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Remove Pollutants from Water

("Using Boiling Water to Create Clean Water" is provided courtesy of the Center for Innovation in Engineering and Science Education at the Stevens Institute of Technology.)

In this lesson for grades 6 through 12, the goal is for students to figure out how to collect steam from boiling "polluted" water and then let it condense to create pure, clean water.

Objectives

This lesson will take 2-3 class periods of 40 minutes each. The goal is for students to figure out how to collect the steam from boiling "polluted" water and then let it condense in a new container. Ideally, the new, condensed water will be pure because any particles originally contained in the boiling water would be left behind as it turned into steam.

IMPORTANT NOTE: Since materials like plastics, foam, and tape may be used in this project, the condensed water may not actually be pure. Glue from the tape, and any particles from the foam and/or plastics may make it into the collected water due to the high temperatures, especially if any melting of the material occurs. Furthermore, there is some concern about the ingestion of certain chemicals contained within a few types of plastic products. While there is currently little evidence to suggest that any of these substances are dangerous, it is probably best not to have anyone drink the distilled water. At the very least, the taste would be unpleasant!

MATERIALS
A few or all of the following items:

- **Aluminum foil**
- **Microwave-safe plastic (Saran) wrap**
- **Aluminum pie pans**
- **Microwave-safe or dishwasher-safe plastic cups**
- **Foam or paper hot cups (coffee cups)**
- **Straws**
- **A lid to a pot**
- **Tape (Duct tape holds up well in the heat.)**
- **A clear glass or cup**
- **Ice and/or cold water (optional)**

Preparation:

To make "polluted" water, you may use salt, sand, or even a Kool-Aid type of mix. (NOTE: If you use a mix, some components will actually evaporate along with the water. Thus, the final product, while clear, will still have a weakly sweet smell and taste. This can lead to a good conversation about the limits of the distillation process.)

Day 1

***Lesson Objectives*: Students will learn what the process of distillation is all about, will see a demonstration of an extremely simple distillation of "polluted" water, and will begin designing their own distillation system.**

Procedure:

Show your students the “polluted” water. Ask where they might find water that is unsafe to drink. (Such as from the sea or from a polluted lake or river.) Discuss the ramifications of not having clean drinking water. What do the people living near a polluted river do?

Bring the “polluted” water to a boil. (You may want to have this started before class.) Being very careful not to get burned by the steam, hold the pot lid above the steam to catch it. The steam will condense on the lid, and after a decent amount has built up, bring the lid near a cup, tilt it, and let the condensed water flow into the cup, using a straw to help get as much as possible. You will not collect very much and will have to do this several times to get just a little puddle in the cup. (You can speed this up by putting the lid on the pot, thus trapping a lot more steam. However, be aware that the boiling water will most likely splash onto the lid, thus “contaminating” it.

Students should notice right away how clear the water is. Explain what happened and the process of distillation. (Here is some background information. http://www.thefarm.org/charities/i4at/surv/distill.htm)

Even though the method of distillation you just demonstrated was easy to do, it was very slow and lots of steam went to waste. However, rather than tell this to your students, it might be a better idea to ask them to point out all the problems themselves, which they will be happy to do. Your aim is to get the students to understand what makes a good distiller.

The key concepts that should drive the conversation should be:
The steam needs to be contained.
It then needs to be cooled and allowed a place to condense.
Finally, the resulting water is collected.

Break your students up into groups of 3-4 and tell them that it is now their job to come up with a better, more efficient way of collecting the water from the steam. You can show them the materials they will be using and should give them a little time to brainstorm first before actually getting any of the materials yet. Here are the goals for their distillers:

As much water as is possible should be collected from the steam.
The distillers should be stable so that they don’t fall apart or collapse easily.
They should collect the water quickly - the faster the better!
If considering cost, then for the same performace, cheaper is better.

Here is a simple rubric for the goals above. Feel free to add more goals or take some of these away.
http://www.ciese.org/curriculum/boilproj/engineeringlesson_rubric.html

Also, here is a sample blank cost sheet for the fourth criteria.
http://www.ciese.org/curriculum/boilproj/engineeringlesson_costsheet.html You can decide what to charge for each material, and don´t be afraid to make things expensive, like $1000 for a sheet of foil. That really gets students thinking seriously about cost. Also, you may choose to give each team a budget, or maximum amount that they can spend.

Allow students to get or purchase materials and begin construction. For safety reasons, each group should not build away from any boiling water. It would help if you had more containers similar to the one you are boiling water with, and gave each group one so that they would be able to guage the necessary scale of their setup. This construction phase will continue until the end of class.

Days 2-3

***Lesson Objectives*: Students will finish their distillation setups and test them out.**

Procedure:

If you are running this project over a three-day period, the whole second day should be devoted to allowing the students to continue building and testing their distillers. Otherwise, ignore this step.

On the last day of the project, students should finish building their distillers and get them ready for testing.

Test each distiller, and you and/or the class should evaluate it based on the criteria above. You could even come up with a quantitative measure of each group’s work by making a performance index. One example could be:

$$\text{Performance Index} = \frac{\text{mL of Pure Water Collected}}{\text{Total Cost of Distiller}}$$

Where each group is given the same amount of time to collect the water. You could also switch it around and time how long it would take for each group to collect a certain amount of water. Then, the index would be:

$$\text{Performance Index} = \frac{\text{Time to Collect Pure Water}}{\text{Total Cost of Distiller}}$$

In fact, you could even combine everything into one index, in which the numerator would have the time of collection times the amount collected, and the denominator would still have the cost. Which index you use depends on your situation - how much time you have, the level of your students, the measuring devices you have on hand. Choose whichever fits your class best.

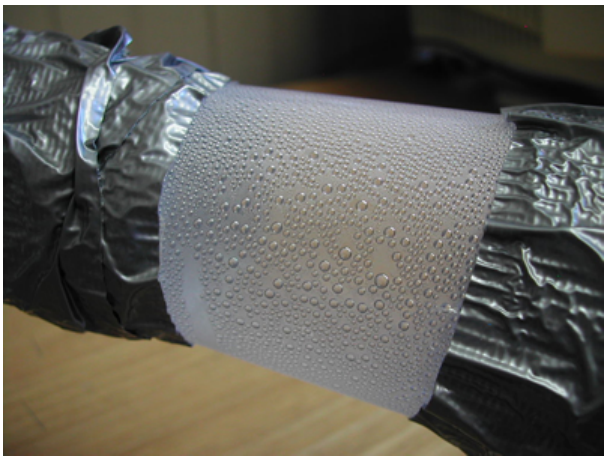
(Optional) If you have access to an actual distiller apparatus used in a chemistry classroom, it would be a great idea to show it to your students and even use it. They could then compare it to their own solutions.

Example Distiller

Here is just one example of a distiller to give you an idea what students might do:

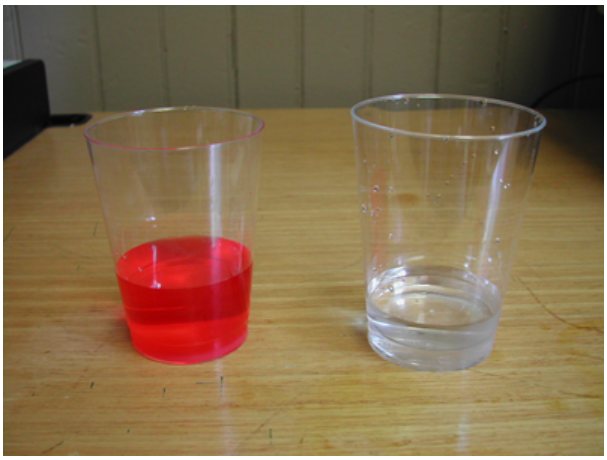
First, to aid in the containment of the steam, a piece of aluminum foil was placed over the top of the pot, and a hole was cut in the center. The distiller is placed over that hole.

Here is the distiller, made of a styrofoam cup, plastic cups, and duct tape.



The realtively large amount of surface area provides plenty of room for the steam to cool and condense. Blowing on the cups or touching them with ice noticeably speeds up the condensation process.

Each cup has a hole cut into its bottom so that the condensed water can trickle down.



Since duct tape, plastic cups, and styrofoam cups were used, the resulting distilled water wasn't that pure, and tasted pretty bad. But look at the color difference.