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Adsorption of Sulfur Dioxide by Spent Molecular Sieve: Preliminary Breakthrough Adsorption Study

Nur Asiah Che Noh[1,2,*], Naimah Ibrahim[1,2], Muhammad Adli Hanif[1,2]

[1]Faculty of Civil Engineering & Technology, Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia.
[2]Centre of Excellence for Water Research and Environmental Sustainability Growth (WAREG), Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia.

KEYWORDS

Industrial waste
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ABSTRACT

The management and utilization of industrial wastes have become a considerable challenge. Thus, in this paper, the potential of industrial waste (spent molecular sieve) as adsorbent in dry desulfurization was investigated. The objective is to measure the breakthrough adsorption capacity using the optimum parameters and through fixed bed system. From the experimental works, related parameters such as temperature, inlet concentration and adsorbent amount were studied. From these results, it can be concluded that spent molecular sieve can be employed as one of the significant adsorbents in sulfur dioxide removal with low cost and high efficiency.

1. INTRODUCTION

Sulfur dioxide (SO_2) is a significant air pollutant, primarily generated from anthropogenic sources, including the burning of fossil fuels in power plants, industrial facilities, and residential heating systems, as well as from natural processes like volcanic eruptions [1]. Its emissions contribute to environmental issues like acid rain, air quality degradation, and adverse health effects. For human health, SO_2 exposure is associated with respiratory problems, such as asthma and bronchitis [2]. As global regulations on air pollution become increasingly stringent, the development of efficient methods to mitigate SO_2 emissions has become a priority. Among various techniques, adsorption has emerged as a highly effective and versatile approach for capturing SO_2 due to its low energy consumption, reusability, and potential for high efficiency [3].

Molecular sieves are currently the most often used adsorbents for SO_2 removal, though they are costly and prone to ignition. These limitations contribute to increased operational and maintenance expenses [4]. To overcome these challenges, researchers have turned their attention to the utilization of industrial waste materials in the desulfurization process. Numerous studies [5]–[8] have demonstrated the feasibility of repurposing various types of waste as adsorbents, aiming to address economic and at the same time aligning with green and sustainable practices.

This paper will focus on assessing the performance of regenerated spent molecular sieves using a fixed-bed reactor system, with an emphasis on measuring the adsorption rate.

2. EXPERIMENTAL PROCEDURE

The spent molecular sieve was collected from local industry. The sample then was crushed into powdery form and prepared for adsorption process. The performance of spent molecular sieve was studied via a breakthrough adsorption experiment. About 1 gram of sample was loaded into the middle of quartz-column and filled with quartz wool. Then, the purified special mix gases of 0.3% sulfur dioxide and balanced in nitrogen was used in this adsorption experiment. The gases passed through the adsorbent reactor with a simulated flue gas containing 1500 ppm of SO_2 with N_2 as balance gas at an operating temperature of 40°C. Total flow rate gas was maintained at 200 mL/min during the experiment.

The concentration of SO_2 was continuously measured using Testo 340 gas analyzer for about 2 hours and until the breakthrough curve achieved an equilibrium. When the gas analyzer detected 5% of inlet SO_2 concentration in the outlet gas, the sorption bed was considered to have achieved breakthrough. Adsorption capacity of the sorbent was calculated at C/C0 = 0.9, using Equation 1 and was expressed as flue gas breakthrough time per unit mass of sorbent.

$$q = \frac{C_0 Q_f y_t}{m_c} \int_0^{\infty} \left(1 - \frac{C_A}{C_0}\right) dt \quad (1)$$

while Q_f represents gas flow rate (L/min), Y_t is gas molar fraction, m_c is mass of the sorbent (g) and C_0 and C_A represent the inlet concentration of the gas and gas concentration at specific time (mg/L).

*Corresponding author: nurasiahchenoh@studentmail.unimap.edu.my

3. RESULT AND DISCUSSION

3.1 SO_2 adsorption (Breakthrough Study)

The adsorption and penetration curve of spent molecular sieve are shown in figure 1. The SO_2 adsorption capacity is calculated at C/C0 = 0.9 and the removal rate achieved is 32.47 mg/g.

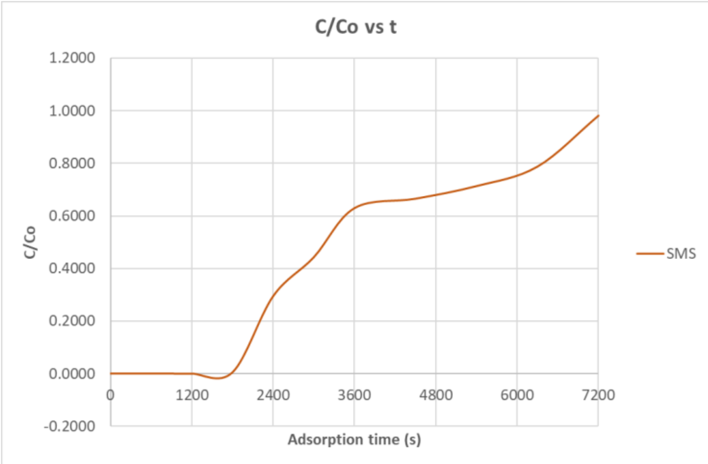

Figure 1. Breakthrough curve of spent molecular sieve at 40°C.

3.2 Influence of Related Parameters

The study was performed through a lab-scale fixed bed adsorption column system. The detail of experimental parameters is tabulated in Table 1.

Table 1 Experimental parameters

Adsorbent	Temperature	Inlet concentration	Mass
 Spent molecular sieve	40°C	1500 ppm	1 g

To obtain the optimum result, significant parameters for adsorption such as temperature, inlet concentration and adsorbent amount was studied and analyzed. A few articles have studied the influence of individual SO_2 on the removal of at different temperatures. The findings had revealed that as the adsorption temperature decreased, the breakthrough time for SO_2 at the outlet increased [9]–[12].

Theoretically, when the inlet concentration increased, the adsorption capacity of the adsorbent may increase until it reaches a point of saturation [13]. However, there was study by hanif et al.[14] and Kumar et al. [5] that the highest adsorption capacity is attained at the lowest SO_2 concentration also.

Inlet concentration influence the required amount of sorbent in adsorption exercise. Higher SO_2 concentrations typically require higher adsorbent dosages. According to Sun et al. [15] the removal rate for SO_2 increase when sorbent dosage was raised due to the increase in active sites on the sorbent.

4. CONCLUSION

This study explored the potential of industrial waste known as spent molecular sieve in sulphur dioxide removal via fixed bed adsorption system. With the optimal conditions of significant parameters, spent molecular sieve have a potential to be used as adsorbent in dry desulfurization process and at the same time promoting green approach in industry.

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