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Mini Carbon Dioxide Capture System Design

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Abstract

This study aims to draw attention to the increasing amount of carbon dioxide in the atmosphere due to growing environmental problems and climate change, and to experimentally demonstrate the capture of this gas with a simple device. To this end, a portable mini carbon dioxide capture system was designed using a mini USB fan, a hose, and a soda ash (sodium carbonate) solution. Ambient air was directed into the solution with the help of the fan; pH, mass, and temperature measurements were taken throughout the process to evaluate the system's effectiveness. After approximately 30 minutes of experimentation, a decrease in the pH of the solution, an increase in its mass, and a slight decrease in its temperature were observed. These findings indicate that carbon dioxide in the air is captured by the soda ash solution and that a chemical interaction occurs. The study demonstrates that the idea of carbon capture can be concretized in educational settings with a low-cost and easily applicable device. Our experiment, prepared as a small-scale design, can be used by developing it into larger projects capable of reducing the amount of carbon dioxide in the air. This project is important in terms of raising awareness about environmental pollution and climate change and providing a foundation for larger systems that can be developed in the future.

Living organisms need clean air—that is, plenty of oxygen—to survive. When examining potential future challenges facing our planet, it becomes evident that numerous studies highlight environmental issues such as air, water, and soil pollution, climate change, ecosystem degradation, and loss of biodiversity. Upon analyzing these issues, we can conclude that oxygen imbalance emerges as a common underlying cause. In this study, guided by this idea, we aimed to identify the regions where elevated levels of carbon dioxide in the air—a result of environmental issues—might occur, and to develop measures to reduce these levels.

In the world we live in, many human-induced factors—such as a growing population, industrial activities, and the decline of green spaces—contribute to environmental pollution. This pollution leads to a decrease in the amount of oxygen necessary for living organisms to survive and an increase in carbon dioxide levels. Factors such as climate change and global warming are negatively affecting photosynthetic species and causing their numbers to decline day by day. Without plants, the reduction in atmospheric carbon dioxide levels through photosynthesis will slow down, putting all living things at risk.

Carbon dioxide is a gas produced by the use of fossil fuels, transportation, industrial activities, and the loss of green spaces. The increase in its concentration in the atmosphere is causing global warming. Carbon dioxide is a greenhouse gas. Global warming is also a cause of potential adverse conditions on Earth. Therefore, reducing the amount of carbon dioxide in the atmosphere would be the most beneficial action we can take for the environment.

In their 2009 study, Akbostancı Özkazanç, Tunç, and Gül discuss how climate change results from an increase in greenhouse gases and note that the rise in carbon dioxide levels is the most significant factor among these.

In their 2005 study titled "Modeling the Distribution of CO_2 Concentrations and an Emissions Inventory Across Turkey," Can, Atimtay, and Tokdemir observed that carbon dioxide emission levels in the air were particularly high in the Aegean and Marmara regions due to their status as industrial areas.

In their study, Doğruparmak, Demirarslan, and Çavuşoğlu (2025) observed that as traffic density increases, so does the amount of carbon dioxide in the air.

There are numerous studies in Turkey and around the world on the increase in atmospheric carbon dioxide levels and its causes. The sheer number of these studies underscores the importance of the issue.

According to the information we have, there are many countries around the world working to reduce carbon dioxide in the atmosphere. A Swiss-based center generates revenue by capturing carbon dioxide from the atmosphere and storing it underground after mineralizing it. Another Canada-based company, meanwhile, generates revenue by capturing carbon dioxide from the atmosphere and converting it into synthetic fuel. Capturing carbon dioxide—a greenhouse gas present in the atmosphere—and utilizing it for various purposes also benefits the environment. However, no information has been found regarding any companies or organizations in our country conducting similar work. For this reason, the work we will undertake is also valuable for our country.

In our project, we built a portable device that removes carbon dioxide from the air. The materials we used and the steps we followed are as follows (Figure 1-5):

Materials used:

- Mini USB fan
- Plastic box (transparent)
- Thin tubing
- 2-liter glass jar
- Soda ash solution
- pH paper
- Small precision scale
- Thermometer
- Syringe

Instructions:

1. We placed a mini fan inside a clear plastic box to draw outside air into the box.

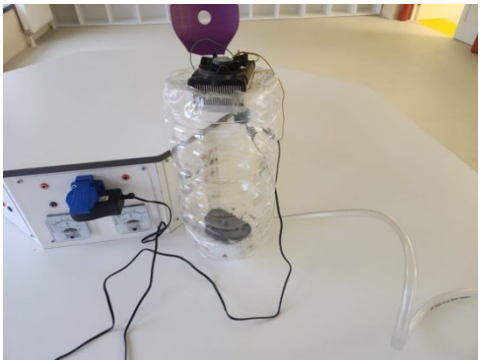

Figure 1. A mini fan inside a clear plastic box

2. We prepared a solution of soda ash in a jar. To capture the carbon dioxide-containing portion of the air, we used the soda ash solution (sodium carbonate), which we can call a carbon dioxide trap.

3. We placed a hose between the fan and the jar, connecting one end to the box where air enters and the other end to the jar filled with the solution.

Figure 2. A hose between the fan and the jar

4. The air drawn in was directed into the solution via a hose, and the solution absorbed the carbon dioxide. During this process, we took measurements using a pH meter. This is because soda ash is actually a substance with basic properties, and when it absorbs carbon dioxide, its basicity decreases. This, in turn, causes a color change on the pH indicator paper.

Figure 3. The solution absorbed the carbon dioxide

5. We also measured the mass of the soda ash solution at the beginning and end of the experiment. This is because if carbon dioxide is absorbed, the mass will increase.

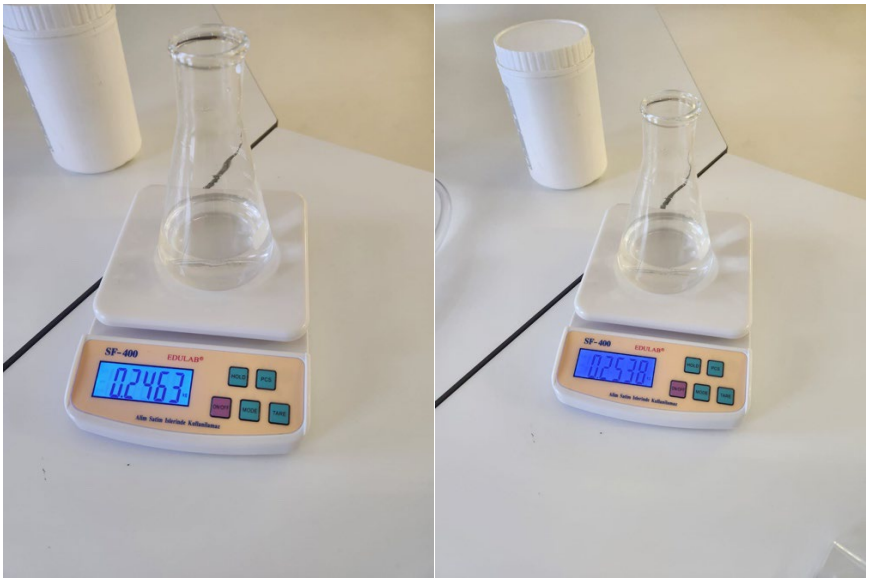

Figure 4. Measurement of the mass of the soda ash solution

6. We took temperature readings at the beginning and end of the experiment with the soda ash solution using a thermometer. This is because a reaction between the soda ash and carbon dioxide causes the temperature to drop. (The initial excess mass was due to the thermometer that was placed in the solution.)

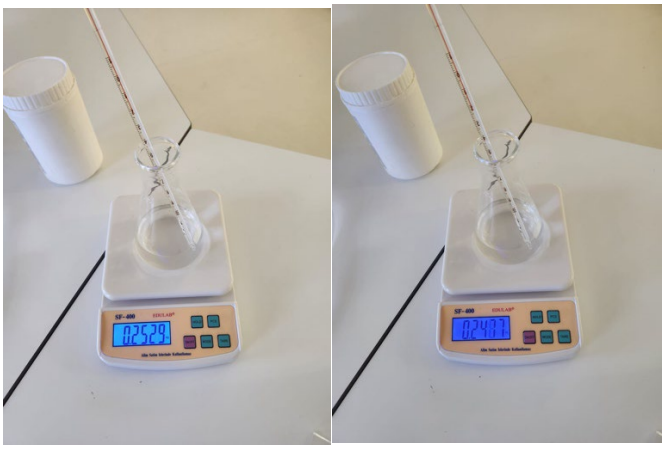

Figure 5. The syringe in the experiment.

In the experimental setup, ambient air was directed into the soda ash solution via a hose using a mini fan. At the end of the approximately 30-minute experiment, the following observations were made:

- pH measurements: A decrease in the pH value of the soda ash solution, which exhibited basic properties at the start of the experiment, was observed. This indicates that carbon dioxide gas passed into the solution and that a reaction had begun.
- Mass measurements: Measurements taken before and after the experiment revealed an increase in the mass of the solution. This increase supports the conclusion that the carbon dioxide in the air was absorbed by the soda ash solution.
- Temperature measurements: Measurements taken with a thermometer showed a slight decrease in temperature at the end of the experiment. This indicates an energy change resulting from the interaction that occurs during the dissolution of carbon dioxide.

These findings demonstrate that the system we developed is capable of capturing carbon dioxide from the air and that this process can be monitored using measurement instruments. We conducted this study as a simple experiment, and our goal is to contribute to reducing environmental pollution by installing the system on a weather balloon or drone to lower carbon dioxide levels in the air, particularly in industrial areas.

In this study, an experimental design was developed to demonstrate that carbon dioxide in the air can be captured using a simple, low-cost setup with a soda ash solution. By evaluating the decrease in pH, the increase in mass, and the change in temperature together, it was concluded that carbon dioxide is captured within the solution. Although our study was conducted under laboratory conditions and on a small scale, it draws attention to environmental issues and raises awareness among students.

In our study, experiments could be conducted using other carbon dioxide scrubbers instead of soda ash. A more powerful fan system could be used to increase the volume of air drawn in, thereby improving air purification. Our study could be tested in industrial areas. The prototype we aim to develop could be integrated into balloons, drones, or fixed air stations, enabling its application in real-world settings.

Keywords
Carbon dioxide, environmental pollution, carbon capture, climate change, soda ash

Biographies
Alp Faik Kavak is a 5th grade student at Özel Çankaya Beştepe Koleji Middle School. He has participated in TÜBİTAK project competitions, shows a broad interest in scientific research and project development, and aims to develop his scientific thinking and problem-solving skills by actively participating in detailed research and academic activities.

Uğur Poyraz Dalkılıç is a 5th grade student at Özel Çankaya Beştepe College Middle School. He has participated in TÜBİTAK project competitions. He is interested in science lessons and scientific research processes. He is eager to conduct research and aims to develop his scientific thinking and problem-solving skills by actively participating in academic activities.