Penetration of Commercial Filter Materials in Detailed Study

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PENETRATION OF COMMERCIAL FILTER MATERIALS IN DETAILED STUDY

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INTRODUCTION

Aerosol filtration is the most widely used process to capture aerosol particles (Hinds, 1998). It is used in such diverse applications as emissions cleaning, occupation safety and health, air-conditioning, or vacuum cleaning. In aerosol science, filters are used either for aerosol sampling or for production of particle-free air (HEPA filters), e.g. in clean rooms or laminar boxes. In most of these applications, it is commendable to determine penetration, or filtration efficiency, of the chosen filtration unit.

There are well-known standards describing how to perform the testing of filter efficiency, such as EN 1822 for HEPA and ULPA filters; EN 143 and 149 for respirators. Nevertheless, all these tests are performed using polydisperse aerosol with given Count Median Diameter (CMD) positioned close to the Most Penetrating Particle Size (MPPS), assumed to be at 300 nm in diameter. Moreover, these tests measure only overall penetration giving no information about the real MPPS that is often shifted towards smaller diameters. It also means that the standard omits the fact that penetration is a function of particle size. Thus, the results of such an analysis give only limited information about penetration of tested filter material.

Another issue regarding the official filter testing methods is related to the choice of testing particle material. Shape of these particles (cubical shape for NaCl) does not fully comply with the commonly used theoretical assumption in aerosol science – spherical particles (e.g. when we select monodisperse particles in the DMA). Therefore, precise and detailed filter testing requires size-resolved measurement using well-defined aerosol particles having proper shape (e.g. (NH4)2SO4 – ammonium sulphate (AS)).

EXPERIMENTAL SET-UP

Even though commercial filter testers exist on the market (e.g. Automated Filter Tester 3160, TSI), we have developed our own filter testing instrument. The filter tester (see Fig. 1) is based on a DMA (Vienna type, home-made at ICPF) built into a home-made electrostatic classifier, two CPCs (TSI UCPC 3025A), ^{85}Kr neutralizers and a filter holder. A commercial nebulizer (AGK 2000, Palas) was used to generate AS particles dried by passing through a diffusion dryer. Drying of aerosol particles before entering the DMA is vital for proper particle size selection. For example, in the case of ammonium sulphate, the over-sizing could make up to 20 % in diameter at 40% RH. The correction for differences in counting of the two CPCs as well as for the different location of each CPC (upstream or downstream of the filter) was taken into account in our calculations. The size range of size resolved measurement was set from 20 nm to 450 nm. The flow rate was set to several tens of lpm (typical flow rates through filters). The whole system is controlled by the means of home-made LabVIEW code. The minimum penetration of such a filter testing system is limited by the accuracy of CPCs used – in our case it corresponds to penetration of 0.001% (or filtration efficiency of 99.999%).

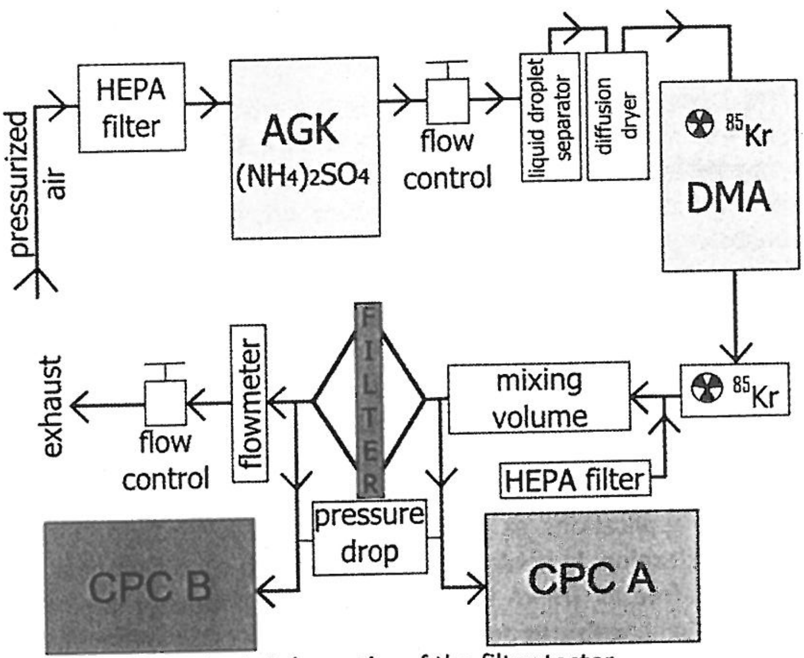

Fig. 1: Schematics of the filter tester.

In order to check the consistency of tested filter material and the variability between individual filtration sheets or pieces, we have usually repeated the measurement several times. The monitoring of filter material loading was also included within this study.

TESTED FILTER MATERIALS

During the testing of filtration materials we have measured several commercial filter materials including standard filters (Whatmann, Milipore) and personal respirators (e.g. 3M). List of the standard filters is included in Tab. 1.

Filter No.	Manufacturer	Material	Type	Δp [kPa]
1	Millipore	cellulose acetate and nitrate	RAWP04700	9.7-10.0
2	Millipore	glass fiber	APFA04700	4.9-5.0
3	Millipore	quartz fiber	AQFA04700	4.9-5.0
4	Whatman	quartz fiber	QM-A 1851-047	5.9-6.1
5	Whatman	glass fiber	GF/C 1822-047	8.0
6	Millipore	cellulose acetate and nitrate	SSWP04700	9.0-9.3
7	Whatman	quartz fiber	QM-A 1851-047	6.4-6.5
8	Millipore	cellulose acetate and nitrate	SSWP04700	8.5-8.8
9	Whatman	glass fiber	GF/C 1822-047	7.5-7.7
10	Millipore	cellulose acetate and nitrate	SSWP04700	3,55
11	Whatman	glass fiber	GF/A	1,72
12	Whatman	glass fiber (cleaned)	EPM 2000	2,43
13	Whatman	quartz fiber	QM-A	2,17

Tab. 1: Commercial filter materials used in this study.

RESULTS

The measured penetration for various filter materials showed a large span (see Fig. 2), starting from commercial filters having penetration about tenths of percents and ending up with medical PPE having penetration in orders of tens of percents. Extremely low filtration efficiency was measured for a sock, which is sometimes recommended as an emergency filtration material in a case of sudden explosion or other unexpected event, having almost 100 % penetration, in other words very low filtration efficiency in minimum.

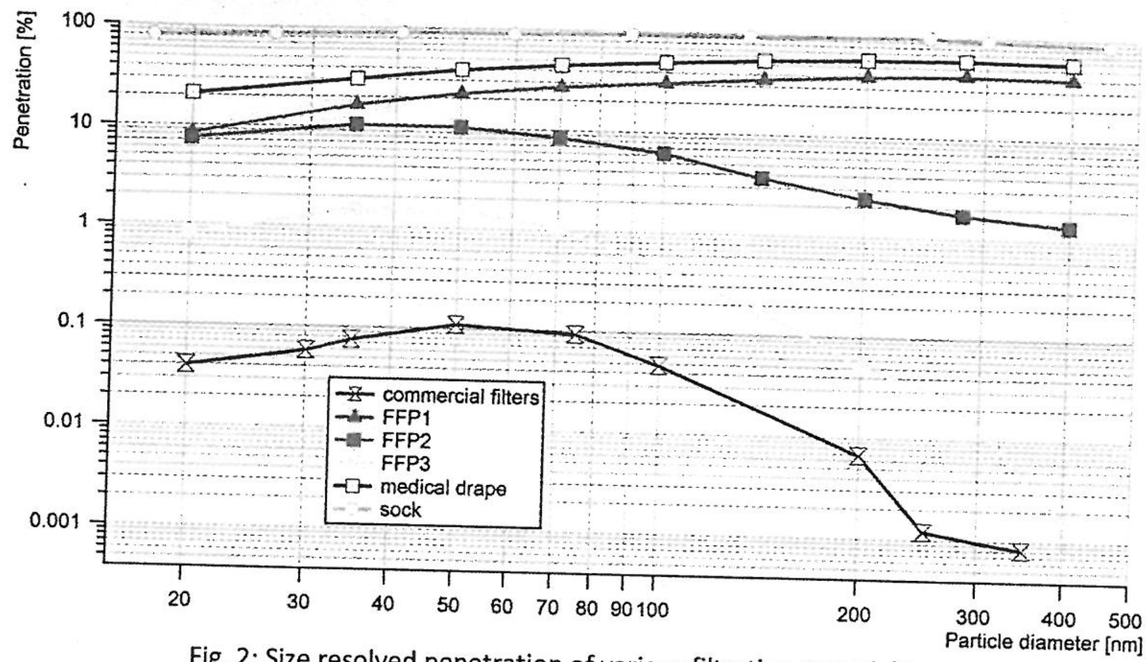

Fig. 2: Size resolved penetration of various filtration material types.

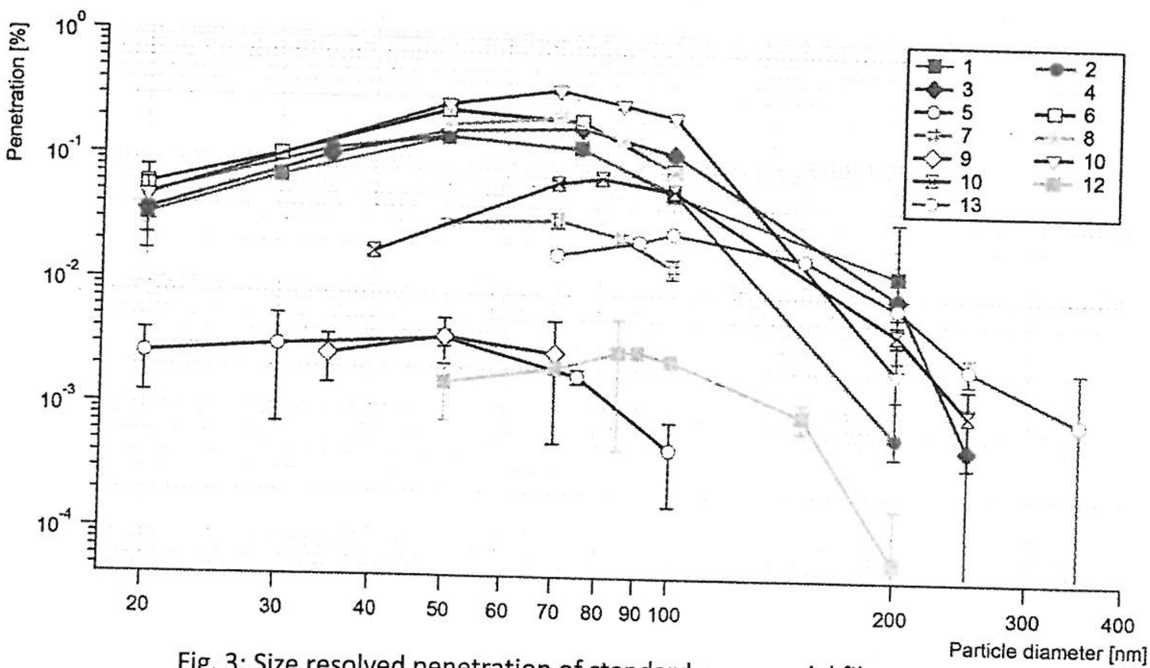

Fig. 3: Size resolved penetration of standard commercial filter types

In the case of Personal Protective Equipment (PPE, respirators) the maxima of penetration were ranging from units to the tens of percent, while the pressure drops were usually in hundreds of

Pa. The measurements of PPE showed pronounced differences among the individual filter classes such as FFP1, FFP2 and FFP3.

The most valuable information can be found in the results from the measurements of standard commercial filter materials (see Fig. 3), which are usually used for aerosol sampling. The figure shows that the penetration of different commercial filtration materials can differ in orders of magnitude. The maximum penetrations were in orders of tenths to hundredths of percent having pressure drops in orders of kPa units. The MPPS were in a vast majority of cases bellow 100 nm. Furthermore, the pressure drop across the filtration material does not necessarily increase with a decrease in penetration, as can be seen from comparison of Fig.3 with Tab.1.

The tests of reproducibility proved to be a very robust measurement routine giving only minor deviations in results for the same filter types. In most of cases, long term exposition of the filtration material to the challenging aerosol showed negligible filter loading.

Different pieces of the same type of PPE showed significant differences in measured penetration. Also samples of filtration material taken from different parts of one piece of PPE resulted in a significantly different penetration.

CONCLUSIONS

Testing of various filter materials proved the functionality, good precision and reproducibility of a home-made filter tester. The measurements of penetration for standard commercial filter materials might be useful for many scientists and other users working with these materials. The comparison of penetration for different types of filtration materials showed wide variety of penetration curves, MPPS and the maximum penetration. This study also confirmed our initial doubts about the standard filter efficiency testing method, regarding the used testing material, setting of MPPS and measuring only the total penetration of a polydisperse aerosol. Therefore, such a study could serve also as a basis for improvements in the filter efficiency standard method, which seems to give insufficient and in some perspectives limited or even misleading information.

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LITERATURE

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