

EFFECT OF PREKOTAC AS FILTER AIDS ON PRESSURE DROP AND PARTICLE PENETRATION IN PILOT PLANT FABRIC FILTRATION SYSTEM

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ABSTRACT

Filter aids are powdered materials which are produced from a wide variety of raw materials used as precoat to improve filtration in fabric filter. Based on previous study, filter aids build up a porous, permeable and rigid cake structure that retains solid particles and allow the gas pass through in filtration. This study aims, to investigate the performance known as PrekotAC on pressure drop and particle penetration in pilot plant fabric filtration system with varying material loadings and filtration velocities. The PrekotAC is an admixture of PrekotTM and activated carbon mixed in different weight compositions. Based on the result obtained, consistent pressure drop across the filter cake where the pressure drop decreases as the ratio of PrekotTM contained in the formulated PrekotAC mixture increases as influenced by the porosity of the former which forms more permeable filter cake resulting in lower pressure drop. Since pressure drop across the filter cake determines the cleaning frequency which closely related to the life span of the filter media, applying filter aids helps to reduce its pressure drop thus extending the life span of the fabric filter. The finding also showed that the total particle penetration through the fabric media was proportionally related to addition of PrekotTM in the PrekotAC admixture. It is observed that higher ratio of PreKotTM in the formulated PrekotAC materials leads to higher number of particles that are able to penetrate through the filter media. Nevertheless, PrekotAC 10:90 which have the minimal ratio of PreKotTM, demonstrated better collection efficiency among the mixtures.

Keywords: Filter aids; Precoating material; Fabric filters; Pressure drop; Penetration

INTRODUCTION

The increasing concern about air pollution, lately compounded by industrial growth, has made the development of techniques and equipment for the purification of gases absolutely important. Recently as claimed by previous researcher, huge amounts of fly ash are produced as a result of the increase in coal combustion. Due to the possible

release of contaminants to the surrounding soils, surface and groundwater, the disposal of fly ash have environmental impacts [1]. Moreover, exposure to air pollution has deleterious effects on both physical and mental health to human respectively [2]. In addition to environmental issues, improving the techniques for filtering various kinds of emitted particles is important to the industries that recover them [3]. Fabric filtration has been used as an air pollution control system because of its excellent separation efficiency even for ultrafine dust particles [4]. Filtration possesses several advantages such as ease of installation and operation. In addition, fabric filters are also a very promising option for compliance with possible future emission regulations of fine particulates [5]. Flue gas cleaning agents such as activated carbon and lime are normally used along with fabric filtration for air emission control especially in waste incineration processes. However, the life span of the fabric filter is usually shortened and influenced by the dust cake formation that required frequent cleaning of the fabric filter. Thus, in order to reduce the pressure drop during operation and to prevent clogging of the filter media by sticky and ultrafine particles it is essential to use a precoat. Alternatively, a simple technique is to apply so called 'pre-coat' material to coat a layer of inert material onto the each of the fabric as a barrier for protection as well as to allow a uniform air flow passing through the filter media. Precoat filtration or filter aids filtration process has found to provide a high quality separation over a wide range of industrial applications such as food and beverage processing, oil refining and chemical engineering for many years [6].

Previously, filter aids have been applied in the air filtration system in order to increase the collection efficiency during the filtration process. As reported, filter aids consisting groups of inert materials used to coat the fabric as a 'barrier' for protection as well as to allow a uniform airflow passing through the filter cake [7]. Typically, filter aids build up a porous, permeable and rigid cake structure that retains solid particles and allow the gas pass through. The filter cake that deposited on the surface of the filter media acts as a new filter media that helps to increase the filtration efficiency. Unfortunately, during cake filtration process, some particles do not participate in the formation of the filter cake. The particles either penetrating through the filter media or clog and block the pores of the filter media. Therefore, understanding the parameters affecting the filtration efficiency is important in determining the characteristics of the filter aids where high performance filtration requires low particle penetration without excessive pressure drop builds up across the filter media [8]. In this study the performance of a formulated precoating material designated as PrekotAC which is a combination of activated carbon and a potential precoat material (PreKot™) was investigated. A detailed result of the study is presented in this paper.

MATERIALS AND METHOD

The Raw Material and Preparation of Filter Aids

A powder form coconut based activated carbon and PreKot™ was used in this study. Table 1 summarized the specifications of the material used in the formulation. Filtration aids was formulated by mixing the adsorbent activated carbon with the pre-coating material PreKot™ in a selected proportion of PreKot™ from 10 to 20% by weight. Both activated carbon and PreKot™ were dried in an oven at 105°C for 24 hours before

mixing. Table 2 presents the particle size distribution of the raw materials activated carbon and PreKot™ that showed that particle size fraction of smaller or equal to 75 μm or $\leq 75 \mu\text{m}$ for activated carbon is about 80 percent that is three times much more than PreKot™. As shown in Table 2, PreKot™ has a higher percentage of coarser particles with 75% of it consists of particle size fraction higher than 75 μm .

Table 1: Specifications of activated carbon and PreKot™ used in the formulation

Activated carbon	PreKot™
Form and colour: powder, black	Form and colour: 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
Surface area: 850 (m^2/g)	(kcal/mh °C at 0°C)
Bulk density: 440 (kg/m^3)	Bulk density: 119 (kg/m^3)

Note : PreKot™ is a proprietary of AMR Environmental Sdn. Bhd

Table 2: Particle size distribution of activated carbon and PreKot™

Particle size (μm)	Cumulative percentage (%)	
	Activated carbon	PreKot™
≤ 75	80.0 ± 0.6	24.5 ± 1.0
≤ 150	98.3 ± 1.1	79.0 ± 1.7
≤ 600	99.7 ± 0.1	99.7 ± 0.2

Pilot Plant Fabric Filter

The pilot plant filtration system is built with 16 bag type filters (200mmD, 700mmL), consists of a dust feeder, hopper pulse jet cleaning system and an induced fan as shown in Figure 1. The experiment was performed under different dust loading and filtration velocities. Under these experimental conditions, the pressure drop and particle penetration were determined before and after the filter aids is introduced into the system. GRIMM Aerosol Portable Laser Spectrometer (Model 1.109) was placed at the stack sampling point for measuring and sampling purposes. The pilot plant operation conditions are summarized in Table 3.



Figure 1: a) Pilot plant fabric filtration system.

b) Fabric filter from top view

Table 3: Operating variables and conditions of the study

Description	Range	Unit
Dust loading	0.2-0.6	mg/ mm ²
Total Filtration Area	4.57	m ²
Upper pressure drop limit $\Delta P_{\max}$	0-4	inch H ₂ O
Filtration velocity, u	1-3	m/min

Pressure Drop across the Unit

The pressure drop of pilot plant was determined using Magnehelic® Differential Pressure Gauge pressure gauge installed across the pilot plant. The pressure drop across the unit was taken in every experimental run.

Efficiency of PrekotAC materials as filter aids material.

The particle count penetration was monitored using GRIMM Aerosol Portable Laser Aerosol Spectrometer (GRIMM, Model 1.109). In order to study the performance of the PrekotAC, the ratio of the number of penetrated particles with respect to the blank filter under various filtration velocity and material loadings was calculated. The ratio was calculated based on Eq. 1 as listed below.

Ratio penetrated particles

$$(R_{pp}) = T_f / T_i \quad (1)$$

Where;

R_{pp} = the ratio of the number of penetrated particles
 T_i = total number of penetrated ambient air particles across the fabric media
 T_f = total number of penetrated particles across the fabric media after filter aids added

The performance of each of the formulated materials in terms of its total penetration was evaluated based on Eq. 1. If the calculated R_{pp} is less than 1.0 ($R_{pp} < 1.0$), it shows that filter aids help to improve the collection efficiency compared to the performance of ryton fabric filter alone. However, if the R_{pp} is greater than 1.0 ($R_{pp} > 1.0$), it shows that with the introduction of filter aids, the total particle penetration is higher across the ryton fabric filter alone. It can be summarized as illustrated in Table 4.

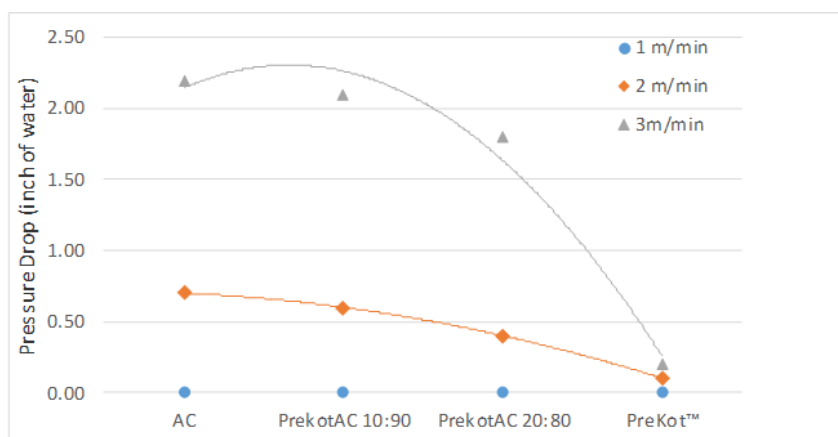
Table 4: Ratio penetrated particles

$R_{pp} = 1$	equal ratio of the number of penetrated ambient particles compared to the addition of filter aids
$R_{pp} < 1$	better filtration efficiency, less particle penetration compared to fabric filter alone
$R_{pp} > 1$	poor filtration efficiency, higher penetration compared to fabric filter alone

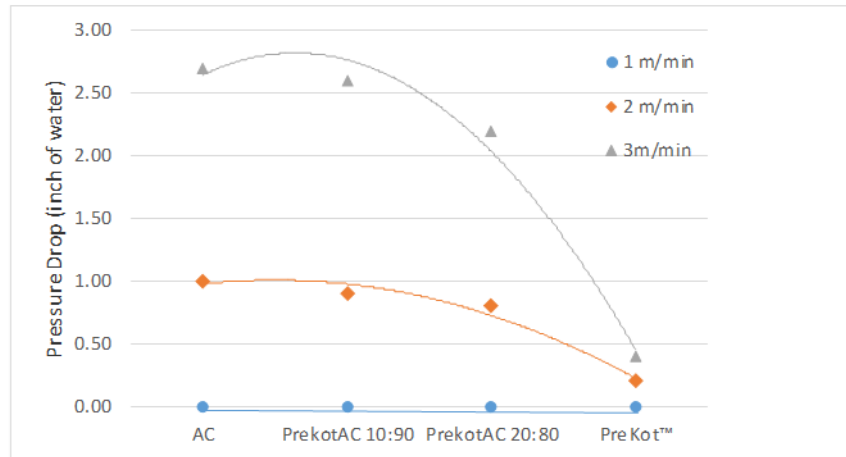
RESULT AND DISCUSSION

Effects of formulated filter aids mixture ratio on pressure drop.

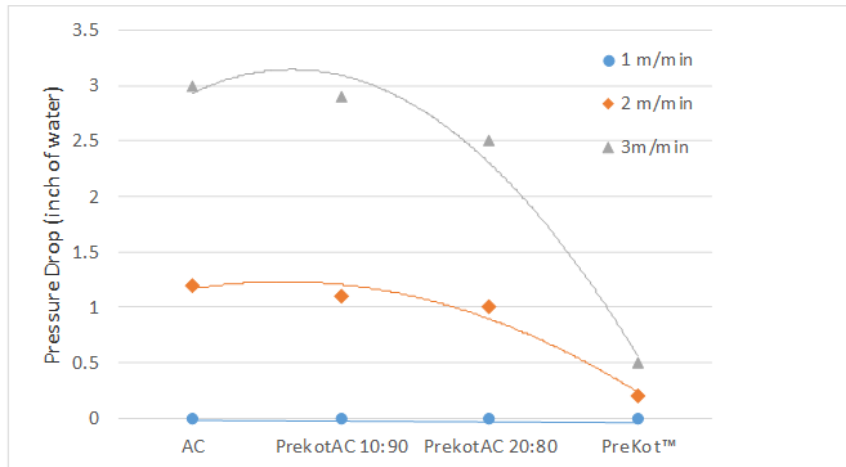
Figure 2 presents the pressure drop across the different formulated filter aids under various filtering velocities (1-3 m/min) and material loadings from 0.2 to 0.6 mg/mm² which showed that pressure drop increases with increasing filtration velocity. As observed, the pressure drop across the fabric media showed a consistent trend in which the admixture of filter aids having pressure drop recorded in between activated carbon and PreKot™. Both PrekotAC 20:80 and PrekotAC10:90 present a reasonably good pressure drop value of ranging from 0.4 to 2.9 inch of water for filtering velocity ranging from 1 to 3 m/min. A higher pressure drop is expected in actual industrial application where the filter cake is not merely the filter aids but also contributed by other dust material generated in the process. Similar finding by previous study also found that as the filtration velocity increases, the pressure drop of the filtration system increases [9, 10]. The pressure drop increases with the cake formation on the filter medium and end of the cycle is reached as soon as the pressure drop reaches a certain maximum value usually for the industrial range is from 4-6 inch of water. The finding revealed that formulated filter aids able to reduce pressure drop by 16 to 42% compared to activated carbon alone.



(a)



(b)



(c)

Figure 2: Pressure drop across the filter media and dust cake at various material loadings. (a) 0.2 mg/mm², (b) 0.4 mg/mm², and (c) 0.6 mg/mm²

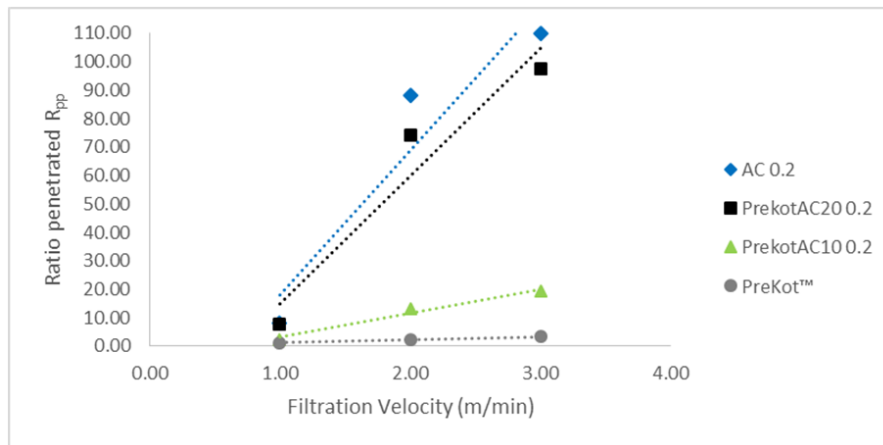
The fluffy structure and coarser particle size distribution characteristics of PreKot™ help to form a porous filter cake allowing a uniform airflow passing through the filter media resulting in low pressure drop. This could be explained by the porosity of the filter aids. It is believed that, the porosity of the dust cake decreases as the filtration velocity increases because greater compaction of dust cake occurred at higher velocities [11]. As observed the addition of PreKot™ in the admixture simultaneously decreases the pressure drop across the fabric filter due to this effect. Thus, the addition of the material with activated carbon in the formulation, significantly contribute to the properties of the admixture as filter aids.

Previous studies by [7] indicate that the particulate size distribution also plays a substantial role in decreasing the pressure drop with the addition of PreKot™. PreKot™ has coarser particle size distribution compared to activated carbon which mainly consists of fine particles that resulting to this effect. As reported by [12] observed that

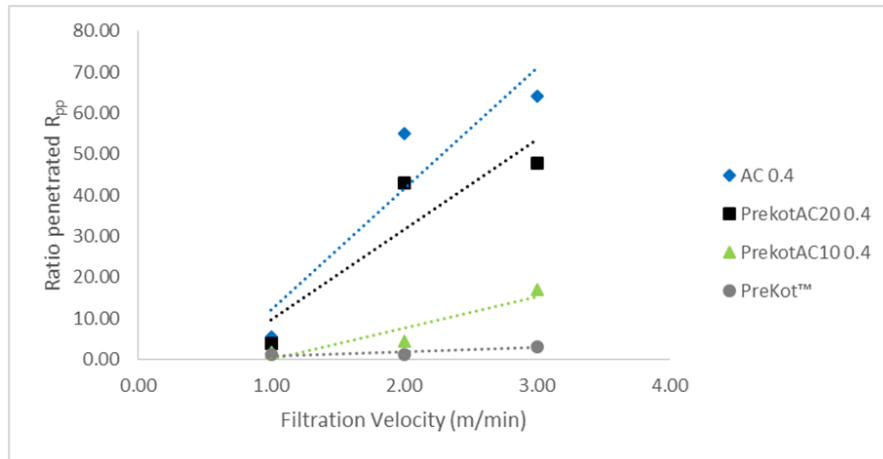
filter aids applied in the air filtration system reduces the pressure drop across the filter cake as well increase the filtration efficiency. The filter cake that consists of fine particles will form a compacted dust cake of low permeability which makes it difficult for the detachment of dust cake during cleaning process. Nevertheless, filter cake that form from a filter aids which has coarser particle size can be easily removed from the filter media as compared to filter aids that has finer particles because it has sufficient inertia to break free from the filter media during a cleaning process [13]. Thus, a marked difference between the particle size distribution of activated carbon which consists of finer particles and PreKot™ that has coarser particles presents a good combination as one component material that works as a filter aids for fabric filtration system.

Effects of formulated filter aids mixture ratio on collection efficiencies

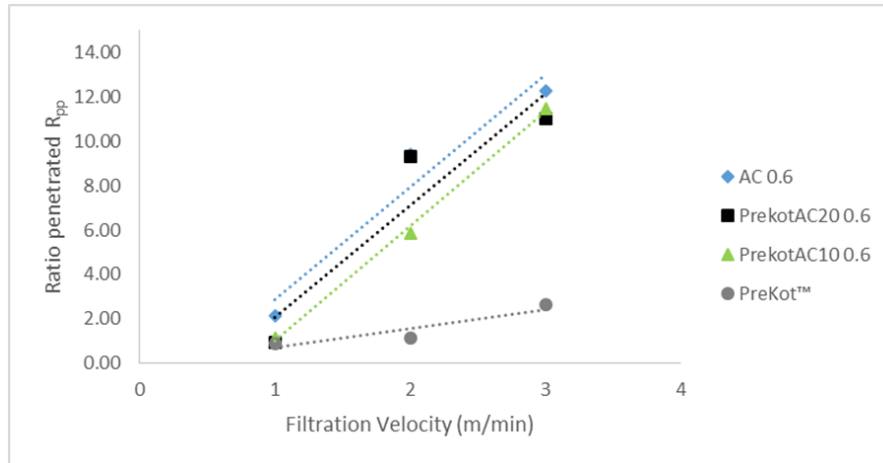
The penetration behaviour of filter aids was evaluated further in pilot plant fabric filter. Figure3 present the ratio penetrated against various filtration velocities from 1m/min to 3m/min for activated carbon, PreKot™, PrekotAC 20:80 and PrekotAC 10:90 under different material loading. As observed the R_{pp} increases with filtration velocity illustrating that more particles are able to penetrate through the media under high filtration velocity. PreKot™ alone showed the lowest number of particles penetrated 0.9 to 3.3 through the fabric media in all cases while activated carbon presents the highest.



(a)



(b)



(c)

Figure 3: The ratio of the number of penetrated particles under three different material loadings. (a) 0.2 mg/mm², (b) 0.4 mg/mm², and (c) 0.6 mg/mm²

This is expected as more of fine particles are found in activated carbon particle size distribution which can escape through the pore size of the filter media easily. In addition, PrekotAC 10:90 and PrekotAC 20:80 also gave low particles penetration with the ratio range of 0.9 to 7.6 at filtration velocity 1 m/min. This can be explained by the addition of Prekot™ that helps to block the fine particles from penetrating through the filter media. As observed in figure, at filtration velocity 1 m/min ratio penetrated for all cases shows lower ratio penetrated for all cases. However, at 2 and 3 m/min of filtration velocity increase rapidly up to 100 value of ratio penetrated. The results obtained in this study suggest that to use lower filtration velocity during filtration in fabric filter. In addition, the higher filtration velocity leads to greater total ratio penetrated due to deep penetration of particles where particles can easily penetrating through the filter media. Previous study also indicates that the most penetrating particle size decreases as filtration velocity increases because as velocity increases, the most penetrating particle size shifts to a smaller size [14].

PreKot™ coarser particles decreases as the open pores of the filter media were closed where its capture and block particles with larger size from penetrating through the filter media, gradually reducing the penetration of larger sized particles. Precoat layer that form by the PrekotAC, due to their complex shape and surface properties, are able to capture very fine particles as well as macromolecules. In previous research indicates that the number of particles penetrating through the filter media is very high during the initial stage of the filtration process and decrease exponentially as the first dendrites are formed inside the filter media pores which capture and block more particles from passing through the filter media [15]. Consequently, no particles pass the filter media and all particles are deposited either inside the filter media or the filter cake itself with time.

This finding revealed that, the characteristics of the material in terms of its particle size distribution contribute to the result obtained. As listed earlier in Table 2 activated carbon has more than 80% of particles $\leq 75 \mu\text{m}$ compared to PreKot™ only 20% of it is particles $\leq 75 \mu\text{m}$. Therefore, it is expected that activated carbon which predominantly consists of fine particles has higher number of penetrated particles compared to PreKot™. On the contrary for admixture, PrekotAC 10:90 has the lowest while PrekotAC 20:80 maintain the highest total penetrated particles under a constant material loading. The features of PreKot™ with high porosity and multi cellular shape of the leads to higher particle penetration since fine particles can easily passing through the material under high filtration velocity.

Figure 4 presents the relation between particle penetrated and material loading for various filter aids at a constant filtration velocity of 1 m/min which normally applied in industry. The figure showed that the total particle penetration across the fabric with PreKot™ and activated carbon was the lowest and highest, respectively. The latter registered as high as R_{pp} of 8.2 at 0.2 mg/mm^2 , contributed by the penetration of its fine particle size fraction. On the contrary, PreKot™ which mainly consists of coarse particle size fraction gave a better collection efficiency with the $R_{pp} = 1.1$ at the same filtration velocity and material loading.

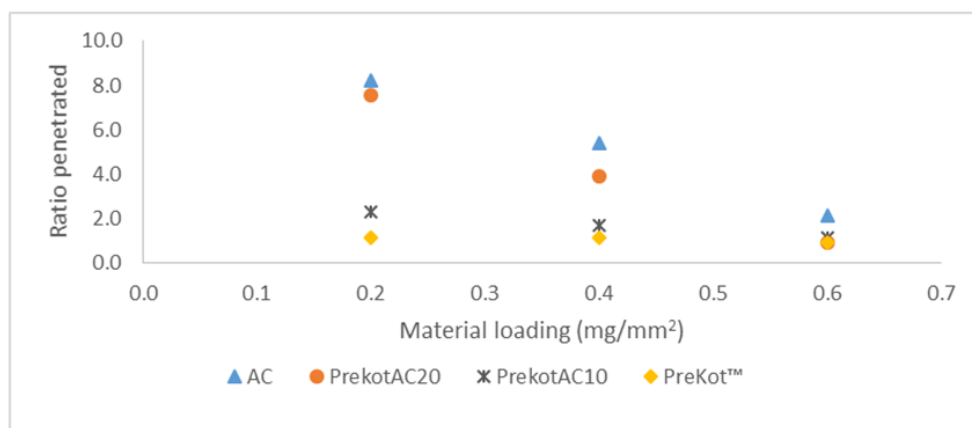


Figure 4: Effects of material loading on total particle penetration at filtration velocity 1 m/min

In tandem with the requirement of industry seeking for filter aids that has high filtration efficiency with low pressure drop across the filter cake, the filter aids material, PrekotAC seems to be suitable combination to be applied as filter aids and flue gas cleaning agent in fabric filtration system. PrekotAC as filter aids able to reduce the pressure drop across the filter cake and total particle penetration compared to the performance of the raw material, activated carbon alone.

CONCLUSION

This study has shown the actual performance of pilot plant fabric filter via assessment of pressure drop and penetration with the application of filter aids. The performance of the unit was evaluated by varying the filtration velocity and material loading. As observed from the experiment, the higher the filtration velocity and material loading are, the higher the pressure drop across the filter cake layer becomes with activated carbon exhibits the highest while PreKot™ has the lowest pressure drop across the filter cake. PrekotAC admixtures shows a consistent pressure drop behaviour across the filter cake with PrekotAC 10:90 has the highest and PrekotAC 20:80 experiences the lowest between the PrekotAC admixtures. As found through the experiment, the pressure drop across the filter cake decreases as the ratio of PreKot™ contained in the PrekotAC mixture increases, proven the capability of PreKot™ to form more porous filter cake thus reducing the pressure drop even under high air flow rate and material loading. In addition, it reduces the total particle penetration compared to the performance of the raw material, activated carbon alone. PrekotAC admixtures can still be considered as a good filter aids since particle that able to pass through the filter media are fine particles.

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