Solar Still

Student Objective:
The student:
- will be able to explain a simple way to desalinate water using solar energy
- will understand the evaporation and condensation process, and relate it to the water cycle on Earth.

Key Words:
condensation
conduction
convection
desalinization
evaporation
Heat of Vaporization
radiation
solar still
thermal energy

Materials:
- large glass and metal bowls of various sizes (one per group)
- glass cup, 1" shorter than sides of bowl or heavy plastic cup cut to size (one per group)
- clear plastic food wrap
- tape or rubber band large enough to go around bowl (one per group)
- small rock or weight (one per group)
- salty and/or dirty water
- Laboratory Manual

Time:
1 class period

Background Information

Stills are commonly used to purify liquids. Through the process of distillation, non-volatile impurities can be separated from the liquid. Distillation can be a simple process. Heat is first added to a liquid to evaporate it and produce a gas or vapor, then heat is removed from the vapor to condense it back to a liquid.

A solar still uses the greenhouse effect to trap energy from the sun. The still captures evaporated water by condensing it onto a cool surface. The rate of evaporation can be accelerated by increasing the water temperature and the area of water in contact with the air. A wide shallow pan painted black makes an ideal vessel for the water. However, after painting, the container should be baked in the sun for several days before being used in the still to free the paint of any volatile compounds which would otherwise evaporate and condense along with the drinking water.

Procedure

1. **Engage:** Lead the class in a discussion of desalination. Questions that might be asked:
    - What can we do as our supply of fresh water gets smaller?

- If you were lost in a desert without drinking water, and the only water was in a salty pond, how could you survive? *(Eating plants with a high water content, or collecting water using a solar still)*
- Can evaporation be used on polluted water to make it drinkable? *(Yes)*

2. Divide the class into working groups of 2 - 3 students per group.
3. Give each group their construction items. They should all receive the items listed below; however, you may add extra 'confounding' items to make the construction process more interesting. The items they will need:
   - large bowl
   - small beaker or plastic cup–students can calibrate this cup for measuring the collected distilled water using known amounts of water and marking the cup
   - plastic wrap
   - rock or other weight
   - rubber band or tape

   Suggestions for 'confounding' items
   - test tube
   - piece of fabric
   - aluminum foil
   - bag of small rocks
   - wooden dowels or tongue depressors
4. **Explore:** Explain to the class that they will be designing a device (a still) to extract clean water from 1 pint (600g) of saltwater or dirty water using the energy of the sun. The goal is to extract the most drinking water
5. Here's an example of a simple solar still to give you an idea of what their designs could be like:

6. When they finish assembling their stills, the teams should place them in full sun.
7. Check the still's progress as often as you desire, in ½ - 1 hour increments. Solar stills can be left out overnight if desired.
8. Taste the water in the cup.
9. **Explain and Elaborate:** Discuss the physics behind their solar still. Points to cover should include thermal radiation, conduction, convection, the change of state of the water, and the conservation of energy. The students should use terminology correctly and reveal an understanding of the water cycle.
10. Does the size and shape of the outer (evaporating) container affect its efficiency? Compare containers with different surface areas to see how this affects the evaporation

rate. Does the depth (volume) of the liquid in the evaporating container affect its efficiency?

11. Why does the water taste different than tap water?

Evaluation and Student Assessment

Post these criteria or discuss them with your students before they begin this project. You may use a checklist or develop a rubric for evaluation.

Activity and Teamwork: 40%

- Are the students communicating within the group?
- Are the students using critical thinking and problem solving strategies following the lab procedures to produce valid results?
- Are the students developing the social skills needed to work as a team?
- Are the students adapting their roles and responsibilities as needed to work effectively in their team?

Lab Results: 40%

- Data table is neat and complete (20%)
  a) units are used with all measurements
  b) observations connect to the objectives of the lesson

Problems and Applications: 20%

- Questions 1 - 5 answered correctly and completely - 15% (5 questions at 3 points each)
- Question 6 - answer demonstrates complete thoughts and ideas effectively - 5% (5 points - using a holistic FCAT Writes rubric

Related Research:

1. Research the drawbacks of using a solar still to distill drinking water from sea water in a large (citywide) scale.
2. Can you use a still to remove the water from a solution? Are there solutions from which a solar still would not work to remove water? Research whether bacteria and toxic chemicals are removed during the distillation process.
3. In Florida, a good solar still design should be capable of producing ½ to 1 gallon of fresh water per day for each square meter of still area. Using the knowledge that you have about solar stills, build a solar still capable of producing this amount of water
4. Solar stills can be very useful after a hurricane when clean, safe water may not be available. Using the knowledge that you have learned about still design, draw plans for a solar still to be used by a family of four after a hurricane (assuming sunny days), that would provide each member of the family with a gallon of drinking water a day.
5. Contact your local water management district to obtain their annual water quality test results. Research your city's results. For each recorded contaminant, what is considered a dangerous level? Is this level different for adults, children, or elderly? What are the health risks associated with this contaminant? Do home filters remove this contaminant? Present your results to the class.

Related Reading

- ***A Golden Thread: 2500 Years of Solar Architecture and Technology*** by Ken Butti & John Perlin (Cheshire Books, 1980)
  A Golden Thread provides a historical perspective of the influence of solar energy on society throughout the ages. The book provides information relating to the scientific, societal and economic influences contributing to the development of solar technology, as well as explanations of how the various forms of solar technology function.
- ***The Return of the Solar Cat*** by Jim Augustyn (Patty Paw Press, 2003)
  "A cat sunning itself in the doorway of a barn knows all about solar energy. Why can't man learn?" (E.B.White). The Return of the Solar Cat book decisively answers this question. Jim Augustyne takes the Suessian approach to showing the reader our myopia when it comes to the nature of renewable energy, politics, and economics through the fun-house mirror of technologically advanced felines and their 'natural' instincts and behavior which are optimized for solar utilization. Augustyne has developed an alternate universe of whimsy and pointy satire where kitties rule and our human foibles and blindness to the advantages of solar energy are entertainingly exposed.

Internet Sites

http://www.fsec.ucf.edu/en/publications/pdf/FSEC-EN-3-80.pdf
Florida Solar Energy Center's Energy Note on Solar distillation of water contains information on the basic principles and economics of home water distillers as well as a discussion on the quality of the water produced.

http://seasteading.org/seastead.org/book_beta/refs/itdg_solar_distillation.pdf
Intermediate Technology Development Group, Solar Distillation page. Includes drawings of several types of solar distillation devices as well as suggestions on how to improve a design and how to estimate the output of a solar still of a given design.

http://apollo.lsc.vsc.edu/classes/met130/notes/chapter2/index.html
University of Missouri, Heat Transfer lecture notes - Warming the Earth and the Atmosphere

http://science.howstuffworks.com/environmental/green-science/sun-clean-water.htm
How Stuff Works page "Can the Sun's Energy Be Used to Clean Water?"

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Answers - Laboratory Manual

1. Answers will vary, however, data table should be complete.
2 - 3. Answers will vary. Students should be able to relate completely the problems the group encountered and the solution they adopted.
4. Students should realize that increasing the surface area will increase the amount of evaporation that occurs.
5. Students should realize that shallow pans will increase the amount of evaporation.

Answers - Problem Set

1. 2.26×10^5 J
2. Answers will vary. Students should show ability to convert units and apply the formula to their results.

3a. 2.26×10^5 J
3b. 4.52×10^5 J (twice the mass and volume, twice the energy)
3c. 8.136×10^6 J (36 times more energy due to the change in mass and volume)

4. 3.28×10^7 J
5. Answers will vary - energy to evaporate and/or condense is dependent on mass and volume. Time for this physical reaction depends on the energy source and design.
6. Answers will vary, but these ideas should be incorporated in the students' answers:
   - The Sun produces electromagnetic waves in the infrared range that **radiates** through space to the Earth and the container
   - The clear plastic top transmits the Sun's radiation to the air and water in the still where the energy is absorbed and changed into heat
   - The air and water molecules conduct the energy by absorbing and increasing their kinetic energy transferring it to neighboring molecules
   - Convection currents are created that transfer the heat to the remaining water molecules in the container
   - The surface water evaporates
   - The convection of the heated moist air allows the water to cool and condense on the top surface as energy is released into the air
   - Gravity causes the condensed water to flow to the lowest level of the top where it collects, gets heavier, and drops to the collecting beaker.

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		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 1	**SC.912.N.1.**	**X**																			
Physical Science																					
Standard 10	**SC.912.P.10.**	**X**			**X**										**X**						
Mathematics Standards		**MA.912.A.1.4, MA.912.A.1.5**																			

Standard 1: The Practice of Science
- AC.912.N.1.1- Define a problem based on a specific body of knowledge, and do the following:
  1. pose questions about the natural world
  2. conduct systematic observations
  3. examine books and other sources of information to see what is already known
  4. review what is known in light of empirical evidence
  5. plan investigations
  6. use tools to gather, analyze, and interpret data
  7. pose answers, explanations, or descriptions of events
  8. generate explanations that explicate or describe natural phenomena (inferences)
  9. use appropriate evidence and reasoning to justify these explanations to others
  10. communicate results of scientific investigations, and
  11. evaluate the merits of the explanations produced by others.

Standard 10: Energy
- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.4 - Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or state of matter.
- SC912.P.10.14 - Differentiate among conductors, semiconductors, and insulators.

Mathematics Standards
Algebra - Standard 1: Real and Complex Number Systems
- MA.912.A.1.4 - Perform operations on real numbers
- MA.912.A.1.5 - Use dimensional analysis to preform conversions between units of measure, including rates

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condensation - a reduction to a denser form as from steam to water

conduction - the movement of heat through materials by transferring kinetic energy directly from particle to particle

convection - the circulatory movement or transfer of heat through fluids such as gasses or liquids due to differences in temperature. (Hotter fluids rise, cooler fluids sink)

desalinization - process of removing salt and other chemicals and minerals from water

evaporation - process of changing a liquid into vapor or gasses

Heat of Vaporization - the amount of heat required to change one kilogram of mass from the liquid state to the gaseous state.

radiation - the way we receive heat from the sun each day. The energy is emitted in the form of waves/particles, and can be transferred through the vacuum of space.

solar still - a device that uses solar energy to evaporate a liquid

thermal energy - a measure of the internal motion of an object's particles; symbol is 'Q'

Solar Still

1. Construct a solar still using the materials provided. Use what you know about evaporation and condensation to help you in your design process.

    - Put salty water in the large bowl and place your solar still in the sun.
    - Record your observations below.
    - If your solar still is not working very well, change your design and continue to monitor the results

Interval of time	**Amount of water collected**	**Observations**

2. If you changed the construction during the middle of your observations, write below what you did and during which time interval (above) you made the change.

3. Did your design modification result in more water being collected? Explain.

4. Based on the data collected in your class, does the size and shape of the outer (evaporating) container affects its efficiency? Explain.

5. Does the depth of the liquid in the evaporating container affect its efficiency?

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Answer each question completely demonstrating your math skills.

Given:

- Q = heat energy - units are Joules (J)
- m = mass - units are kg
- $Q = mH_V$
- 1.0 ml water = 1.0g of water
- 1 kg = 1000g

1. The amount of thermal energy needed to turn 1 Kg of water into steam is **2.26×10^6 J/Kg**. This is known as the Heat of Vaporization (H_V). How much thermal energy will be needed to turn 100 g of water into steam?

2. Using the volume measure of the water that you purified in your still, change the units to mass units (see formulas above). How much energy was required to evaporate the water you collected?

3. How much heat energy is released when the 100 g of water condenses?
   b) 200 g of water?
   c) 3.6 kg of water (3.6 kg is equivalent to the amount of water in one gallon)

4. During a disaster, it is suggested that a family of four have four gallons of clean water available to drink per day. How much energy is released when 14.5 kg of water condenses?

5. Based on your small sample experimental data modeling the distillation process from the sun, how long would it take for you to distill one gallon of clean water from your solar still to meet your daily consumption needs?

6. Using the terms convection, conduction, and radiation, describe the flow or transfer of heat energy in this activity from the sun to the final production of collecting clean water.