PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 5 No. 2 (2024) p. 452-456
https://publisher.uthm.edu.my/periodicals/index.php/peat

Volatile Organic Compound Adsorption by Natural Materials

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DOI: https://doi.org/10.30880/peat.2024.05.02.048

Article Info

Received: 27 June 2024
Accepted: 18 July 2024
Available online: 25 November 2024

Keywords

VOC, adsorbtion, activated carbon

Abstract

Volatile organic compounds (VOCs), major environmental pollutants, are mainly released by industrial processes such as fuel combustion, chemical synthesis, and petroleum refining. These substances pose serious threats to human health and ecosystems by contributing to secondary organic aerosols and photochemical ozone formation. Traditional VOC removal methods are often expensive and energy-intensive, highlighting the need for more eco-friendly alternatives. This study examines the effectiveness of zeolite, activated carbon from rice husk, and coconut shell activated carbon as natural adsorbents for removing acetone and methylene chloride from air. Controlled tests revealed that rice husk was highly stable in acetone adsorption, zeolite rapidly eliminated acetone at lower concentrations, and coconut shell was most effective for high concentrations of methylene chloride. These findings underscore the importance of selecting appropriate adsorbents for specific VOC removal needs and provide valuable insights into integrating natural materials into air purification systems, thereby promoting environmentally friendly VOC mitigation strategies and cleaner air.

1. Introduction

Emissions of volatile organic compounds (VOCs) are becoming one of the most stringent environmental regulations in many industrial processes. VOCs are identified as one of the main contributors to secondary organic aerosol (SOA) and photochemical ozone, both of which are serious threats to the environment and public health [1]. Different definitions of volatile organic compounds are provided by major international organisations. Any carbon compound that engages in atmospheric photochemical reactions is classified as a volatile organic compound (VOC) by the US Environmental Protection Agency (US EPA), with the exception of ammonium carbonate, carbon monoxide, carbon dioxide, carbonic acid, and metallic carbides or carbonates [2]. The extraction, refining, storage, transportation, and use of fossil fuels are the main sources of volatile organic compounds (VOCs), which also include alcohols, ketones, alkenes, and aromatic compounds. Due to their propensity to permeate and accumulate in a variety of environmental media, including soil, water, and air, these compounds have a detrimental effect on ecological and environmental processes [3].

Principal sources of VOC emissions include petroleum refineries, the chemical and fuel sectors, fuel combustion, pharmaceutical plants, the automotive sector, textile manufacturers, solvent operations, cleaning products, printing presses, insulating materials, office supplies, and printers. These sources make highly effective VOC removal solutions for environmental remediation urgently and extremely necessary. These tactics

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include destructive methods like burning, ozone catalytic oxidation, photocatalytic oxidation, and biological degradation, as well as non-destructive (recovery) methods including membrane separation, adsorption, and condensation. However, as individual healing or destruction techniques are not very effective, hybrid therapies have proven to be more desirable than discrete strategies. Due to its low energy consumption, environmental friendliness, and high removal effectiveness, the combination of photocatalytic degradation and adsorption stands out as one of the most promising techniques for eliminating low-concentration VOCs [4].

The recent surge in industrialization and urbanisation has resulted in a notable rise in volatile organic compound (VOC) emissions, posing a serious threat to both human health and the environment [5]. Concerns have been raised about the sustainability and long-term consequences of conventional VOC removal procedures on ecosystems since they frequently need expensive and energy-intensive equipment. Investigating greener, alternative techniques for reducing volatile organic compounds is becoming more popular. Natural materials with the ability to absorb volatile organic compounds (VOCs) from the environment include minerals, plants, and other organic materials [6]. Nevertheless, little is known about the efficiency, workings, and real-world uses of these natural materials' ability to adsorb volatile organic compounds. The purpose of this work is to investigate the key variables affecting the adsorption of volatile organic compounds (VOCs) by natural materials. Optimising adsorption efficiency requires an understanding of the intricate processes involved in the adsorption of various volatile organic compounds (VOCs) by a variety of natural materials.

The goal of this research is to increase our understanding of how natural materials adsorb volatile organic compounds (VOCs) and to provide workable, affordable ways to enhance air quality. The goal is to make activated carbon out of coconut shell and rice husk for use as adsorbents. It also aims to ascertain the ideal dose of these adsorption materials in order to attain the maximum percentage of acetone and methylene chloride elimination. Additionally, employing synthetic adsorbents like commercial zeolite and natural adsorbents such activated carbon from rice husk and coconut shell, the study will assess the adsorption effectiveness of these chosen adsorbates. By tackling these goals, this study hopes to make a substantial contribution to the advancement of effective VOC removal methods. The results will contribute to a cleaner and healthier environment by lessening the negative effects of VOCs on ecosystem health and human well-being.

2. Methodology

Careful procedures were taken in the manufacture of the materials to maximise their adsorptive capabilities for volatile organic compounds (VOCs). Activated carbon was made from rice husk and coconut shell, and contaminants were removed by washing with deionized water. The activated carbon samples were dried at 100°C, then impregnated with a zinc chloride solution. To guarantee neutral pH and moisture removal, the samples were washed, pH-balanced with NaOH and H_2SO_4, and dried once more. In a similar manner, to get them ready for testing, zeolite samples that were purchased from a supplier were cleaned, dried, sprayed with zinc chloride solution, and had their pH corrected.

To spread VOCs evenly, a specially constructed airtight plexiglass test container with an air circulation fan was used as shown in Fig. 2. To ensure the integrity of the experiment, this chamber underwent extensive testing for leaks. Before and after experiments, VOC levels were recorded in parts per million (ppm) in order to monitor concentration changes over time and gain understanding of the adsorption process.

Experiments conducted at UTHM Pagoh's controlled laboratory evaluated the rates at which zeolite, activated carbon from rice husks, and coconut shells adsorb acetone and methylene chloride. VOC monitors and data recorders were among the tools used to continually monitor the chamber, which was placed for safety and ventilation. The steps were carefully followed, beginning with the introduction of VOCs, stabilisation, addition of materials, and continued monitoring until stable values were obtained. The goal of this methodical approach was to identify the ideal parameters for efficient VOC adsorption at various material weights and VOC concentrations.

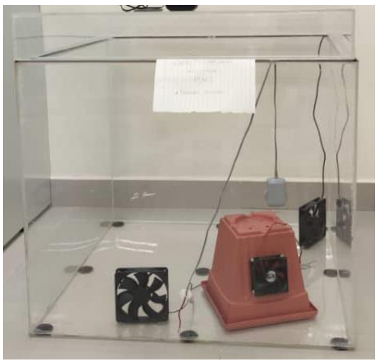

Fig. 2 The airtight plexiglass chamber

3. Results

Acetone was evaluated in this investigation at two different concentrations: 15 ppm and 30 ppm. Because two measurements eliminated abnormalities and other effects, they helped confirm the consistency and dependability of the findings.

The acetone decrease rates of the adsorbents varied at 15 ppm (Fig. 3). Acetone levels were lowered to zero in around 90 minutes using rice husk. Zeolite reached zero in around 120 minutes, whereas coconut shell did so more slowly—it took 150 minutes. Fig. 4 shows that the adsorption rates decreased to 30 ppm. With a decrease time of 180 minutes, rice husk continued to have the quickest rate, followed by zeolite at 300 minutes and coconut shell at 360 minutes.

All adsorbents operate more quickly at the lower concentration of 15 ppm, according to the data. At both concentrations, rice husk outperforms zeolite and coconut shell in terms of efficiency. When the concentration of acetone rises, the efficiency of all materials falls, but rice husk always works the best. According to [7], its large surface area and porous structure are responsible for its efficiency.

In conclusion, at acetone concentrations of 15 ppm and 30 ppm, rice husk is the most efficient adsorbent, followed by zeolite. When used in larger doses, coconut shell is the least effective. The order of adsorbent efficacy does not change between the two trials, despite the fact that all adsorbents lose efficiency as acetone concentration rises.

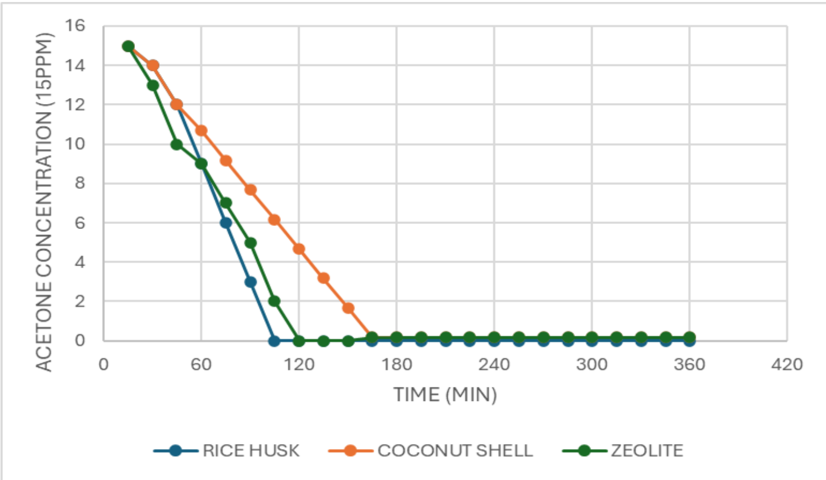

Fig. 3 The adsorption RCAC, CSAC and zeolite to acetone with concentration of 15 ppm

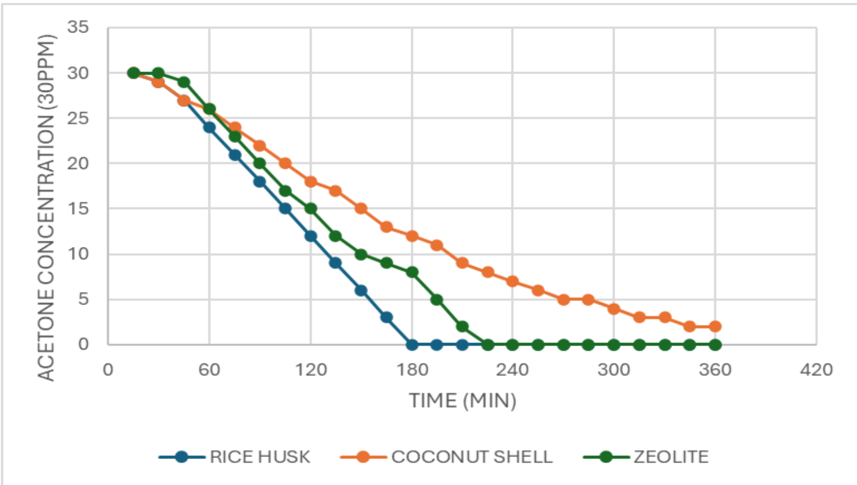

Fig. 3 The adsorption RCAC, CSAC and zeolite to acetone with concentration of 30 ppm

Methylene chloride was evaluated in this experiment at two different concentrations: 10 ppm and 25 ppm. Independent measurements validated the initial values as consistent and unaffected by outside influences.

Fig. 4 illustrates how rice husk and zeolite, starting at 10 ppm concentration, efficiently lowered the concentration to almost zero in 360 minutes. On the other hand, throughout the same time period, coconut shell was less effective, lowering the concentration to about 5 ppm. This suggests that at this lower concentration, zeolite and rice husk are more effective.

All three of the adsorbents—rice husk, coconut shell, and zeolite—performed noticeably better at the 25 ppm concentration, as seen in Fig. 5. In 360 minutes, each lowered the concentration to almost nothing. Zeolite and rice husk both remained very efficient, but coconut shell—which performed worse at 10 ppm—performed better at 25 ppm.

When the efficiency at both concentrations is compared, it can be shown that coconut shell is less efficient at 10 ppm than rice husk and zeolite. Nonetheless, all three adsorbents exhibit comparable high efficiency at 25 ppm, suggesting that the effectiveness of coconut shell increases with increasing concentrations.

In conclusion, at 10 ppm, methylene chloride may be more effectively absorbed by rice husk and zeolite than by coconut shell. All three adsorbents work equally well at 25 ppm. Higher quantities of this improvement imply that coconut shell can withstand higher methylene chloride loads. since of its tunable pore size, zeolite is a dependable option for VOC adsorption since it is consistently efficient at both concentrations. Additionally demonstrating its flexibility as an adsorbent, rice husk functions effectively, particularly at lower concentrations.

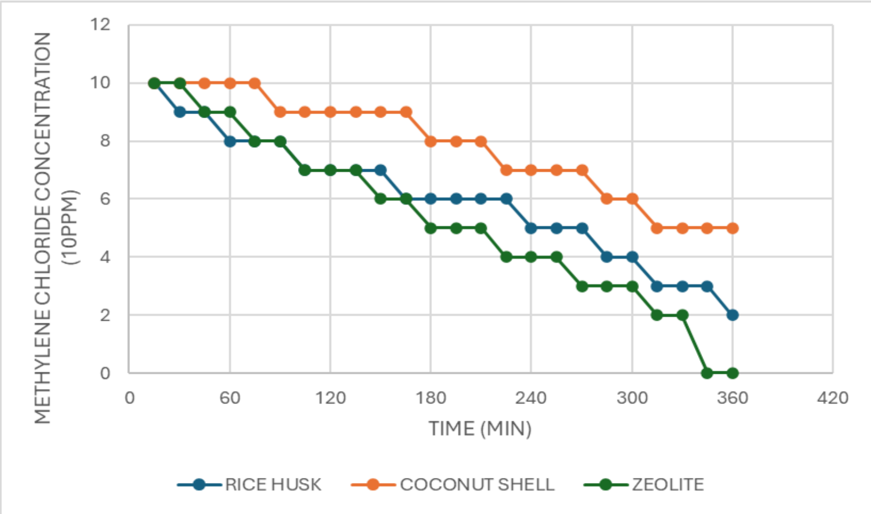

Fig. 4 The adsorption RCAC, CSAC and zeolite to methylene chloride with concentration of 10 ppm

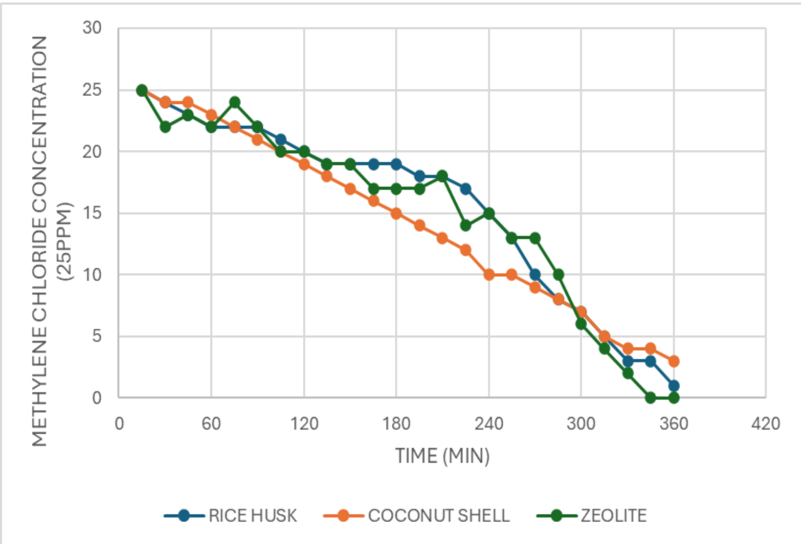

Fig. 5 The adsorption RCAC, CSAC and zeolite to methylene chloride with concentration of 25 ppm

4. Conclusion

The results of the investigation show that, although performance varies with concentration and contact duration, all three adsorbents—rice husk, coconut shell, and zeolite—are efficient at extracting acetone and methylene chloride from solutions. Zeolite and rice husk demonstrated quick and high removal efficiency for acetone, with zeolite being the quickest. Zeolite worked better at lower concentrations of methylene chloride, whereas coconut shell was more effective at greater concentrations.

In summary, particular needs for adsorption rate and stability should guide the selection of adsorbent. Coconut shell works best for greater concentrations of methylene chloride, rice husk for steady and high acetone adsorption, and zeolite for quick acetone removal. This thorough investigation emphasises how crucial it is to choose the right adsorbent for efficient VOC removal in a range of applications.

5. Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot H222). This study was not supported by any grants from funding bodies in the public, private, or not-for-profit sectors.

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