Characteristics of PrekotAC as Formulated Filter Aids and Its Performance to Adsorb Volatile Organic Compound

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Abstract. The characteristics of a formulated filter aids material known as PrekotAC which is a combination of an adsorbent, activated carbon with a pre-coating material was investigated in this study. PrekotAC, was formulated into two different weight ratios of 5:95 and 10:90 respectively. The relationship between the adsorption properties and the characteristics of the formulated materials in terms of its particle size distribution, particle density, bulk density, moisture content as well as its BET surface area was investigated. A specific amount of 100mg of formulated filter aids was placed in a fixed glass tube and subjected to a given concentration of toluene at the temperature of 25°C and 1.0 l pm gas flow rate. The adsorption properties of each filter aids material was tested under various time where the amount of toluene adsorbed by the filter aids was analysed using gas chromatography equipped with flame ionization detector (GC-FID). The ability of the formulated filter aids to adsorb toluene was presented and discussed in this paper.

1 Introduction

The environmental issue has become a major subject in the last few decades, affecting developed as well as those of developing nations. For an example, air pollution emission from waste incineration such as acid gases, particulate matter, heavy metals and volatile organic compounds (VOCs) are released into the atmosphere [1]. Organic compounds that include dioxin-furan is recognized to be one of the most potent pollutant resulted through post-combustion in incineration process.

Organic compounds are carbon-based compounds derived from many sources. It (author) was reported that 37% of total VOCs emissions comes from coal-fired power plants [2]. These emissions are of public concern especially VOCs considered as toxic chemicals causing severe health problems [3]. Prolonged exposure to VOCs has been shown to induce eye and throat irritation, damage to the liver and central nervous system as well as increase relative rates of leukemia and lymphoma [4]. Therefore, the removal of VOCs from a flue gas stream is of significant interest. There are five methods of removing VOCs from contaminated gas stream and these are adsorption, absorption, condensation, incineration, and biofiltration. However, adsorption seems to be the most commonly used in this case [5].

Activated carbon has been extensively used in variety of environmental applications as adsorbent in gas purification, solvent recovery and waste water treatment, due to its large surface area and high adsorption capacity [6]. Activated carbon has been used as an adsorbent in fabric filtration system which is commonly found in most waste incineration plant. In addition, filter aids is also applied to coat a layer of inert material onto each of the filter bag acting as a barrier for protection as well as to allow a uniform air flow passing through the filter media [7].

Thus, the aim of the present study is to investigate the characteristics of a formulated filter aids material which is a combination of activated carbon and precoating agent. In addition, the ability of the formulated filter aids to adsorb VOCs is presented and discussed in this paper.

2 Materials

Table 1 presents the specifications of the two main powder materials used in this study, which are activated carbon and PreKot™. The toluene solution of 99.99% purity (Merck) was used in the adsorption study.

Table 1. Specification of the materials used in the study.

Activated carbon	**PreKot™**
Colour: black	Colour: snowy white
Origin: coal based	Origin: silica based
Surface area: 1094.96%	Surface area:2.52%
Moisture content:23.39%	Moisture content: 0.73%

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3 Experimental methods

3.1 Formulation of the Filter Aids

PreKot™ and activated carbon were mixed into 5:95 and 10:90 of two different weight percentage respectively. Initially before formulation, the raw materials were dried in an oven (Memmert, Model UNB 200) for 24 hours at 110°C. Then, the properties of the formulated filter aids designated as PrekotAC were characterized in term of its surface area (BET), particle size distribution, particle density, bulk density and moisture content.

3.2 Material characterization

Particle size distribution was determined using a particulate sizer (Malvern Mastersizer 2000). The measurement was repeated two times and the average particle size distribution was taken by the software. The determination of the particle density of the material was measured using a gas pycnometer (Micromeritics AccuPyc II 1340), using nitrogen as a carrier gas. While the bulk density of the sample was measured based on the equation (1) where the sample was filled and compacted in a pre-weighed 10mL standard measuring cylinder up to the specific volume and re-weighed in order to determine the bulk density [8].

$$\text{Bulk density} = Wm / Vc \quad (1)$$

Where;
W_m = weight of the dried material (g)
Vc = volume of the cylinder (10mL)

The specific surface area (SBET) was estimated by the BET equation (2). The porous structure of the sample was characterized by N_2 adsorption isotherms at 77 K using TriStar II 3020 V1.04. The specific surface area is an important characteristic in determining the chemical and physical interaction of the adsorbent and its surroundings. This is due to the fact that adsorption take place at the surface of particles.

$$(v/vm)=C(P/P_0)/\{[1-(P/P0)][1+(c-1)(P/P_0)]\} \quad (2)$$

Where;
υ = volume of gas adsorbed per unit weight of material at pressure P
υm = volume of gas adsorbed for monolayer coverage
(P/P_0) = partial pressure of the gaseous adsorbate
C = constant

The moisture content of the formulated sample was determined based on a standard measurement (ASTM D2867-09) [9]. Approximately 2 g of the formulated sample was placed in a pre-weighed petri dish and exposed to the atmosphere for a few days. Then the sample was dried in an oven at 110°C for 24 hours to discard the moisture content in the sample. Later, the sample was removed from the oven and cooled to an ambient temperature in a desiccator before it was re-weighed. The experimental procedure was repeated twice and the average moisture content was taken. The moisture content of the sample was then calculated using equation (3) as written below.

$$\text{Moisture content (\%)} = [(S_i - S_a)/ (S_i - Wp)] \times 100 \quad (3)$$

Where;
Wp = weight of the petri dish (g),
S_i = initial weight of petri dish with sample (g)
S_a = weight of petri dish with sample after drying(g)

3.3 Adsorption Study

3.3.1 Sample preparation

Figure 1 shows the schematic diagram of the adsorption experimental set up which consist of toluene solution, temperature sensor, adsorbent packed –glass (formulated filter aid), flowmeter and vacuum pump. Stopcock was used to control the toluene's flow during adsorbent exchange. Prior to start any experiment, all samples of formulated filter aids were dried for 24 hours in oven at 110ºC to remove all adsorbed gases and moisture content [10]. A fixed glass with inside diameter of 4mm, outside diameter 8mm and total length 60mm was used for dynamic study. A 100mg of adsorbents were filled and compacted in a glass enclosed with glass wool and covered with a cap. After packaging, all prepared samples were stored in desiccator prior to use for sampling.

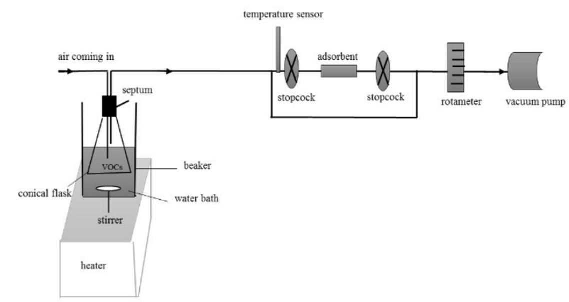

Fig. 1. Schematic diagram of experimental set-up

3.3.2 Adsorption Test

For each set of experiment, 100mL of toluene with 99.99% concentration was adsorbed by 100mg amount of total adsorbent dose at 25ºC with 1lpm flowrate. Initially, 100mg adsorbent dose were packed in glass and placed in the adsorption system (Figure 1). The toluene's solution was bubbled and pumped through the system towards adsorbent. A water bath was used to keep the toluene solution in a desired constant temperature (50ºC). Before the start of experimental run, toluene gas were freely pumped throughout the system for 10 minutes to ensure the gas distribute properly across the system. Sampling was done continuously and the effluent gas was collected at time intervals between 5 and 40 minutes and its concentration was determined by using gas chromatography equipped with flame ionization detector (GC-FID).

3.3.3 Analytical method

The sample was analysed using GC-FID with capillary column. FID detects analytes by measuring an electrical current generated by electrons from burning carbon particles in the sample. The adsorbed toluene was analysed using the NIOSH method [11]. The sample was desorbed in 2 mL of dichloromethane and allowed to stand with occasional shaking for 30 minutes [12]. A 1µL of sample extract was used for one injection. Each sample was injected twice and the average result was calculated. The oven temperature was set initially at 40°C for 3 minutes and then raised to 88°C per min. Both the auxiliary and detector temperatures were set at 250°C. The standard of toluene solution was used for quantification of the compounds.

4 Results and discussions

4.1 Material characterization

4.1.1 Characteristics in terms of particle size distribution

Figure 1 and 2 presents the particle size distribution of raw materials and formulated filter aids materials. Figure 1 showed that activated carbon has a finer particle size distribution compared to PreKot™. This results were in a good agreement with the previous study by Hajar *et al.* (2013) and Hajar *et al.* (2015) where it was reported that activated carbon has finer particle size distribution compared to PreKot™ [7,13]. By having a small particle material, it is good for adsorption purpose because as the particle size decreases, the degree of contact area between the particles increase and lead to a better adsorption properties.

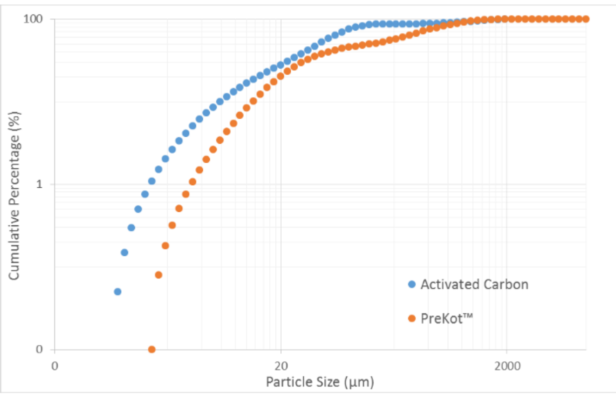

Fig. 1. Particle size distribution of raw materials

As shown in Figure 2, the formulated filter aids materials (PrekotAC 5:95 and PrekotAC 10:90) fitted perfectly with the original materials which proved that it has a very well distributed particle size distribution (Figure 2). It was reported that PrekotAC helps to improve the filtration performance by reducing the pressure drop across the filter cake as well as increases the filtration efficiency [7]. In addition, having a well distributed particle size distribution, PrekotAC could also be used as flue gas cleaning agent where it can be applied as a two in one filter aids material, pre-coating material as well as an adsorbent.

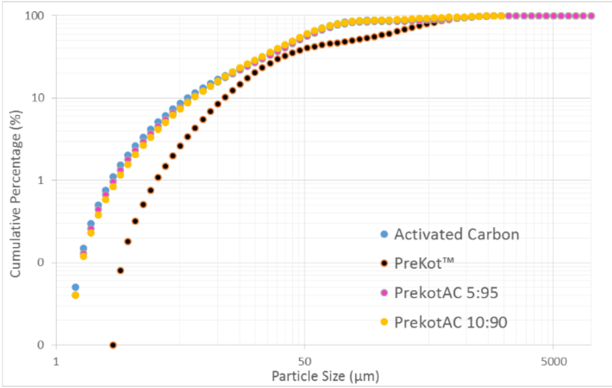

Fig. 2. Particle size distribution of raw materials and formulated samples

4.1.2 Characteristics in terms of bulk density and particle density

Figure 3 illustrates the results on the bulk density and particle density of the filter aids materials where it was found that activated carbon gives the highest while PreKot™ has the lowest density. PrekotAC laid nicely between their original materials with PrekotAC 5:95 showed slightly higher in bulk density (0.64 g/cm^3) and particle density (1.48 g/cm^3) compared to PrekotAC 10:90. There is not much different in bulk density and particle density for the formulated filter aids because of the close ratio of formulation.

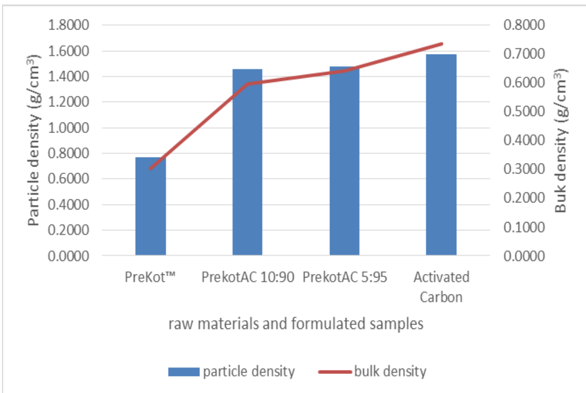

Fig. 3. Bulk density and particle density of raw materials and formulated samples

However, from the results, it showed that as the amount of PreKot™ in the formulation increases, the bulk and particle density decrease which explained the linear trend relationship of bulk density and particle density with the addition of PreKot™. It also showed that PreKot™ plays an important role in reducing bulk density and enhancing the porosity of the material for better filtration due to its particle characteristics [7].

By applying a filter aids material with a high porosity helps in reducing pressure drop across filter cake and also good for adsorption purpose. This is because, greater porosity materials lead to better roughness and larger specific surface area.

4.1.3 Characteristics in terms of BET surface area

Specific surface area is a fundamental measurement in the field of fine particle characterization especially in adsorption process. Specific surface area is defined as the surface area per unit mass of sample. Figure 4 showed a BET surface area of raw materials and formulated samples which showed that activated carbon has the largest while PreKot™ has the smallest surface area with 1094.96 m^2/g and 2.52 m^2/g, respectively.

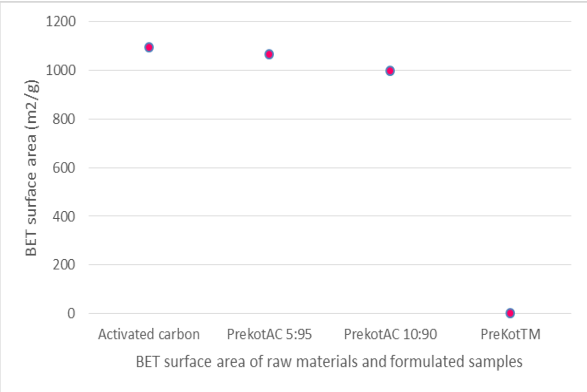

Fig. 4. BET surface area of raw materials and formulated samples

As shown in the figure, surface area consistently increases with the decreasing amount of PreKot™ with PrekotAC 5:95 gives higher surface area compared to PrekotAC 10:90. Both formulated filter aids have high surface area which is 1066.064 m^2/g (PrekotAC 5:95) and 999.8710 m^2/g (PrekotAC 10:90) where slightly lower than activated carbon alone. The large surface area accounts for the highly effective adsorptive characteristics.

4.1.4 Characteristics in term of moisture content

Figure 5 presents the moisture content of the raw materials and formulated samples which showed that activated carbon has the highest while PreKot™ has the lowest moisture content with 23.39% and 0.73%, respectively. The formulated PrekotAC were consistent in term of their moisture content where PrekotAC 5:95 (22.60%) presents slightly higher moisture content compared to PrekotAC 10:90 (22.27%). The difference in moisture content due to the addition of the different amout of PreKot™. It was found that the addition of PreKot™ into the formulation helps to reduce the moisture content which is perquisite for adsorption purpose.

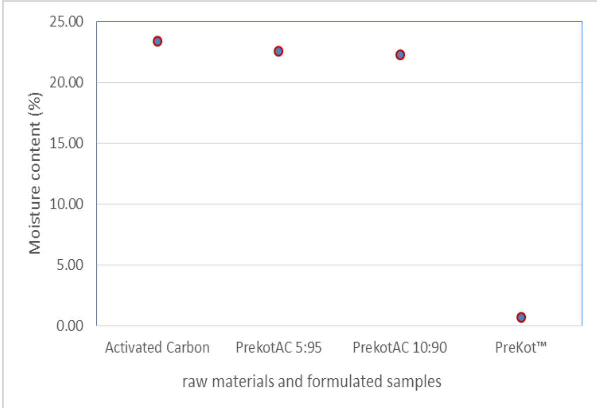

Fig. 5. Moisture content of raw materials and formulated samples

Moisture content is an important parameter since it directly influences the adsorption performance. According to Farzad *et al,* presence of water or moisture, trapped in activated carbon pores could lead to decrease in the amount of methane adsorption [14]. Therefore, low existence of moisture in the formulated material is better for adsorption process and indicates a good filter aids property [7]. However, the application of PrekotAC as a filter aids and flue gas cleaning agent may not be influence by moisture content since the operation occur in hot environment (~ 200°C) such as in incineration plant where high temperature will evaporate the moisture content exist in the material, thus maintained the performance as an adsorbent.

4.2 Toluene adsorption

4.2.1 Comparison of adsorption performance between raw materials and formulated samples

Figure 6 shows the total toluene adsorbed in 100mg of filter aids materials under four different time duration of 5, 10, 30, and 40 minutes. Results showed that activated carbon gives the highest amount of toluene adsorbed (331µg) at 5 minutes compared to the other materials. It was also found that as time of adsorption increase, the amount of toluene adsorbed also increased. However, PreKot™ do not give a good result in adsorption where it was observed that the amount of toluene adsorbed decreased by the time of adsorption process. It showed that PreKot™ did not give much contribution on adsorption process compared to the other filter aids materials.

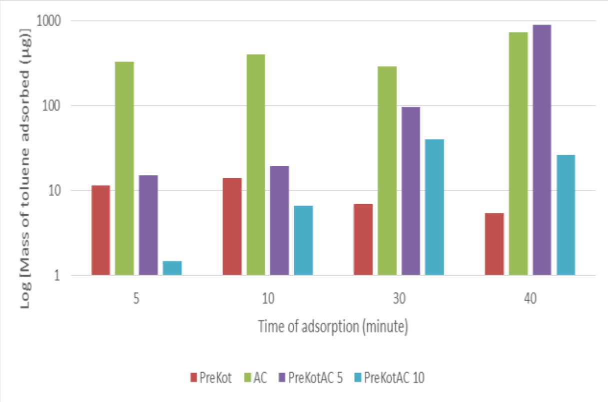

Fig. 6. Toluene's adsorption by raw materials and formulated samples at various time

As shown in the figure, PrekoatAC showed high adsorption of toluene, proving that the combination of activated carbon and PreKot^{TM} still give a good adsorption properties. This can be explained by the fact that high number of surface area of formulated samples contribute to adsorb higher amount of VOC [14]. As the time increases, toluene loading volume increases until the saturation rate achieved. In this study, both formulated filter aids have a good potential as an effective adsorbent in fabric filter for flue gas cleaning purpose.

5 Conclusions

The formulated filter aids material PrekotAC showed a promising characteristic as an adsorbent for VOCs in fabric filter system. Having a small particle size with a large surface area will contribute to a better adsorption properties in a flue gas cleaning process. In addition, the improvement in terms of particle and bulk density would increase the porosity of material and maintain the adsorption performance of formulated material due to the higher surface area. It was also found that the combination of activated carbon and PreKot™ helps to reduce the moisture content in the formulated material. Results showed that PrekotAC has the capability to be applied as an adsorption for volatile organic compound (VOC) during flue gas cleaning process.

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