Direct Air Capturer: The Effect of a Direct Air Capturer on the Reduction of Carbon Dioxide

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Acknowledgments

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Abstract

In an engineered direct capture system, carbon dioxide levels will be monitored and analyzed as a result of the system's ability to chemically alter its environment. This proposed research is a response to the issue of increasing carbon dioxide emissions, potentially addressing its relevance to rising global temperatures. The system's main component is the chemical reaction between sodium hydroxide and carbon dioxide with the resultant chemicals of sodium carbonate and water. Ambient air will be taken into the system to be chemically altered and released back into the atmosphere. The chemical equation being used for reference is: $2NaOH + CO_2 = Na_2CO_3 + H_2O$. A concentration of water will react with a given amount of powdered sodium hydroxide. This system will be tested in various locations with different variations to evaluate the versatility of the system's abilities. A carbon dioxide level of 1000 ppm is deemed acceptable for most environments. Analysis of data will involve analytical tools available in the software corresponding with the carbon dioxide meter that collects the data. Additionally, an analysis of covariance will be performed between the varying qualities of the system, the varying locations, and the changes in the CO_2 levels as a result. The results of this proposed research have the potential to introduce a novel method of carbon dioxide emission reduction.

Introduction/Background

A readily increasing concentration of carbon dioxide in the environment has led to the major threat of the greenhouse gas effect. Excessive carbon dioxide essentially traps the sun's heat energy, increasing the overall temperature of the Earth and its atmosphere. This has resulted in changes within the Earth's climate that are predictably harmful for the future of this planet. According to the Occupational Safety and Health Administration (OSHA), safe levels for CO_2 are 1000 ppm *(Climate).* However, many political leaders have not been taking this issue as seriously as they should be. There are various misconceptions regarding the effects of climate change, one of them being that the high levels of carbon dioxide are not increasing the temperature in the atmosphere. The goal of this project is to address and refute this misconception by building a model of an effective direct air capture system and evaluating its efficiency in varying locations and conditions.

A 2006 article compares various carbon dioxide storage systems including: biological, oceanic, and geologic storage systems. Biological carbon dioxide storage has received the most attention in the environmental field. Another potential storage system is the oceanic storage system, which is seen as a potentially dangerous method, due to the ecological impacts of CO_2 in the ocean. This article finally establishes geological storage as a novel field requiring further research, which our project aims to address (Verma et. al 2006).

Supporting our proposed engineering design, there is a 2021 article that is centered around the effects of direct air capture (DAC) systems on carbon dioxide emission removal from the atmosphere. Climeworks, an organization in Switzerland, was one of the first groups to build a novel DAC system (Climeworks Latest Direct Air Capture). Through this system, carbon dioxide is separated from the atmosphere using amine adsorbents. An important aspect of DAC systems involves the practice of storing CO_2 underground and changing it to stone (Evans, 2019).

Moreover, a 2010 article elaborates on the specific technology used to separate carbon dioxide from flue gases (chemical byproduct of combustion reactions). The researchers used membrane gas absorption technologies for their research goal. Their method involved a fiber membrane contactor. Their methods provide a basis for the most effective CO_2 separation technologies (Zhang et. al, 2010). Our research project plans to employ these technologies within the Direct Air Capture system.

Additionally, a recent 2020 article highlights various studies done in Illinois using carbon capture storage methods to limit carbon emissions in the atmosphere. In one of their projects, data analysis was performed using seismic monitoring, through which the geographic terrain was analyzed to monitor the depth at which the carbon dioxide was buried underground. Their methods of data analysis provide a basis for how the storage of carbon dioxide in our proposed model can be examined (Dunlap et. al, 2020).

Ultimately, the purpose of this study is to address the misconceptions regarding climate change by engineering a system that reduces carbon emissions; hence, decreasing the atmospheric temperature through direct air capture. This project also aims to address the gap within research about geological storage of carbon dioxide. The implications of this project include a greater public awareness of the validity of climate change research.

Questions and Hypotheses

Questions

What is the effect of a direct air capture system that chemically alters carbon dioxide tested in different locations on the system's ability to decrease carbon dioxide levels?

What is the effect of a developed carbon dioxide capture system in an environment on the temperature cooling rate of that environment?

Engineering Goals and Expected Outcomes

We expect to observe a direct relationship between the removal of carbon dioxide and the decrease of temperature in an environment.

We expect to observe similar efficiency across variations made on the system.

Hypotheses

The scientific alternative hypothesis is:

If an ambient air capture system chemically alters captured CO_2 and is tested in different locations, then the system will be efficient across all settings and variations because the CO_2 levels in each environment will decrease to a safe level of 1000 ppm.

The scientific null hypothesis is:

If a direct ambient air capture system that chemically alters captured carbon dioxide is engineered and tested in different locations, then the qualities of the system will have no correlation with the CO_2 levels within each of the settings.

Materials and Methods

Materials

- RS232 software
- Plastic container
- Mini Aquarium Air Pump
- 4” Ducting Pipe 90 Degree Elbow
- 5” Solder Absorber Fan
- 4” Ventilation Fan
- Carbon Meter
- Sodium Hydroxide (NaOH)
- Clear Acrylic Sheet
- * Hot Glue and caulking
- Drilling and cutting equipment

We received several of our materials on 12/07/2021, which included the air pump, sodium hydroxide, suction fan, plastic sheets, and the four-inch pipe. On 12/09/2021, we received an exhaust fan, five-inch pipe, plastic containers, and carbon meter. We began by creating the plastic filter, which was cut to 20.35 cm by 6 cm but found that it was too small to properly divide the container. We then cut another piece to a size of 20.7 cm by 10.4 cm which fit more snugly than the previous cut.

* Hot glue and caulking were used to fill in any gaps that occurred as a result of the container shape.

Figure 1: The image above is the carbon meter along with its CD and other components on the day it was received.

After receiving all our materials, we placed them on the container lid as shown below to reflect how the device would be set up once we began the construction process.

Figure 2: The image above is our tentative setup for the carbon capture device.

Methods

Building

The following are the steps that were taken when the basic apparatus of the system was built:

1. Using the plastic storage container as our enclosed system, we cut two, 4-inch diameter holes onto the lid by drilling with a hole saw (Figures 5 and 6).
2. The suction fan was screwed directly onto a part of the lid, after a hole with a 4-inch diameter was cut into the lid in order to allow easy passage of ambient air into the container (Figure 7). We first outlined the proper measurements of the suction fan by placing it onto the lid (Figure 9). The radius of the four screws on the corners of the suction fan were 5/16 of an inch, and this radius was measured before cutting the holes for the machine screws (Figure 9).
3. Another hole was drilled to have a diameter of four inches, and the corresponding 4-inch ducting pipe was inserted into the hole, secured with caulking (Figure 10). The exhaust fan was then connected to the pipe. 7/8 of an inch was cut off the ducting pipe, so the exhaust pipe fit snugly into the pipe.
4. The diameter of the third hole, for the air pump, (4 millimeters), was measured using a micrometer (Figure 13). The tubing of the air pump was put through the hole.
5. We then made a plastic sheet to fit the dimensions of the box which will be attached to the center of the container, staying 3 inches above the bottom. We began by creating the plastic filter, which was cut to 20.35 cm by 6 cm but found that it was too small to properly divide the container. We then cut another piece to a size of 20.7 cm by 10.4 cm which fit more snugly than the previous cut.

6. Ultimately to secure the lid's contents together, we used hot glue. More specifically, we used it to place the air pump on the lid. Additionally, we used caulking to fill the exhaust fan's tubing as a result of the gaps that occurred with the natural container shape.
7. In the future, a fourth hole will be cut to the size of the wire of the CO_2 meter. The CO_2 meter will be connected to the inside of the container on the left side by Velcro strips so it can be removed when taking data.
8. Additionally, the suction fan, exhaust fan, and air pump require electricity to function, so they will be connected to a separate power outlet outside of the environment. It was noted that the exhaust and suction fans may have different air flows measured in CFM (cubic feet per minute), but we did not find a major difference in the suction/exhaust powers of each fan.

Testing

Water will be poured into the container and NaOH will be mixed in. The carbon meter will be attached to the left section of the container and connected to the computer to record the CO_2 levels throughout testing. The suction fan will take in ambient air, which will then react with the aqueous NaOH solution. The air pump will speed up the reaction process by agitating the solution, and the CO_2-free air will exit the container through the exhaust fan. Before beginning actual experimentation, a round of preliminary testing will be conducted to ensure the system is working as intended and that the CO_2 is reacting properly with the sodium hydroxide (NaOH). The carbon meter will be collecting data on the CO_2 levels in the container throughout the testing. We will also determine how long the solution is able to capture CO_2 before becoming too saturated, and how often it should be changed. After the system is fully functional, the CO_2 and temperature will be measured throughout experimentation. Our initial testing, which will be our preliminary and control group testing, will occur in a school classroom. We will later test our device in different environments, including a power plant, a location of heavy traffic, and an area with car exhaust.

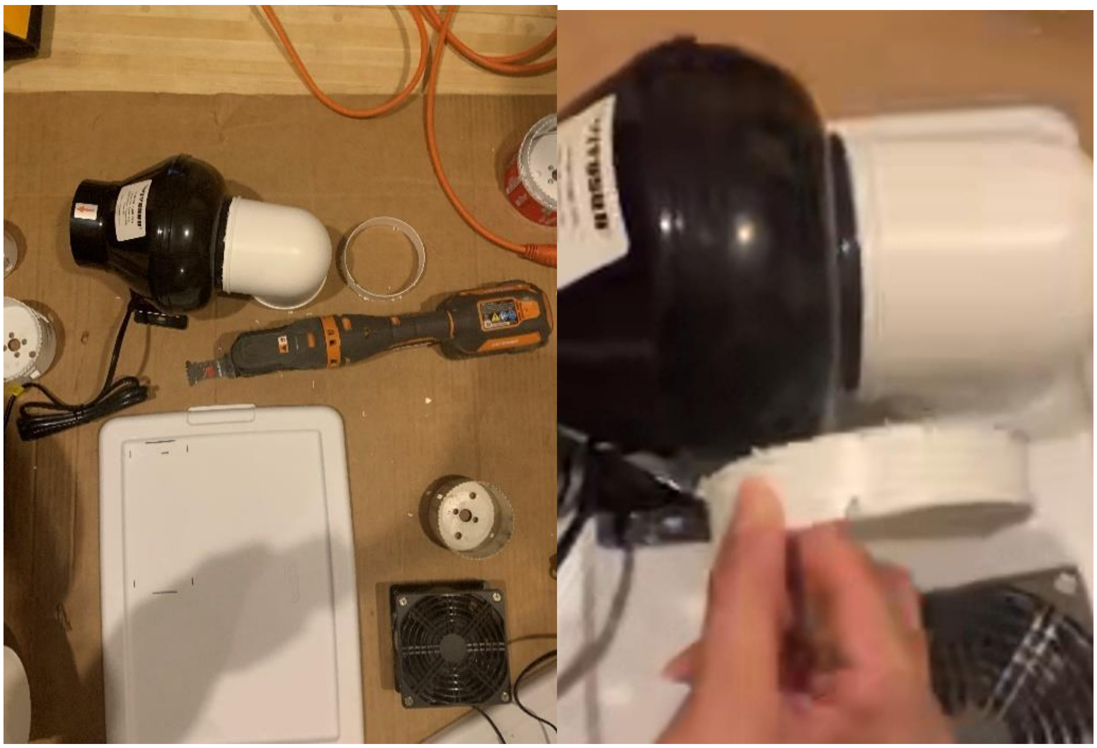

Figure 3: The image above demonstrates the cut off portion of the 4-inch tubing. We did this to ensure that the exhaust fan and the tube fit well on the lid together.

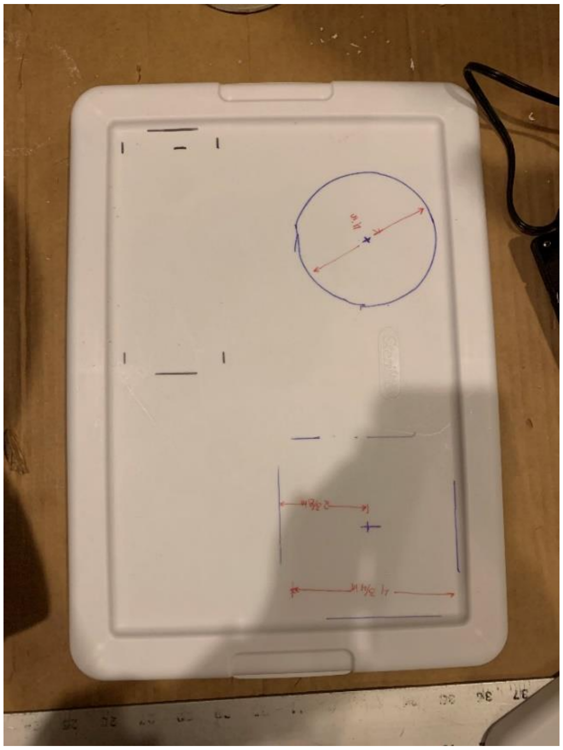

Figure 4: The image above is the configuration of the two holes.

Figure 5: The image above is the drill bit and hole cutter working to cut the hole for the suction fan.

Figure 6: The image above is the drill bit and hole cutter working to cut the hole for the exhaust fan’s tube.

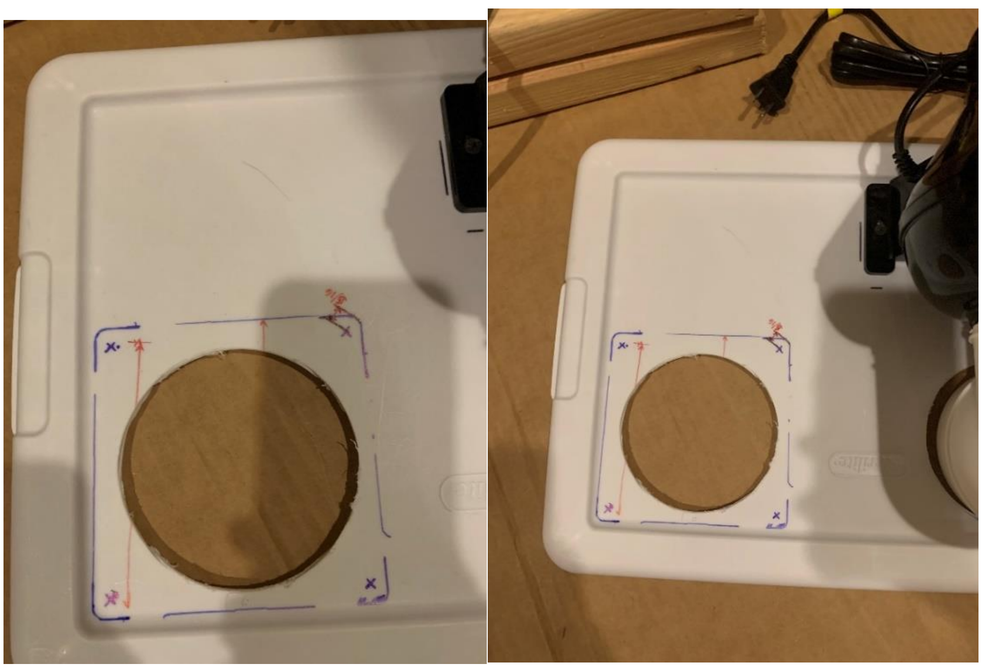

Figure 7: The image above is the aerial view for the cutting of the suction fan’s holes.

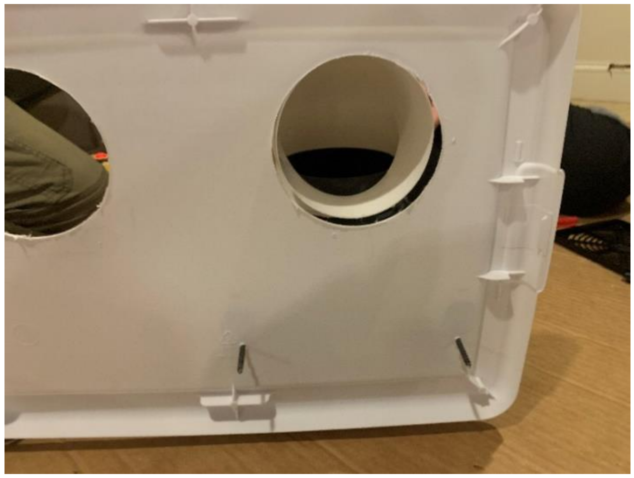

Figure 8: From an inside view, the image above shows the two cut holes and their placements internally.

Figure 9: The image above is the measurement of the radius of the screws on the suction fan, which was measured to be 5/16 of an inch from the corner.

Figure 10: The image above is the overall final look of the system, before any securing with hot glue or caulking.

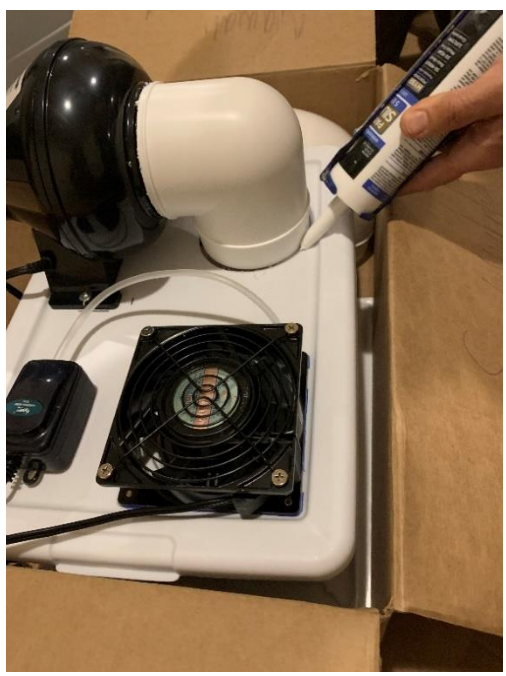

Figure 11: The figure above demonstrates how we put caulking around the 90-degree ducting pipe to fill in any gaps around it.

Figure 12: The figure above shows how we used a micrometer to find and measure a drill bit (0.223 in) that corresponded with the size of the Air Pump tube (0.184 in).

Figure 13: The image above is the Air Pump tube being inserted into the corresponding hole.

Data and Analysis

The primary data in this experiment will be analyzed through an RS232 software that corresponds to the AZ7755 Carbon Meter being used, which is recommended for standard serial transmission by USB. In the preliminary dataset, the system's functionality will be tested based on the amount of carbon dioxide captured and stored in the modeled environment. We will analyze the effectiveness of our created capture system, with which the CO_2 levels of the modeled environment will be determined based on the amount that will be either captured or released. This will be measured with the meter, and the outputs will be recorded with the attained values graphically.

Additionally, methodologically, the carbon levels entering the system after the preliminary testing will be captured as ambient air across different locations. With varying pollution and exhaust levels of CO_2, the data collection will occur at a power plant, a traffic filled area, and an area of high car exhaust. As the control group, a school classroom will be the area of preliminary testing. The effectivity of the system will be measured based on the amount of carbon dioxide captured and chemically altered in each trial. This level will be deemed effective if the CO_2 levels of the modeled environment decrease to be the safe values of less than 1000 ppm. As a varied amount, this carbon dioxide will be included in the final data's results as the independent variable. The carbon dioxide will be in a continuous stream that will relay the levels to the software as the Direct Air Capture process is occurring.

As a means to measure the statistical significance of the system, either an analysis of variance (or covariance) or a correlational statistic will be used to determine the existence of a relationship between the carbon dioxide levels and the effectivity of the modeled environment across the several locations. Currently, the system is only a control group, and any testing pertains to the effectivity of the Direct Air Capturer on its own. However, we will quantify the system's relationship with the decreasing levels of CO_2 present and changing in the testing locations.

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