Project Proposal

Project Title: CO2 Filtration Device for Automobile Exhausts

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Date: 10/6/2025

Project Description:

Transportation is one of the largest contributors to atmospheric Carbon Dioxide (CO_2), a primary greenhouse gas responsible for global warming. Existing car exhaust systems release CO_2 directly into the atmosphere without mitigation. The engineering goal of this project is to develop a compact, low-cost exhaust-mounted filtration device capable of chemically scrubbing CO_2 before it exits the tailpipe. The proposed system uses Sodium Hydroxide (NaOH) as a reactive scrubbing agent, which converts CO_2 into Sodium Carbonate (Na_2CO_3) and water through a process known as chemical scrubbing (House et al., 2011).

Laboratory testing using an impinger demonstrated that NaOH can remove approximately 75% of CO_2 within one minute under controlled conditions, making it a strong candidate for real-world exhaust filtration. The device will be designed to attach universally to circular and rectangular exhaust pipes, allowing scalability and broad accessibility. The ultimate objective is to validate whether CO_2 scrubbing can be achieved on-vehicle and to determine the viability, efficiency, and limitations of NaOH-based filtration under real exhaust conditions.

Background:

Engineering Need:

Cars release significant amounts of CO_2 directly into the atmosphere. While catalytic converters reduce toxic pollutants like NOx and CO, they do not remove CO_2. There is currently no consumer-level technology that directly captures or removes CO_2 at the point of emission. As climate change intensifies, the need for accessible, low-cost carbon mitigation technologies increases dramatically. A car-mounted filter could reduce personal CO_2 output and provide an immediate, user-level method of combating greenhouse gas emissions.

Engineering Objective:

The engineering objective is to design and prototype a chemical-scrubbing exhaust attachment that uses NaOH-based filtration material to remove CO_2 from car exhaust streams. The system must maintain airflow, resist exhaust temperatures, allow gas–chemical contact, and be replaceable once the NaOH becomes saturated. Prototype effectiveness will be measured by analyzing CO_2 concentrations before and after filtration during both controlled and real-world driving tests.

Context:

Transportation accounts for a major percentage of global CO_2 emissions due to combustion of fossil fuels in conventional engines (EPA, 2023). CO_2 traps heat in the atmosphere, intensifying global warming and accelerating climate-driven disasters such as flooding, ice melt, and sea-level rise (IPCC, 2021). Unlike pollutants such as carbon monoxide or unburned hydrocarbons, CO_2 is not removed by catalytic converters because it is a stable byproduct of complete combustion. As internal combustion engines continue to be widely used, small-scale carbon-capture innovations could help bridge the gap until cleaner technologies fully replace fossil-fuel vehicles.

Capturing the CO2

CO_2 can be removed from air streams using physical adsorption, membrane separation, or chemical absorption. Chemical absorption using alkaline solutions—particularly Sodium Hydroxide—is among the most effective small-scale methods due to NaOH's fast reaction rate with CO_2 (Stern et al., 2012).

In this project, an impinger was used to test various candidate chemicals for CO_2 capture. The impinger allowed CO_2-containing gas to be pushed through each chemical while outgoing CO_2 levels were measured. NaOH demonstrated the highest capture efficiency, removing ~75% of CO_2 in under one minute, confirming its suitability for exhaust scrubbing.

The primary chemical reaction is:

$$\mathbf{2\,NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O}$$

As NaOH reacts, it gradually converts to Sodium Carbonate. Once fully converted, the scrubbing medium becomes saturated and must be replaced.

Using the Filter Material:

The proposed filter will consist of a porous, high-surface-area matrix coated with NaOH. Exhaust gas will pass through this matrix, maximizing contact between CO_2 molecules and the reactive chemical.

This "chemical scrubbing" method differs from physical filtration because the CO_2 is not trapped but chemically transformed into a solid salt. This allows high efficiency in a compact space, which is essential for a device mounted on a vehicle tailpipe.

However, NaOH can only remove CO_2 until it is fully reacted, so periodic replacement of the filter cartridge will be necessary. Future research may explore alternative reagents, regenerable absorbents, or greater surface-area materials to prolong operational lifespan.

Purpose and Specifics:

This project aims to create a consumer-accessible, low-cost car exhaust device that reduces CO_2 emissions at the source. There are two main purposes:

1. Demonstrate that significant CO_2 scrubbing is feasible at small scale.
2. Develop a prototype that can attach to different exhaust shapes and withstand real exhaust conditions.

Two main designs will be developed:

- A circular exhaust-compatible device
- A rectangular exhaust-compatible device

Both will house NaOH-based filters and will be attached via clamps or bolt-on mechanisms. After design and fabrication, the device will be tested by running a vehicle for 15 minutes while measuring differences in CO_2 output before and after filtration.

This project fills a current gap in personal-scale carbon capture technologies by offering a potentially inexpensive, immediately deployable solution for individual emitters.

Experimental Design/Research Plan Goals:

Major Parts of the Project (rough outline) will continue to evolve over time and should be updated frequently. Make sure the goals are SMART-oriented.

Rough initial outline:

1. **Research CO2 filtration methods and technologies**
2. **Develop Experiment/Testing methods**
3. **Acquire Materials**
4. **Build Prototype**
5. **Test Prototype**
6. **Analyze Data**
7. **Create a Conclusion or Presentation**

IDV (Independent Variable):

- Type of NaOH filter design
- Amount of NaOH coating / packing density

DV (Dependent Variable):

- CO_2 concentration in exhaust before vs. after filtration
- Duration until filter saturation

Standardized Variables / Controls:

- Car used for testing
- Exhaust temperature
- CO_2 measurement equipment
- Duration of test drive (15 minutes)
- Vehicle operating conditions

Control Group:

- Normal exhaust CO_2 concentration without any filter device

Materials List

- Sodium Hydroxide (NaOH) pellets or solution
- Porous filter matrix (ceramic, metal foam, or mesh)
- Exhaust-mountable metal housing (cylindrical and rectangular)
- CO_2 gas detector / analyzer
- Impinger testing apparatus
- Air pump / CO_2 calibration gas
- Stainless steel clamps and mounting hardware
- Heat-resistant gloves
- Safety goggles
- Lab Coat
- Mask
- Lab glassware and tubing
- Protective coating or heat shielding for external housing

Procedure

1. **Prepare CO_2 scrubbing materials**
    a. Coat or pack porous matrix with NaOH.
    b. Allow to dry/cure if necessary.
2. **Laboratory testing using impinger**
    a. Pump controlled CO_2 mixture through chemical samples.
    b. Measure CO_2 concentration before and after exposure.
    c. Select the highest-efficiency chemical.
3. **Prototype design and assembly**
    a. Construct heat-resistant housings sized for common exhaust shapes.
    b. Load NaOH filter matrix inside housing.
    c. Install seals to prevent leakage.
4. **Attach device to car exhaust**
    a. Mount securely using clamps.
    b. Ensure airflow is not blocked.
5. **Run real-world test**
    a. Operate the vehicle for 15 minutes.
        i. The engine will be running, but the car will be idling
    b. Use CO_2 analyzer to measure before/after concentration.
        i. Remove device to get concentration level without filtration, then re-attach device to measure concentration level with filtration over the span of 15 minutes.
6. **Collect and analyze data**
    a. Compare scrubbing efficiency to lab results.
    b. Assess saturation time and filter lifespan.

Risk/Safety Concerns:

Caustic Material:
NaOH is highly caustic and can cause chemical burns. Gloves and goggles are mandatory. (OSHA, 2022)

High Exhaust Temperatures:
Exhaust gases may exceed 400°C. Components must be heat-resistant; handling requires protective equipment.

Pressure and Backflow:
Improper design could restrict airflow, so pressure monitoring during testing is crucial.

Chemical Saturation:
Once NaOH becomes Sodium Carbonate, CO_2 capture stops. Used filters must be disposed of appropriately.

Real World Testing:
Due to the chemical dangers of NaOH as well as the possibility of other toxic chemicals, heat-resistant protective gear such as goggles, gloves, lab coats and masks will be worn during testing.

Data Analysis:

Analysis will determine real-world scrubbing efficiency compared to laboratory values and evaluate whether NaOH remains effective under high-temperature, high-flow exhaust conditions.

Data will include:

- CO_2 concentration (ppm) before filtration
- CO_2 concentration after filtration
- % removal efficiency
- Time until filter saturation

Graphs will relate:

- CO_2 removal vs. time
- Filter saturation rate

Potential Roadblocks:

NaOH saturation occurs too quickly:

- Explore higher-surface-area matrices or increased chemical loading.

Excess exhaust heat degrades chemical effectiveness:

- Add thermal shielding or pre-cooling passive elements.

Airflow becomes restricted:

- Redesign housing to reduce pressure drop.

CO_2 capture is lower than in lab conditions:

- Modify internal geometry to improve gas–chemical contact.

Device does not fit all car exhausts:

- Introduce adjustable mounting mechanisms.

References: (In APA Format with in-text citations):

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Timeline: (with action steps identified- sub-deadlines will continue to evolve):

Rough timeline of major phases. As these phases get established, specific tasks under these phases will be defined further.

August	September	October	November	December	January
Completed some of the General Research	September 21th: Complete Carbon Capture Research	October 4: Start collecting Preliminary data Also check for feasibility	November 1: Look into gathering materials	December 1: Finalize and Analyze Data	January: After fair, evaluate necessary changes
	September 28th: Complete all general research (can research more later if needed)	October 18: Develop Experiment/Testing Methods Also check for feasibility.	November 10th: Begin constructing & testing prototype	December 8: Create conclusion/ presentation	Possibly do more research
		October (whole): Do More research where applicable	November 20: Begin collecting official data.	Rest of December: Make changes and edits where applicable	