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Investigation of The Effects of Carbon Dioxide from Paper Combustion on Temperature Changes

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ABSTRACT

This study explores the relationship between carbon dioxide (CO_2) concentration from paper combustion and temperature changes using a greenhouse effect simulation. Two desiccators were used: desiccator A with an LED lamp as an additional heat source, and desiccator B without an external heat source. The results showed that an increase in CO_2 in desiccator A significantly raised the temperature, demonstrating CO_2's role in heat retention. However, in desiccator B, a temperature drop occurred due to the endothermic effects of paper combustion and water evaporation. These findings highlight the importance of external energy sources in manifesting the greenhouse effect and explain the complexity of the thermodynamic processes involved. This study contributes to a deeper understanding of CO_2-induced temperature changes and its relevance to global warming. The experiment can be used as an effective educational tool to introduce students to the greenhouse effect concept.

Introduction

The climate change crisis has become a significant issue in the modern era and is increasingly gaining attention from the international community (Phelia et al., 2021). Its impact has been felt globally, from rising temperatures, changing weather patterns, to an increase in natural disasters. In this context, understanding greenhouse gases, particularly carbon dioxide (CO_2), is crucial. Carbon dioxide (CO_2) emissions from the combustion of fossil fuels, deforestation, and industrial processes have become one of the main factors in global climate change, including the increase in Earth's average temperature (Laubereau & Iglev, 2013).

Ideally, greenhouse gases play an important role in maintaining the Earth's temperature balance by absorbing and emitting radiation within the thermal infrared range (Houghton, 2004). The greenhouse effect is a natural phenomenon that occurs when some of the sun's radiation is trapped in the Earth's atmosphere by greenhouse gases, which then increases the Earth's temperature (Mitchell, 1989). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other gases. This phenomenon is named as such because the process is similar to what happens in a greenhouse, where heat from the sun is trapped, keeping the temperature inside warm (Kweku et al., 2018).

However, human activities have led to an increase in greenhouse gas concentrations in the atmosphere, primarily due to the combustion of fossil fuels such as coal, oil, and gas, as well as deforestation (Mooney, et al., 1991). The addition of these greenhouse gases traps more heat in the atmosphere, which in turn causes an increase in global average temperatures, a phenomenon known as global warming (D'Amato &

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Akdis, 2020). Global warming has various impacts on the Earth's climate and ecosystems, including increased frequency and intensity of extreme weather events, rising sea levels due to polar ice melting, and changes in rainfall and temperature patterns that can affect agriculture and other ecosystems (Jain, 1993).

Although the theoretical understanding of the greenhouse effect has developed, there is still a gap between students' knowledge and direct experience in this field (Ratinen, 2013). Observations show that practical experiments involving the effects of CO_2 on temperature in classrooms are still limited. Previous studies, such as those conducted by Lueddecke et al., showed that increased CO_2 concentrations could cause significant temperature increases, but practical implementation at the educational level remains minimal. Another study by Laubereau conducted a detailed study of the infrared properties of carbon dioxide to estimate its contribution to global warming. The results of the study indicated that CO_2 plays a role in increasing Earth's temperature. Additionally, research conducted by Coe et al., found that CO_2, H_2O, and CH_4 gases affect temperature changes on Earth. A literature review of previous research indicates that carbon dioxide concentration significantly impacts temperature. However, this research aims to build on these findings by investigating this relationship in more detail. Thus, this research not only deepens our understanding of the greenhouse effect but also opens opportunities for further research.

This research aims to bridge the gap by introducing an experiment using desiccators to simulate the greenhouse effect. By burning paper to increase CO_2 concentrations and observing the resulting temperature changes, students can gain hands-on experience in understanding the greenhouse effect. This research aligns with the Merdeka Belajar Curriculum, which emphasizes experiential learning and the development of 21st-century skills, such as critical thinking and problem-solving (Baharuddin, 2021).

This experiment is designed to investigate how changes in CO_2 concentration from paper combustion in a desiccator affect temperature. The research question to be answered is whether an increase in CO_2 concentration will cause an increase in temperature, and to what extent temperature changes occur as CO_2 concentration changes. This research is important as it can provide a better understanding of the relationship between carbon dioxide and global temperature, as well as open opportunities for further research.

Methods

This research methodology includes design, processing, and testing to investigate the effect of carbon dioxide generated from paper combustion on temperature change. The research was designed to simulate conditions relevant to the greenhouse effect.

Designing

This experimental design uses two desiccators to test the effect of carbon dioxide on temperature changes in a greenhouse effect simulation. In Figure 1, Desiccator A is shown, where a heat lamp is used as an additional heat source. Inside, there is a digital thermometer that monitors the temperature in real-time during the experiment. The heat lamp serves to increase the temperature inside the desiccator, mimicking the conditions that occur due to an increase in carbon dioxide.

Figure 1
Desiccator A, where a heat lamp is used as an additional heat source.

Meanwhile, in Figure 2, Desiccator B is used without a heat lamp. It relies solely on the heat from burning the paper placed inside, and is also equipped with a digital thermometer to record the temperature during the test. The remains of the burnt paper are visible at the bottom of the desiccator, which is the source of carbon dioxide in this experiment.

Processing

After the design phase, the next step is to conduct the experiment using desiccators to test the effect of carbon dioxide on temperature. The experiment was carried out by placing paper inside the desiccator and burning it to produce carbon dioxide gas. In Desiccator A, an additional heat source in the form of a heating lamp was used to warm the interior, while Desiccator B did not use any additional heat source. A digital thermometer placed inside both desiccators automatically recorded the temperature every minute for 5 minutes after the burning process.

Figure 2
Desiccator B is used without a heat lamp.

As for the tools and materials needed can be seen in Table 1.

Table 1
Tools and Materials

Tools and Materials	Amount
Desiccator non-vacuum	1
Thermocouple TM-902C	1
Stopwatch	1
200 watt IP66 LED light	1
Solar power meter SM206	1
Lighter	1
Documentation tools	1
A4 size HVS paper	10
Petroleum jelly	in taste

Testing

The experiment using desiccators was conducted to test the impact of carbon dioxide on temperature changes. The testing process aimed to determine how effectively the digital thermometer recorded temperature variations in response to carbon dioxide generated from burning paper. This testing stage was crucial to understand the influence of different amounts of paper burned on the temperature inside the desiccators.

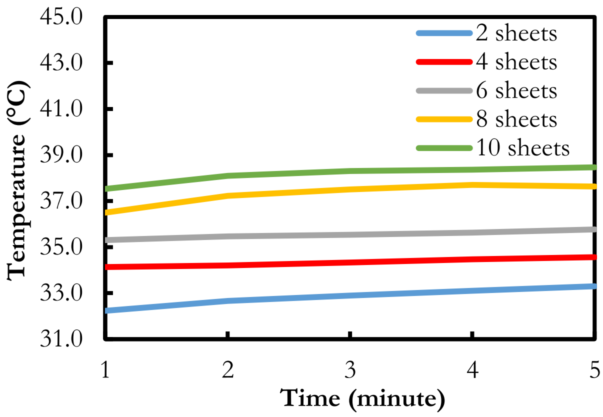
During the testing phase, various quantities of paper (ranging from 2 to 10 sheets) were burned in each desiccator to observe how the temperature reacted. Additionally, the experiments were performed in two distinct setups: Desiccator A, which utilized an external heat source from a heating lamp, and Desiccator B, which relied solely on the heat generated by the burning paper.

To enhance the reliability of the results, each experiment was repeated multiple times under controlled conditions. This allowed for a comprehensive analysis of how different quantities of carbon dioxide affected the temperature within a closed environment, providing valuable insights into the relationship between gas concentration and thermal response.

Result and Discussions

This experiment was designed to investigate the relationship between carbon dioxide (CO_2) production from paper combustion and temperature changes, using two different setups: Desiccator A equipped with a 200-watt IP66 LED lamp (with a measured light intensity of 8.4 W/m²), and Desiccator B without additional illumination. This dual setup allowed for a comparative analysis of the greenhouse effect in controlled environments.

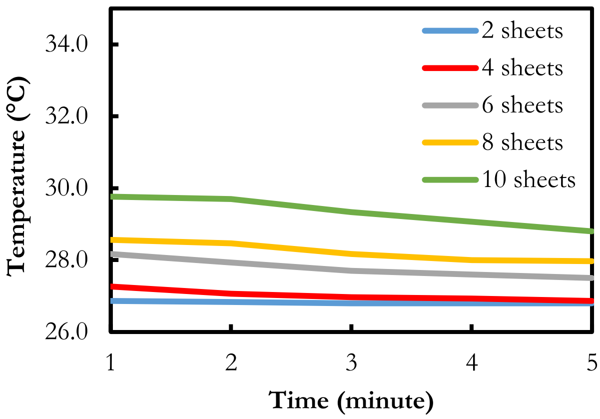
Figure 3
Graph of Desiccator A.



In Desiccator A, a clear and consistent pattern of temperature increase was observed across all quantities of paper tested. Figure 3 shows the diagram of the measurement results in Desiccator A. The experiment began with 2 sheets of paper, which raised the temperature from 32.2°C to 33.3°C over a five-minute period. As the quantity of paper increased, so did the magnitude of the temperature change. With 4 sheets, the temperature rose from 34.1°C to 34.6°C; 6 sheets saw an increase from 35.3°C to 35.8°C; 8 sheets raised the temperature from 36.5°C to 37.6°C; and finally, 10 sheets caused the most significant rise, from 37.5°C to 38.5°C. This progressive increase in both initial and final temperatures with each increment of paper quantity suggests a cumulative effect of CO_2 production and heat retention within the closed system.

The observed temperature rise in Desiccator A aligns with the fundamental principles of the greenhouse effect. As paper burns, it releases CO_2, which, like other greenhouse gases, has the capacity to absorb and re-emit infrared radiation. In the presence of the LED lamp, which simulates solar radiation, the CO_2 molecules absorb the infrared energy emitted by the desiccator's surfaces and re-radiate it in all directions. This process effectively traps heat within the system, leading to the observed temperature increases. The amplification of this effect with increasing paper quantities corresponds to higher CO_2 concentrations, mirroring on a micro-scale the enhanced greenhouse effect observed in Earth's atmosphere due to increasing anthropogenic CO_2 emissions (Laubereau & Iglev, 2013).

Figure 4
Graph of Desiccator B.



In contrast, Desiccator B exhibited unexpected and seemingly paradoxical results. Across all quantities of paper, a consistent decrease in temperature was recorded. Figure 4 shows the diagram of the measurement results in Desiccator B. With 2 sheets, the temperature dropped slightly from 26.9°C to 26.8°C. The effect became more pronounced with increasing quantities of paper: 4 sheets saw a decrease from 27.3°C to 26.9°C; 6 sheets from 28.2°C to 27.5°C; 8 sheets from 28.6°C to 28.0°C; and 10 sheets exhibited the most significant cooling, from 29.8°C to 28.8°C. This cooling trend, occurring in the absence of an external heat source, reveals the complexity of thermodynamic processes at play during combustion in a closed system.

The counterintuitive cooling observed in Desiccator B can be attributed to a combination of several simultaneous thermodynamic processes. Firstly, the initial stages of combustion involve endothermic reactions. The breaking of chemical bonds in the paper structure requires energy input. This energy is absorbed from the surrounding environment, resulting in a localized cooling effect (Atkins & de Paula, 2014). Secondly, the combustion of paper produces water vapor alongside CO_2. The phase change of water from liquid to vapor is an endothermic process that absorbs significant amounts of heat from the surroundings, contributing to the observed cooling. This evaporative cooling effect can be substantial, especially in a closed system where the water vapor remains trapped (Incropera et al., 2007). Thirdly, the combustion process creates temperature gradients and pressure differences within the desiccator. These differences can induce micro-scale air currents. These currents can lead to convective heat transfer, potentially causing uneven heat distribution and localized cooling at the point of temperature measurement (Çengel & Boles, 2023).

The stark contrast between the results of Desiccators A and B underscores the critical role of an external energy source in manifesting the greenhouse effect. In Desiccator A, the LED lamp provides a constant input of energy, analogous to solar radiation in Earth's climate system. This energy input allows the CO_2 to effectively trap heat, overwhelming the cooling processes observed in Desiccator B. Without this energy source, as in Desiccator B, the heat-absorbing processes dominate, leading to net cooling despite the increase in CO_2 concentration.

These findings have significant implications for our understanding of climate science and the greenhouse effect. They demonstrate that the warming effect of greenhouse gases is not simply a function of their concentration but critically depends on the balance between energy input and various heat transfer processes. This aligns with the complex energy balance of Earth's climate system (Trenberth et al., 2009). In our planet's system, the sun provides the constant energy input, analogous to the LED lamp in our experiment, allowing the greenhouse effect to manifest on a global scale.

While this small-scale model provides valuable insights into greenhouse gas effects, it's crucial to recognize its limitations in fully replicating the intricate feedback mechanisms of Earth's climate system. The global climate involves complex interactions between the atmosphere, oceans, land surfaces, and biosphere, with numerous feedback loops that can amplify or dampen temperature changes (Trenberth et al., 2009). This experiment, while illustrative, is a simplified representation that cannot capture all these complexities.

From an educational perspective, this experiment serves as an excellent tool for fostering critical thinking and interdisciplinary understanding among students. It demonstrates core principles of the greenhouse effect while also revealing the complexity of real-world systems. The counterintuitive results from Desiccator B, in particular, provide an opportunity for students to grapple with unexpected outcomes, formulate hypotheses, and engage in scientific reasoning to explain their observations.

Conclusions

This study aimed to investigate the effect of increased carbon dioxide (CO_2) concentration produced from paper combustion on temperature changes. Using two desiccators with different treatments, one with an additional heat source (200-watt LED lamp) and one without, it was found that the increase in CO_2 concentration led to a rise in temperature in the desiccator with the heat source. Conversely, the desiccator without a heat source exhibited a temperature decrease, attributed to the endothermic reactions of combustion and the evaporation of produced water. These results suggest that the warming effect of greenhouse gases depends on the balance between energy input and heat transfer. This experiment provides a better understanding of the complexity of the greenhouse effect phenomenon and the role CO_2 plays in temperature changes in Earth's atmosphere.

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References

Atkins, P., & de Paula, J. (2014). Atkins' Physical Chemistry. Oxford University Press.

Baharuddin, M. R. (2021). Adaptasi Kurikulum Merdeka Belajar Kampus Merdeka (Fokus: Model MBKM Program Studi). *Jurnal Studi Guru Dan Pembelajaran*, *4*(1), 195–205. https://doi.org/10.30605/jsgp.4.1.2021.591

Çengel, Y. A., & Boles, M. A. (2023). Thermodynamics: An Engineering Approach. McGraw-Hill Education.

D'Amato, G., & Akdis, C. A. (2020). Global warming, climate change, air pollution and allergies. *Allergy: European Journal of Allergy and Clinical Immunology*, *75*(9), 2158–2160. https://doi.org/10.1111/all.14527

Houghton, S. J. (2004). *Global Warming*. New York: Cambridge University Press.

Incropera, F. P., Dewitt, D. P., Bergman, T. L., & Lavine, A. S. (2005). Fundamentals of Heat and Mass Transfer (6th ed.). John Wiley & Sons.

Jain, P. C. (1993). Greenhouse effect and climate change: scientific basis and overview. *Renewable Energy*, *3*(4–5), 403–420. https://doi.org/10.1016/0960-1481(93)90108-S

Kweku, D., Bismark, O., Maxwell, A., Desmond, K., Danso, K., Oti-Mensah, E., Quachie, A., & Adormaa, B. (2018). Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming. *Journal of Scientific Research and Reports*, *17*(6), 1–9. https://doi.org/10.9734/jsrr/2017/39630

Laubereau, A., & Iglev, H. (2013). On the direct impact of the CO2 concentration rise to the global warming. *Epl*, *104*(2). https://doi.org/10.1209/0295-5075/104/29001

Mitchell, J. F. (1989). The "greenhouse" effect and climate change. *Reviews of Geophysics*, *27*(1), 115-139.

Mooney, H., Drake, B., Luxmoore, R., Oechel, W., & Pitelka, L. (1991). Predicting Ecosystem Responses to Elevated CO_2 Concentrations. *BioScience*, 41, 96-104. https://doi.org/10.2307/1311562

Phelia, A., Pramita, G., Bertarina, Ashruri, & Misdalena, F. (2021). Pemanfaatan Limbah Minyak Jelantah Menjadi Sabun Sebagai Upaya Pengendalian Limbah Domestik Masa Pandemi Covid-19. *Jurnal Pengabdian Kepada Masyarakat Radisi*, *1*(3), 181–187. https://www.jurnal.radisi.or.id/index.php/PKMRADISI/article/view/76

Ratinen, I. J. (2013). Primary Student-Teachers' Conceptual Understanding of the Greenhouse Effect: A mixed method study. *International Journal of Science Education*, *35*(6), 929–955. https://doi.org/10.1080/09500693.2011.587845

Trenberth, K. E., Fasullo, J. T., & Kiehl, J. (2009). Earth's global energy budget. *Bulletin of the American Meteorological Society*, *90*(3), 311–323. https://doi.org/10.1175/2008BAMS2634.1