

Purifying Our Atmosphere

A Deep Dive into Chemical-Based
CO₂ Scrubbing Techniques

Ansika Zuri Hewapathirane

Age 10

Year 6

Strathcona Girls Grammar School

Submitted Date: 16 July 2024

INTRODUCTION

The survival of life on Earth requires improving our planet for all living beings and exploring other planets for future habitation.

Making Earth a Better Place for Living Things

Earth, our home, is a delicate ecosystem where every species plays an important role. Ensuring the survival of living things requires creating a balanced and healthy environment. This involves reducing pollution, conserving natural resources, and enhancing biodiversity. One of the pressing issues today is the increasing concentration of carbon dioxide (CO₂) in the atmosphere, which significantly contributes to global warming and climate change.

The Challenge of Carbon Dioxide

Carbon dioxide is a key problem because it is a greenhouse gas, trapping heat in the atmosphere and leading to global temperature rise. This warming effect disrupts natural ecosystems, causes extreme weather events, and threatens the survival of many species. Addressing CO₂ emissions is critical for mitigating climate change and preserving the planet's biodiversity.

AIM

The experiment aims to compare the effectiveness of different carbon scrubbing methods in reducing CO₂ levels.

Experiment Design:

- Independent Variable: Type of carbon scrubbing method used.
- Dependent Variable: Reduction in CO₂ levels measured over a 5min interval for 30 mins time.
- Controlled Variables: Initial CO₂ concentration, volume of the container, environmental conditions, duration of the experiment

HYPOTHESIS

Different carbon scrubbing methods, including Calcium Hydroxide, Activated Charcoal and Sodium Hydroxide Solution, will vary in their effectiveness at reducing CO₂ levels in a controlled environment. It is hypothesised that Sodium Hydroxide Solution will be the most effective at reducing CO₂ levels due to its strong chemical reactivity, followed by Calcium Hydroxide and Activated Charcoal.

MATERIALS

- **CO₂ Production:**

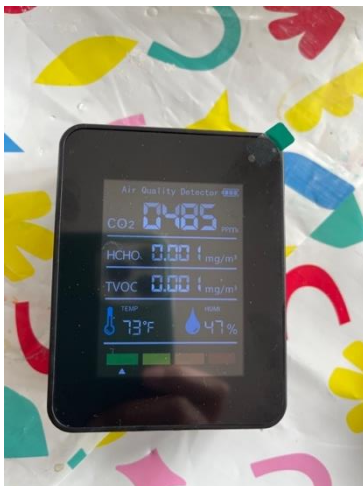
- Baking Soda (Sodium Bicarbonate)



- Vinegar (Acetic Acid)



- **CO₂ Sensor**



- **Airtight Containers**
- **Blu Tack**

- Plastic spoons
- Plastic cups
- Scrubbing Materials:

- Calcium Hydroxide (Limewater)



- Sodium Hydroxide Solution



- Activated Charcoal



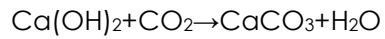
- Timer
- Notepad and Pen
- Safety Gear: Gloves and goggles



Why These Scrubbing Materials Were Selected:

1. Calcium Hydroxide (Limewater):

- Reacts with CO₂ to form calcium carbonate (CaCO₃) and water:



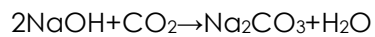
- Reason for Selection: Simple and effective chemical method to absorb CO₂, easy to prepare and handle.

2. Activated Charcoal:

- Adsorbs CO₂ molecules onto its porous surface.
- Reason for Selection: Commonly used in air and water purification, readily available and easy to use.

3. Sodium Hydroxide Solution:

- Reacts with CO₂ to form sodium carbonate (Na₂CO₃) and water:



- Reason for Selection: Strong base that efficiently absorbs CO₂, commonly used in industrial applications.

METHOD

Step 1: Setting Up the CO2 Sensor

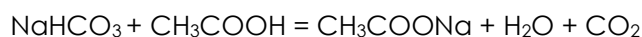
Calibrate the CO2 Sensor:

- Follow the manufacturer's instructions to calibrate the CO2 sensor.
- Ensure it is functioning properly before starting the experiment.

Step 2: Preparing the CO2 Source

CO2 Generation:

- Measure out 50 grams of baking soda and place it in a small container.
- Measure 100 millilitres of vinegar.
- Quickly add the vinegar to the container with baking soda inside the airtight jar.
- Immediately seal the jar to capture the CO₂ produced by the reaction:



- Wait for 5 minutes to allow CO₂ to fill the container.

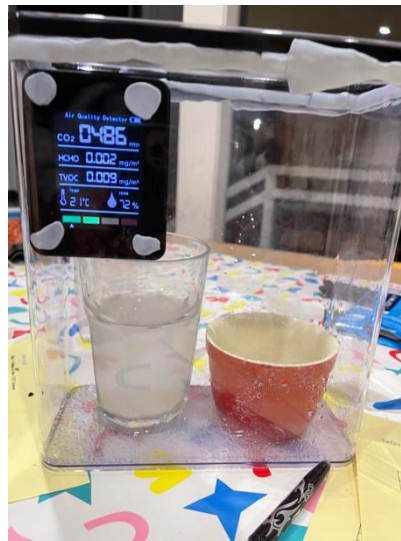
Step 3: Placing Scrubbing Materials

Prepare Scrubbing Materials:

- Calcium Hydroxide (Limewater): Fill a small container with limewater. 2g of Calcium Hydroxide mixed with 200ml water.



- Activated Charcoal: Measure a fixed amount of activated charcoal and place it in a small container.



- Sodium Hydroxide Solution: Prepare a sodium hydroxide solution and pour it into a small container. 4g Sodium Hydroxide mixed with 100ml water.



Place Scrubbing Material in the Container:

- Place the scrubbing material inside the airtight container with CO₂. Ensure it is done quickly to minimise CO₂ loss.

Step 4: Sealing the Container

Seal the Container:

- Immediately seal the jar after placing the scrubbing material inside to prevent CO₂ from escaping.
- Use blu tack to seal the lid.

Step 5: Monitoring and Recording Data

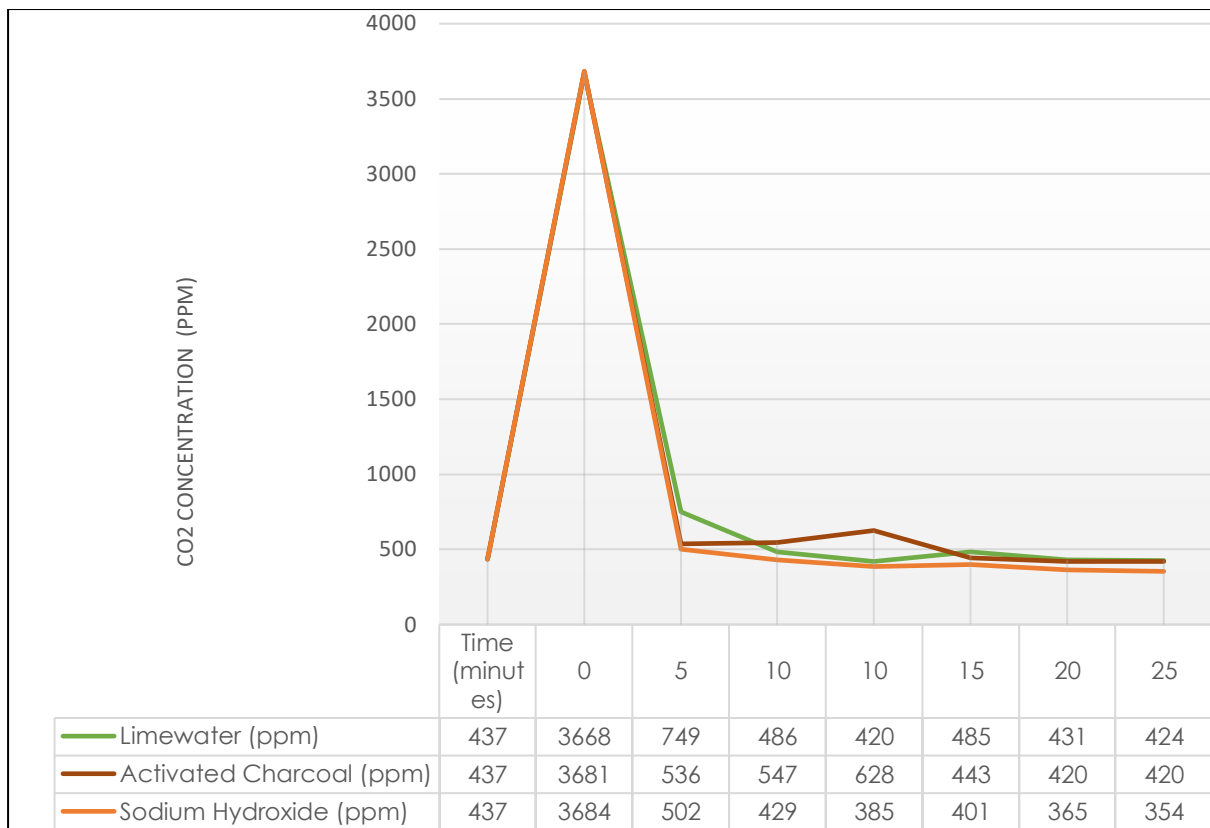
- **Start the Timer:**
 - Begin timing as soon as the container is sealed.
- **Monitor CO₂ Levels:**
 - Use the CO₂ sensor to monitor and record the CO₂ levels at regular intervals (e.g., every 5 minutes) for 30 minutes.
- **Record Observations:**
 - Note the initial CO₂ level and subsequent readings at each interval

Results

Baseline Carbon Dioxide concentration: 437 ppm

PPM stands for "parts per million." It is a unit of measurement used to express the concentration of carbon dioxide (CO₂) in the air.

Time (minutes)	Limewater (ppm)	Activated Charcoal (ppm)	Sodium Hydroxide (ppm)
0	437	437	437
5	3668	3681	3684
10	749	536	502
10	486	547	429
15	420	628	385
20	485	443	401
25	431	420	365
30	424	420	354



DISCUSSION

Initial CO₂ Concentrations

At the start (0 minutes), the CO₂ concentrations in the containers were nearly identical for all three scrubbing agents:

- Limewater: 3668 ppm
- Activated Charcoal: 3681 ppm
- Sodium Hydroxide: 3684 ppm

CO₂ Concentration Reduction Over Time

5 Minutes:

- **Limewater:** The concentration dropped significantly to 749 ppm, indicating a rapid initial reaction.
- **Activated Charcoal:** The concentration decreased to 536 ppm, showing a significant reduction but less dramatic than limewater.
- **Sodium Hydroxide:** The concentration dropped to 502 ppm, indicating a very effective initial absorption.

10 Minutes:

- **Limewater:** The concentration continued to decrease, reaching 486 ppm.
- **Activated Charcoal:** The concentration increased slightly to 547 ppm, suggesting possible re-release or slower absorption dynamics.
- **Sodium Hydroxide:** The concentration decreased further to 429 ppm, maintaining its effectiveness.

15 Minutes:

- **Limewater:** The concentration decreased slightly to 420 ppm.
- **Activated Charcoal:** The concentration increased to 628 ppm, indicating a possible release of previously adsorbed CO₂.
- **Sodium Hydroxide:** The concentration dropped significantly to 385 ppm, showing strong continued effectiveness.

20 Minutes:

- **Limewater:** The concentration increased slightly to 485 ppm, suggesting a potential re-release or equilibrium point.
- **Activated Charcoal:** The concentration decreased to 443 ppm, indicating resumed adsorption.
- **Sodium Hydroxide:** The concentration increased slightly to 401 ppm, suggesting a minor re-release or reduced absorption rate.

25 Minutes:

- **Limewater:** The concentration decreased to 431 ppm.
- **Activated Charcoal:** The concentration remained stable at 420 ppm.
- **Sodium Hydroxide:** The concentration decreased to 365 ppm, showing consistent performance.

30 Minutes:

- **Limewater:** The concentration slightly decreased to 424 ppm.
- **Activated Charcoal:** The concentration remained stable at 420 ppm.
- **Sodium Hydroxide:** The concentration decreased slightly to 354 ppm, indicating it continued to absorb CO₂ effectively.

Comparative Analysis

- **Sodium Hydroxide** proved to be the most effective carbon scrubber, consistently reducing CO₂ levels more than the other two agents. Its strong chemical reactivity makes it highly suitable for applications requiring efficient CO₂ absorption.
- **Activated Charcoal** showed potential but had issues with CO₂ re-release, making it less reliable for sustained CO₂ scrubbing.
- **Limewater** demonstrated good initial absorption but was less effective over time compared to sodium hydroxide.

Challenges With the Experiment Setup

Creating an airtight container proved to be the biggest challenge. After testing many containers, one that worked was finally found. Experiments were conducted with cling wrap, lids with rubber rims, and playdough, but the carbon dioxide continued to seep out. Finally, applying blu tack around the rim of the container as a sealant solved the issue.

Although the blu tack worked, it was not possible to validate whether there was still leakage. There is uncertainty about whether the initial drop in CO₂ concentration was due to seepage caused by the air pressure created by the reaction.

Further Improvements To The Experiment Setup

1. Better Sealing Techniques

- Use high-quality, laboratory-grade airtight containers designed for gas retention to ensure no CO₂ leakage.
- Consider using vacuum grease or specialised sealing compounds instead of blu tack for a more reliable seal.

2. Controlled Environment

- Conduct the experiment in a controlled environment where temperature, pressure, and humidity are monitored and kept constant to minimise their effects on the results.

3. Extended Monitoring

- Extend the monitoring period beyond 30 minutes to observe the long-term effectiveness of each carbon scrubbing method.
- Record data at more frequent intervals initially to capture rapid changes, then at longer intervals as the reaction stabilises.

Further Testing

- **Temperature Variations:**

- Conduct experiments at different temperatures to study the effect of temperature on the absorption capacity and rate of the scrubbing materials.

- **Pressure Variations:**

- Test the scrubbing efficiency under different pressures to simulate different environmental conditions, such as those found at different altitudes or in controlled environments like submarines or space habitats.

- **Humidity Effects:**

- Investigate the impact of different humidity levels on the effectiveness of CO₂ scrubbing materials, as moisture can influence the absorption process.

- **Other Scrubbing Materials:**

- Experiment with house plants such as Snake Plant (*Sansevieria trifasciata*), Spider Plant (*Chlorophytum comosum*), Peace Lily (*Spathiphyllum* spp.), Aloe Vera (*Aloe barbadensis miller*), etc to investigate which plants scrub CO₂ the best.

Industrial Applications:

- Limewater
 - Power Plants: To reduce CO₂ emissions from coal, oil, or natural gas power plants.
 - Cement and Steel Industries: Both industries produce significant CO₂ emissions and can integrate limewater scrubbing in their exhaust treatment systems.
 - Waste Burning Plants: To capture CO₂ emissions from waste combustion processes.
- Activated Charcoal
 - Air Purification Systems: In buildings and industrial facilities to improve indoor air quality by removing CO₂ and other pollutants.
 - Carbon Capture and Storage (CCS) Systems: Activated charcoal can be used in conjunction with other technologies to capture and store CO₂ from industrial emissions.
- Sodium Hydroxide
 - Chemical Manufacturing: Sodium hydroxide scrubbing can be used in chemical production processes that emit CO₂.
 - Refineries: To scrub CO₂ from refinery gases and improve the purity of hydrogen production.
 - Carbon Capture and Utilisation (CCU): Captured CO₂ can be converted into valuable products like sodium bicarbonate, further used in various industries.

CONCLUSION

The hypothesis that sodium hydroxide would be the most effective at reducing CO₂ levels was confirmed, with the solution absorbing CO₂ down to 354 ppm. Activated charcoal proved less reliable due to re-release issues, and limewater, while initially effective, was less so over time compared to sodium hydroxide.

This experiment provides valuable insights into effective carbon scrubbing methods, contributing to efforts to reduce CO₂ emissions and enhance environmental sustainability. Future experiments should focus on improving sealing techniques, controlling environmental variables, and exploring a wider range of scrubbing materials to develop even more effective CO₂ capture methods.

Acknowledgements

- I am grateful for my mum's assistance in taking photos and videos, and for helping me format my report.
- I would like to thank my dad for helping me with proofreading and for assisting me in finding my materials from Bunnings, Kmart, and Coles.

References

Reports:

- Intergovernmental Panel on Climate Change (IPCC) (2018) Global Warming of 1.5°C. Available at: <https://www.ipcc.ch/sr15/> (Accessed: 12 July 2024).

Websites:

- Climeworks (2024) Our Technology. Available at: <https://www.climeworks.com/our-technology> (Accessed: 12 July 2024).
- Carbon Engineering (2024) Direct Air Capture. Available at: <https://carbonengineering.com/our-technology/direct-air-capture/> (Accessed: 12 July 2024).
- Shell (2024) Quest Carbon Capture and Storage. Available at: https://www.shell.ca/en_ca/about-us/projects-and-sites/quest-carbon-capture-and-storage-project.html (Accessed: 12 July 2024).
- Boundary Dam Carbon Capture Project (2024) SaskPower. Available at: <https://www.saskpower.com/our-power-future/infrastructure-projects/carbon-capture-and-storage/boundary-dam-carbon-capture-project> (Accessed: 12 July 2024).
- Algenol (2024) Algae Technology. Available at: <https://www.algenol.com/algae-technology> (Accessed: 12 July 2024).
- CarbonCure Technologies (2024) How It Works. Available at: <https://www.carboncure.com/how-it-works/> (Accessed: 12 July 2024).
- Project Vesta (2024) Coastal Enhanced Weathering. Available at: <https://www.projectvesta.org/our-solution> (Accessed: 12 July 2024).
- Sleipner CO₂ Storage Project (2024) Equinor. Available at: <https://www.equinor.com/energy/sleipner> (Accessed: 12 July 2024).
- Gorgon Carbon Dioxide Injection Project (2024) Chevron. Available at: <https://australia.chevron.com/our-businesses/gorgon> (Accessed: 12 July 2024).

SAFETY REQUIREMENTS

Name of Entry: Investigating Carbon dioxide scrubbing methods

Student Name: Ansika Zuri Hewapathirane

Signature:

Date: 15 July 2024

Type of Risk	Hazard (Material, Equipment, Procedure)	Level of Risk	Precaution Taken to Control Risk	Source of Information
Chemical	Baking Soda (Sodium Bicarbonate)	Low	Wear gloves and goggles to avoid skin and eye contact	https://shop.chemsupply.com.au/documents/SL0011CH6E.pdf
Chemical	Vinegar (Acetic Acid)	Medium	Use gloves and goggles to prevent skin and eye irritation; work in a well-ventilated area	https://shop.chemsupply.com.au/documents/AA0091CH0J.pdf
Equipment	CO ₂ Sensor	Low	Follow manufacturer's instructions for calibration and use	Manufacturer's Manual
Chemical	Calcium Hydroxide (Limewater)	Medium	Wear gloves and goggles to avoid skin and eye irritation; handle carefully	https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory/documents/sds/chemicals-chemicals-c/S25225.pdf
Chemical	Activated Charcoal	Low	Avoid inhalation of dust; use gloves when handling; wear safety goggles	https://www.pharmachem.com.au/wp-content/uploads/2023/10/Activated-Charcoal-Pharmachem-SDS-Revised-

				October-2023.pdf
Chemical	Sodium Hydroxide Solution	High	Use gloves, goggles, and a lab coat to avoid severe skin and eye burns; work in a well-ventilated area	https://www.chemsupply.com.au/uploads/sds/2137.pdf
Procedure	Mixing Vinegar and Baking Soda	Medium	Add vinegar to baking soda carefully to prevent splashes; seal container immediately	Standard Laboratory Practice
Procedure	Monitoring CO ₂ Levels	Low	Use CO ₂ sensor according to instructions; avoid unnecessary movements	Manufacturer's Manual