater for safe release back into the environment is more common than immediately treating wastewater for re-use. Re-using treated waters is most common in higher income areas. Answers for part c will vary depending on the country examined.

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

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INVESTIGATION 5B: TREATING WASTEWATER USING HEAT AND LIGHT

Facilitator Background

Connection to SDG 6: Target 6.3 aims to "improve water quality by…halving the proportion of untreated wastewater" (**https://sdgs.un.org/goals/goal6**). To generate *safe drinking water*, it is important that *wastewater* and other contaminated sources undergo *water quality* testing and then, if necessary, a form of *water treatment*. A common method to treat either contaminated *freshwater* or salt water, is distillation. The distillation process removes salt and other minerals from water, which is a method of *desalination*. In Investigation 5B, learners will distill contaminated water to help understand how distillation works and the limitations of distillation as a water treatment method. Learners will also discuss a demonstration that treats contaminated water with ultraviolet (UV) radiation and discuss the benefits and limitations of this treatment method.

Key Concepts: *safe drinking water, wastewater, water quality, water treatment, freshwater, desalination*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider the benefits and drawbacks to using distillation or UV treatment as water treatment methods, as well as if or how these processes could be used in the town they design.

PACING GUIDE

PREPARATION

- **10 minutes** preparing simulated wastewater
- **30 minutes** preparing the Facilitator Demonstration, 24 hours prior
- **10 minutes** setting materials out for groups

WHAT TO DO

- **20 minutes** for discussing and testing the treated water in the Facilitator Demonstration
- **10 minutes** for water quality testing (optional)
- **50 minutes** for the Investigation

Materials

Simulated wastewater, per group:

Notes for the Facilitator: The following list and amounts are recommended, but not necessary. You can create your own simulated wastewater using similar materials you have available. Puddle or lake water is preferred so it contains bacteria or viruses. Be sure the water used within these investigations is not consumed.

- puddle or lake water, 1 L
- coffee grounds, 5 grams
- sand, 30 grams
- fertilizer, 10 grams
- small plastic beads, 3 grams, such as PH Purple Seed Beads (**https://amzn.to/3SRrkQB)**

For Facilitator Demonstration:

- simulated wastewater, about 300 mL
- clear glass or plastic bottle or jar with lid
- sunny area or UV lamp
- camera or phone with camera (optional)

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**)

Notes for the Facilitator: Learners can conduct water quality tests on the samples at the beginning and end of the different water treatment processes. Communicate with learners about the procedures associated with the kit you provide. Be sure the water used within these investigations is not consumed.

What to Do

Facilitator Demonstration:

1. Conduct water quality tests on the water sample(s), similar to that in procedure 4B.
2. Put the water sample in the clear bottle or jar and cap it with the lid. Take a picture of it, if possible.
3. Set the bottle or jar out in a sunny spot for at least 6 hours. Alternatively, you can put it under a UV light.
4. On the day of the Investigation, introduce water treatment methods to the learners using Solar Water Disinfection (SODIS) and show them the treated sample.

Notes for the Facilitator: UV rays from the sun or lamp destroy the DNA of the microbes that were in the water, given enough UV exposure.

Optionally, have learners conduct water quality tests on the treated water sample that includes a bacterial culture test. Compare the results to the tests done prior to UV treatment.

Facilitate a discussion about using UV rays as a treatment method. Discuss the advantages and limitations to UV treatments. Some advantages include low cost (if using the sun), chemical free, taste and odor free, effective at removing disease-causing microbes, and low maintenance. A big limitation of UV purification as a treatment method is it does not remove contaminants, so the water must first be filtered before being treated with UV light. Another drawback is that different wavelengths of light are required for different to destroy different bacteria and viruses,

Learner Investigation:

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

Notes for the Facilitator: If the collection bowl is a smaller beaker instead of a bowl that floats, weigh the beaker using a sanitized weight to keep the beaker in place. Also be sure the water remains below the collection bowl.

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.

Notes for the Facilitator: Learners can begin working on the Consider questions as they are waiting for the water to boil and distillation to take place.

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?

Notes for the Facilitator: The distillation began when the water started boiling. The original water sample changed into water vapor. When it contacted the bowl, it cooled down from the contact of the bowl and changed back into liquid. It dripped down to the center of the bowl and into the collection bowl.

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?

Notes for the Facilitator: Some mass will be lost during the distillation method. The contaminants will remain behind in the original container and there will be some water vapor lost during the process.

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

Notes for the Facilitator: A sample of distilled water should consist of only water molecules and any other substances with a boiling point lower than 100˚C such as alcohol and some oils. The distillation process should remove all items that don't vaporize or that have boiling points higher than 100˚C such as heavy metals, microorganisms, bacteria, and sediments.

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

Notes for the Facilitator: Distillation is extremely effective in removing many contaminants and microorganisms. A limitation of distillation is water loss, if using equipment as done in this Investigation. If better equipment is used, then a limitation would be cost and amount of equipment needed. Distillation is slower than other decontamination methods, so the amount of time needed to clean the water would be a limitation. Heating the water also requires an energy source, which could be costly or use up valuable resources. Also, drinking water ideally has some electrolytes and nutrients in it which the distillation process removes. If using distillation as a treatment method, electrolytes should be added into the pure water.

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

Facilitator Background

Connection to SDG 6: Target 6.3 aims to "improve water quality by...halving the proportion of untreated wastewater" (**https://sdgs.un.org/goals/goal6**). To generate *safe drinking water*, it is important that *wastewater* and other contaminated sources undergo *water quality* testing and then, if necessary, a form of *water treatment*. A common method to treat either contaminated *freshwater* or salt water is reverse osmosis. This treatment method uses pressure to reverse the natural direction water flows in osmosis to remove contaminants of all sizes, including metal ions. Since reverse osmosis also removes salt, it is considered a *desalination* method. In this Investigation, learners will experiment with diffusion and osmosis in order to help understand how reverse osmosis works.

Key Concepts: *safe drinking water, wastewater, water quality, water treatment, freshwater, desalination*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners can consider the benefits and drawbacks to using reverse osmosis as a water treatment method, and if or how it could be used in their town.

PACING GUIDE

PREPARATION

10 minutes preparing Facilitator Demonstration #1, two days prior to the Investigation

2 minutes setting out potatoes to air dry, two days prior to Investigation

10 minutes setting materials out for groups

WHAT TO DO

50 minutes for the Investigation

Materials

For Facilitator Demonstration 1:

- cups, x3
- marker
- water
- salt
- gummy bears, x3

- fork
- scale (optional)

For Facilitator Demonstration 2:

- water sample from puddle, lake, or simulated wastewater
- reverse osmosis system, such as FS-TFC Portable System **(https://amzn.to/3w9Ib7t)**
- water quality tests, such as Labtech H2O OK Plus Complete Water Analysis Test Kit (**https://bit.ly/WaterQualityTestKit**)

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)

Note for the Facilitator: To enhance the potato experiment results, allow the potatoes to air-dry for two days before the Investigation.

What to Do

Facilitator Demonstration 1:

Notes for the Facilitator: If you see the learners two or three days prior to leading this Investigation, learners could complete this experiment themselves. Be sure the water and food used within this Investigation is not consumed.

1. Two days before leading this Investigation, set up three cups. Leave one empty cup, fill one with 200 mL water, and another with 200 mL water and 15 grams (about 1 Tablespoon) of salt. Label the cups as "air, "water," and "water and salt," respectively.
2. Place a gummy bear in each cup.
3. After two days, and on the day of the Investigation, discuss the setup with learners. Remove the gummy bears and have learners make observations of each gummy bear. The gummy bear soaked in water will be very fragile. Carefully slide a fork underneath to transfer it.
4. Optionally, have learners take the mass of each gummy bear and determine the percent change in mass.

Learner Investigation:

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.

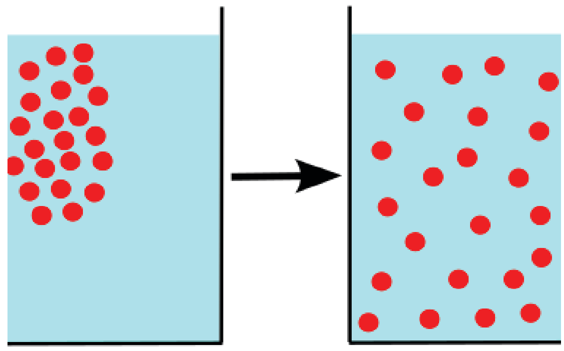
Notes for the Facilitator: Ideally, the hot water should be 10–20°C (18–36°F) warmer than the room temperature water. The cold water should be approximately the same number of degrees away from the room temperature water as the hot water. The cups of water should also rest briefly after filling or moving them to ensure there is minimal water motion and the water isn't swirling in the cup, which would act like intentionally stirring the cups.

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.

Notes for the Facilitator: Discuss the results as a whole group. In all situations, the food coloring was concentrated when it entered the water, and by the end of one minute, it should have been evenly (or at least more evenly) distributed in the water, making the color more transparent because it was less concentrated. The liquid molecules are constantly moving, so stirring speeds up the process but is not necessary to mix the food coloring into the water. Also, temperature will make water molecules move faster, so the color distributed faster in the hot cup vs. the cold cup. Introduce the term diffusion, and explain it is the net movement of molecules from areas of high concentration to low concentration. Drawing or displaying a particle diagram like the one below could be helpful. Diffusion was also introduced in Investigation 4A.



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.

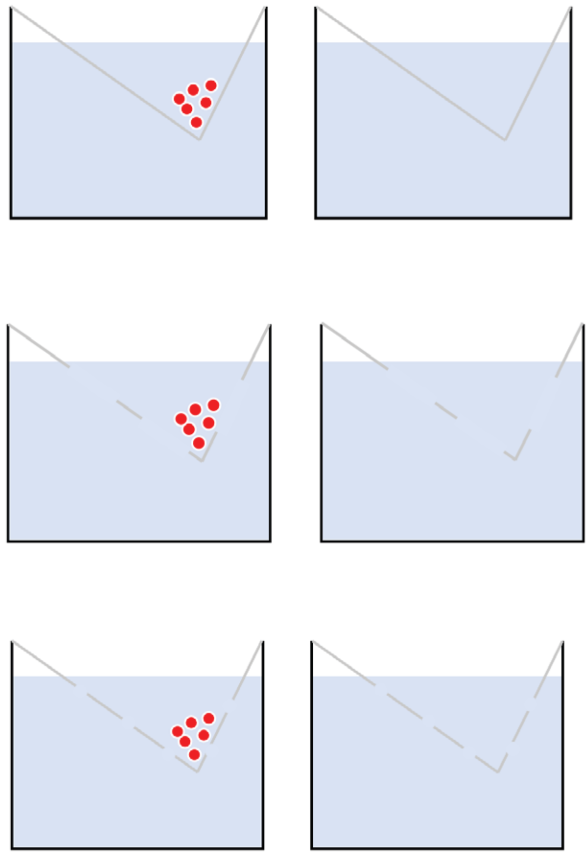
h. Add 100 mL water inside the bag.

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.

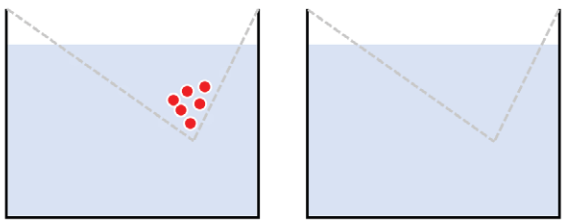
k. Pour out the contents of the cups and baggies. Discard the bags and rinse the cups.

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

Notes for the Facilitator: The red molecules are too large to fit through the microscopic holes. Therefore, only water would move through the membrane and the red molecules would stay contained in top area.

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:

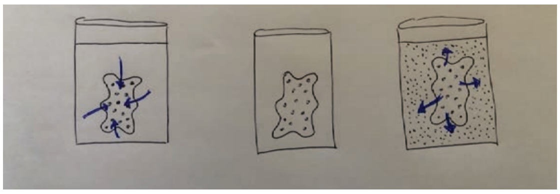
Notes for the Facilitator: Take time to explain the semipermeable membrane. Introduce the term *permeable* (when a material or membrane allows liquids and/or gases to pass through it) and *impermeable* (when no liquids or gases can pass through a material or membrane). An impactful demonstration of movement restriction across a semipermeable membrane can be done with starch and iodine as outlined at **https://bit.ly/3wdpT5o**.

- **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.

Notes for the Facilitator: The two potatoes that are in cups with water should be mostly submerged, although the potatoes may float in saltwater.

During the 15 minutes of wait time, share the procedure and results from Facilitator Demonstration #1 with the gummy bears. Have the learners make observations and make predictions of what happened. Then use diagrams to help explain the change in size for the gummy bears.

There should be no size change in the gummy bear set out in air (middle bear in image and middle setup in diagram) because there is no net water movement into or out of the gummy bear. The gummy bear in water (on the left in the image and diagram) about doubled in size due to a net diffusion of water into it. Since there was less water inside the gummy bear than in the cup in which it was placed, more water molecules moved inside the gummy bear to reach equilibrium. The gummy bear in saltwater (right in image and diagram) should shrink compared to the other two. There was a lower concentration of water in the saltwater than in the gummy bear, so there was a net diffusion of water molecules out of the gummy bear.



Credits: L. Brase

- **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.

Notes for the Facilitator: Walk through the first example as a whole group, then let learners work together to complete the remaining osmosis examples. The practice page can just be for making predictions, but it is recommended to review the answers to dispel misconceptions. Image 1 would result in a net movement of water from the right chamber to the left due to there initially being a higher concentration of water in the right chamber. The water would rise in the left chamber as diffusion occurred. Image 2 would result in net movement of water from the left chamber to the right. Image 3 would result in equal water movement between the two chambers due to an equal water concentration. This is called dynamic equilibrium and occurs because the molecules do not stop moving even when at equilibrium. In image 4, there would be no water movement because the wall between the chambers is impermeable.

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."

Notes for the Facilitator: If possible, watch videos explaining reverse osmosis to learners (**https://www.youtube.com/watch?v=4RDA_B_dRQ0** and **https://www.youtube.com/watch?v=aVdWqbpbv_Y**). Discuss reverse osmosis before learners begin their work on the activity page. After giving learners time to work with their groups on the activity page, discuss predictions and answers as a whole group. The practice page can just be for making predictions, but it is recommended to review the answers to dispel misconceptions. In image 1, the result would be equal water movement between the two chambers. The difference in water concentration would favor water movement to the right but this could be offset if enough pressure is applied to the left side. Images 2 and 3 would result in water movement into the right chamber, so the water would rise in the right chamber. In image two, the pressure to the left side reinforces the water movement occurring due to concentration differences. In image 3, no net diffusion would occur due to concentration differences, but the pressure in the left chamber would move water to the right side. In image 4, there would be no water movement because the wall between the chambers is impermeable.

Facilitator Demonstration #2:

1. Conduct water quality tests on the water sample either before the Investigation, or during the Investigation with learners.

2. Use the reverse osmosis hand pump to filter the water.

3. Conduct water quality tests on the treated water.

4. Depending on the reverse osmosis unit, you may be able to remove the filter. If possible, examine it with learners.

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.

> **Notes for the Facilitator:** The potato in water should have become slightly larger and gained mass, and firmer since water will have traveled into the potato (similarly to the gummy bear demonstration). The potato in saltwater should have lost mass and become slightly smaller and mushier or shriveled due to water traveling out of the potato (similar to the gummy bear demonstration).

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?

> **Notes for the Facilitator:** Both use a semipermeable divider to separate contaminants from water. Filtering through a coffee filter uses gravity to push water through the filter while the filter catches the larger sand particles. Similarly, in reverse osmosis a semipermeable membrane catches contaminants. These processes are very different in that pressure needs to be applied to force water to move through the semipermeable membrane in reverse osmosis. Also, the membrane holes are much smaller in a reverse osmosis membrane compared to a coffee filter. This allows reverse osmosis to remove more contaminants, no matter their size.

3. Consider the process of diffusion:

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

> **Notes for the Facilitator:** If the contamination can dissolve in water, it will diffuse through (or mix with) the water. The contamination will spread throughout the lake or river and may have greater consequences than a contaminant that does not dissolve in water. Oil and other contaminants that cannot mix with water will either float on the surface of the water or will sink to the bottom and can still be harmful to organisms and the environment.

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

Notes for the Facilitator: As contamination diffuses through a volume of water, the concentration of the contaminant in a particular area decreases. Some contaminants are harmful at any concentration while others are only harmful above a certain concentration. If the contaminant is within a large enough body of water or enough water is added, the concentration could be reduced below the harmful limit. However, other processes (like biologic food chains) can act to concentrate contaminants even though environmental levels are overall low.

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.

Notes for the Facilitator: Fish eggs are frequently used as bait for fishing and can often be found at stores that sell tackle and other fishing supplies.

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?

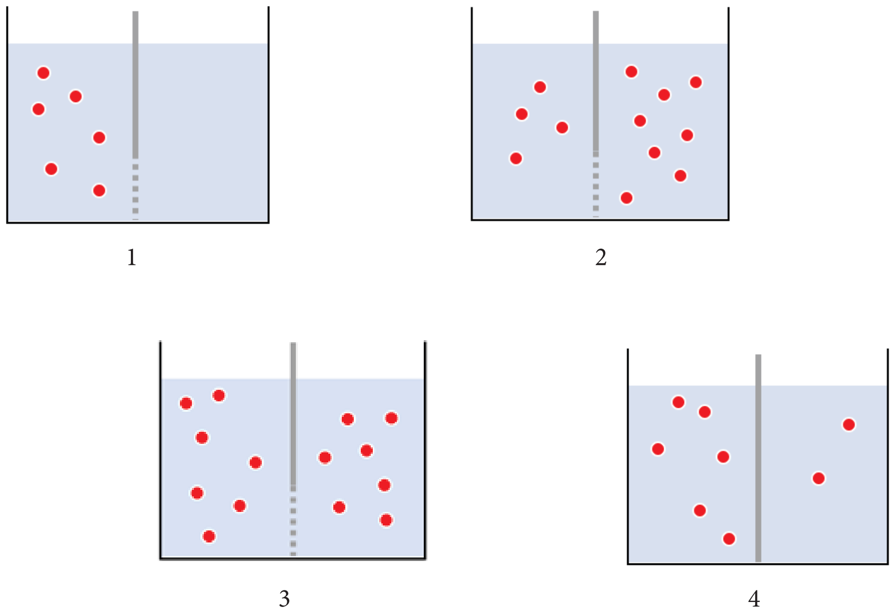
3. Using *Scratch*®: Create a *Scratch*® project or remix an existing project to explore diffusion, osmosis, and reverse osmosis. Here are three projects to look at and possibly remix:

   - 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

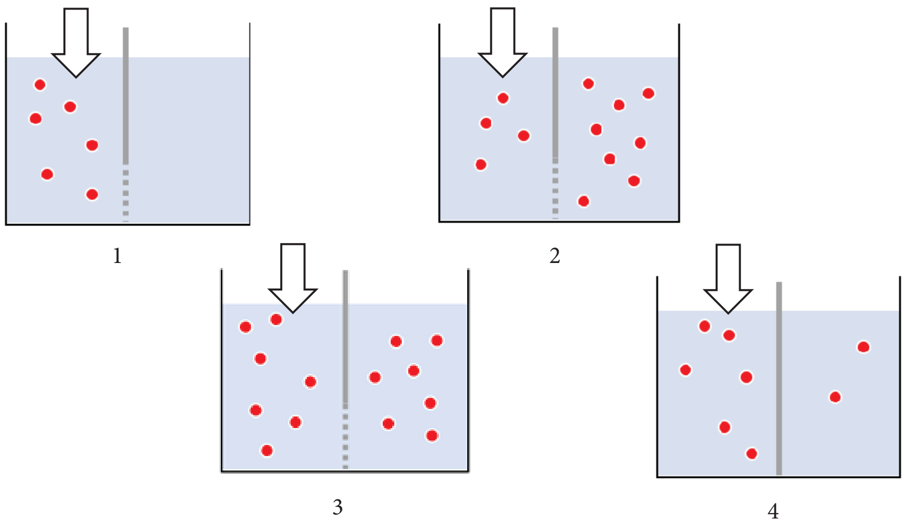
On each particle diagram, determine if there is a side that has a higher or lower concentration of particles. By osmosis, water would move from the lower to the higher concentration through a permeable membrane. Draw an arrow showing overall how you predict the water would move.



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

Sustainable Development Goal 6: Clean Water and Sanitation

INVESTIGATION 6A: ASSESSING YOUR WATER FOOTPRINT

Facilitator Background

Connection to SDG 6: Target 6.4 seeks to "substantially increase water-use efficiency" (https://sdgs.un.org/goals/goal6). Water is a prized resource that many people, communities, or industries don't realize is as scarce as it really is. *Water scarcity* is a global issue, making *water-use efficiency* and conservation more important than ever. To help *water management* and direct where improvements can be made, water usage — what is sometimes called a *water footprint* — can be calculated. A water footprint measures the amount of water that is used for a single process, product, household, or on a larger scale, such as for an entire company or nation. Water consumption can be measured directly (such as the water used in a household) or indirectly, called virtual water. In this Investigation, learners will assess their water footprint and determine ways they could reduce their water use.

Key Concepts: *water footprint, water management, water scarcity, water-use efficiency*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water if not re-using it. After this Investigation, learners could consider how citizens will directly and indirectly use water, and make plans for how to reduce water use, as well as how to re-use water, and how to reduce virtual water use in their town.

PACING GUIDE

PREPARATION
10 minutes printing "Assessing Your Water Footprint" handout

WHAT TO DO
40 minutes for the Investigation

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?

Notes for the Facilitator: Some other examples of household water include drinking water, cooking, washing dishes, watering plants, and others listed in the "Assessing Your Water Footprint" handout. Some examples of virtual water use are the water used to make dog food (if you have a dog), water used to make takeout food, and others listed in the "Assessing Your Water Footprint" handout.

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.

Notes for the Facilitator: Facilitate a class discussion about the assessment, what contributes to water use, learners' answers and scores, and solutions learners could take to reduce their water use.

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

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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?

Notes for the Facilitator: Answers will vary.

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

Notes for the Facilitator: Answers will vary. Learners could consider water use at school, daycares or after school care, at friends' houses, outdoor activities such as a community swimming pool, and so on.

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?

Notes for the Facilitator: Water is used in the production of most items whether they are disposable or reusable. When items need to be continually purchased, such as disposable items, the virtual water-use adds up quickly. Another factor to consider is that although direct water-use does decrease with the use of disposable items, these items contribute a large amount of garbage that goes into landfills as well as a high carbon footprint.

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?

Notes for the Facilitator: Answers will vary. Some of the major areas of buildings that contribute to water footprints are kitchens, bathrooms, and gardens. Also, a major contributor for virtual water is the products (like food, clothing, furniture, and so on) that are within the building. The larger the building, the more bathrooms/kitchens, and/or the more items inside the building usually correlate with a higher 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?

Notes for the Facilitator: Answers will vary but could include turning off running water when not in use, shower instead of bathing, fix leaky taps or pipes to reduce wasted water, purchasing high-efficiency appliances, using rainwater for outside watering needs, only buy what is needed to reduce virtual water use.

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?

Notes for the Facilitator: Most uses of water require treated, drinkable water whether it is for domestic use, food production, manufacturing, and so on. Untreated water should only be used for outdoor purposes. Access to clean water is vital for human survival from a health perspective and for the economy.

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?

Notes for the Facilitator: Collecting rainwater in open containers increases the chances of the water evaporating before use. Collecting rain in open containers is not allowed in some regions or countries because of the risk of mosquitoes laying their eggs in the water and possibly spreading disease. Other areas that are prone to drought may also prevent individual water collection because it delays recharge of groundwater and bodies of water.

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.

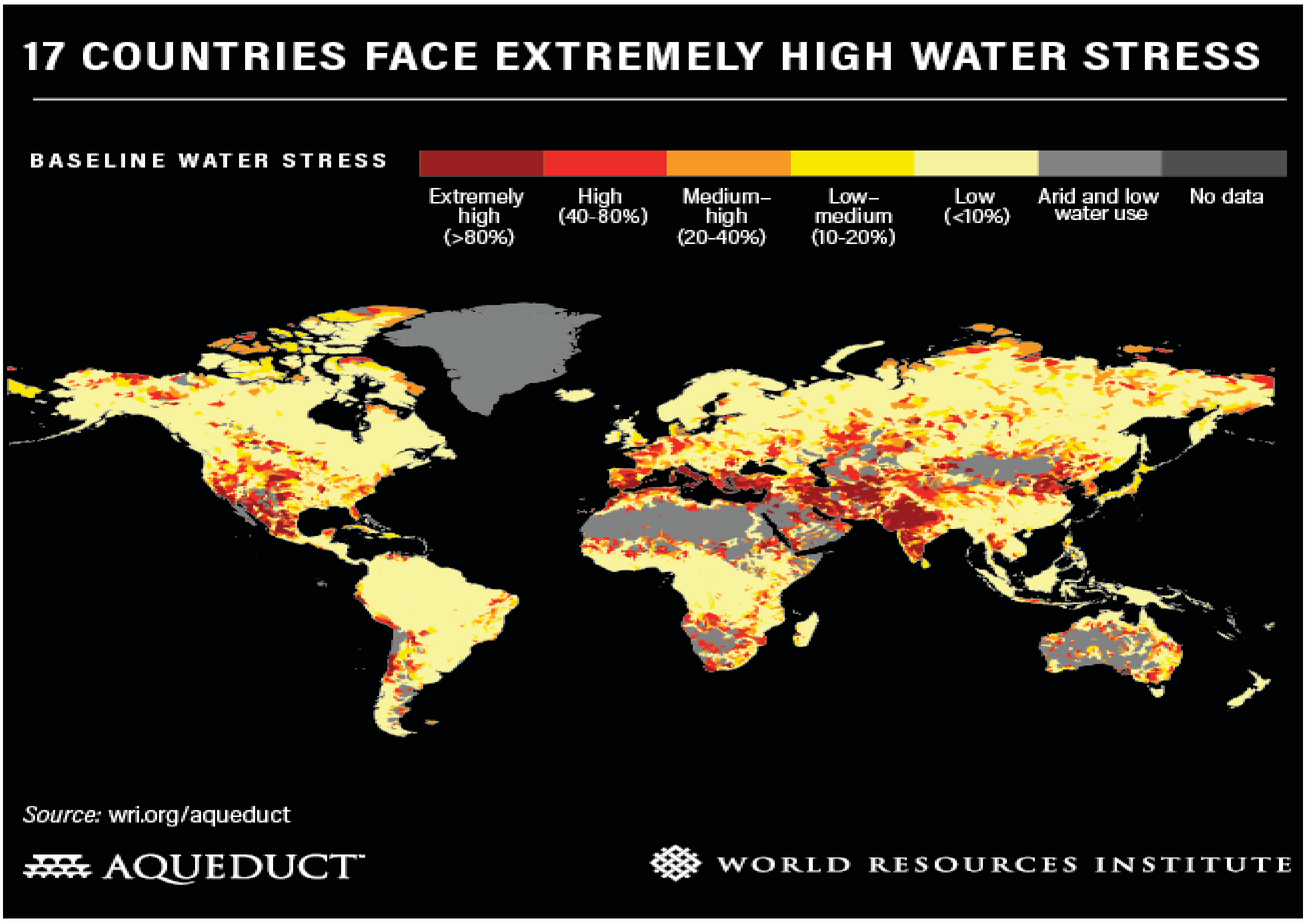
   a. What areas are experiencing high or extremely high water stress? Is there a trend between or similarities between these locations?

   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?

Notes for the Facilitator: Areas in dark red such as southwest North America, southern Europe, the Middle East, North Africa, and southwest Asia are experiencing high water stress. These locations are near 30°North latitude (and similarly, some of the dark reds in western South America, southern Africa, and Australia are around 30°South), which is due to large scale atmospheric circulation patterns that result in drier climates. Other factors may contribute to high water stress could include population, limited local water resources, high withdrawal from industries and agriculture, and urbanization.

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**

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 6B: WATER USE AROUND THE GLOBE*

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

Facilitator Background

Connection to SDG 6: Target 6.4 seeks to "substantially increase *water-use efficiency* across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity" (**https://sdgs.un.org/goals/goal6**). It is important for water management to balance the water needs between agricultural, industrial, and domestic needs of a population. Access to water is dependent on a variety of factors, including physical and economic access. When areas struggle with access or there is poor *water management*, populations may deal with *water scarcity* issues. In Investigation 6B1, learners will need to act as water managers and determine how to fill the agricultural, industrial, and domestic needs of a population given different water-access scenarios. In Investigation 6B2, learners will examine data about *water scarcity* including *water withdrawals.*

Key Concepts: *water management, water scarcity, water-use efficiency, water withdrawals*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water if not re-using it. After this Investigation, learners could consider the different water needs of the population in their town, and how accessible water is in terms of physical and economic access.

PACING GUIDE

PREPARATION

30 minutes labeling containers and setting up the Groups

WHAT TO DO

30 minutes for Part 6B1 (Groups 1–3)
30 minutes for Part 6B2

INVESTIGATION 6B1: WATER AVAILABILITY SCENARIOS

Notes for the Facilitator: 6B1 includes 3 stations, which each take about 10 minutes (5 minutes for the Investigation and 5 minutes for clean-up and answering the Consider questions). If time allows, have the learners rotate and complete each station. Ideal group sizes are 2–5 learners. If the groups are larger and you have enough materials, you can have two set ups of each Group (total of 6 groups) to create smaller learner groups. If there is not time to have learners rotate to each station, have learners share their experience with the whole class.

Label the materials for each group. Label 30 cups: 21 cups “Agricultural Needs,” 6 cups “Industrial Needs,” and 3 cups “Human Needs.” Add number labels according to the tables below (Agricultural 1, Agricultural 2, and so on). Label the gallon containers: 1 “Potential” and 1 “Resources.” Label the opaque pitcher and small container both “Resources.” Label the 3 water bottles “Population.” Label the three large bowls: “Water Abundant,” “Physical Scarcity,” and “Economic Scarcity.”

Fill up both gallon containers, the opaque pitcher, and the small container until almost full. Place the gallon container at the table where Group 1 (Water Abundance) will be working. Place the small container at a table nearby where Group 2 (Physical Scarcity) will be working. Stir coffee grounds into the opaque pitcher to make it dirty. Place the opaque pitcher across the room from Group 3 (Economic Water Scarcity). Ensure learners have clear paths to the small container and the pitcher.

After learners have completed the activity. facilitate a discussion about each of the groups. How did the amount of water the population received (amount in the “Population” water bottle) compare between the Water Abundant, Physical Water Scarcity, and Economic Water Scarcity groups? Which needs did they prioritize when filling the cups, and why? Discuss effects of not meeting some needs, such as hunger, poverty, health issues, etc. How did the amount of work and the quality of the water compare for each group? How did learners feel about the fairness of each scenario?

GROUP 1: WATER ABUNDANCE

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

Notes for the Facilitator: Explain the labels on the cups. Start a five-minute timer right when learners get to their station for them to read the scenario and carry out the activity.

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

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

Notes for the Facilitator: Explain the labels on the cups. Start a five-minute timer right when learners get to their station for them to read the scenario and carry out the activity.

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

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

Notes for the Facilitator: Place the opaque pitcher across the room from the group. This represents that populations in economic distress usually spend more time collecting water.

What to Do

Notes for the Facilitator: Explain the labels on the cups. Start a five-minute timer right when learners get to their station for them to read the scenario and carry out the activity.

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?

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

Materials

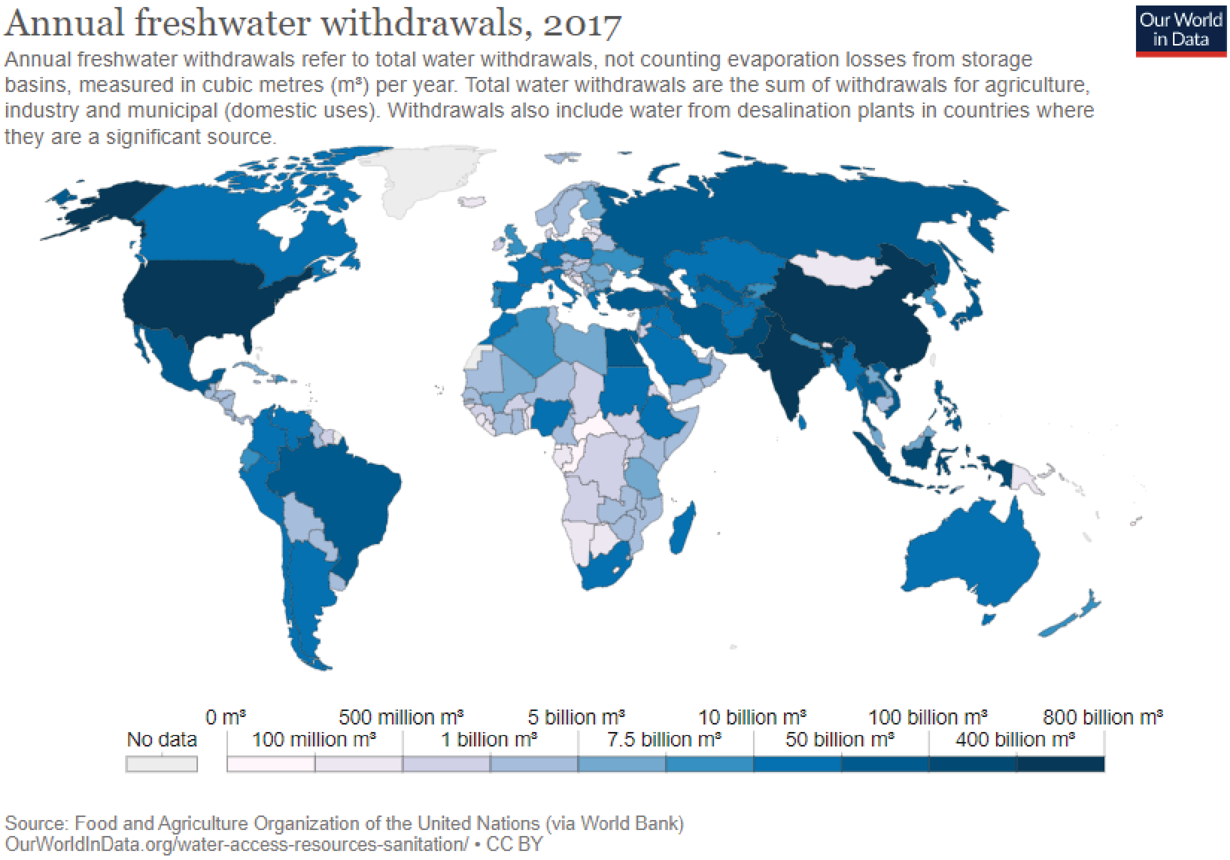
Per learner:

- copy of maps within Investigation

Notes for the Facilitator: Most of the data in this Investigation was made available by Our World in Data **https://ourworldindata.org/water-use-stress**. If possible, allow students to explore the data online as some maps have interactive components.

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?

Notes for the Facilitator: North America and Asia have countries with the highest agricultural, industrial, and municipal withdrawals. Most likely due to large populations and higher per capita water demands.

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

Notes for the Facilitator: Countries in Africa have low water withdrawal, possibly due to low water availability or smaller population sizes.

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."

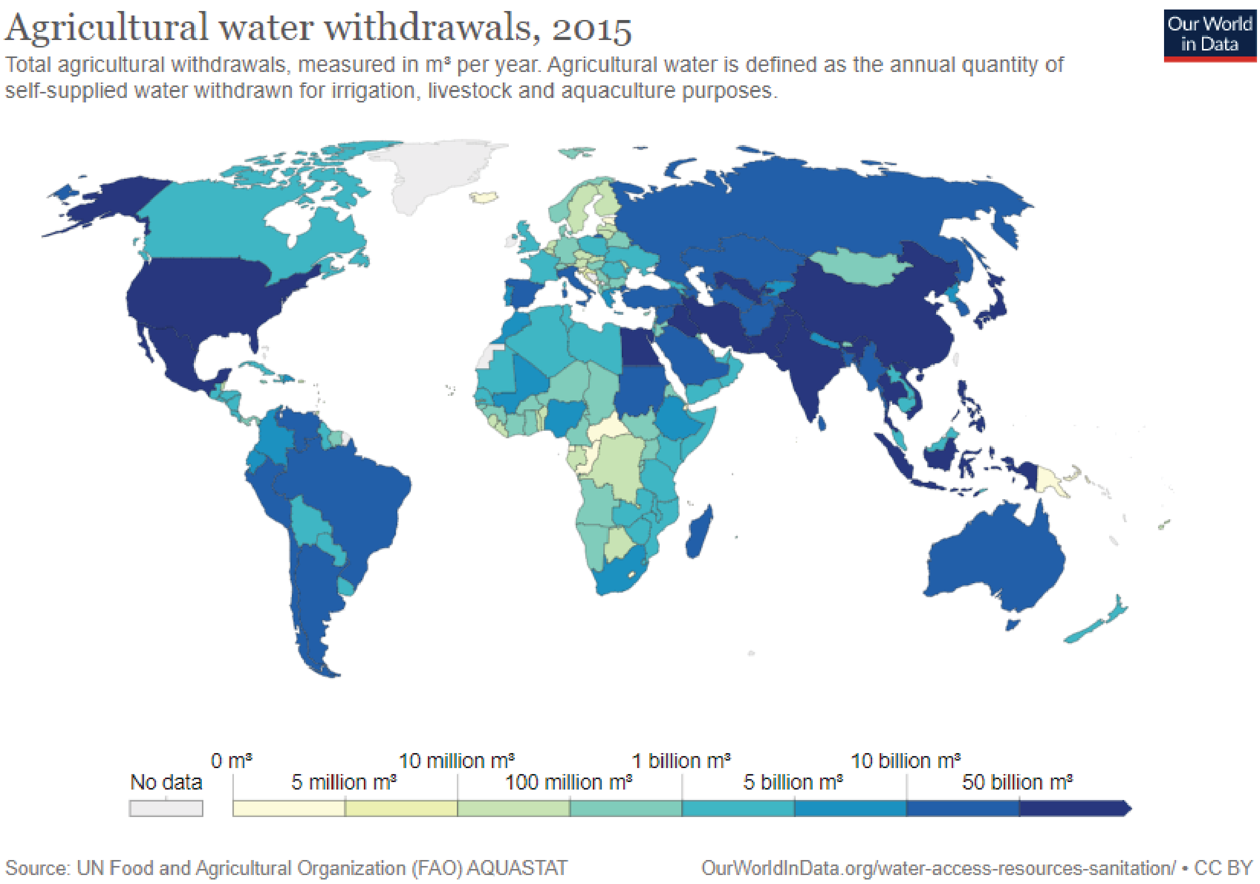
e. Observe the time lapse of the graph. How has water withdrawal changed since 1965?

Notes for the Facilitator: For most countries, water withdrawal has increased.

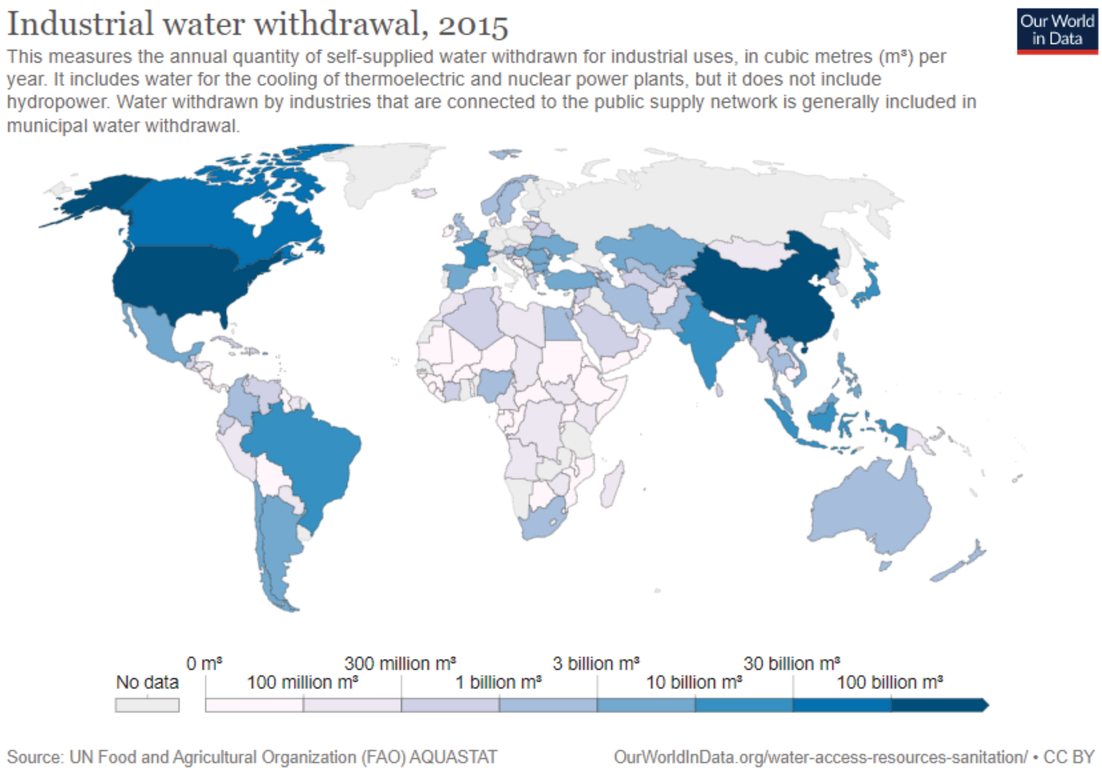
- In the drop-down menu on the right of each graph, select the continent where you are located to zoom in on the data near you. How do the countries on your continent compare to each other in 2017?

- 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?

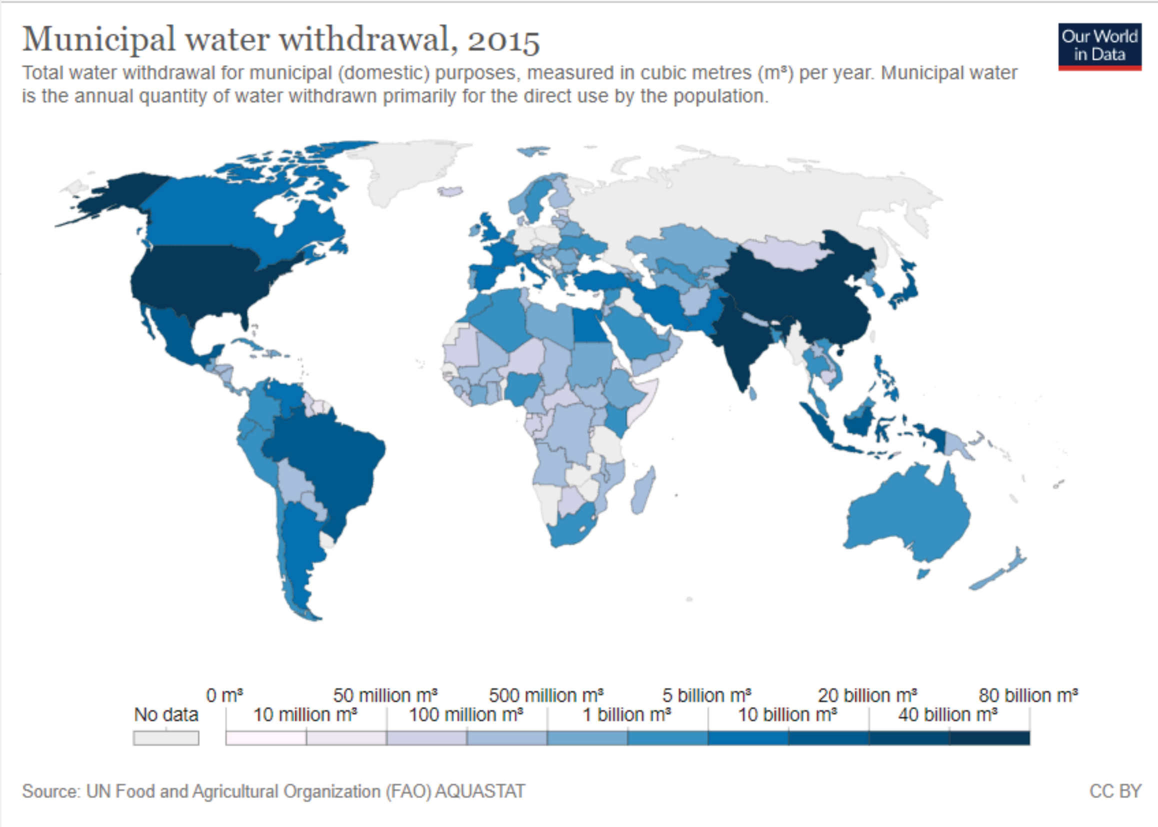
2. Examine the maps and read the map descriptions of three sectors of water use “Agricultural water withdrawals, 2015, “Industrial water withdrawals, 2015,” and “Municipal water withdrawals, 2015.”



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



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



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?

Notes for the Facilitator: Most water is used for agricultural use; it accounts for about 70% of freshwater withdrawals. The percentage of water use for agriculture correlates with income – lower income, middle income, and high income countries' agricultural water use is around 90%, 79%, and 41%, respectively (Our World in Data, **https://ourworldindata.org/water-use-stress**).

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?

Notes for the Facilitator: All countries have different amounts of withdrawal for the three sectors but are similar in how they compare relative to other countries. For example, China has high water withdrawal compared to other countries for all three sectors. In general, agricultural water withdrawal is much higher than industrial and municipal withdrawal.

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?

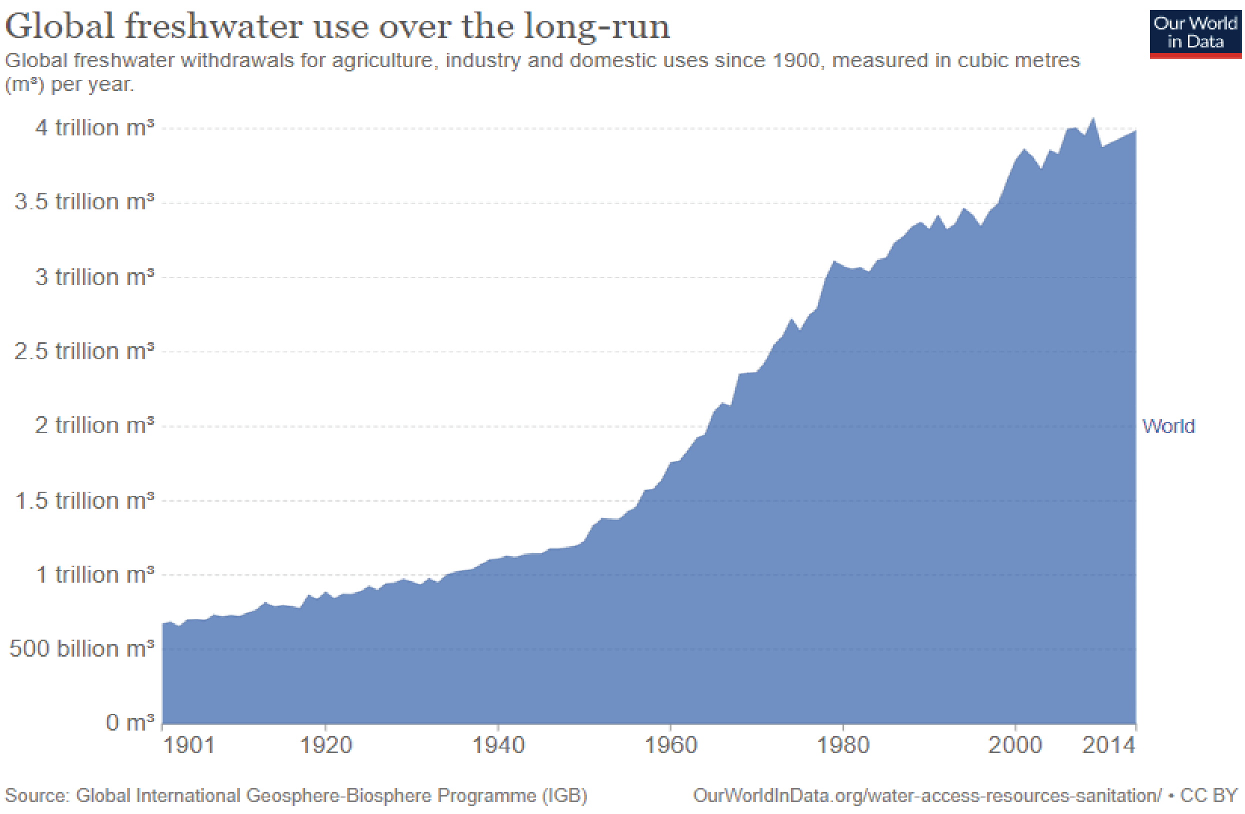
Notes for the Facilitator: For most countries, water withdrawal has increased in all three sectors. There are some countries that have a reduced water withdrawal between 2010 and 2020.

- 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?

Notes for the Facilitator: Global freshwater use has increased over the past 100+ years. The rate of increase was slower from 1901–1950's than it was between 1950's-2014. The increasing use of fresh water is due to a growing global population and an increase in freshwater withdrawal for industry, agricultural, and municipal uses.



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."

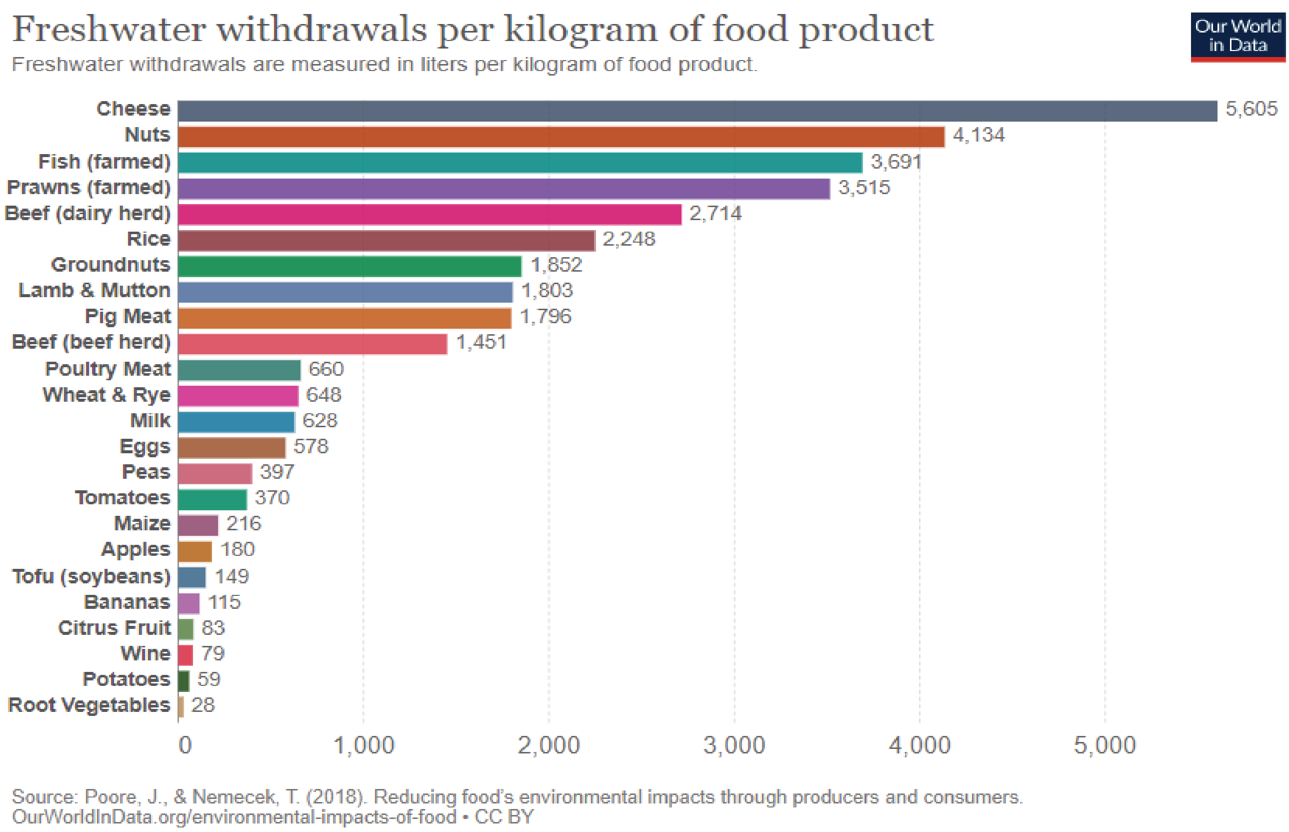
a. What trends, if any, do you notice any trends in the data?

Notes for the Facilitator: Proteins generally have higher freshwater withdrawals per kilogram.

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?

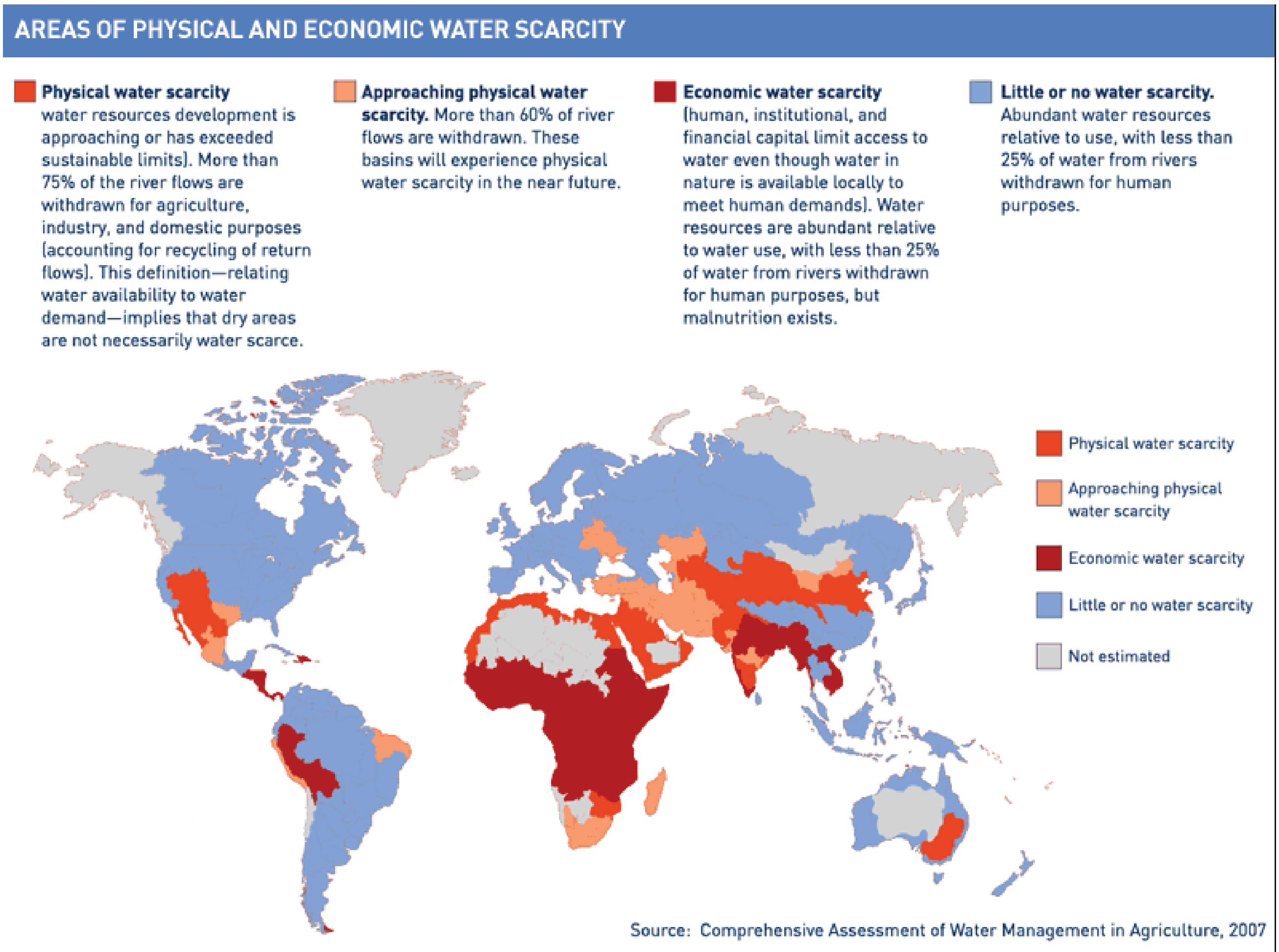
Notes for the Facilitator: Policies are in place in most countries that regulate water withdrawal. Sustainable water management policies also would help reduce water stress and/or scarcity. Promoting education, innovation, and action have also been helpful in bringing awareness and improving water stress/scarcity.

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

Facilitator Background

Connection to SDG 6: Indicator 6.2.1 aims to increase the "proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water" (https://sdgs.un.org/goals/goal6). Access to *sanitation* and *hygiene* facilities is critical in maintaining health and preventing diseases. Sanitation includes having access to safe waste disposal including human waste, garbage, wastewater, and so on. Hygiene facilities more specifically refer to access to washing facilities that have clean water and soap. Although people may not be able to control their access to facilities, there are still best practices that can be followed when access is limited. In this Investigation, learners will experiment with different handwashing methods to evaluate the effectiveness of germ removal. They will also consider how to conserve resources while implementing good hygiene practices and how to implement good hygiene when access to resources is limited.

Key Concepts: *hygiene, sanitation*

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

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners may consider the different ways citizens need water in addition to drinking.

PACING GUIDE

PREPARATION

10 minutes reading the facilitator notes and copying handout

10 minutes creating and printing community maps for extension activity

WHAT TO DO

30 minutes for the Investigation

10 minutes discussing ESD Kit Project (optional)

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

Notes for the Facilitator: It would be best for each group to have access to their own UV light but having one or two for the groups to share would also work.

If learners will be using a container with a nozzle, such as a cooler or detergent bottle, for their water source, make sure to thoroughly wash the container out before use. The cleaned-out container should be filled with water and then placed at the edge of the table. Underneath the nozzle, lay a large towel down and place the bucket on top to catch the running water. To reduce the mess, use a large bucket and place the water source with nozzle and bucket as close together as possible.

Credit: L. Brase

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.

Notes for the Facilitator: Lead a whole group discussion about the least effective and most effective procedures for removing Glo Germs, using evidence from the experiments.

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?

Notes for the Facilitator: Soap has properties similar to both water and materials you clean off your hands, such as dirt and bacteria. Regular hand soap (bar or liquid) works by mechanically removing the dirt and bacteria. The soap adheres to these materials and can also adhere to water. Scrubbing aids in the removal of dirt and bacteria from the skin, and water can rinse away both the soap and these materials. Antibacterial soap kills the bacteria on the skin before mechanically removing them.

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.

Notes for the Facilitator: Discuss results from the soap experiment as a whole group. Pepper is both hydrophobic and floats on water due to the surface tension of water. When a finger is placed in the water and removed, pepper will remain relatively stationary in the bowl and will stick to the finger. When soap is on the finger, it breaks down the surface tension of the water molecules and the water molecules spread away from the finger bringing the pepper with them. The result is no or very little pepper on the finger when it is removed from the water.

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?

Notes for the Facilitator: Answers will vary.

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?

Notes for the Facilitator: Poor handwashing can lead to increases in illness. In addition to harming your health, poor hygiene could lead to missing school or work. Poor handwashing can also lead to spreading diseases and impacting others around you.

3. Access to clean water is a global concern.

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

Notes for the Facilitator: Answers will vary but could include drinking, cooking, cleaning, hygiene, sanitation, gardening, farming, recreation, energy production, manufacturing, tourism, medical needs, and for animals.

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

Notes for the Facilitator: Answers will vary.

   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?

Notes for the Facilitator: Procedures which had the water running for more than 5 seconds used more water (A2, B2, and C2). Other procedures had the water running for 5 seconds and therefore used less water in comparison. Procedure D2 (and possibly D1) conserved water while effectively removing Glo Germs.

   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?

Notes for the Facilitator: Answers will vary but could include using very limited water, using hand sanitizer if available, catching the gently used water (greywater) to use elsewhere (but not for drinking water), and using treated greywater for hygiene purposes.

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.

Notes for the Facilitator: Hand soap works by mechanically removing germs, while antibacterial hand soap kills germs on contact and mechanically removes the germs. Hand sanitizer kills germs on contact but does not remove them from the skin. The experiment assesses how handwashing mechanically removes Glo Germs, and therefore the hand sanitizer may seem ineffective to learners since it kills real germs instead of removing them and Glo Germs will still be visible under UV light. Since hand sanitizer kills germs, the amount does matter – the more hand sanitizer, the more germs killed, up to a point.

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?

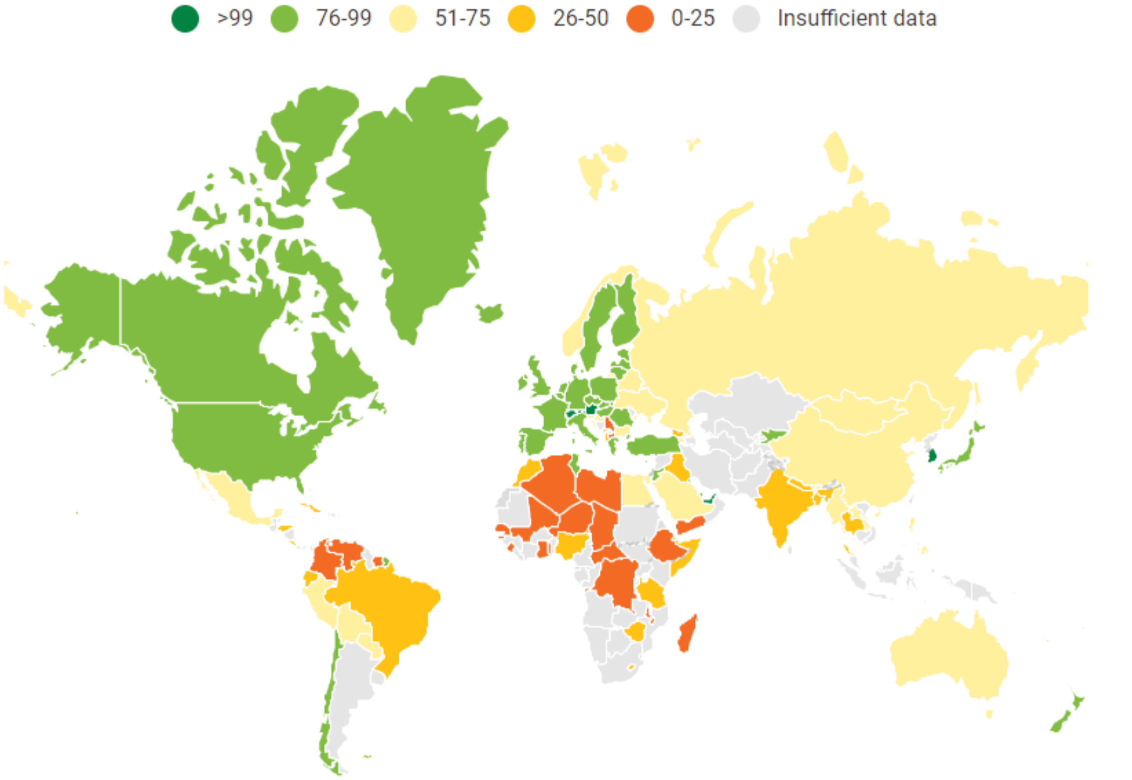
    c. Locate your country on the map. What data was reported in 2020? What might you infer from the data about your country, and why?

    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.

Notes for the Facilitator: Countries in Africa and parts of South America have lowest rates of safely managed sanitation services, while countries in North America and Europe have highest amounts of safely managed sanitation services. Differences could be due to …. Areas with a higher rate of safely managed sanitation services are more likely to have less illnesses due to water-borne diseases since the water is treated in these areas. Areas with lower rates of safely managed sanitation correspond with areas with more limited access to basic hygiene facilities, as seen on the map in extension question 2.

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

Notes for the Facilitator: Global data on sanitation and hygiene can be found at: https://data.unicef.org/topic/water-and-sanitation/drinking-water/. You can share data with learners using already-made graphs and charts, or you can download country-specific data to create your own representations.

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.

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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

Facilitator Background

Connection to SDG 6: Target 6.6 aims to "protect and restore water-related ecosystems" (**https://sdgs.un.org/goals/goal6**). A wetland is an important *water-related ecosystem* that can be exist as *freshwater* (at edges of streams, lakes, rivers) or salt water (tidal salt marshes), and in estuaries. Aquatic plants in wetlands filter the water and therefore improve the *water quality*. Many contaminants travel as surface *water pollution*, and if the surface water makes it to a wetland, the wetland acts as a natural *water treatment* plant. Wetlands also slow down water and sediment transport and so act as a screen between land and water. In this Investigation, learners will build a model landscape with and without wetlands to test the positive effects of wetlands on water quality.

Key Concepts: *freshwater, water quality, water pollution, water-related ecosystems, water treatment*

Learning Outcome: Build a model landscape to determine the potential impacts of a wetland on water quality.

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners could consider their town's proximity to wetlands and other aquatic ecosystems.

PACING GUIDE

PREPARATION

10 minutes setting up materials for groups

WHAT TO DO

10 minutes to discuss questions 1 and 2

30 minutes for remainder of the Investigation

Introduction

Wetlands are a type of aquatic ecosystem that are transitional areas that are either permanently or seasonally inundated. They hold abundant biodiversity and play an essential role in food production. They also act as a natural water reservoir or filter. They can slow down the transport of water, limit flooding, and can protect against storm damage. Also, the plants within wetlands purify water by taking in nitrates and other runoff chemicals. Any contamination that is not taken up by plants usually sinks to the bottom and is buried within the wetland. Wetlands play a vital role in our world and are worth protecting. With increasing urbanization however, many wetlands have been destroyed for building-purposes and damaged by too much contamination for the wetlands to process.

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?

> **Notes for the Facilitator:** Use the questions above to discuss aquatic ecosystems and introduce wetlands to learners. Consider if there are any wetlands near you that can be used as examples in the discussion.

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?

Notes for the Facilitator: Discuss results as a whole group. The sponges (wetlands) should have filtered most of the dirt and colored powder or sprinkles, so the water in the other side of the pan (river) should be mostly clear. Wetlands act as a natural filter and remove many (but not all) contaminants.

Ask the learners what they think would happen if a wetland is destroyed to build structures like home or roads, before moving on to the next steps.

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?

Notes for the Facilitator: Discuss the results as a whole group. The dirt and colored powder or sprinkles should have made its way to the river without the sponges present. The water should also have traveled to the river much faster, which in real life could translate to more flooding. Discuss with learners why they think wetlands are important.

Consider

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

Notes for the Facilitator: Wetlands are natural sediment traps and therefore help retain loose sediments and limit erosion. If wetlands were removed and the sediment were to travel to other water sources like rivers and lakes, the resulting muddy water (or water with a high turbidity) would have less light for plants, leading to a lower oxygen supply, which can then limit photosynthesis, reduce fish reproduction, and promote growth of certain algae and bacteria.

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.

Notes for the Facilitator: Since wetlands act as natural filters, the removal or destruction of them will cause an increase in contaminants moving into other bodies of water. This will affect the immediate areas and areas downstream of where the wetland used to be located. This may also affect the health of any animals or plants in these areas. Wetlands also slow down the speed at which the water travels to the river. If wetlands are removed, water would travel faster leading to flooding.

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?

Notes for the Facilitator: Other common pollutants are pesticides, salts and chemicals from roads, garbage, and sewage leaks and waste products. Wetlands act as natural filters, removing sediment and toxins from water like nitrogen and phosphorus, but they can only take in or store so much. If the pollution exceeds the wetland's natural holding capacity, the wetland will degrade.

4. Protecting and restoring wetlands will improve aquatic ecosystems.

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

Notes for the Facilitator: Learners can become more informed about where wetlands and other aquatic ecosystems are located, as many are located on private property, and help raise awareness and advocate for their protection and restoration. Learners can also assist in protecting aquatic ecosystems. Non-native and invasive species are a threat to wetlands and other aquatic ecosystems as they outcompete native species for resources and space. Learners, with the assistance of an adult, could help remove invasive species.

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

Notes for the Facilitator: Adults can also promote the benefits of wetlands and advocate for their protection and restoration. Additionally, they may have the ability to create wetlands and help with larger restoration projects by supplying the resources themselves or through funding. Community leaders could also impose restrictions on wetland removal or destruction and implement laws to help reduce pollution that harms wetlands. These strategies can also be applied to other aquatic ecosystems (oceans, lakes, rivers, streams, and estuaries) local to the community.

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

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INVESTIGATION 8B: RESTORING HABITATS

Facilitator Background

Connection to SDG 6: Target 6.6 aims to "protect and restore *water-related ecosystems*" (**https://sdgs.un.org/goals/goal6**). Contaminants that enter aquatic ecosystems affect the quality of water but also affect the organisms within these habitats. *Water pollution* is easily spread by water and can potentially affect much larger areas than contaminants in terrestrial ecosystems. Oil has particularly detrimental effects on aquatic ecosystems and billions of dollars are spent annually on the removal of oil from aquatic ecosystems.

Key Concepts: *water pollution, water-related ecosystems*

Learning Outcome: Design and carry out a plan to clean an oil spill to understand potential environmental effects.

Connect to the ESD Kit Project: Designing a net-zero water town: The goal of the ESD Kit Project is to design a small town that uses local water, has low water consumption, and safely disposes of water back into the watershed. After this Investigation, learners will understand the efforts of cleaning up an ecosystem and can enact measures to prevent or minimize water pollution.

PACING GUIDE

PREPARATION

10 minutes making copies of the "Oil Spill Cleanup Guide"
15 minutes setting up materials for groups
10 minutes dyeing oil

WHAT TO DO

15 minutes to discuss the introduction material
40 minutes for the Investigation

Introduction

NOAA (2015) estimates nearly a billion liters of oil end up in waterways each year, most of which enters or ends up in oceans. Most oil that enters waterways is from natural seepage from oil deposits. The second most common source of oil in waterways is runoff from land or leakage from boats. Oil spills from large tankers are occurring less frequently, and account for 10–15% of the oil in oceans.*

Regardless of the source, oil has numerous negative effects on ecosystems and wildlife considering its toxicity as well as how difficult it is to remove from the environment. Most types of oil float on water, creating a slick across the surface. Some oils will form small beads and disperse throughout the water. Many methods have been developed to remove oil from waterways, especially slicks, since they float and are easiest to contain.

The most common first step in cleaning oil from waterways is containing it. Booms are large floating devices set around an oil slick to prevent it from spreading across the water. Booms are often plastic but are now being developed out of absorbent materials that can also help collect the oil.

Credit: K. Krüg, Creative Commons, https://commons.wikimedia.org/wiki/File:Tedx-oil-spill-0075.jpg

There are many methods for removing the oil from the top of the water. A machine called a *skimmer* contains a belt made of a material that attracts oil. The machine pulls the belt through an oil slick, and as the belt runs through the machine, it is wiped clean to collect the oil. *Sorbents* are materials that will adhere to oil, such as the belt that runs through a skimmer. While some oil can be recovered from a sorbent, it is less than when a skimmer is used. Peat moss, hay, and sawdust are examples of natural sorbent materials.

Dispersants are chemicals that will break an oil slick into droplets that will more readily disperse through the water with the intent being that they will be dilute enough to have less effect that the concentrated slick. Dispersants are often applied by aircraft, and often used on smaller oil slicks or after all other methods of collection have been exhausted. They are also used when an oil slick is close to shore, to quickly prevent the slick from affecting the coastline.

Less common methods of removing oil slicks include burning and the use of microbes.

Burning an oil slick can quickly remove oil from the water. The downsides to burning are that it creates a lot of smoke, which presents a different kind of environmental hazard, and that the oil cannot be reclaimed. Microbes (bacteria) that consume oil can be released into the water. A downside to using microbes is that because they thrive in oil-rich environments, they outcompete other bacteria in the water and can drastically affect the health of aquatic ecosystems.

* NOAA. (2015, November 2). *How Does Oil Get into the Ocean?* Retrieved May 5, 2022, from https://response.restoration.noaa.gov/about/media/how-does-oil-get-ocean.html

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.

Notes for the Facilitator: If you have the time and resources, learners could try the other cleanup methods to remove the oil from the bowl now that it has been dispersed.

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:

Notes for the Facilitator: If you need to set a time limit for this activity, it is best to let learners know before they begin.

   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.

Notes for the Facilitator: The currency on this sheet is in American dollars and may need to be converted to local currency.

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?

Notes for the Facilitator: Answers will vary but should describe the efficiency or speed at which the tool cleans the oil.

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?

Notes for the Facilitator: Soap is a dispersant because it causes the oil to move, or disperse, around the container. Oil and water do not mix because they have opposite chemical properties. Soap also has opposite properties as water, but soap will mix with oil. The interaction of the soap and oil can cause the oil to break into droplets which allows it to spread through water rather than floating in one large mass at the top of the water.

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?

Notes for the Facilitator: Answers will vary but learners should reference specific evidence from their trials to support their choices.

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?

Notes for the Facilitator: As seen when placing the rock in oil, oil adheres quite well to many types of surfaces. If the oil were to touch sand or soil, this would make removal near impossible. This would cause an oil spill to affect terrestrial ecosystems and organisms. Feathers are waterproof, so more oil should have adhered to the feathers than water. The chemical properties of the feather are more similar to oil than to water. When birds come into contact with oil, their feathers get coated in it, which can cause the feathers to stick together. This can prevent birds from flying and being able to maintain a stable body temperature. The birds can also be sickened as they try to clean their feature and ingest some of the oil.

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?

Notes for the Facilitator: Answers will vary based on the tools available and which were chosen by the groups. Groups should take into consideration how much of the 50 mL of oil was reclaimed, while the volume of wastewater and total cost should be low.

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

Notes for the Facilitator: Answers will vary but could include plastics, which can sometimes be skimmed off the surface. Many microplastics sink and mix with sand, making it difficult to remove from the water. Runoff from the land can also add pollutants such as fertilizers, sewage, and industrial waste, all of which are difficult to clean up or remove from the water.

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.

Notes for the Facilitator: Answers will vary but could include wind, water currents, storms, animals, and boats moving through the water.

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:	

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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.

Notes for the Facilitator: Instead of designing an entire net-zero water community, the scale of the project can be adjusted so that learners can instead design a net-zero water building. Projects can then be combined as a whole group to create a community design. Another alternative could be considering water use in your community, and redesigning some water uses so the community comes closer to being a net-zero water community.

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?

Notes for the Facilitator: The United States Office of Energy Efficiency and Renewable Energy has good resources for information about net-zero water strategies and scenarios (**https://bit.ly/EEREnetzerowater**), as does the US Water Alliance *(Net Zero Plus | US Water Alliance)*. The U.S. Green Building Council describes the first commercial office building that has net zero water, located in Brazil (**https://bit.ly/LEEDzerowater**).

Some common net-zero water strategies include reclaiming water by collecting condensate from systems like air conditioners, saving storm water, gathering grey water, filling up during fire sprinkler or hydrant tests; educating community members about benefits of water conservation to reduce consumption and improve water use behaviors; and reusing water safely both indoors and outdoors.

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?

Notes for the Facilitator: The answers to many of these questions will vary depending on where you live. It may help for learners to have access to local maps that show bodies of water or details about the local watershed. Consider where in your area there are significant reservoirs of water, such as lakes, aquifers, the atmosphere (i.e., high humidity or frequent rainfall), or others where water can be sourced. Learners may also benefit from maps showing where farms and businesses are located, as this could help them make inferences about sources of contaminants.

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?

Notes for the Facilitator: The answers to many of these questions will vary depending on where you live. Learners may need help accessing information on water treatment facilities or processes commonly used in your area.

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?

Notes for the Facilitator: The answers to many of these questions will vary depending on where you live. Research is necessary to find regional or city water footprints, but a good place to start is at the national level, such as by using the National Water Footprint Explorer: **https://www.waterfootprintassessmenttool.org/national-explorer/**. Providing local maps can help learners understand how accessible hygiene and sanitation facilities are. Providing local data on water use can help inform learners' decisions on their community designs.

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?

Notes for the Facilitator: Learners can do research to describe and name the biome or ecosystem of their area. A map of biomes can also be made available to learners, such as: **https://commons.wikimedia.org/wiki/File:Vegetation.png**. Research may be necessary for learners to know when their town or city was first established, as well as how it has changed over time. Maps of the town over time would allow learners to make observations of expansion or changes to their area. Water withdrawal affects ecosystems in many ways, but the primary impacts are on groundwater, which are described well by the United States Environmental Protection Agency (**https://bit.ly/GroundwaterEPA**).

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

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.

Notes for the Facilitator: You should be familiar with the basics of *Scratch*® so as to be able to assist learners with their activities and projects. You can achieve this by following *Getting Started with Scratch*®, working on the same tutorials that learners will use.

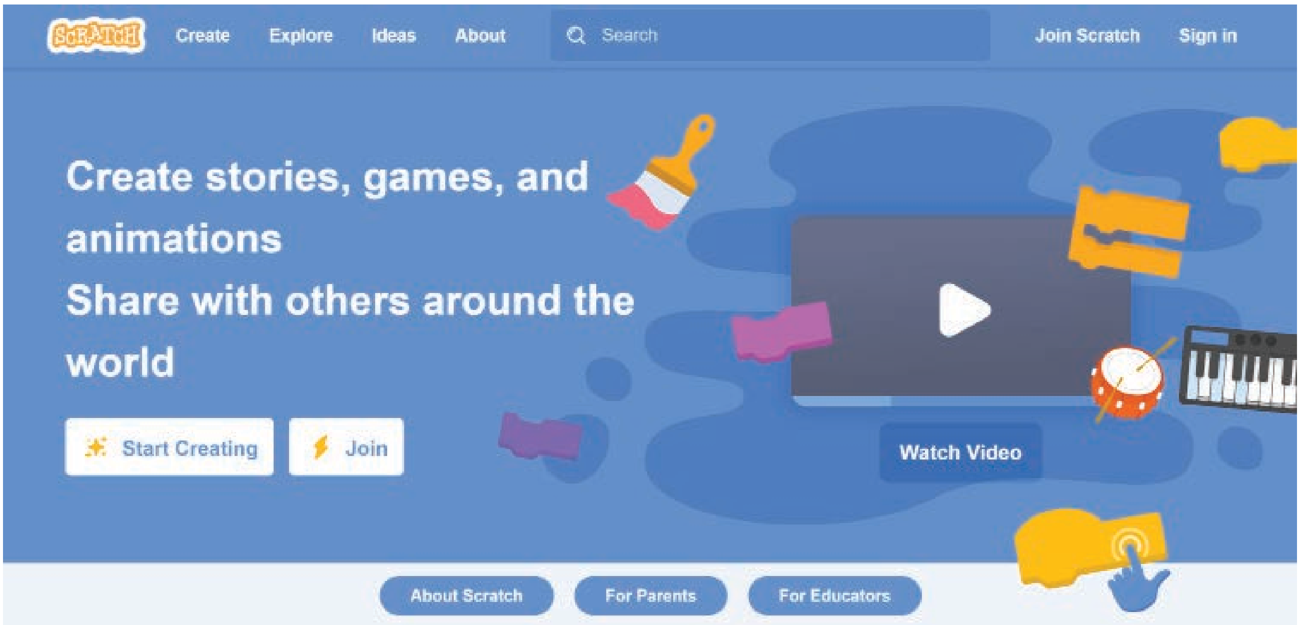
Scratch® *Tips and Techniques* goes into detail about topics that are directly relevant to ESD Kit activities, especially how to incorporate data into *Scratch*® projects and create interesting and novel visualizations of that data. There are links to sample *Scratch*® projects that both facilitators and learners can look at, learn from, and remix.

Some of the Investigations include suggestions for optional *Scratch*® activities. In your preparation to facilitate Investigations, review the *Scratch*® activity and look at any sample *Scratch*® projects that are linked to it.

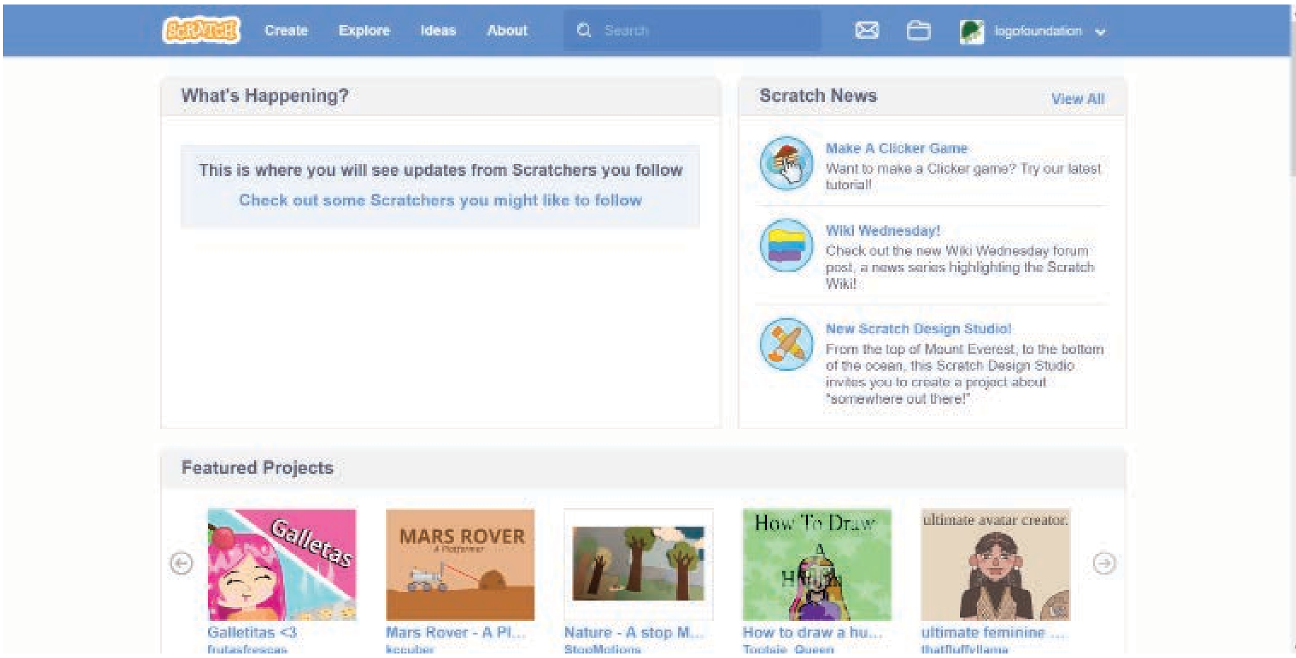
Getting Started with *Scratch*®

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.

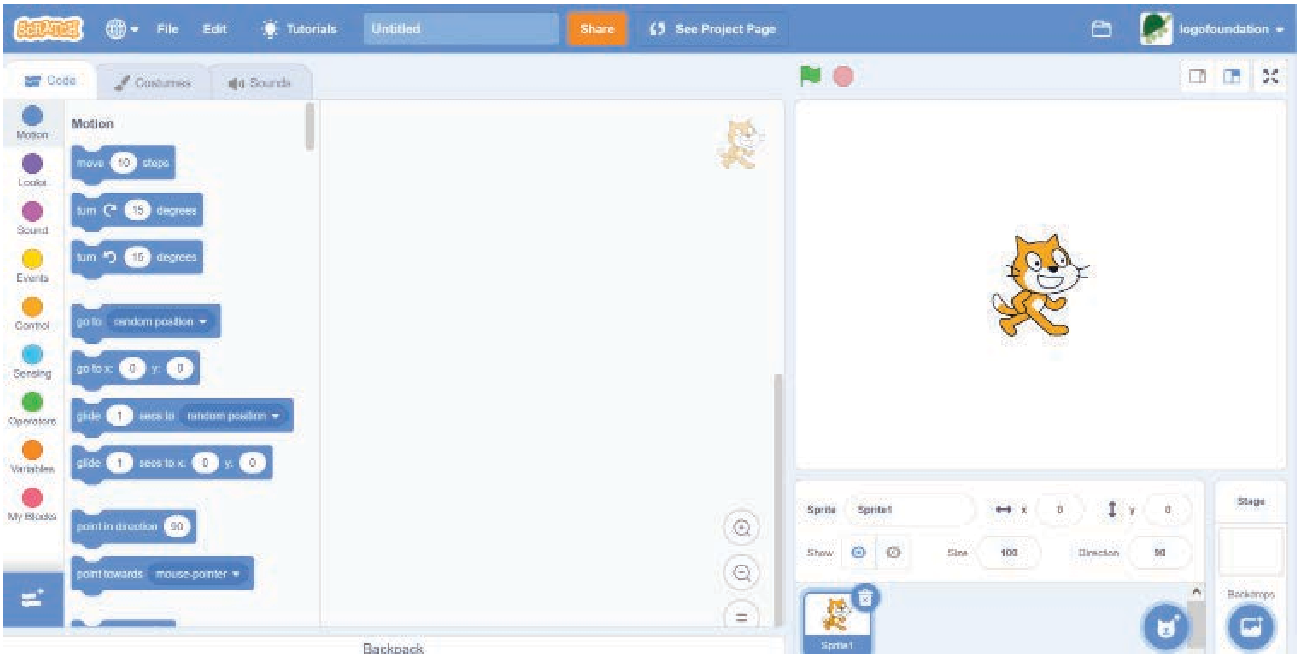
To get started, go to the *Scratch*® website: https://scratch.mit.edu/ This is what you'll see:



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:

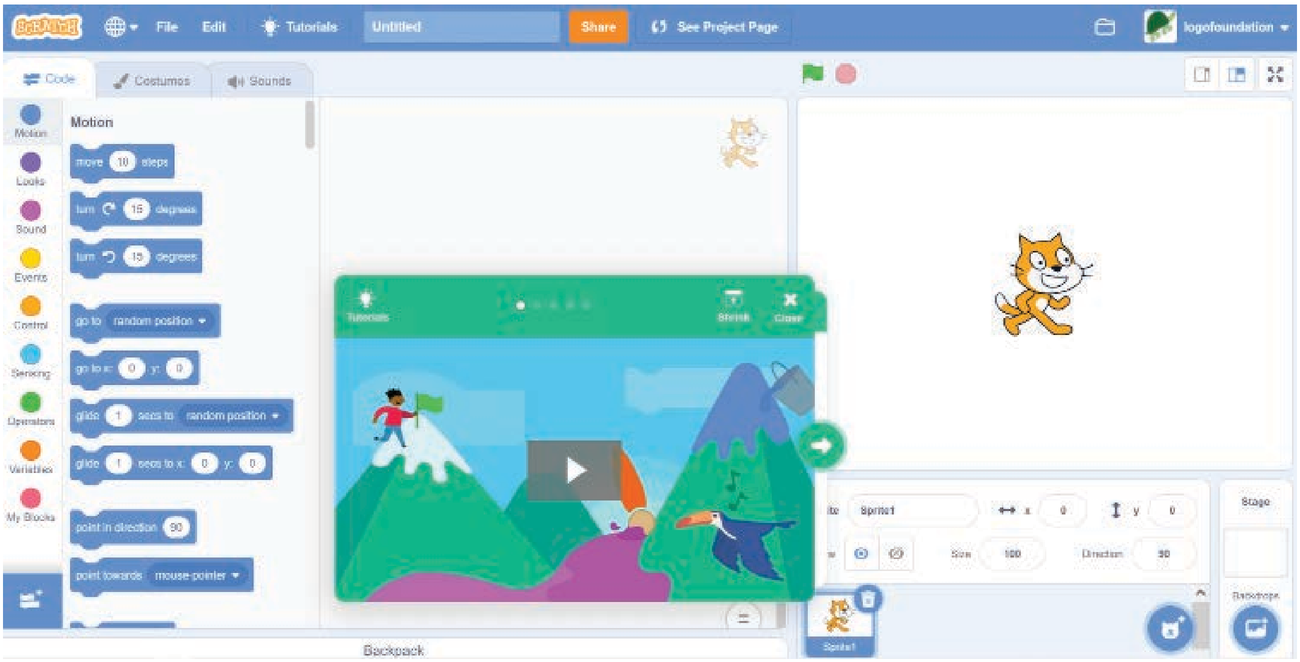


Your username appears at the upper right. You can browse the **Featured Projects** and other projects that appear as you scroll down the page. To get started yourself, click on **Create** at the upper left. This will take you to the *Scratch*® Editor. Your screen will look like this:



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.

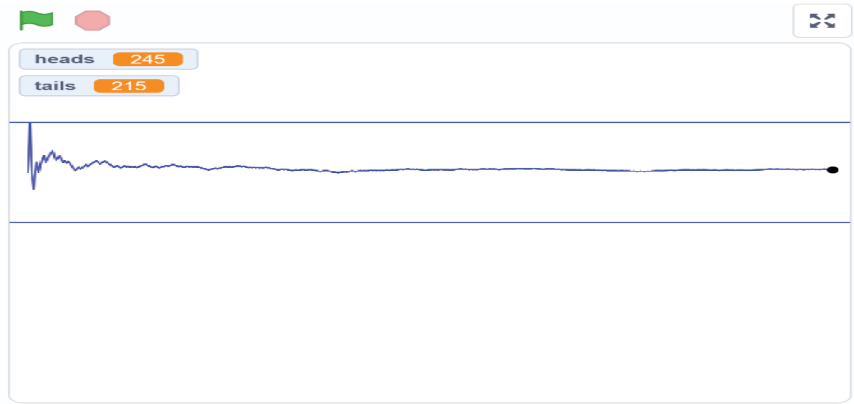
In addition to recorded music, there is a music extension that you can use to create melodies note by note, to be played by a variety of online instruments.

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/**

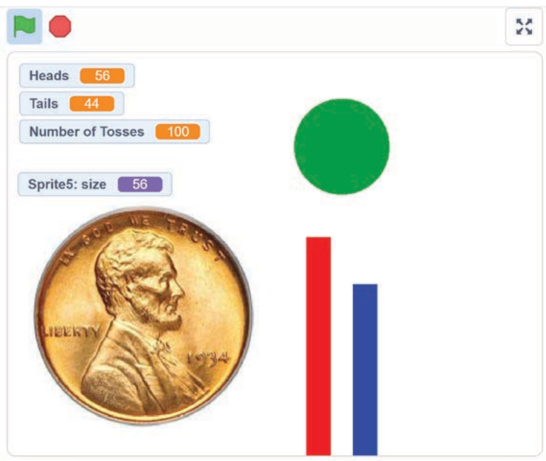
It uses the **pick random** block to simulate tossing a coin 460 times. It creates a graph showing the percentage of heads as the tossing progresses. The graph looks different each time the program is run, but the following image is typical. In *Scratch*®, you can watch this emerge as the graph is drawn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



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

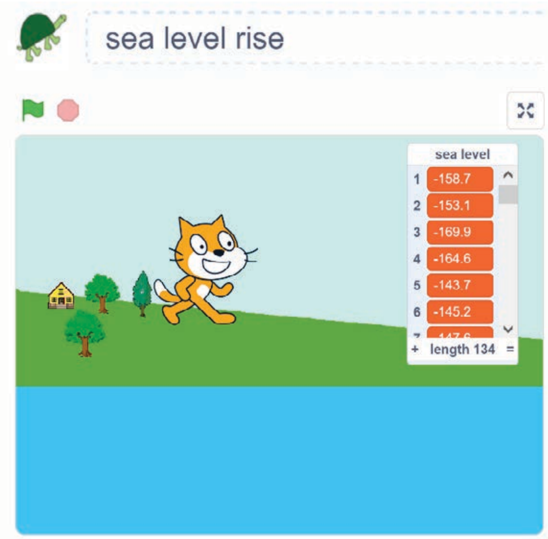
The coin is flipped 100 times and the visual representations of the proportions of heads and tails emerge dynamically. In addition to a bar chart, the size of the green circle increases and decreases based on the percentage of heads up to that point.

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

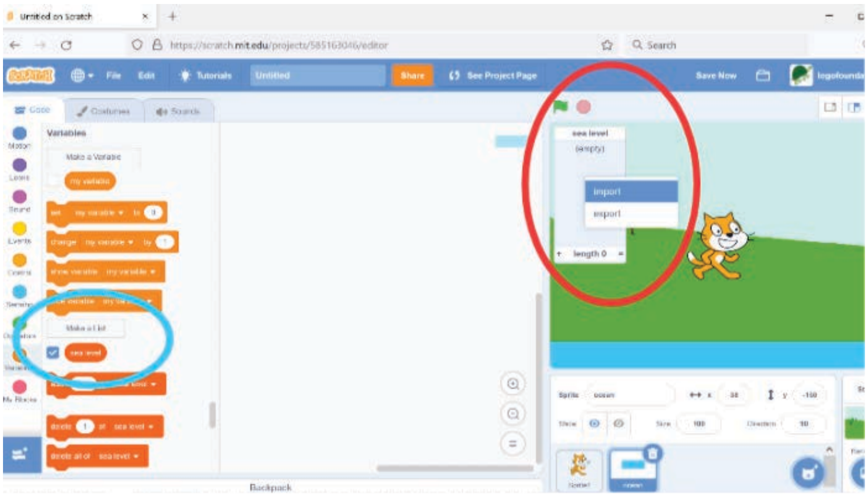


In the coin tossing projects, the program generates the data for the visualizations. You can also bring outside data into a *Scratch*® project.

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.



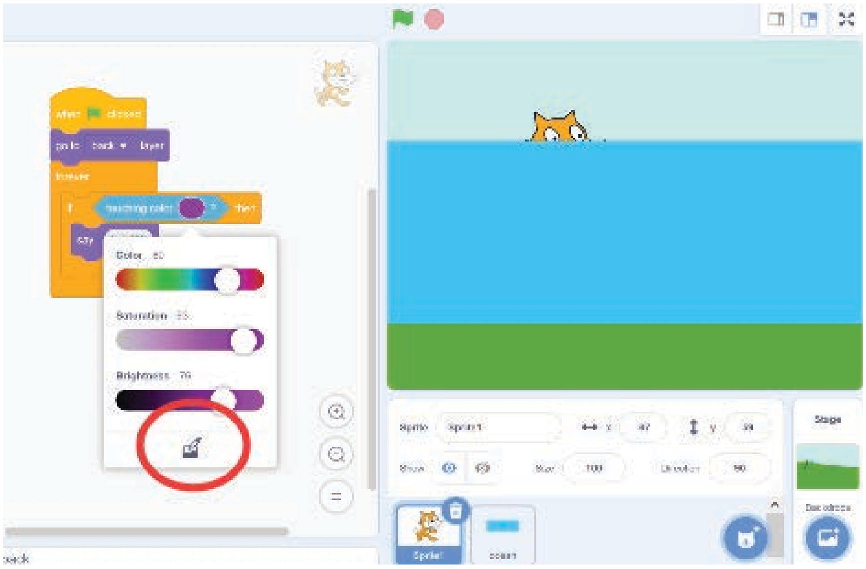
Once the data is imported, you may have to do some touching up. Often a .csv file will have a label in the first row of each column. This label will be imported into the *Scratch*® list along with the data below it. To remove this label and leave only data in the list, click on that first item. An X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

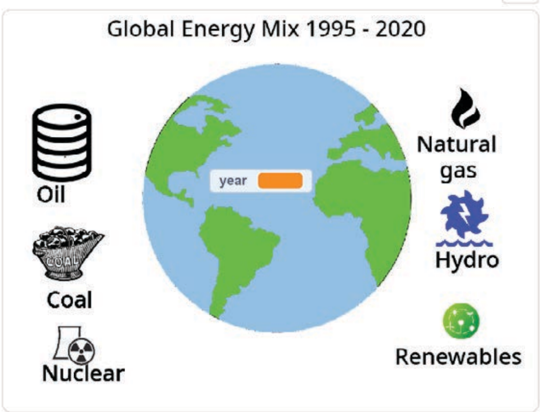
To see more about how the program works, go to the code tab of the ocean sprite, and look at the comments attached to the code for an explanation.

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.

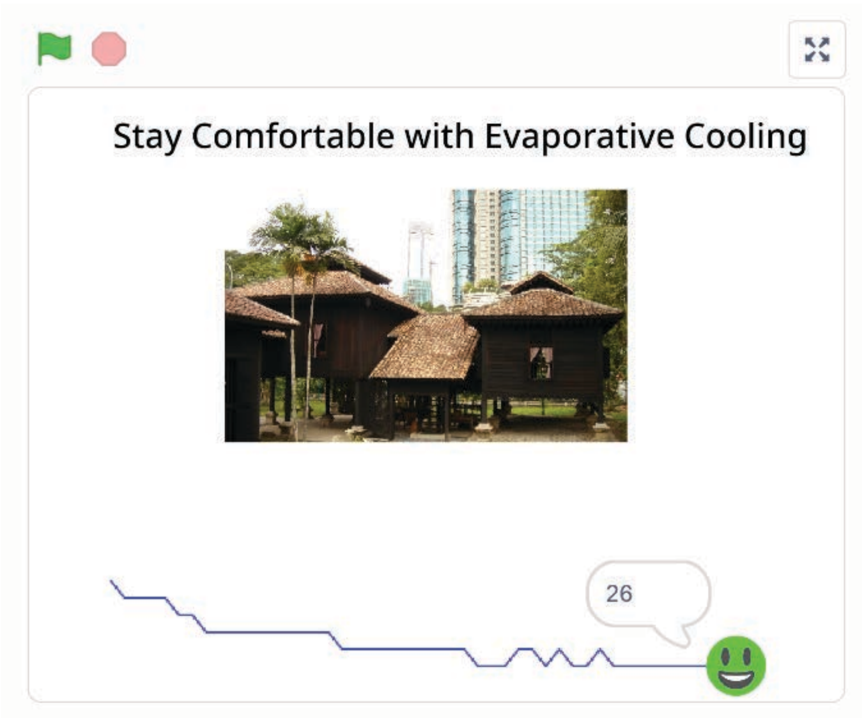


Investigation 4: Understanding Our National Energy Mix looks at the distribution of different energy sources over time. The data are represented by line graphs. The *Scratch*® project *Global Energy Mix* https://scratch.mit.edu/projects/573662932/ visualized that same data by increasing and decreasing 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.

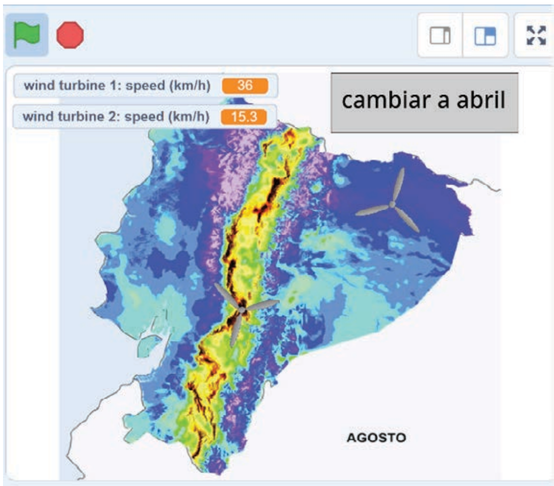


Making Your *Scratch®* Project Interactive

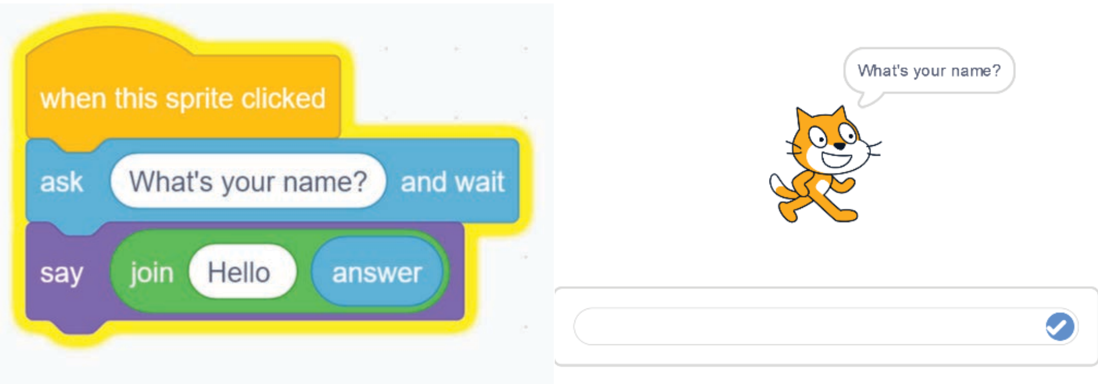
Anyone who uses an interactive *Scratch®* program can affect the course of action, what appears, and the sounds, voices, and music that are heard. Here are some examples:

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.

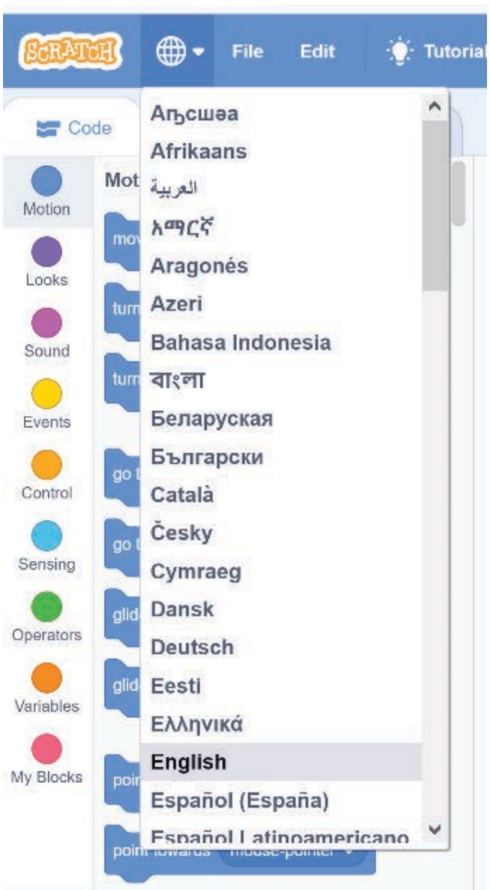
Look at the Sensing section of the Blocks Palette for some additional ways to make your *Scratch*® project interactive.

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.

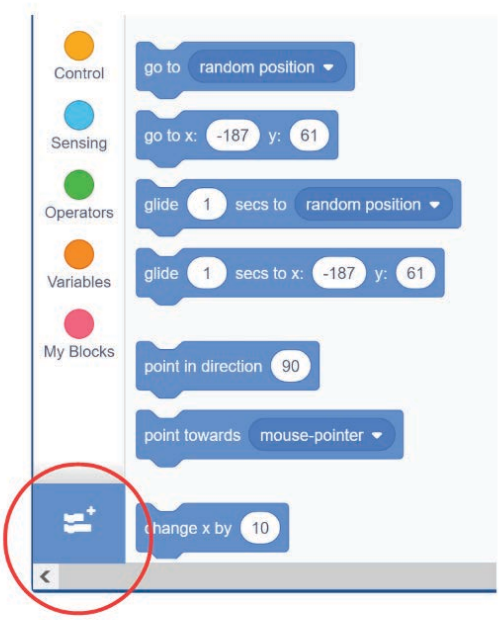
This feature does not change the text that the user has written on backdrops or sprite costumes, or text written into the **ask**, **say**, or **think** blocks. There is a separate translation extension to change these features.



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.

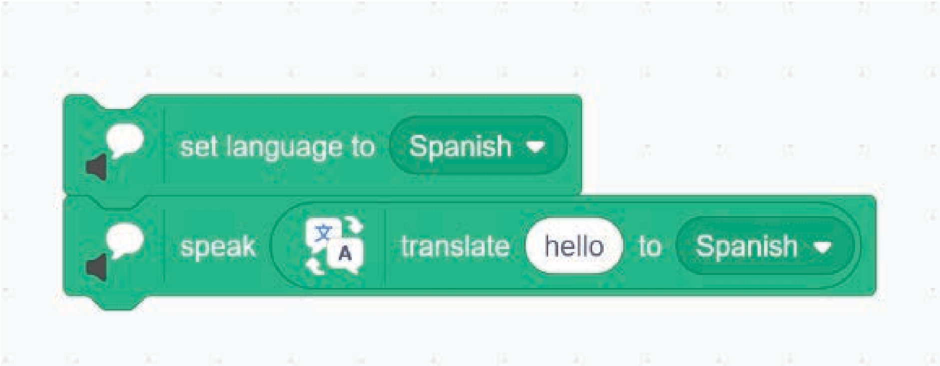
To use an extension, click the icon at the lower left of the *Scratch*® Screen. This brings you to a page where you can select the extension you want to load.



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

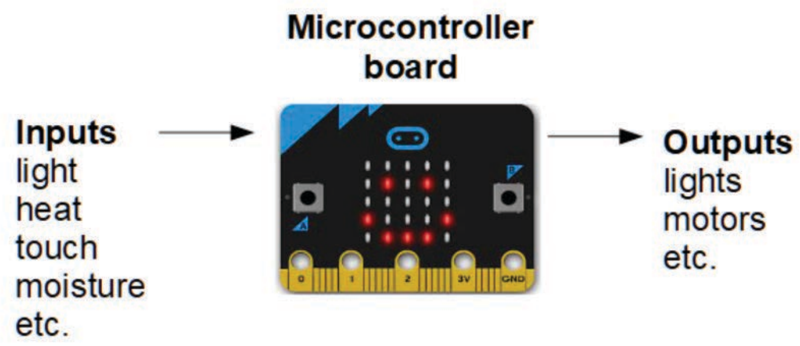
1. designed for education and has extensive support for teachers and students,
2. relatively low cost, and
3. widely available around the world.

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.