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Research paper

Preliminary Investigation of Formulated Two in One Filter Aids Material as VOC Adsorbent

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Abstract

Continuous adsorption of toluene gas onto newly formulated filter aids was studied in packed-bed column. Two different ratios of formulated filter aids prekotAC (prekotAC 5:95 and prekotAC 10:90) which is a mixture between pre-coating material of PreKot™ and activated carbon was experimentally adsorbed toluene gas (100 ppm) at constant temperature (25ºC) and flow rate (0.55 lpm) onto two different amount of adsorbents (5 and 10 mg) and the experimental breakthrough curve was obtained. The results showed that, bu using 10 mg samples, prekotAC 10:90 had longer time (28 min) to reach equilibrium point compared to prekotAC 5:95 (22 min) and the amount of adsorbent used significantly affect the adsorption performance where adsorption performance was directly proportional to the amount of adsorbent used.

Keywords: *Adsorption, Filter Aids, Fabric Filter*

1. Introduction

There is an increasing public concern on the need to remove VOCs from flue gas as its affect the health of human beings and all animals (Khan & Ghoshal, 2000). Besides, VOCs are one of the main sources of photochemical reaction in the atmosphere leading to various environmental hazards (Khan & Ghoshal, 2000). In Malaysia, according to Clean Air Regulation, 2014, VOCs limit is 10mg/Nm^3 which becomes more stringent and restrictive. Therefore, their removal from flue gas streams became important issue for researchers and engineers. Incomplete oxidation during the incineration of municipal solid waste leads to the presence of VOCs in the gaseous emissions [Pierre, 2012 and Su *et al*, 2015]. Among VOCs, BTEX (benzene, toluene, ethyl-benene and xylene) were the most common VOCs compounds in the atmosphere [Wang *et al*, 2002]. Besides, it was reported that toluene was found to be one of the most abundant species of VOCs from coal combustion in power generation [Yan *et al*, 2016].

In order to reduce the emission, fabric filtration system is commonly used in plant to remove particulate matter, acid gases and VOCs simultaneously in the same unit. During the operation, filter aids is applied into the system to ensure better air flow across the filter media as well as to coat a layer of inert material onto each of the filter bag [Hajar *et al*, 2015]. Examples of filter aids that always been used is diatomite [Martinovic *et al*., 2006], however, the only problem with diatomite is the presence of impurities such as calcium in the material which directly coats the surface of diatomite particles and limits the use of this material for filtration application [Hadjar *et al.*, 2008]. In addition, activated carbon and lime also have been used during filtration process and were attached to the fabric filter and act as an adsorbent and filter aids in order to overcome the problem of wear and tear in fabric filter. Previously [Hajar *et al*, 2015], newly formulated filter aids known as PrekotAC (combination of PreKot™ and activated carbon) was introduced and it was able to reduce the maintenance cost and also extending the life span of fabric filter [Hajar *et al*, 2015]. However, the study only revealed on a particulate matter and no report was made on adsorption of VOCs. Therefore, in this study formulated filter aids prekotAC which consist of pre-coating material and adsorbents was experimented to adsorb toluene and the results are presented in this paper.

2. The Aim of Study

The aim of this study is to investigate the performance of formulated filter aids which consist of adsorbent (activated carbon) and pre-coating material of PreKot™ (designated as PrekotAC) as flue gas cleaning agent. The ability of the formulated filter aids to remove VOCs in gas streams was observed.

3. Method of Study

i) Formulation of Formulated Filter Aids

Activated carbon that was used in this study is a coconut based material which commonly used as flue gas cleaning adsorbent product in the incineration process. PreKot™ (proprietary of AMR Environmental Sdn. Bhd.) is a commercially available filter aids material consisting essentially of an amorphous hydrated glassy volcanic rock primarily fused aluminium silicate. In this study, the newly formulated filter aids known as PrekotAC5:95 and PreKotAC10:90 is a combination between Prekot™ and activated carbon with two different ratios respectively. Initially, all original materials were dried in an oven (Memmert, Model UNB 200) for 24 hours at 105°C before formulation. Then, the properties of the formulated filter aids was characterized in terms of its surface area (BET), porosity and N_2 adsorption desorption behavior using surface area analyzer (TriStar II 3020 V1.04).

ii) Experimental procedures on adsorption test

Figure 1 showed the experimental set-up for this study. Prior to start any experiment, formulated filter aids was dried for 24 hours in oven at 115ºC to remove all adsorbed gases and moisture content. The adsorption experiments were carried out in a fixed glass column (40IDmm;80ODmm) under inlet gas concentration of 100ppm, temperature (25ºC), gas flow rate (0.55 lpm) and two different amounts of adsorbent (i.e 5 and 10 mg) was tested in the study. Toluene's breakthrough curve was obtained for the two formulated samples.

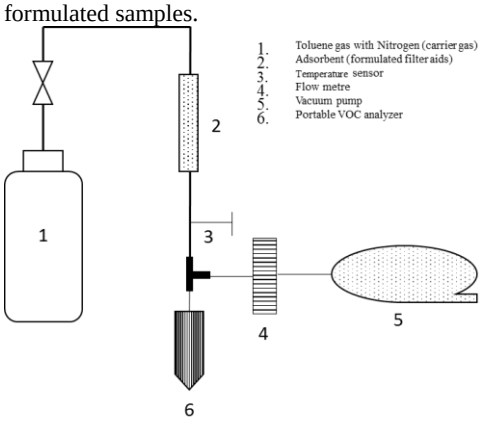

Figure 1. A schematic diagram of the experimental set-up to study VOC adsorption over formulated filter aids

4. Analysis and Discussion

Material Characterization

Table 1 showed the results of surface area and porosity of the raw materials and formulated filter aids. From the results, activated carbon has the largest surface area with 1094 m^2/g and lowest porosity (53%) while PreKot™ only has about 2 m^2/g of surface area and highest porosity (60%). The addition of PreKot™ material in formulated samples, resulted to slightly decreased the surface area and increased the porosity of the prekotAC 5:95 and prekotAC 10:90. However, the amount of surface area exist in both formulated samples is still consider high and able to adsorb gases as the large surface area accounts for the highly effective adsorptive characteristics [Masdiana *et al*, 2017].

Table 1. Surface area and porosity of the raw materials and formulated samples

Materials	Surface area (m^2/g)	Porosity (%)
Activated carbon	1094	53
PreKot™	2	60
PrekotAC 5:95	1066	56
PrekotAC 10:90	999	59

Figure 2 indicates a nitrogen adsorption-desorption isotherms of raw materials and samples. It was found from figure 2 that the curve shape of prekotAC 5:95 and PrekotAC 10:90 had small changed compared to raw material of activated carbon due to addition of Prekot™ material and it proved that PreKot™ particles loaded on activated carbon. For raw materials PreKot™, the N_2 adsorption-desorption isotherm showed that the material was not able to adsorb gases effectively at low and high relative pressure due to its behavior of small surface area and high porosity.

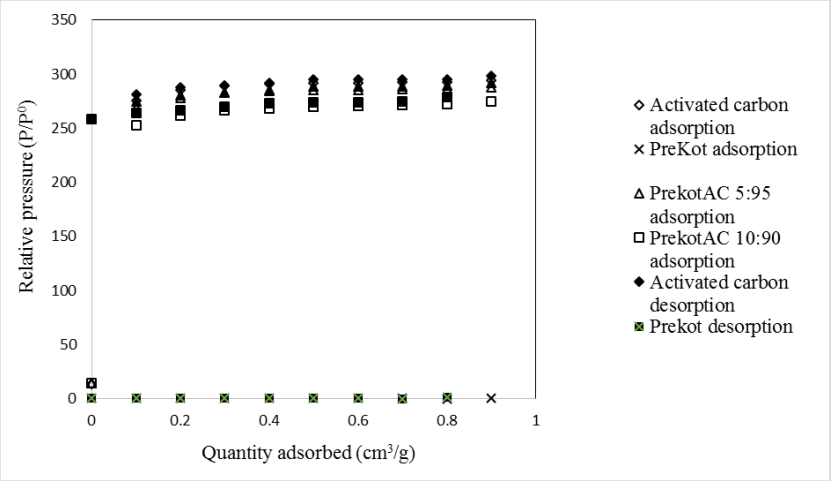

Figure 2. N_2 adsorption-desorption isotherms of raw materials and formulated samples

5. Adsorption Test

i) Breakthrough curve

Figure 2 presents the results of breakthrough time based on toluene for raw materials and formulated prekotAC, which showed that activated carbon (20 min) showed a longer breakthrough time compared to PreKot™ (4 min), while for prekotAC samples the breakthrough of both samples are slightly lower than raw activated carbon. Unexpectedly, the results clearly showed that PreKotAC 10:90 (19 min) gives a longer breakthrough time compared to PreKotAC 5:95 (10 min) which may be due to the high numbers of porosity of the relative to PreKotAC 5:95. In this case, activated carbon is characterized having large surface area and able to adsorb toluene gas effectively. Besides, activated carbon is a common material and has widespread applications in the air pollution control, because of their variety of porosity, rich surface chemistry and huge adsorption capacity [Luo *et al*, 2006 and Li *et al*, 2010]. In this study, activated carbon alone give a good performance in term of VOCs (toluene) adsorption, however for real applications, it is not suitable to use as it will produce a compact layer on the surface of fabric filter, thus increase the pressure drop in the filtration system [Hajar *et al*, 2015]. Therefore, prekotAC samples could be a good option to be used in a real application especially in adsorption of organic compound.

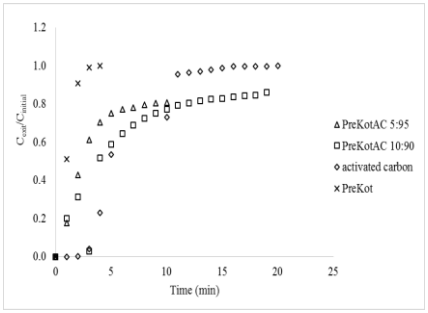

Figure 2. The breakthrough curve of toluene gas over raw materials and formulated PrekotAC

ii) Effect of adsorbent quantity

The effect of adsorbent quantity on touluene adsorption breakthrough curve is shown in Figure 3. As observed in the figure, the breakthrough time of PreKotAC 10:90 (10 mg) was greater than PreKotAC 5:95 sample under same condition of adsorption process and the time taken to reach initial inlet concentration was 28 and 22 min, respectively. As expected, increasing the amount of adsorbent shifted the breakthrough curves to the right, implying longer breakthrough time and greater amount of total adsorbed toluene. It is clear from Figure 3 that using less amount of adsorbent, the breakthrough time was less due to the less amount of active site present in the sample [Das *et al*, 2004]. According to Razaei *et al*, increasing amount of adsorbent significantly increased the adsorbed gases and indirectly increased the adsorption capacities [Razaei *et al*, 2017].

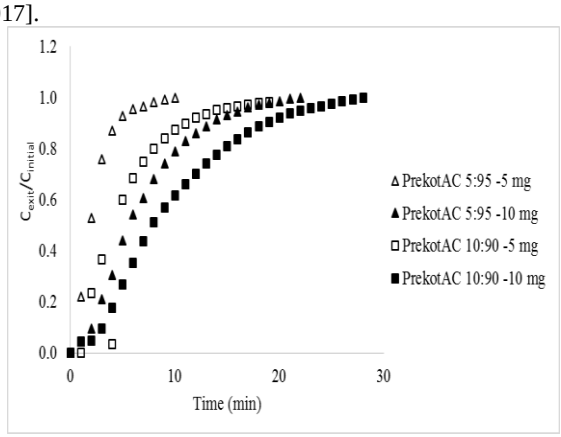

Figure 3. The effect of amount of adsorbent on breakthrough curve of toluene gas over formulated filter aids

6. Conclusion

The experimental results revealed that formulated filter aids not merely serve as a precoating material but also a potential adsorbent for capturing VOC (two in one function) in air filtration system.

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