CARBON CRAZY

CO_2

CO_2

Abstract

This experiment tested how different household materials affected carbon dioxide (CO_2) levels produced by a baking soda and vinegar reaction. The materials tested were limewater solution, activated carbon, Pothos plants, and Dracaena plants, along with a control group that used no CO_2-removal material. From these materials, the hypothesis was that the Dracaena plant would efficiently remove the most carbon dioxide in the air if placed in the jar, due to how it continuously reduces carbon dioxide. CO_2 was generated inside an airtight container by combining baking soda and vinegar, and only one carbon-capture material was tested at a time. A digital CO_2 sensor was used to record CO_2 concentration, temperature, and humidity at five-minute intervals until levels returned close to the starting value. CO_2 levels were measured over time and compared between groups. The results showed that the limewater solution reduced CO_2 the fastest, starting the decrease about 57.6% sooner than the control. Pothos plants lowered CO_2 about 40.5% faster, while Dracaena plants reduced CO_2 about 35.7% faster. Activated carbon reduced CO_2 levels about 32% faster than the control group. The control group maintained high CO_2 levels until about 25 minutes into the experiment. Limewater was the most effective because it reacts directly with carbon dioxide. Plants and activated carbon worked more slowly, but they still lowered CO_2 levels compared to the control. This shows that chemical carbon capture methods are faster than biological methods, even if they can still be useful.

Introduction

Carbon dioxide is a greenhouse gas that is naturally found in the air and is one of the most common gases. As of now, there is around 424.87 ppm of carbon dioxide in the air on average. This gas is necessary for plants to grow, but excessive amounts of carbon dioxide can contribute to global warming and climate change. High concentrations of carbon dioxide can lead to health risks such as asphyxiation, headaches, and other risks. CCS (carbon capture and storage) systems can improve air quality and slow down global warming, but most households are not equipped to effectively operate these systems. This project focuses on developing more efficient and cost-effective solutions to reduce carbon dioxide emissions. From this project, we hope to become better researchers and gain general knowledge. This will help us gain more experience with the scientific method and its specific processes. Additionally, the project will help us learn background knowledge about the function of carbon-capture materials and how these materials reduce CO^2 in the air. We will also gain knowledge about the chemical reactions behind our science experiment. All in all, this project will significantly help the human cause and give us a better grasp of CCS.

Testable Question/Purpose

Testable Question

"How does the type of household carbon capture material affect the reduction of carbon dioxide levels in simulated indoor conditions?"

The purpose of the experiment

This experiment poses a clear real-world solution for the earth/chemistry subcategories. Too much carbon dioxide can create dangerous environments and affect humans and the earth. Unfortunately, CO^2 emissions are an increasing danger to the current world we are living in, because of the recent global warming and climate change crisis that has been happening. Additionally, CO^2 is the leading greenhouse gas in the world, and it directly affects human health and animal ecosystems, and it even affects the daily food supply we have today. However, with CCS (carbon-capture storage), this experiment can possibly reduce the dangerous amount of CO^2 in the air we have nowadays. This will be done by changing the type of carbon-capture household material to see which one reduces the amount of carbon dioxide in the air. As a result, we can possibly make human life significantly better by eradicating the problems CO^2 causes from this project.

Variables

Independent Variable

Type of household carbon capture material (dracaena, calcium hydroxide, activated charcoal, and golden pothos houseplant) - This is the variable that will be varied in the experiment. Changing the type of household carbon capture material will affect the dependent variable, and it will be important to the overall experiment and the data collected.

Dependent Variable

The reduction of carbon dioxide - This is the variable that will be changed, depending on the independent variable. The dependent variable's carbon dioxide reduction will vary because of the change in type of material. Additionally, this variable will be the main source of data throughout the experiment. The temperature and humidity inside the jar will additionally be measured and will not be the main source of data.

Constants

There will be many constants in this experiment that will stay the same, due to the fact that there is a requirement of only one factor affecting the outcome of the experiment. The location where the experiment is conducted will be the same due to how the experiment must be simulated in the same environment, or the results may be inaccurate or varied. Another constant will be the type of measuring units used. This is because throughout the trials, changing the measuring units will make the experiment results invalid. The duration of the experiment will stay the same since there needs to be a certain starting time and ending time for the experiment. Finally, the type of CO^2 sensor used does not change, because different CO_2 measuring sensors could mess up the results and possibly use different measuring units as well.

Control group

The control group in this experiment will be the container with no carbon capture material inside it. This group will start with the initial CO_2 concentration, and it will be a comparison basis for the experimental groups.

Hypothesis

If the type of household carbon-capture material is changed (among Dracaena, activated carbon, golden pothos, and calcium hydroxide), then the amount of carbon dioxide removed from the air will differ, with Dracaena expected to remove more CO_2 than activated carbon, the Pothos plant, and the limewater solution because of its ability to absorb carbon dioxide through photosynthesis at a continuous rate.

Supporting Thesis

Dracaena is expected to be the most effective at reducing carbon dioxide because it is a living plant that continuously absorbs CO_2 during photosynthesis and converts it into oxygen and organic matter. In contrast, activated carbon and calcium hydroxide rely on non-biological chemical or physical processes, and the golden pothos houseplant is predicted to remove less CO_2 due to differences in growth rate and leaf structure. This makes Dracaena the most effective option among the tested materials in this comparison.

Background Information

We gained lots of knowledge throughout the six sources we researched, and it helped with background knowledge surrounding our experiment and better understanding of carbon capturing. The main research points were CCUS, carbon capture technologies, household carbon capture removal/ CO_2 removal in the environment, and the science behind how the CO_2 capture materials in this experiment take carbon dioxide from the surrounding atmosphere. With the information we have learned, we can work towards better air quality.

Carbon capture usage and storage was a major point in our research. People have identified the problem of excessive amounts of CO_2 in the air, recognized the daily problems it is causing us humans, and are working together to reduce the amount of carbon dioxide in the air. Scientists and researchers created CCUS to take out significant amounts of carbon dioxide in the air without hurting the environment. With CCUS, we have created many technologies that try to reduce the amount of carbon dioxide in the atmosphere. World Researchers Institute states that, "Moving forward, diverse methods of carbon dioxide removal must be built into climate change strategies around the world to avoid dangerous levels of global warming" (*6 Ways to Remove Carbon Pollution from the Atmosphere*). Some of these technologies include biomass removal, planting more trees and making air quality healthier, advanced ventilation technologies, and even carbon mineralization.

Another focus throughout the background information we researched was about CO_2 removal in the environment and in indoor spaces. Indoor carbon dioxide is in much lower concentrations than atmospheric carbon dioxide emissions, so therefore it is much harder to capture than in outside conditions where emissions are present in many places. Scientists that were part of a research team stated that, "To keep the indoor CO_2 concentration at healthy levels, in this work, we creatively developed an indoor CO_2 purification module that can be readily integrated into the air-conditioning system" (*Indoor CO_2 Removal*). Purification technologies and ventilation systems can make breathing space better for humans. Additionally, CCUS could be incorporated into living spaces at a much smaller scale, using pre-combustion, post-combustion, and oxy-fuel combustion.

The last major point in our research was the science behind our carbon capture materials and how they absorb CO_2 from the air. Baking soda and vinegar has a formula of $NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2$. The baking soda (base) reacts with the vinegar (acid) to create carbon dioxide gas and bubbles. The activated carbon picks up carbon dioxide from adsorption, where carbon dioxide molecules attach to the surface area of the charcoal. Dracaena and the Pothos plant both absorb CO_2 through photosynthesis with the formula $6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$. A researcher that is part of a chemistry resource website states that, "When lime water and carbon dioxide reacts, calcium carbonate is generated along with the water. Calcium carbonate is an insoluble salt" (*Superprof*). The chemical equation for limewater reaction with CO_2 is $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$.

All in all, the knowledge from the research we have gained summarizes what we have learned throughout this experiment. This research additionally raises awareness about carbon dioxide emissions and global warming. If we use these technologies and household materials to our advantage, we can create a better living space for all humans.

Data Analysis

Throughout the 15 trials of testing, three graphs are organized based on the three different carbon dioxide tests for each material, and the surrounding environmental conditions were measured during the experiment. Note that when there was a drop in the graph, the ppm sensor did not suddenly decrease to normal amounts, taking about 30 seconds on average to go down completely. Additionally, note that the carbon dioxide meter caps out at 5000 ppm but is still reaching the same amount of ppm each time for each material due to the baking soda and vinegar proportions being the same every time for testing. None of the graphs supported the original hypothesis stated.

In the graph for Test 1, the initial amounts and the ppm amounts after the baking soda was poured were relatively similar. The control variable went as expected, staying at the 5000-ppm mark for the 25 minutes of testing due to there being no carbon capture material present inside the airtight container. The control variable did decrease after our testing period was finished. The activated charcoal reduced much more quickly than the control, at 16:15. The Pothos plant reduced by about 2 minutes slower, at 18:09, capturing carbon at medium amounts compared to the activated carbon which was capturing carbon in greater amounts. However, the Dracaena plant captured slightly less carbon than the Pothos plant, timing in at 18:46. Additionally, the Dracaena plant took a little over a minute to get to 5000 ppm, which could have slightly affected its results. The limewater solution took 7:23, which proves that it captured the most carbon.

In the graph for Test 2, the initial amounts were still similar with each material, with a pattern that the ppm increases slightly after the baking soda is poured. The control variable stayed at the 5000 ppm mark once it spiked up. The activated carbon reduced carbon dioxide faster than it did in Test 1, at 14:14, but was in between the times of Pothos and Dracaena. The Pothos plant was reduced by 12 minutes and 36 seconds, the fastest it was throughout the whole experiment. The Dracaena plant still reduced the least out of the other carbon capture materials other than the control, at 16:20. The limewater solution still reduced the quickest of the materials, at 11:29.

In the graph for Test 3, the initial amounts were as expected. The control variable still stayed at the 5000 ppm mark, this time reducing right after we ended the experiment. The activated carbon this time went unexpectedly and took over 2 minutes to reach 5000 ppm, and it reduced at 22:31, significantly more than any other material other than control did. This could be due to too much air getting out of the jar. The Pothos reduced at 14:11, and the Dracaena reduced at 13:06, which was faster than it was reduced in any other test. The limewater was the fastest carbon capture material again, at 11:16.

The mean average of each material was 25:13 for control, 17:40 for activated charcoal, 15:02 for Pothos plant, 16:06 for Dracaena plant, and 10:02 for limewater solution. This shows that limewater was the most effective carbon capture material in the whole experiment.

Discussion

This project's practical purpose was to solve global warming and climate change issues through household carbon capture materials by small amounts. Figuring out that limewater was the best carbon dioxide reducing household material shows that limewater should be used more in households to reduce more CO_2. These findings support the idea that chemical methods like limewater work much quicker than biological methods like plants over a short period of time. There were several sources of error that may have affected the results. Some CO_2 may have remained in the container from previous trials if the airtight jar was not cleaned completely, which could make the capture materials appear less effective. Releasing even a small amount of air when closing the jar could also have lowered the CO_2 concentration, affecting the measurements. These factors likely influenced the results and addressing them could improve future experiments. More careful cleaning of the jar between trials, ensuring minimal air release when sealing the container, and standardizing the amount and condition of materials would make the measurements more reliable. These changes could lead to more accurate results and a clearer understanding of how household materials reduce indoor CO_2.

Control

Activated Carbon

Golden Pothos

Dracaena

Limewater

Data Tables

Baking Soda + Vinegar & Control (+/- 50)

	Initial Amount	After Baking Soda	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	Time when reaction starts decreasing
Trial 1	426 ppm	430 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	25:31
Trial 2	416 ppm	421 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	25:08
Trial 3	439 ppm	443 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	25:01

Baking Soda + Vinegar & Activated Carbon (+/- 50)

	Initial Amount	After Baking Soda	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	Time when reaction starts decreasing
Trial 1	448 ppm	451 ppm	>5000 ppm	>5000 ppm	>5000 ppm	433 ppm	426 ppm	16:15
Trial 2	416 ppm	421 ppm	>5000 ppm	>5000 ppm	425 ppm	427 ppm	425 ppm	14:14
Trial 3	433 ppm	436 ppm	>5000 ppm	>5000 ppm	>5000 ppm	>5000 ppm	449 ppm	22:31

Baking Soda + Vinegar & Pothos Plant (+/- 50)

	Initial Amount	After Baking Soda	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	Time when reaction starts decreasing
Trial 1	432 ppm	437 ppm	>5000 ppm	>5000 ppm	>5000 ppm	438 ppm	432 ppm	18:09
Trial 2	424 ppm	426 ppm	>5000 ppm	>5000 ppm	444 ppm	437 ppm	430 ppm	12:36
Trial 3	413 ppm	416 ppm	>5000 ppm	>5000 ppm	427 ppm	444 ppm	441 ppm	14:11

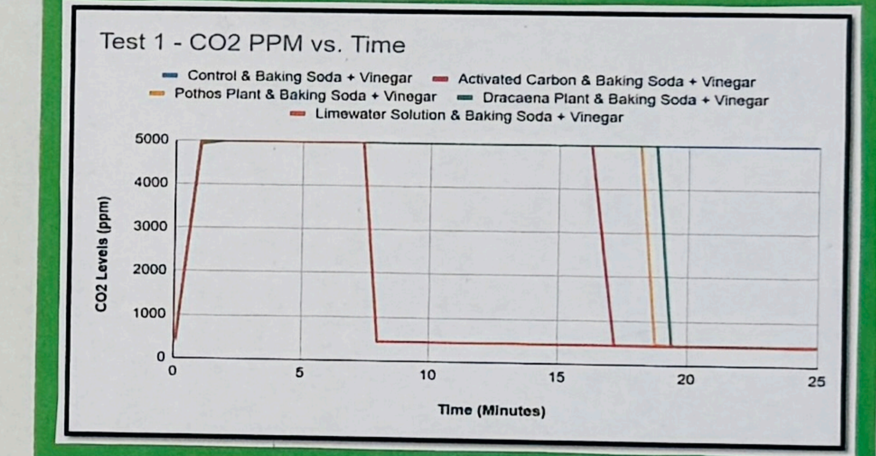
Baking Soda + Vinegar & Dracaena Plant (+/- 50)

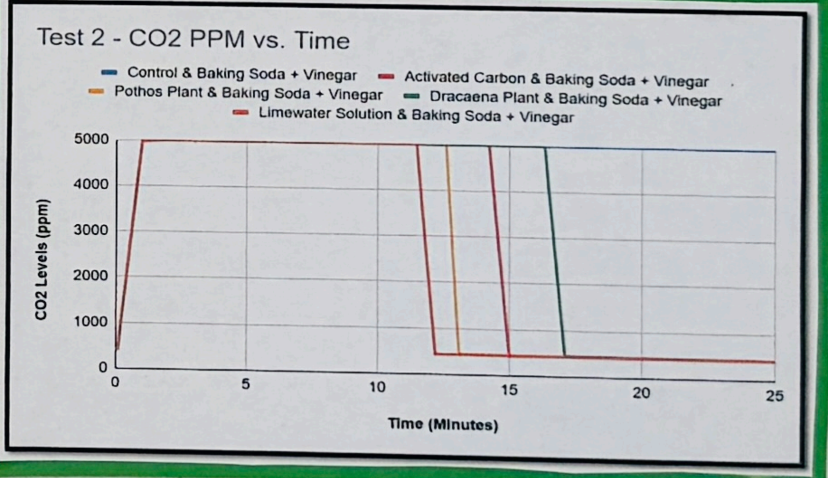
	Initial Amount	After Baking Soda	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	Time when reaction starts decreasing
Trial 1	452 ppm	458 ppm	>5000 ppm	>5000 ppm	>5000 ppm	442 ppm	438 ppm	18:46
Trial 2	422 ppm	424 ppm	>5000 ppm	>5000 ppm	>5000 ppm	440 ppm	431 ppm	16:20
Trial 3	436 ppm	440 ppm	>5000 ppm	>5000 ppm	433 ppm	430 ppm	424 ppm	13:06

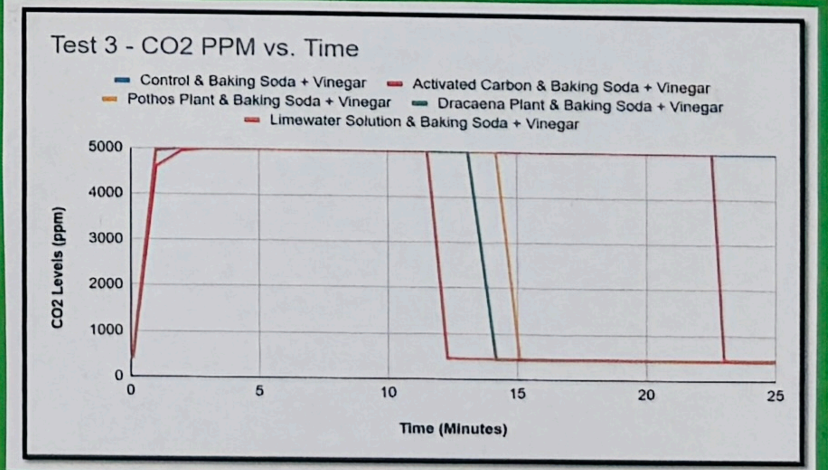
Baking Soda + Vinegar & Limewater Solution (+/- 50)

	Initial Amount	After Baking Soda	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	Time when reaction starts decreasing
Trial 1	419 ppm	420 ppm	>5000 ppm	437 ppm	437 ppm	433 ppm	431 ppm	7:23
Trial 2	416 ppm	418 ppm	>5000 ppm	>5000 ppm	431 ppm	429 ppm	431 ppm	11:29
Trial 3	439 ppm	445 ppm	>5000 ppm	>5000 ppm	447 ppm	436 ppm	432 ppm	11:16

Data Graphs







Chemical Reactions

- Baking Soda + Vinegar - $NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2$
- Activated Carbon – Takes in CO_2 from adsorption (process for adsorption)
- Dracaena/Golden Pothos - $6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$
- Limewater - $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Materials List

MATERIALS AND EQUIPMENT	QUANTITY	ITEM DESCRIPTION
Mounting Putty	4 (wrapped into balls)	Material that will be used to stick the CO_2 sensor onto the jar
Clear Tumblers / Glasses	3 (tall & will be reused) (one for baking soda + vinegar)	Transparent containers used for holding the carbon capture materials and holding the baking soda + vinegar solution. Will be placed inside the airtight jar
Sticky Note	30 (2 per trial)	Material that is stuck onto the clear tumblers for labeling
Observation Notebook	1	Organized notebook used for detailed recording of data, sketches, and measurements
Safety Goggles	2 (one per person)	Protective eyewear used to shield eyes from chemicals, splashes, and debris in this experiment
Glove Pairs	2 (one per person)	Protective hand coverings used to prevent skin contact with harmful or messy materials
Measuring Cup	1 (in tablespoons)	A 1 tablespoon cup used to measure the baking soda and other carbon capture materials that will be in our experiment
Dracaena (snake plant)	1 (will be trimmed)	A slow-growing perennial, evergreen shrub that captures carbon well. Will be our first carbon-capture material
Baking Soda	250 mL	A white powder used in baking to help dough rise by making bubbles. This will be poured into the vinegar to emit the CO2
Distilled White Vinegar	946 mL	An acidic liquid that the baking soda will be poured onto to create the carbon dioxide
Scoop	1	The baking soda from the measuring cup will be poured into this material and then poured into the glass tumbler
Soil	Approx. 3/4 of the small glass tumbler	Used to allow living conditions for the Draceana plant inside the clear glass tumbler.
Pothos Houseplant	1 (will be trimmed)	A genus of flowering plant that is part of the family Araceae. This is a common houseplant that captures carbon. Will be the second carbon capture material
Activated Carbon	1 tablespoon (one per trial)	A highly porous form of carbon that has been treated to increase its surface area. Used to clean fish tanks. This will be our third carbon capture material
Glass Beaker	1	Cylindrical containers made of glass or plastic, used in our experiment to measure liquids such as vinegar or water
CO_2 Sensor	1 (measured in ppm)	A device that can effectively detect and measure the concentration of carbon dioxide in a certain area. The outputs of ppm from this device will be our main source of data
Water (H_2O)	1-2 L	This will be used to wash the excess materials on the tumblers or the air-tight jar and be used for the Dracaena and Pothos plants
Transparent air-tight container (sealable lid)	1	This will be the main container that all the carbon-capture materials needed to do the experiment will be in
Calcium Hydroxide Powder (limewater)	1 oz per trial	Found in cement and sometimes used in gardening. Our fourth and last carbon capture material for this experiment
Jar	1 (with tightly sealable lid)	This material is used to contain the limewater solution that will be made throughout the experiment
Stopwatch	1	Used to time the reaction process and see when the ppm starts reducing
Phone	1	Used to take a video of the reaction that happens to write down more accurate data of what the ppm and other indoor conditions were at an exact time

Experimental Procedures

Completing CO_2 Sensor Experiment

1. Put safety goggles on to protect eyes and wear gloves on hands to prevent skin irritation.
2. Gather one airtight container for the main testing of the experiment. Make sure it is highly sealable and tight enough so it will not cause any leaks throughout the testing process. If there is any excess material in the jar, wipe it out.
3. Take the CO_2 sensor and stick it to the air-tight container. Position the sensor towards the top of the jar so that all labels and carbon capture materials are visible during the experiment. Rotate the jar so it can be seen in videos or photos that will be taken during the experiment.
4. Acquire a form of mounting putty. Smoothen them out to 4 small balls that are approximately ½ inch in diameter and apply each of the balls of mounting putty to all 4 corners of the CO_2 sensor (the mounting putty facing towards the screen of the CO_2 sensor).
5. Gather five specific carbon capture materials. These materials will be activated charcoal, Dracaena plant, Pothos houseplant, calcium hydroxide powder (eventually limewater), and the control for the experiment.
6. Take 2 slender small-sized glass tumblers. After this, get a permanent marker and write "Baking Soda + Vinegar" on a small sticky note (apply tape if necessary). Stick this onto one of the glass tumblers and repeat the same procedures for the other glass tumbler, writing "Control" instead (label will be changed depending on carbon capture material being used).
7. Get a measuring beaker and measure out 1 full ounce of white distilled vinegar. Pour this into the cup labeled "Baking Soda + Vinegar"
8. Place both slender tumblers into the air-tight jar, making sure that the baking soda and vinegar cup is on the left, and control is on the left. Check whether both glass cups are evenly placed inside the big container.
9. Use a measuring cup to measure 1 tablespoon of baking soda. Use a plastic spoon to even out the baking soda and make sure it is exactly one tablespoon. The baking soda and vinegar reaction is an approximate 2:1 ratio.
10. Get a stopwatch ready to time the experiment and take a video to see what happens at which exact time.
11. Gather an observational notebook and prepare it to take data for 5-minute intervals. Note down that the carbon dioxide sensor is plus or minus 50 ppm and any data between that range is one of the same. Additionally, write down initial observations including ppm, humidity, and temperature (in Celsius).
12. Pour the baking soda into the cup with the vinegar and quickly close the lid of the container, making sure that absolutely no carbon dioxide gets out of the jar. When doing this, start the timer and take the video as quickly as possible.
13. Take data for 5-minute intervals until the PPM returns to within 50 ppm of the initial amount. Write down the temperature, humidity, and PPM inside the jar every 5 minutes and make a graph. Record any other observations during the experiment.
14. Repeat steps 23-32 two more times for more accurate data points with the remaining different carbon capture materials and the different labels to match the material. The materials should be completed in a specific order (activated carbon, Pothos plant, Dracaena plant, then limewater solution). Use measurements from step 29 to help find the results for the experiment.
15. Measure out 1 tablespoon of activated charcoal and 2 tablespoons of limewater each time they are tested. The Pothos plant and the Dracaena plant both require 1 oz of water, and the Dracaena plant needs ¾ of the cup to be filled with soil. The plants additionally need to be properly trimmed with a stem for testing.
16. Find the percentage of time it took quicker than the control variable for each different carbon capture material tested. Find the average of all the times for each of the carbon capture materials and compare them with each other to find the results of which material reduced carbon dioxide the greater amount.

Creating Limewater for CO_2 Sensor Experiment

17. Gather a 1 medium-sized can. The limewater solution will be made here.
18. Take 2 tablespoons of calcium hydroxide powder from the powder packet and pour it into the mug.
19. Get 10 tablespoons of cold tap water and pour it on top of the calcium hydroxide powder to make the solution.
20. Shake the solution well and let it rest in a well-ventilated place for the next 24 hours to let the powder settle and create the true limewater on top of the powder.

Conclusion

The hypothesis was not supported, as limewater reduced CO_2 faster than the Dracaena plant, which was expected to be the most effective. The data demonstrated that limewater lowered CO_2 levels about 57.6% faster than the control, while the Dracaena plant only reduced CO_2 concentration by only about 35.7%. Pothos plants and activated carbon also lowered CO_2 at slower rates, and the control group maintained high CO_2 levels for approximately 25 minutes, until the CO_2 concentration started to decrease back to 400-450ppm. Limewater reacts directly with carbon dioxide, allowing rapid CO_2 removal, while plants rely on slower biological processes such as photosynthesis. These results demonstrate that chemical methods are more effective for quickly reducing CO_2, although biological methods like plants still contribute to lowering CO_2 concentration over time.