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# THE EFFECT OF PrekotAC ON PARTICLE PENETRATION THROUGH A PTFE FILTER MEDIA

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## ABSTRACT

A study on the effect of a filter aids material known as PrekotAC on particle penetration through a PTFE filter media was carried out in a laboratory-scale filtration test system. PrekotAC is a combination of an activated carbon with a pre-coating material, PreKot™ which was formulated into four different weight ratios and tested under three different air flow rates of 4, 5, and 6 L/min and a constant material loading of 0.2 mg/mm². The results showed that the penetration of particle was reduced significantly with the use of PrekotAC compared to activated carbon alone. The study also showed that total particle penetration is highly influenced by the air flow rate where a higher air flow rate leads to the increase of total particle penetration during the filtration process.

***Keywords:*** *filter media, PTFE, particle penetration, activated carbon, and PreKot™.*

## ABSTRAK

Kajian mengenai kesan bahan bantuan turas yang dikenali sebagai PrekotAC ke atas penusukan partikel melalui media penapis politetrafluoroetilena (PTFE) telah dijalankan dalam satu sistem ujian penapisan berskala makmal yang telah difabrikasi. PrekotAC merupakan gabungan antara karbon teraktif dan bahan bantuan turas, PreKot™ yang telah diformulasikan ke dalam empat kombinasi nisbah berat yang berbeza dan telah diuji di bawah tiga kadar aliran udara yang berlainan iaitu 4, 5, dan 6 L/min serta bahan muatan yang seragam iaitu 0.2 mg/mm². Keputusan menunjukkan bahawa kadar penusukan partikel berkurangan dengan penggunaan PrekotAC berbanding dengan karbon teraktif sahaja. Kajian juga menunjukkan bahawa jumlah penusukan partikel amat dipengaruhi oleh kadar aliran udara di mana kadar aliran udara yang lebih tinggi membawa kepada jumlah penusukan partikel yang lebih besar ketika proses penapisan.

***Kata kunci:*** *media penapis, PTFE, penusukan partikel, karbon teraktif, PreKot™*

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## 1.0 INTRODUCTION

The assembly of fabric filter bags, commonly called baghouses, is widely used in order to control particulate pollutants from industrial activities. The term baghouse refers to the filtration or separation technology that uses cloth (also known as fabric filter) to control pollutants emission. It has been utilized in various industrial activities such as power generation, chemicals, metal processing, cement and minerals, waste incineration, and food processing.

It has been stated by previous researcher that one of the major advantages of using fabric filter is its ability to cope with a wide range of fly ash, with practically no change in the outlet emission. The electrical properties of ash do not influence the collection efficiency of particles in the fabric filter system [1]. A fabric filter consists of cylindrical bags hanging vertically from a horizontal support plate inside a rectangular housing. The bags are made of cotton, wool synthetic or glass fibers. The filtration process is limited to relatively low filtration velocities of less than 5 cm/s in order to avoid the particles from permeating deep into the fabric filter and reentraining [2].

Figure 1 presents a typical schematic diagram of a fabric filter installed in an incineration plant where both lime and activated carbon are used as the adsorbents or as flue gas cleaning agent. The fabric filter works as a barrier by allowing the air flow to pass through but hinders any undesired particles from penetrating that will form a dust cake layer retained on the fabric filter. The accumulated dust cake further acts as a highly efficient filter media that is capable of removing sub-micron particles [3].

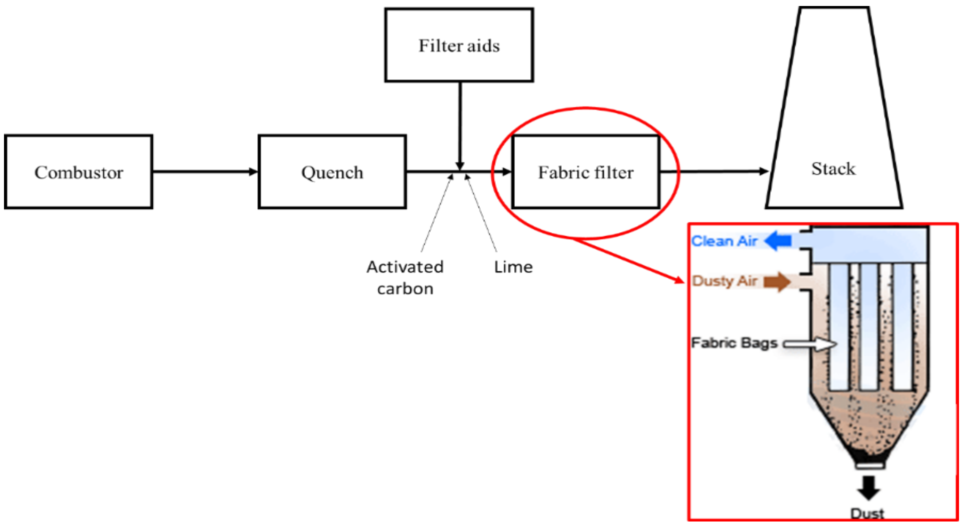


**Figure 1**: Fabric filter in an incineration plant

In comparison with other air purification techniques, fabric filter generally has a higher collection efficiency on particles up to 99.9+% [4]. However, the main concern of fabric filter is its short life span due to the wear and tear problems associated with frequent cleaning requirement. Thus, filter aids are used in the air filtration system to overcome the drawback. In addition, filter aids are needed to enhance as well as to improve the efficiency of filtration and separation process. Filter aids may be applied in various ways and pre-coat filter aids is one of the methods which has been widely used in this case.

Figure 2 depicts the effect of pre-coating filter on handling particulate matter from penetrating through the filter media. As in Figure 2(a), without filter aids material, extremely fine particles can bleed through the interstices of the fabric filter, and thus allow some of it to be imbedded in the media and cause blinding of the filter.

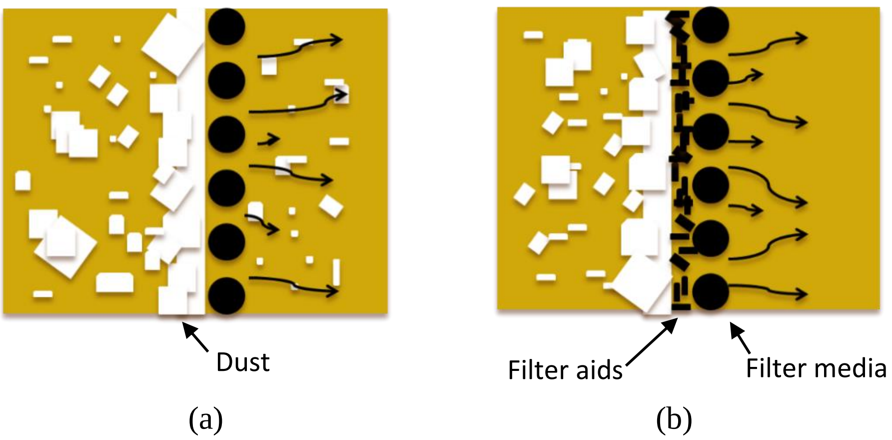


**Figure 2**: Fabric filtration system; (a) without filter aids and (b) with filter aids

In comparison, as shown in Figure 2(b), filter aids build up an initial dust cake on the surface of the filter media, and thus reduces the premature failure of a new filter media. This prevents blinding and clogging of the filter media from fine dust particles that flow into the pores and simultaneously ensures a uniform airflow passing through the filter media. In addition, filter aids help to increase the filtration efficiency while extending the lifespan of the filter media with less cleaning cycle requirement during its operation [5, 6].

Hence, in this study, the effect of PrekotAC on particle penetration through a PTFE filter media is carried out in a fabricated laboratory-scale filtration test system. It is tested under three different air flow rates (4, 5, and 6 L/min) and a constant material loading of 0.2 $mg/mm^2$. PrekotAC is evaluated based on the total particle penetration across its filter cake as a mean of measuring its performance as a newly formulated filter aids material.

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## 2.0 METHODOLOGY

### 2.1 Raw materials, activated carbon and PreKot™

An activated carbon and PreKot™ which are commonly used as an adsorbent and pre-coating material, respectively, were utilized in this study. The specifications of both raw materials are summarized in Table 1.

**Table 1:** Specifications of activated carbon and PreKot™

| Activated carbon | PreKot™ |
|---|---|
| Form, color: Powder, black | Form, color: Powder, snowy white |
| Origin: Coal based | Fusion point: 1300-1400°C |
| pH: 9-11 | Softening point: 900-1100°C |
| Ash content: 8% max | Thermal conductivity: Less than 0.0500 (kcal/mh°C) at 0°C |
| Bulk density: ~440 kg/m³ | Bulk density: ~120 kg/m³ |

### 2.2 Formulation of PrekotAC materials

PrekotAC was formulated into four different ratios as listed in Table 2. Both raw materials, activated carbon and PreKot™, were dried in an oven at 110°C for 24 hours to discard any moisture contained in the material before mixing.

**Table 2:** The formulation ratio of PreKot™ to activated carbon

| Ratio (wt%) PreKot™ : Activated carbon |
|---|
| 10:90 |
| 20:80 |
| 30:70 |
| 40:60 |

### 2.3 Filtration test system

Figure 3 showed the experimental setup of the fabricated laboratory-scale filtration test system which consisted of dust feeder, filter media, pressure manometer, rotameter, particle counter (GRIMM), and vacuum pump [7]. The experimental setup consisted of two cylinders with a dust feeder on the top and a filter holder in between the two cylinders. The experiment

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was performed using a PTFE filter media under three different air flow rates (4, 5, and 6 L/min) which were controlled by using a vacuum pump located at the end of the filtration system and monitored by a rotameter. The particle penetration in terms of counts was monitored using a GRIMM Aerosol Portable Laser Aerosol Spectrometer placed after the filter media. The properties of the PTFE filter media as well as the overall experimental procedures are summarized in Table 3 and Table 4, respectively.

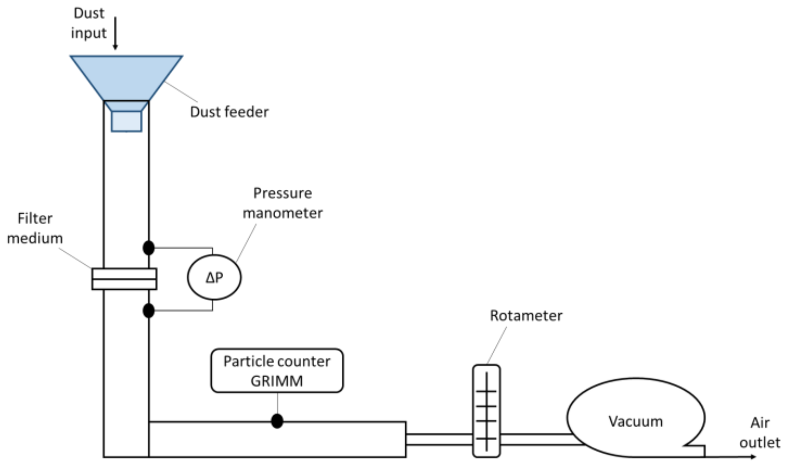


**Figure 3:** Laboratory-scale filtration test system used in this study

**Table 3:** Properties of PTFE filter media

| | |
|---|---|
| Material | PTFE |
| Weight (g/m²) | 800 |
| Thickness (mm) | 1.3 |
| Density (g/cm²) | 0.62 |

**Table 4:** Experimental procedures

| | |
|---|---|
| Filtration area (mm²) | 755 |
| Material loading (mg/mm²) | 0.2 |
| Air flow rate (L/min) | 4, 5, and 6 |
| Filtration velocity (m/min) | 5, 6, and 8 |

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## 3.0 RESULTS AND DISCUSSIONS

### 3.1 Efficiencies of a newly formulated PrekotAC materials as a filter aids material

The performance of the filter aids was calculated by using the ratio of the number of penetrated particles to the blank filter media under various air flow rates and a constant material loading as in Equation 1.

$$R_{pp} = T_f/T_i \qquad \text{(Eq. 1)}$$

where $R_{pp}$ is the Ratio of Penetrated Particles, $T_f$ is the total number of particles after filter aids was added, and $T_i$ is the total number of particles in ambient air particles (without the introduction of filter aids material).

$R_{pp} \leq 1.0$ shows that it has a better collection efficiency with the introduction of filter aids. However, if the $R_{pp} \geq 1.0$, it shows that it has a higher number of particle penetration with the introduction of filter aids.

Figure 4 depicts the ratio of the number of penetrated particles ($R_{pp}$) through a PTFE filter media, with the introduction of filter aids materials under a constant material loading of 0.2 mg/mm² and various air flow rates of 4, 5 and 6 L/min. $R_{pp}=1$ indicates an equal number of particle penetration without the addition of filter aids and is marked with dashed lines in the figure. As illustrated in Figure 4 and in all cases, the activated carbon retains the highest while PreKot™ has the lowest ratio of particles count that are able to penetrate through the filter media. Interestingly, a small addition of PreKot™ in the formulation showed the lowest count of particle penetration as compared to other combinations. It seems that particle size distribution of the respective original and combined material has a major role in this finding.

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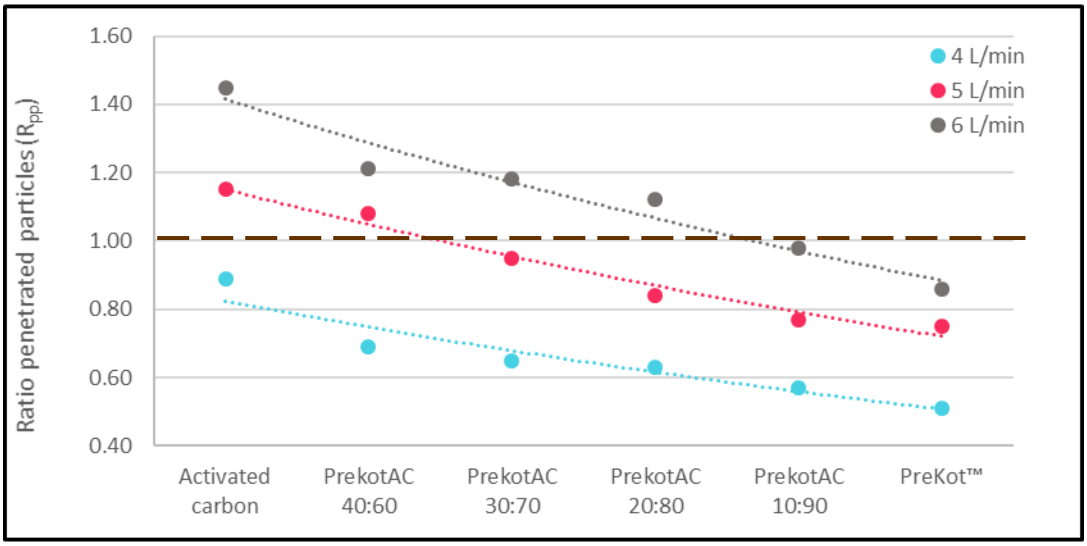


**Figure 4**: The ratio of total penetrated particles of PrekotAC filter aids under constant material loading of 0.2 mg/mm²

As reported by previous authors, raw materials, activated carbon, and PreKot™ have distinctive differences in terms of its particle size distribution [8, 9]. Activated carbon has slightly more than 80 percent of particles ≤ 75 µm compared to PreKot™ that merely has 25 percent of particles ≤ 75 µm (Figure 5). It was expected that activated carbon will result in a higher ratio of penetrated particles compared to PreKot™ since it mainly consisted of fine particles. It was reported that, an increase in particle size will reduce the total particle that can penetrate through the filter media [10]. In comparison to PreKot™, activated carbon has a higher ratio of penetrated particles counts as depicted in Figure 4.

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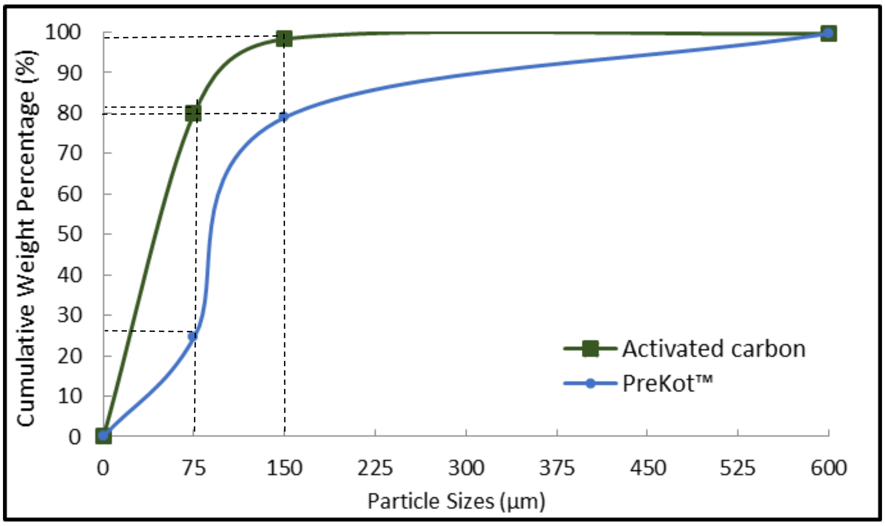


**Figure 5**: Particle size distribution of activated carbon and PreKot™

As depicted in Figure 4, the formulated filter aids material fitted perfectly between these two materials with PrekotAC 40:60 retained the highest while PrekotAC 10:90 had the lowest $R_{pp}$ value. It was found that as the weight of activated carbon decreased, an increase in the ratio of the penetrated particles can be noticed for all materials under the experimental conditions. It was expected that PrekotAC 40:60 will give a better collection efficiency compared to PrekotAC 10:90 since the addition of PreKot™ to activated carbon reduced the number of fine particles contained in the mixture. On the contrary, as plotted in the graph, the results obtained were completely different from the preliminary prediction. It was found that the higher the ratio of PreKot™ in the formulated mixture, the more the total count of particle penetration. This occurs because of the effect of the combined characteristics of activated carbon and PreKot™.

It was stated that PreKot™ has an oddball shapes of a loosely pack material with larger size particles and porosity (Figure 6) [11]. Thus, the characteristics of the material itself lead to higher particle penetration since fine particles can easily penetrate through it. It can be concluded that a higher ratio of PreKot™ in the formulation leads to bigger particle penetration. Hence, as portrayed in Figure 4, PrekotAC 10:90 which showed the minimal ratio of PreKot™ gave a better collection efficiency among these four formulations. On the contrary, PrekotAC 40:60 which showed the highest ratio of PreKot™ in the formulation presented the highest $R_{pp}$ value.

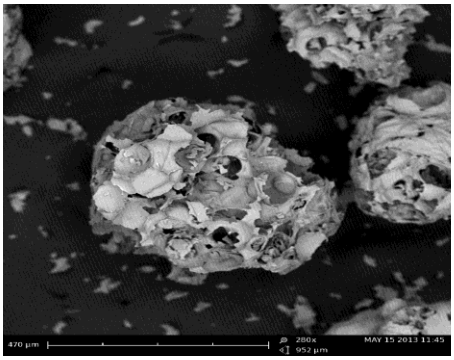

**Figure 6:** Physical view of PreKot™

### 3.2 The efficiency of a newly formulated PrekotAC materials under high filtration velocity

As observed throughout the study, $R_{pp}$ value decreased as air flow rate increased showing that higher air flow rate leads to increase the number of particle penetration. The $R_{pp}$ value for all filter aids material was the lowest at 4 L/min and the highest at the air flow rate of 6 L/min. As expected, the higher the filtration velocity (also referring to air flow rate), the higher the total particle penetration becomes. This phenomenon occurs because higher air flow rate forces more particles to penetrate deep into the filter media pores and therefore causes more particles to pass through the filter media, increases the total particle penetration.

As shown in Figure 7, under a constant material loading, the collection efficiency for all combination of filter aids decreases as the air flow rate increases. All the formulated filter aids materials gave poor performances with an increase in the total particle penetration at the highest air flow rate of 6 L/min. The activated carbon material which consisted of more fine particles presented high $R_{pp}$ = 1.42 at the air flow rate of 6 L/min. However, PreKot™ that mainly consisted of coarse particle size distribution gave a better collection efficiency with $R_{pp}$ = 0.86 at the same air flow rate.

PrekotAC 10:90 presented a better collection efficiency even at the highest air flow rate of 6 L/min with $R_{pp}$ = 0.97. The addition of PreKot™ in the PrekotAC 10:90 mixture helps to block fine particles from penetrating through the filter media. On the contrary, the other three PrekotAC mixtures (i.e. PrekotAC 20:80, PrekotAC 30:70, and PrekotAC 40:60) showed poor collection efficiency as the air flow rate increased where the particle penetration was higher compared to the performance of the PTFE filter media alone. Among these three mixtures, PrekotAC 40:60 showed the worst collection efficiency at the highest air flow rate of 6 L/min. As shown in Figure 7, at 6 L/min, more particles of PrekotAC 40:60 able to penetrate through the filter media compared to the collection efficiency of PTFE filter media alone which contradicts the performance of PrekotAC 10:90.

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It was observed that excessive addition of PreKot™ in the mixture will lead to higher total particle penetration. This is presumably due to the effect of the characteristic of the material itself that has a multi-cellular shape with higher porosity where fine particles can easily penetrate through it especially at a higher air flow rate.

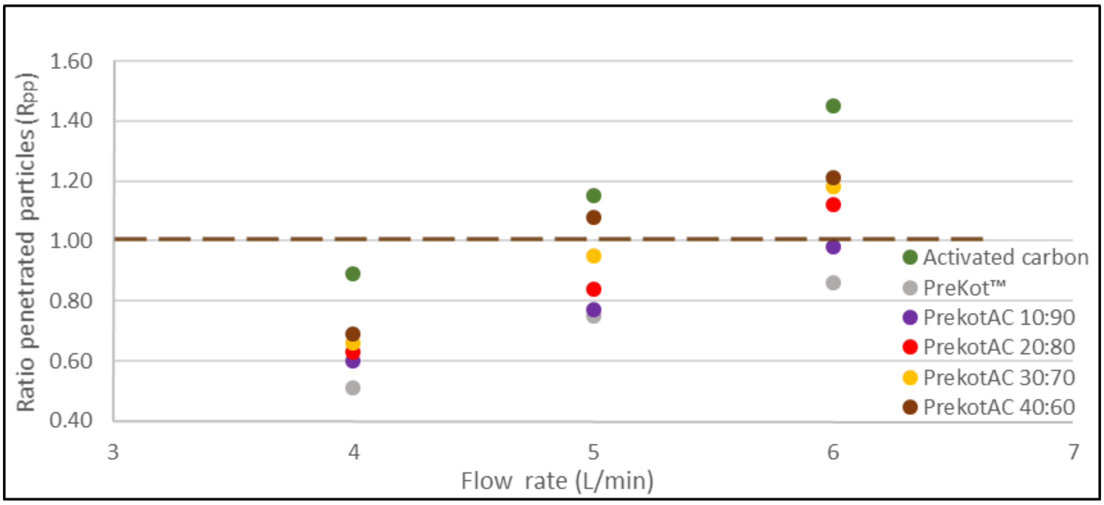


**Figure 7:** The ratio of the number of penetrated particles for all materials involved in this study under three different air flow rates of 4, 5, and 6 L/min and a constant material loading of 0.2 $mg/mm^2$.

Through the observation by previous authors, it was found that total particle penetration is highly influenced by the air flow rate of the filtration process. The authors reported that, the total particle penetration increases rapidly as filtration velocity increases. It was also found by the authors that the total particle penetration increased 16 times higher as the filtration velocity increased from 5 cm/s to 12.5 cm/s showing that the ability of the fabric filter to collect and retain particles degrades markedly with the increase of filtration velocity [12]. The maximum particle size that may deposit on the filter cake is influenced by the air flow rate used during the filtration process. Lower air flow rate leads to bigger particle size since the drag force decreases as the air flow rate decreases [13].

Higher air flow rate reduced the filtration efficiency for all combination of filter aids materials in this study. At the lowest air flow rate of 4 L/min, filter aids material increased the filtration efficiency by reducing the number of particles that can penetrate through the filter media. It has been stated by previous authors that the accumulated filter cake works as a barrier to remove the sub-micron particles or impurities from the air gas stream in air filtration system. Applying filter aids material increases the collection efficiency of the filtration process and reduces the number of penetrable particles through the filter media [14].

As observed in this study, the total particle penetration is dependent on the air flow rate of the filtration process. It can be seen that a higher air flow rate leads to higher total particle penetration as more particles are able to penetrate deep into the filter media pores and pass through the filter media. However, the application of PrekotAC mixture as a filter aids and flue gas cleaning agent in the actual filtration process may not be influenced by this finding since a very low filtration velocity in the actual fabric filter filtration system is normally applied. In an actual plant, the filtration process is limited to relatively low filtration velocities of less than 5 cm/s. In tandem with the requirement of industry seeking for filter aids that have high filtration efficiency, the newly formulated filter aids material, PrekotAC seems the most ideal and suitable combination to be applied as a filter aids and a flue gas cleaning agent in fabric filter filtration system. It was found that PrekotAC has a higher filtration efficiency compared to the performance of raw material, activated carbon.

## 4.0 CONCLUSIONS

The study dealt with the effect of particle size distribution as well as the air flow rate on the total particle penetration of a newly formulated filter aids material, PrekotAC. It was found that particle penetration is highly influenced by particle size distribution of the material. Raw material activated carbon showed the highest $R_{pp}$ while PreKot™ retained the lowest $R_{pp}$ since the former mostly consisted of fine particle size distribution. In terms of PrekotAC materials, PrekotAC 10:90 showed the lowest $R_{pp}$ while PrekotAC 40:60 showed the highest $R_{pp}$ among these four mixtures. It was also found that, as the ratio of PreKot™ in the PrekotAC mixtures increased, the number of particles penetration increased as well. PrekotAC mixtures perform a better collection efficiency with less particle penetration compared to activated carbon alone due to the effect of diverse in different particle size distributions of non-uniform particle size fractions of the PrekotAC mixtures. The total particles that penetrate through a filter media is also dependent on the air flow rate of the filtration process in which the increase of air flow rate forces particles to permeate deep into the filter media, eventually penetrate the filter media.

## REFERENCES

[1] Wieslander, P. and Francis, S. L. (2008). Cost Effectively Increasing the Filtration Area in Fabric Filters for Large Power Plants. *Presented in 11$^{th}$ International Conference on Electrostatic Precipitaion.* Hangzhou, China.
[2] Abdullah, L. C. and Ismail, M. H. S. (2010). Hot Gas Cleaning; Particle Removal & Desulphurisation. Universiti Putra Malaysia Press, Selangor, Malaysia. 47-49.
[3] Turner, J. H., Viner, A. S., McKenna, J. D., Jenkins, R. E. and Vatavuk, W. M. (1987). Sizing and Costing of Fabric Filters. *Journal of the Air Pollution Control Association.* 37(6): 749-759.

[4] Saleem, M. and Krammer, G. (2007). Effect of Filtration Velocity and Dust Concentration on Cake Formation and Filter Operation in a Pilot Scale Jet Pulsed Bag Filter. *Journal of Hazardous Materials.* 144: 677-681.

[5] Hajar, S., Nurnadia, A., Rashid, A. and Ammar, M. (2013a). Precoating Material as Filter Aids and Flue Gas Treatment for Fabric Filter. *Article Berita Ensearch.* April-June 2nd quarter. 4-9.

[6] Kinnarinen, T., Golmaei, M. and Häkkinen, A. (2013). Use of Filter Aids to Improve the Filterability of Enzymatically Hydrolysed Biomass Suspensions. *Industrial and Engineering Chemistry Research.* 52: 14955-14964.

[7] Nurnadia, A., Rashid, M., Hajar, S. and Ammar, M. (2015a). Effect of Filter Aids on Two Different Filter Media under High Filtering Velocities. *International Conference on Sustainable Initiatives 2015 (ICSI 2015).* 24th – 25th August 2015. Kuala Lumpur, Malaysia.

[8] Hajar, S., Rashid, M., Nurnadia, A. and Ammar, M. (2013b). Formulation of a New Pre-coating Material for Fabric Filtration in Air Filtration System. *Malaysia-Japan International Institute of Technology (MJIIT) – Japanese University Consortium (JUC) Joint International Symposium.* 6th – 8th November. Hiratsuka, Japan.

[9] Nurnadia, A., Rashid, M., Hajar, S. and Ammar, M. (2015b). Penetration of Particle across a Newly Formulated Filter Aids Material. *3rd International Science Postgraduate Conference.* 24th – 26th February 2015. Johor Bahru, Malaysia.

[10] Bénesse, M., Le Coq, L. and Solliec, C. (2006). Collection Efficiency of a Woven Filter made of Multifiber Yarn: Experimental Characterization during Loading and Clean Filter Modelling based on a Two-tier single Fiber Approach. *Journal of Aerosol Science.* 37: 974-989.

[11] Hajar, S., Rashid, M., Nurnadia, A. and Ammar, M. R. (2015). The Characteristics of a Formulated Filter Aids for Fabric Filters. *Powder Technology.* 283: 315-320.

[12] Leith, D., First, M. W. and Feldman, H. (1977). Performance of a Pulse-jet Filter at High Filtration Velocity, II. Filter Cake Redeposition. *Journal of the Air Pollution Control Association.* 27(7): 636-642.

[13] Li, X. Z., Hess, H. and Höflinger, W. (2003). Influence of Operating Parameters on Precoat Layers Built Up Under Crossflow Condition. *Separation and Purification Technology.* 31: 269-280.

[14] Ravert, E. (2006). Precoating New Filters for Better Airflow, Longer Filter Life. *Powder Bulk Engineering,* CSC Publishing. Minnesota, United States.