Name ________________________________

Clmiate Engineering Teaching Module

Lesson 2: Cloud in a Bottle

Through the experiment and this worksheet, students will learn:

- The components of a cloud.
- How clouds are created.
- How altering the components of a cloud can impact a cloud's reflectivity (albedo).
- Experiment design and data interpretation.
- The science and engineering behind the geoengineering idea called marine cloud brightening

Questions 1-3 are to be answered before proceeding with the experiment

Lab Instructions

Materials:

500 ml water + more for rinsing, clean 1-liter bottles, hand air pump, #3 hard rubber stopper + tire valve plug, aerosol hairspray, graduated cylinder (precision of 10 ml), lux meter, medium to large size flashlight, dark/non-reflective background (curtain, sheet, cardboard painted flat black, etc.).

Set Up:

- Set up the area for the experiment and have the materials at hand and clean. See the PowerPoint slides and the videos for help with the set-up. Refer to the 15x15x15 cm set up.
- The lux meter sensor should be pointed at the middle of the bottle. Please note that the lux meters are very sensitive. If possible, conduct the experiment in a dark room; if there is a main source of light, set-up with the lux meter pointing away from source (& away from windows).
- Ensure that the rubber stopper and tire valve plug fits securely in the bottle top. A snug fit is necessary to pressurize the bottle. If the plug is loose, try a different plug, or wrap the rubber stopper in a layer of Duct tape to improve the fit.

Data collection-Experiment 1

1. It is helpful to have a student assist with handing materials to the experimenter and to (or have another student) write down the lux meter reading right after the clouds are formed.
2. Begin with Experiment One, the “Low-Aerosol” environment. Experiment One requires 3 sprays of hairspray. Do at least 4 trials for each experiment, up to 10.
3. Start by putting ~20 ml of water into a 1-liter bottle and swishing the water around so it has touched the inner surface area of the bottle.
4. Spray 3 sprays of hairspray into the bottle.
5. Cap the bottle securely with the rubber stopper and valve plug.
6. [Secure the hand pump to the valve and pump 15 times (you want the bottle to be pressurized, but don’t risk injury – the number of air pumps can be altered to your needs but keep the number of pumps consistent across all experiments and trials).] - OR - [with the Fizz Keeper on, squeeze the ball as many times as possible (about 30-35 squeezes) to generate enough pressure to create the cloud.]
7. After the last air pump, [quickly detach the air pump from the valve and remove the rubber stopper] - OR - [Release the Fizz Keeper] (you’ll hear the pressure release).
8. A cloud in the bottle should immediately form and you need to get the lux meter reading ASAP after the cloud forms (note, the lux meter reading will go down as the cloud dissipates, so it is important to get a reading after the bottle is in place and hands are removed).
9. Have an assisting student record the lux meter reading on their worksheets.
10. Let the bottle remain in place until the cloud has completely dissipated. About 1-2 minutes. The lux meter reading will decrease as the cloud dissipates and when the numbers are not changing, record the value. Gather the reading of the bottle without the cloud in it (the reading should be less than with the cloud present). This reading captures the reflectance of the bottle with the residue of the remaining hair spray on the interior of the bottle.
11. Repeat Experiment One until at least 4 trials have been conducted, max 10.
12. After a 1-liter bottle has been used, it is important to rinse out the hairspray/water mixture before using the bottle again. You do not need to use soap or detergent between trials, but after completing the experiment you will want to clean and dry the bottles thoroughly.

Data collection-Experiment 2

1. Conduct the Experiment Two trials, the “High-Aerosol” environment. Experiment Two requires 10 sprays of hairspray. Again, do at least 4 trials for each experiment, up to 10.
2. Repeat the steps 3-12 above for Experiment Two with 10 sprays of hairspray instead of 3 sprays.

Question Set 1 (before Experiment One)

1. What are the two main components of a cloud?

2. Scientists defined the term albedo to quantify the percentage of incoming sunlight that is reflected by an object. For example, viewed from space the Earth has an albedo of about 0.30, meaning that 30% of incoming sunlight is reflected back to space. Given this information, what do you think is the albedo of a forest, of the ocean, of a desert, of snow, of a cloud?

Research Question: Can we engineer brighter Clouds?

3. Do you think by adding additional aerosol particles, we can make clouds brighter? Why would you expect this result?

Collecting Data

Experiment One: **3 Sprays of Hairspray**			
	Lux Meter Reading (lx)		
Trial #	Bottle with Cloud	Bottle without Cloud	Difference
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Average			

Experiment Two: **10 Sprays of Hairspray**			
	Lux Meter Reading (lx)		
Trial #	Bottle with Cloud	Bottle without Cloud	Difference
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Average			

Question Set 2 (after experiments)

4. In the table, calculate the difference between the light being reflected from the bottle with and without the cloud in lux for all trials and experiments. Also, calculate the average of each column. (If calculating T-test, complete this computation with your teacher now.)

5. What were the independent and dependent variables in these experiments? What were the constants?

6. Why did we measure and record the reflectance of the bottle after the cloud dissipated in each trial?

7. Explain why more aerosol particles (10 sprays vs. 3 sprays of hairspray) created a cloud that reflects more light?

8. How could we implement this climate engineering technology to brighten clouds on a larger scale, in the real world?

9. What are some possible limitations and risks to scaling this technology to use in the real-world?