DEVELOPMENT OF ACTIVATED CARBON FIBRE MATS FOR COMBINED PARTICULATE AND VAPOUR FILTRATION (CPVF)

Christopher J Hindmarsh and Paula L Phillips
Dstl, Porton Down, Salisbury, Wiltshire SP4 0JQ, UK

Corresponding author e-mail address: chindmarsh@dstl.gov.uk

Introduction

Respiratory protection filters are generally comprised of two filter media; a glass fibre particulate material to remove aerosols, followed downstream by a layer of granular activated carbon to remove toxic vapours. Whilst this is an effective method for providing protection, there is a drawback in the form of an associated pressure drop across the filter leading to a breathing resistance. A reduction in the pressure drop, whilst maintaining, or improving, the effectiveness of the filter is therefore highly desirable in order to reduce the user burden. A single filter media that is capable of removing both particulate and vapour challenges, could be one possible solution to overcoming this problem. Carbon fibres are potential candidates for this concept, since their fibrous form can be utilised to remove aerosols and in addition they can be modified to impart vapour adsorptive properties. Activated carbon fibres offer a number of advantages over conventional granular activated carbons. These include (i) very high adsorption rates, (ii) they avoid problems arising from channelling and settling, and (iii) they retain some of the mechanical properties of the original carbon fibre[1]

Previous research at Dstl, which has concentrated on assessing the performance of activated carbon fibres on a small-scale, has proved encouraging [2,3]. Recent studies have been aimed at addressing scale-up issues by producing realistic sized carbon fibre filter mats. Mats of varying mass and thickness have been produced in order to assess the optimum configuration for providing protection. This paper describes the performance of the scaled-up activated carbon fibre mats to remove both physisorbed vapours and particulate challenges. In addition, the pressure drop across the mats has been determined.

Experimental

Carbon fibre mats were prepared from an activated carbon fibre (ACF) and small amounts of vapour grown carbon fibres (VGCF). A slurry of fibres and water was poured into a standard sheet former (Messmer Buchel™), drained, and the resulting fibre mat removed. The fibre mat was dried in a vacuum oven at 120°C for eight hours. The mats were placed in a sample cell and subjected to a salt aerosol (mass median diameter 0.6 μm). Salt penetration was measured using a sodium flame photometer

(Moores). A manometer attached to either side of the sample cell was used to ascertain the pressure drop across the filter mat. Regarding vapour testing, the mats were placed in-line and challenged with 2000 mg m^{-3} of hexane at a flow rate of 30 l min^{-1} and 22 ^{o}C. The effluent was monitored using a mass spectrometer (ESS instruments). The characterisation data for the activated carbon fibre (ACF) is shown in Table 1. Surface area and pore volumes were determined using nitrogen adsorption at 77 K.

Table 1. Characterisation data for C-6 activated carbon fibre

Sample	**Specific Surface Area (m^2 g^{-1})**	**Total Pore Volume (cm^3 g^{-1})**	**Micropore Volume (cm^3 g^{-1})**	**Mesopore Volume (cm^3 g^{-1})**
ACF	1503	0.660	0.615	0.045

Initially, three different masses of carbon fibre mat were investigated, 5, 15 and 25 g. Each mass was studied at two different bed depths, 2.5 and 4.5 cm, in order to ascertain the influence of compression performance. The diameter of the mats used was 11 cm.

Results and Discussion

The results for the particulate removal studies are shown in Figure 1. The results indicated that as the mass of carbon fibres in the mat increased, the ability of the mat to remove the salt aerosol also increased. For the 25 g mat approximately 99.5 % of the salt aerosol was removed.

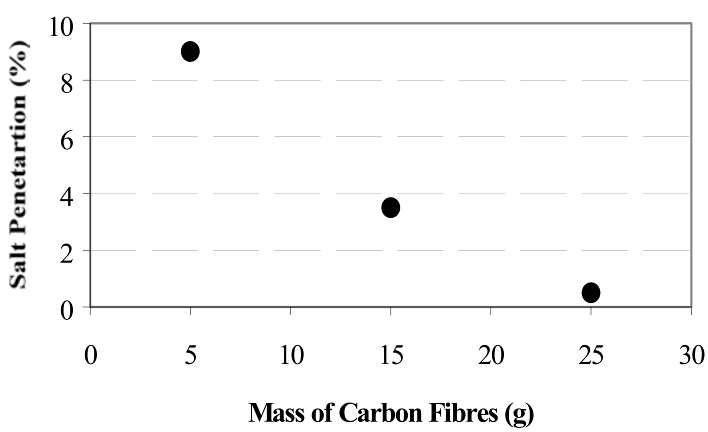

Figure 1. Variation in salt penetration with mass of activated carbon fibres in mat

The results of the pressure drop studies are shown in Figure 2. A control sample was also included in the tests, which represented the pressure drop of a respirator canister containing granular activated carbon and a glass fibre particulate filter. The results show that for a given mass, the pressure drop is greater if the carbon fibre mat is compressed. The results also indicate that at the bed depths and canister diameter studied a mass of carbon fibre greater than 15 g would result in a pressure drop higher than that of the control. It should be noted however that the 25 g mat could expand to a bed depth significantly higher than 4.5 cm, whilst the 5 g mat was at its maximum expansion at 4.5 cm. It is therefore possible to assume that the 25 g mat may give a pressure drop below that of the control if it was tested at its maximum expansion of around 15 cm, at the diameter studied.

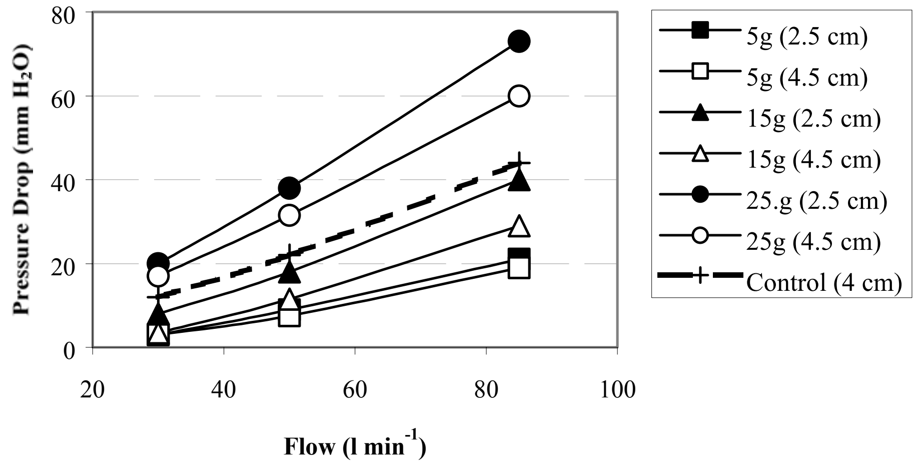

Figure 2. Variation of pressure drop with flow rate for carbon fibre mats of varying mass and bed depth.

The results of the hexane studies are shown in Figures 3 and 4. Figure 3 shows typical breakthrough profiles for the 15 g mat at bed depths of 2.5 and 4.5 cm. Whilst it is evident that the time to reach 1 % breakthrough (20 mg m^{-3}) is greater for the 4.5 cm sample, there is a small leak through the bed. This suggests that the more open structure of the thicker mat may lead to leak paths.

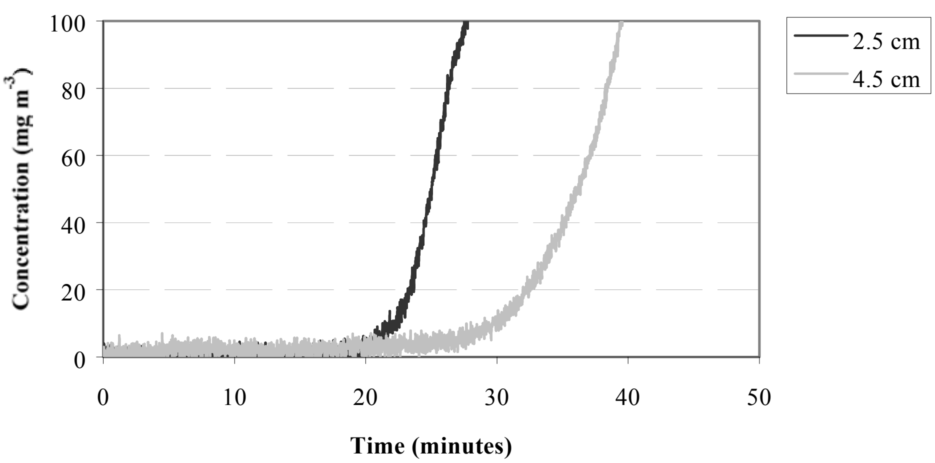

Figure 3. Breakthrough profiles for the 15 g mat (11 cm diameter) at bed depths of 2.5 and 4.5 cm, challenged with hexane (2000 mg m^{-3}) at 22 ^{o}C.

Figure 4 shows the times to 1% breakthrough of hexane for the three different masses of carbon fibres used in the mats at the two different bed depths. The results show that instantaneous breakthrough occurs for both of the 5 g mats, whilst the larger 25 g mats can give protection for times up to 25 minutes. Similar to the observations for the 15 g mats, a small leak was observed in the 25 g mat at 4.5 cm bed depth.

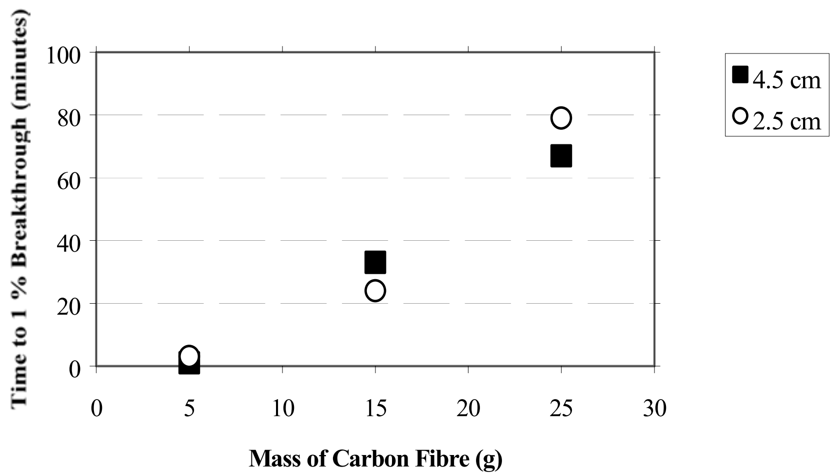

Figure 4. Variation in time to 1 % breakthrough of hexane with mass of carbon fibre at two different bed depths

The time to 1 % breakthrough of hexane for the carbon fibre mats is reduced when compared to a granular activated carbon bed of the same dimensions. It is envisaged, however, that by using mats of a greater diameter, a significant increase in performance will be observed at a reasonably low pressure drop.

Conclusions

The results show that the activated carbon fibre mats are capable of removing >99.5 % of a salt particulate challenge. The pressure drop of the carbon fibre mats is a function of the amount of fibres in the mat and the degree to which the mat is compressed. Pressure drops lower than those currently observed in respirator canisters can be achieved, however their ability to remove physisorbed vapours is reduced compared to a similar sized bed of granular activated carbon. For the uncompressed mats, a small leak path may exist and requires further study.

References

[1] Mays, TJ, in ‘Carbon Materials for Advanced Technologies’ (Ed. Burchell, T.D.), Oxford, Pergamon, 1999.

[2] Chinn MJ, Hindmarsh CJ, and Pears LA, Carbon Fibres for Combined Particulate and Vapour Filtration, Journal of the International Society for Respiratory Protection, 2003, 19, Issue III&IV

[3] Chinn, M.J. Hindmarsh, C.J. Keel, H.E., Pears, L.A. and Pritchard, S.J., Dynamic Breakthrough Studies on Physically and Chemically Activated Carbon Fibres, Conference Proceedings: Carbon 2001, Lexington, July 01