CONSERVATION STATION

WEEK OF RESOURCEFULNESS | CLASSROOM ACTIVITIES

ENERGY-WATER NEXUS STEM INVESTIGATIONS

Quenching the Thirst of the Future

OBJECTIVES

Students will be able to:

- **Describe** the thermal process of water desalination.
- **Construct** a model of a desalination plant.
- **Evaluate** and revise the design of their model by testing for the presence of salt.

OVERVIEW

In this hands-on engineering activity, design teams will plan, build, and test a desalination plant using a thermal process approach. Using a saltwater circuit, they will test and evaluate the efficiency of their prototype and compare their results with other design teams to identify and discuss ways to improve the efficiency of their desalination plant model.

CONNECTION TO THE ENERGY-WATER NEXUS

- Traditionally, fresh water has come from lakes, rivers, streams, and groundwater aquifers, but as demand increases, these traditional sources are becoming unavailable, more difficult, or expensive to develop.
- Alternative water supplies are necessary to provide and maintain water, food, and energy supplies in urban environments as the population continues to increase.

NATIONAL STANDARDS

Next Generation Science Standards

- **MS-ETS 1-4 Engineering Design**
  Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- **MS-ESS3-4 Earth and Human Activity**
  Construct and argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

ITEA/ITEEA Standards for Technological Literacy

- **Standard 8: Students will develop an understanding of the attributes of design**
  Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
  H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying

criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

- **Standard 9: Students will develop an understanding of engineering design**
  H: Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.
- **Standard 11: Students will develop abilities to apply the design process**
  K: Test and evaluate the design in relation to preestablished requirements, such as criteria and constraints, and refine as needed.

BACKGROUND

Desalination is the process of removing dissolved salts and minerals from water. The thermal process involves heating saline water to produce water vapor which is then condensed and collected as fresh water. In nature this process is referred to as the water or hydrologic cycle. The sun supplies the energy needed to cause water to evaporate from surface sources such as oceans and lakes. The water vapor rises into the air where cooler temperatures cause it to condense into clouds and fall back to the earth in the form of precipitation. This process can be imitated artificially and more rapidly than in nature, using alternative sources of heating and cooling.

A saltwater circuit is an electrical circuit that uses saltwater as part of the circuit. Salt molecules are made of sodium and chlorine atoms. When salt is added to water, it dissolves into sodium and chlorine ions. An ion is an atom that has an electrical charge, either positive or negative. The sodium ion is missing an electron which gives it a positive charge and the chlorine ion has an extra electron which gives it a negative charge. When an electric potential is applied, the positively charged sodium ions are attracted to the negative pole, and the negatively charged chlorine ions are attracted to the positive pole. These ions carry electricity through water. Basically, they form an invisible wire that allows electrons to move from ion to ion across the water.

KEY VOCABULARY

- Specifications
- Condensation
- Evaporation
- Input
- Output
- Iteration
- Model
- System

GROUP MATERIALS

- *Engineer Design Plan–Desalination Plant*
- *Failed Desalination Plant Model–Desalination Plant*
- Tin coffee can
- Saltwater circuit
- Aluminum foil (12 in x 12 in)
- Plastic containers (2)
- Popsicle sticks (10)
- Plastic soda bottle (20 fluid ounces)
- Hot plate
- Cups (9 ounce) (3)
- Oven mitt
- Safety goggles

SALTWATER CIRCUIT

- Popsicle sticks
- Aluminum foil
- Electrical tape
- Insulated copper wire
- Miniature light bulb socket
- 3.7 volt light bulb

CLASS MATERIALS

- Roll of aluminum foil
- Duct tape
- Masking tape
- Salt (25 grams per group)
- Water
- Graduated cylinders
- Measuring cups
- Digital scale
- Ice
- Cooler to keep ice cold

TEACHER PREPARATION

- Copies of *Engineer Design Plan–Desalination Plant* for each group
- Copies of *Failed Desalination Plant Model–Desalination Plant* for each group
- Build the failed desalination prototype to use as a demonstration
- Build saltwater circuits for each group
    - Completely wrap 2 popsicle sticks in aluminum foil.
    - Attach a 6-inch insulated copper wire to each covered popsicle stick with electrical tape.
    - Attach the other ends of the insulated copper wire to a miniature light bulb socket (3.7 volt light bulb) using electrical tape.
    - The ends of the popsicle sticks without the wires can be placed in the saltwater to complete the circuit and light the light bulb

PROCEDURE

- Place students into groups of four. Explain that each group will develop an understanding of the engineering design process. Review the descriptions for each role. Students in each group should select a role that appropriately matches their skills and strengths.
    1. Plant Operator–keep the team on task, manage time, share plant design with other teams
    2. Environmental Engineer–develop a 2-D model of the prototype
    3. Water Quality Specialist–conduct saltwater circuit test, graph class data
    4. Analytical Researcher–record brainstormed ideas and the evaluation of other designs

1. To determine prior knowledge, open the lesson by asking the class to sketch the water cycle. Have them add the following terms to their sketches: precipitation, condensation, evaporation. Provide students 2–3 minutes to sketch individually. When finished, have students share their sketches with their group and develop definitions for each term they were asked to include. Invite students to share their definitions and record these on the board.
2. Before showing the *Thirst for Power* video clip, ask students how much of the water on our planet is available for drinking. Ask them if they think everyone has equal access to clean drinking water. Share that according to the World Health Organization, by 2025 at least half of the world's population will be living in water-stressed areas.
3. Show the class the *Thirst for Power* video clip. After the video, invite students to explain the connection between energy and water.
4. Explain to students that engineers have been working on methods to transform ocean water into drinking water for many years. Scientists and engineers have used their knowledge of the water cycle to mimic this thermal process on a smaller scale.
5. Show the class the failed desalination prototype that you have built. Explain that the thermal desalination method involves heating saltwater until it evaporates, and then forcing the evaporated

water to condense. The condensed water is fresh water. This method is used to produce more than 85% of the desalinated water in the world.

6. Distribute the of *Failed Desalination Plant Model–Desalination Plant* to each group. Invite students to work with their group to identify how each step in the prototype is linked to the water cycle. Invite groups to share their thoughts.

7. Explain that each group will redesign this failed prototype to make it functional. An important aspect of the engineering design process is to take initial designs and through a few design iterations, make improvements until their models work. Distribute the *Engineer Design Plan–Desalination Plant* to each group. Have each group brainstorm a list of ideas to improve the failed prototype. Introduce the idea of constraints and show them the materials they will be provided with to design and build their prototype. Have the analytical researcher record all brainstormed ideas. At this point, all ideas are equal!

8. After the brainstorming session, invite each group to review their list, discuss benefits and drawbacks to each, and select an approach or combination of approaches that seems the most promising. Before jumping into building their prototype, stress the importance of creating a 2-D model. Explain that by sketching a 2-D model first, the team can save both time and materials when building. Have the environmental engineer sketch the model of their selected design, including labels and amounts of the materials the model will require. When finished, have the teacher review their redesign for approval.

9. After the redesign has been approved by the teacher, the entire group will work together to build the desalination plant model.

10. When each group has finished constructing their desalination plant model, demonstrate how to evaluate the effectiveness of their design by using the saltwater circuit. Explain that the saltwater circuit is a tool that is used to detect the presence of salt at the output of the desalination plant. If the saltwater circuit conducts electricity, then the plant did not remove a significant amount of salt from the saltwater. The amount of salt in the saltwater solution influences how much current flows through the circuit. The brighter the light bulb glows, the greater the concentration of salt in the water.

11. Explain the importance of controlling variables when conducting investigations. If each group uses the same amount of salt, water, ice, heat, and running time of the plant, then the only variable that is different between each group is the plant design. By controlling these variables, each group can compare data to determine which design worked best in these conditions. Provide each group with 25 grams of salt, 32 fluid ounces of water, and 3 cups of ice. Explain that they will use the highest setting on the hot plate and will run their desalination plant for 20 minutes.

12. While the desalination plants are running, have team members take turns visiting other groups to ask questions about their designs. The plant operator will stay behind to explain their design construction to other groups.

13. After the desalination plants have been running for 20 minutes, have the team check to see if they collected any water. If water was collected, measure the amount using a graduated cylinder or measuring cup. The water quality specialist will evaluate the effectiveness of the model by conducting

the saltwater circuit test. Have each group answer the "Evaluating Our Prototype" questions on the engineering design plan capture sheet.

14. Invite groups to share their results with the class by writing on the board how much water they collected, and whether they passed the saltwater circuit test. The water quality specialist will record the class data on the engineering design plan capture sheet.
15. To close the activity, invite groups to collaborate with two other teams and answer the "Evaluating Other Designs" questions on the engineering design plan capture sheet.

EXTENSION

As an extension of this activity, students can research the advantages, disadvantages, and innovations of desalination plants over the past 30 years. They can use this research to create an infographic that shows where desalination plants are located around the world.

SOURCES

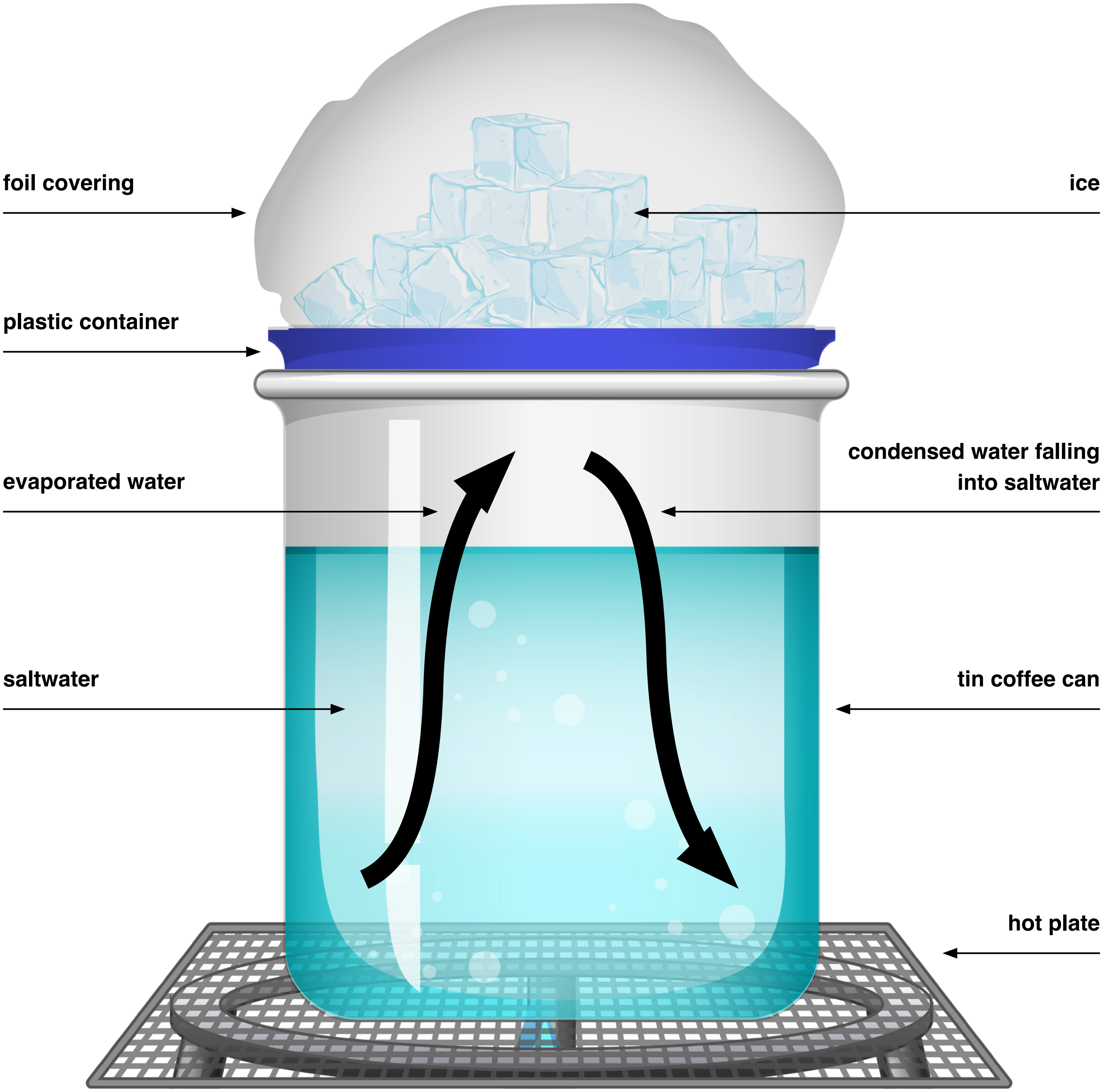
https://www.youtube.com/watch?v=HCZOKmojrkw&feature=youtu.be

https://www.who.int/news-room/fact-sheets/detail/drinking-water

https://www.learntoconserve.com/about

https://sciencing.com/advantages-disadvantages-desalination-plants-8580206.html

https://www.ncbi.nlm.nih.gov/books/NBK83737/


foil covering
ice
plastic container
condensed water falling into saltwater
evaporated water
saltwater
tin coffee can
hot plate

Design Innovations

After examining the failed desalination plant model, brainstorm a list of ways to make it functional. Brainstorming is a group problem-solving design process, so be sure to include all ideas mentioned!

Prototype Redesign

Sketch a model of your desalination plant, including labels of the materials you will be using.

Evaluating Our Prototype

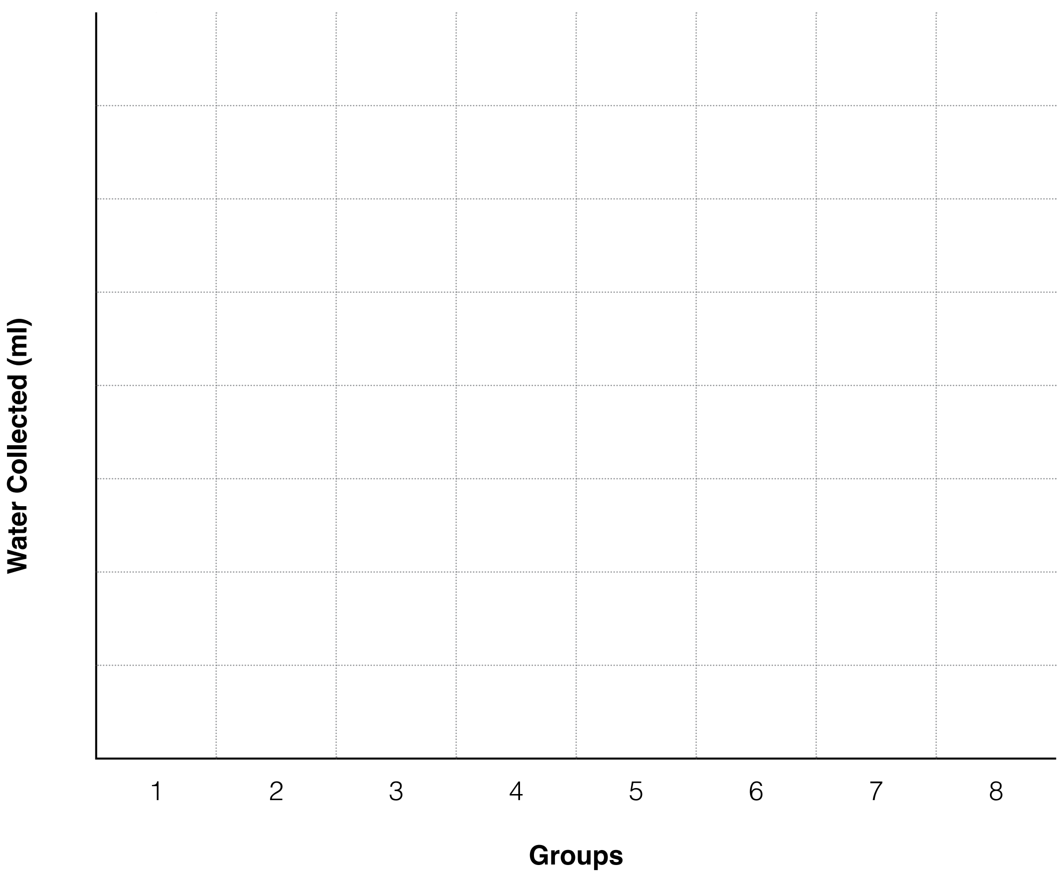
1. How much water did we collect (ml)?

2. Did the saltwater circuit conduct electricity? Provide evidence from the investigation.

3. Did we notice any design features that could be made to improve our results?

Class Data

Sketch a graph of the class data below.



Evaluating Other Designs

Collaborate with a group that collected less water, and one that collected more water, as compared to your prototype.

Group # _____

1. Introduce yourselves. List the names of the group members.
2. List 3 differences between their design and yours.
    1.
    2.
    3.
3. How much water was collected with this design?
4. Discuss and list any design improvements that could be made for this prototype.

Group # _____

1. Introduce yourselves. List the names of the group members.
2. List 3 differences between their design and yours.
    1.
    2.
    3.
3. How much water was collected with this design?
4. Discuss and list any design improvements that could be made for this prototype.