LESSON TITLE	Desalination by Distillation			
SUBJECT (S):	Earth Science, Environmental Science, Life Science, Physical Science			
GRADE LEVEL:	6-12	**AUTHOR:**	Melony L. Walsh	
TYPE OF LESSON (activity, lab, project…)	2 experiments		**DAY(S):**	9 days total run time, but 4.5 of those days are "wait time" that can be used for other assignments

Objectives:

Students will identify the difference between distillation and reverse osmosis. They will construct a functioning distiller then design and perform an experiment to analyze the efficiency of the apparatus.

NGSS/CC STANDARDS	ASSESSMENT(S) & GRADING/RUBRIC
NGSS Science and Engineering: 2, 3, 4, 5, 6, 8 Crosscutting Concepts: 2, 4, 5 Core Ideas: ESS2, ESS3, LS2, PS1 **PERFORMANCE EXPECTATIONS** Earth and Space Sciences: HS-ESS2-3, HS-ESS3-1, HS-ESS3-4 Life Sciences: HS-LS2-6, HS-LS2-8; MS-LS2-5 Physical Sciences: HS-PS1-6; MS-PS1-6 Engineering: MS-ETS1-3, MS-ETS1-4 **CC Math** HS - HSN.Q.A.1, HSN.Q.A.3, MP.2; MS – MP.2, MP.4, 6.SP.B.5 **CC ELA/Literacy** HS - WHST 9-12.2; MS – SL.8.4, WHST.6-8.1, WHST.6-8.7, RST.6-8.3	Answer key provided Mastery considered ≥ 70%

SUBJECT AREA(S):

These experiments could easily fit within the following courses as follows:

PHYSICAL SCIENCE: states of matter, convection/conduction/radiation, equilibrium of chemical systems

EARTH or ENVIROMENTAL SCIENCE: importance of water to society, water as a resource, water cycle, human impact on earth, natural resources, impact to ecosystems

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LIFE SCIENCE: cycles of matter (water), impact to ecosystems, survival of species through changing behavior,

TEXTS/MATERIALS/TECHNOLOGY/AUDIO-VIDEO/OTHER RESOURCES:

10 mL graduated cylinder
400 mL beakers
50 mL beakers
Tap water
Food coloring
Table salt
Plastic wrap
Rubber bands
Small rock, marble, or some other small, relatively heavy object to act as a weight
Conductivity tester (multimeter or saline strips are other options)
Heat lamp (if weather is cold)

INSTRUCTIONAL STRATEGIES/PROCEDURES/GROUPING:

Experiment 1

Pre- lab: Send students home with the Background handout and ask them to read it.

Day 1:
Have students write a one-paragraph summary (5 minutes). You can use the following as questions they need to address:
What is desalination?
What is distillation?
What is reverse osmosis?
How are distillation and reverse osmosis different?
Which process is more efficient?
Which process is the newest?

Hand out Experiment 1 packet and review the purpose and methods with students (15 minutes). Have student groups (2-4 students) set up the model by following the steps 1-5 (30 minutes).

Days 2-3: The models will be left undisturbed for 72 hours. Class time can be used for other assignments.

Day 4: Have student groups complete steps 6-8 (15-20 minutes). Instruct students to complete the Follow-Up questions – they should be considering the information from the Background and their experiment (30 minutes).

Experiment 2

Day 5: Hand out Experiment 2 packet and review the purpose and methods with students (20 minutes). Have student groups share their research with one another and select a variable to change for their experiment. They should produce a hypothesis, a labeled sketch of the

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model with their proposed modification and a short written description and identify the variables in their experiment (30 minutes).

Day 6: Have students set up both models following steps 1-6 (30 minutes). The remainder of the class can be used for other assignments.

Days 7-8: The models will be left undisturbed for 72 hours. Class time can be used for other assignments.

Day 9: Have student groups complete steps 7-8 (15-20 minutes). Instruct students to complete the Results and Conclusion sections – they should be considering the information from their experiment and their research – this should be given with the option of taking it as homework since time may be limiting for some students (30 minutes).

References:

idadesal.org/desalination-101/desalination-overview/
idadesal.org/desalination-101/desalination-by-the-numbers/
howstuffworks.com/reverse-osmosis.htm

NOTES/REFLECTIONS:

Depending on ambient conditions, more or less time may be required for the amount of distillate to be significant enough for the necessary measurements. Adjust timing as needed.

Experiment 1 and 2 do NOT have to be done in order. Depending on class time, you could elect to do one or both experiments.

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Desalination

Only about 2.5 percent of the water on Earth is fresh water. Of that, approximately 70% is currently frozen or in swamps, leaving us with less than one percent available for human consumption. With dramatic changes in weather patterns (including severe droughts in many parts of the world), a rapidly growing population, and burgeoning industries that also rely on a steady supply of freshwater, it is becoming increasingly urgent that we find an efficient and affordable way to make use of saltwater.

Desalination is the process that converts saltwater to freshwater by removing the salts. There are two primary methods used today. The first of these is called **distillation**. This is a simple process that is fashioned after the planet's own water cycle. Essentially, the water is heated until it *evaporates* (changes from a liquid to a gas), leaving behind salts and many other impurities that have a higher *boiling point* **(**the temperature at which a liquid becomes a gas) than water. As the water vapor cools and *condenses* (turns back into a liquid), it is collected, thus providing us with clean, fresh water. This method has been around for thousands of years and is very effective at removing even large quantities of salts, such as those found in seawater.

The second method, **reverse osmosis**, wasn't developed until the 1950's. Osmosis is the movement of water molecules through a semipermeable membrane from an area of higher concentration to an area of lower concentration. This happens naturally and requires no energy. Reverse osmosis makes use of two sources of water simultaneously. One side is filled with freshwater and the other is filled with salt water. These two areas are separated by a semipermeable membrane that allows water molecules to move freely but prevents the movement of salts and other chemicals. Under normal osmotic conditions, we would expect the water to move from the pure water chamber into the saltwater chamber via osmosis as it attempts to reach a state of *equilibrium* (both chambers containing an equal ratio of salt to water). But instead, through the application of physical force, the pressure in the saltwater chamber is increased, thus causing the water molecules to move against their normal gradient. In other words, the water molecules are forced to move from an area of low concentration to an area of higher concentration; the exact opposite, or <u>reverse</u>, of their natural tendency. Since only water molecules can pass through the membrane, the salts and other molecules remain stuck on their original side of the membrane while pure water is collected on the opposite side. This is a more cost efficient method than distillation, but is typically only used with *brackish* (slightly salty) water.

According to the International Desalination Association, in 2013 there were more than 17,000 desalination plants around the world, capable of producing over 21.1 billion gallons of freshwater each day. These plants provide water to over 300 million people living in 150 countries. Looking at these numbers, it is easy to see that much has been accomplished, <u>and</u> we have much more progress to make in order to provide abundant freshwater for the world. Current research is focusing on creating processes that are more energy efficient, cost effective and less damaging to the environment. After all, desalination will only help us solve our problems if we can afford to pay, both financially and ecologically, for the freshwater it produces.

Sources:
idadesal.org/desalination-101/desalination-overview/
idadesal.org/desalination-101/desalination-by-the-numbers/
howstuffworks.com/reverse-osmosis.htm

Experiment 1
Modeling Desalination by Distillation

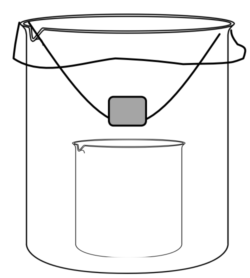
Purpose:
To model desalination by distillation.

Materials:
10 mL graduated cylinder
400 mL beaker
50 mL beaker
50 mL tap water
Food coloring (your choice of color)
1/2 teaspoon of table salt
Plastic wrap (enough to completely cover the opening of the 400 mL beaker)
Rubber band
A small rock, marble, or some other small, relatively heavy object to act as a weight
Conductivity tester
Heat lamp (if weather is cold)

Methods:
Step 1: Add the water, salt, and a few drops of food coloring to the 400 mL beaker and mix.

Step 2: Place the 50 mL beaker in the center of the 400 mL beaker.

Step 3: Loosely cover the opening of the 400 mL beaker with the plastic wrap and use the rubber band to secure it. This should completely seal the unit.



Step 4: Place the weight in the center of the plastic wrap. It should be directly over the opening of the 50 mL beaker and should cause the plastic wrap to dip down a bit.

Step 5: If the weather is warm, place the entire unit in a sunny window and allow it to sit for 72 hours (in case of cold weather, place the model under a heat lamp for 8-10 hours per day for a total of 3 days).

Step 6: Make visual observations of the water collected. The water will be inside the 50 mL beaker. What color is it? Record this in your data table.

Step 7: Remove the 50 mL beaker and use the conductivity tester to test the collected water for the presence of salt. Record the results in your data table. Since the point of this activity is to model desalination, there should be no salt present. You have just created distilled water!

Step 8: Use the graduated cylinder to measure the amount of distilled water collected. Record the results in the table.

Results:

TABLE 1: Distilled Water	
Color of water collected	
Presece of salt (yes/no)	
Initial amount of water (mL)	
Final amount of water collected (mL)	
% water collected $\frac{final}{initial} x100$	

Create a bar graph of the water before and after distillation. Put amount of water on the y-axis and before/after on the x-axis. Make sure to label the graph and provide a title.

Follow-up questions:

1. How is the water you collected different from the water you started with? Be specific.

2. After sitting in the sun (or under the heat lamp), you should have noticed drops of water on the walls of the beaker and on the bottom of the plastic wrap. How did these get there?

3. What is the point of placing a weight on the plastic wrap above the collection beaker?

4. Why didn’t the salt or the food coloring end up in the collection beaker?

5. In your opinion, was this an effective method of desalination? Explain.

6. Has the ability to remove salt from water changed humanity’s ability to survive? Explain.

7. In your opinion, is desalination dangerous to the ecosystem? Explain.

Experiment 2
Increasing the Efficiency of Desalination by Distillation

Purpose:
To design and conduct an experiment to identify a way to increase the efficiency of desalination by distillation.

(This experiment will be run just like Experiment 1 except that you will be setting up two models. The first will be identical to the one used in the last experiment, but the second model will have one change of your choice made to it. For example, you might change one of the materials, the temperature of some component, or the amount of water or salt you begin with, etc. The choice is yours.)

Hypothesis: State your hypothesis.

Variables: Identify the variables of this experiment.

Independent:_______________________________

Dependent:_______________________________

Controlled:_______________________________

Materials:
Conductivity tester
Food coloring (your choice of color)
10 mL graduated cylinder
Heat lamp (if weather is cold)

Model 1 (Control group):

400 mL beaker
50 mL beaker
50 mL tap water
1/2 teaspoon of table salt
Plastic wrap (enough to completely cover the opening of the 400 mL beaker)
Rubber band
A small rock, marble, or some other small, relatively heavy object to act as a weight

Model 2 (Experimental group):

(Depending on what you decide to test with your experiment, your material list for Model 2 may vary slightly from the one given. Just remember, you should only be changing one variable per experiment.)

List the items you have chosen to use for your experimental group.

Methods:

Control group

Step 1: Add the water, salt, and a few drops of food coloring to the 400 mL beaker and mix.

Step 2: Place the 50 mL beaker in the center of the 400 mL beaker.

Step 3: Loosely cover the opening of the 400 mL beaker with the plastic wrap and use the rubber band to secure it. This should completely seal the entire unit.

Step 4: Place the weight in the center of the plastic wrap. It should be directly over the opening of the 50 mL beaker and should cause the plastic wrap to dip down a bit.

Exp. group

Step 5: Set up the second model. Remember, it should be identical to the control group, except for the <u>one thing</u> you decide to modify and test. Below, draw a sketch of the modified experimental group, briefly explaining what is different.

Step 6: If the weather is warm, place both models in a sunny window and allow them to sit for 72 hours (in case of cold weather, place the models under a heat lamp for 8-10 hours per day for a total of 3 days).

Step 7: Use the graduated cylinder to measure the amount of distilled water collected in the control group. Record the results.

Step 8: Use the graduated cylinder to measure the amount of distilled water collected in your experimental group. Record the results.

Results:

TABLE 1: Production of Distilled Water			
	Amount of initial salt water (mL)	Amount of Distilled water produced in 72 hours (mL)	% water collected $\frac{final}{initial} x100$
Control Group			
Experimental Group			

Create a bar graph comparing the amount of distilled water produced (mL).

Conclusion:

Write a 1-2 paragraph reflection on whether or not your modification increased the efficiency of the distillation process. Be sure to also discuss why you think it had the effect it had, and what additional modifications you would like to try in the future (include your reasoning).

Desalination by Distillation Answer Keys

Background: (10 pts)

Students should provide a one paragraph summary of the reading. Main points should include what desalination is, the two main processes (distillation and reverse osmosis), and why we need desalination. (10 pts)

Experiment 1: (90 pts)

The **Table** represents not just the answers, but also demonstrates that the methods were followed correctly. (20 pts for correct answers + 10 pts for following the methods)

TABLE 1: Distilled Water	
Color of water collected	**clear**
Presence of salt (yes/no)	**No**
Initial amount of water (mL)	**50 mL**
Final amount of water collected (mL)	**varies**
% water collected	**varies**

Graph: 10 pts for properly labeled graph.

Follow-up questions:

1. How is the water you collected different from the water you started with? Be specific.
   The water we started with contained salt and food coloring. The water we ended with was pure, distilled water – no salt, no food coloring. (10pts)

2. After sitting in the sun (or under the heat lamp), you should have noticed drops of water on the walls of the beaker and on the bottom of the plastic wrap. How did these get there?
   As the water heated up, it evaporated (turned into a gas) which floated up and touched the beaker walls and plastic wrap, which allowed it to cool down and condense (turn back into a liquid). (10 pts)

3. What is the point of placing a weight on the plastic wrap above the collection beaker?
   So that all the water droplets join together and fall into the 50 mL beaker. (10 pts)

4. Why didn't the salt or the food coloring end up in the collection beaker?
   Because they have a higher boiling point than water, so they stayed in the original solution. (5 pts)

5. In your opinion, was this an effective method of desalination? Explain.
   Answers will vary. Provide credit for explanations. (5 pts)

6. Has the ability to remove salt from water changed humanity's ability to survive? Explain.
   Yes. We need freshwater to drink, grow plants, and run businesses, but there isn't much usable freshwater on the planet (less than 1% of the total water). Desalination allows us to turn saltwater into freshwater so we can use it. (5 pts)

7. In your opinion, is desalination dangerous to the ecosystem? Explain.
   Answers will vary. (5 pts)

Experiment 2: (100 pts)

Hypothesis and Variables: Students should state a hypothesis and identify the variables correctly (10 pts)

Independent: the item they changed

Dependent: the amount of distilled water collected

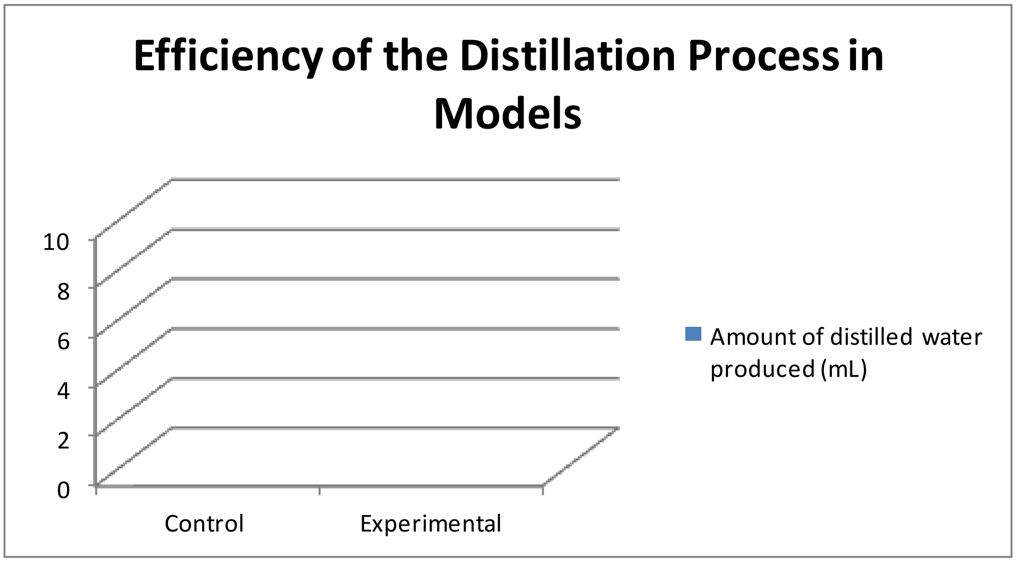
Controlled: the items that stay the same

Experimental Set-up Sketch: Students should provide a labeled sketch showing exactly what their modified model will look like. It should include a short written description of their modification as well. (10 pts)

The **Table** represents not just the answers, but also demonstrates that the methods were followed correctly. (20 pts for correct answers + 10 pts for following the methods)

TABLE 1: Production of Distilled Water			
	Amount of initial salt water (mL)	Amount of Distilled water produced in 72 hours (mL)	% water collected
Control Group			
Experimental Group			

Results: Students should produce a graph similar to the one shown below. The data will come from their experiment. (20 pts)



Conclusion:

Answers will vary, but should include 1-2 paragraphs in which students discuss how their experimental modification affected the amount of distillate produced. Did it increase, decrease, or have no effect on it? Why do they think this happened (look for logical and sophisticated thoughts that indicate real reflection on the question)? There should also be at least one additional suggestion for future experimentation – either expansion of their original idea or a totally different line of thought. (20 pts)