Does the particle size have influence on exhaust filter capacity: a practical investigation on power of different filters

1. **Introduction**

The impact on volatile organic compounds (VOC) is well-known for ages and several regulations and recommendations are in force in the EU to protect both human health and the environment. The chemical industry is one of the biggest emitters of VOC, but other industries like printing, wood and automotive industries are also source of VOC. In lack of appropriate solutions for drainage or adsorption of chemicals, the VOCs present in the air that means serious health concerns including skin, throat and eye irritations, and asthma-like symptoms. Furthermore, VOCs can be source of development of cancer-type diseases and has high influence on ozone concentration in the air. Therefore, the prevention of VOC emission is preliminary. In our study we focus on the chemical industry field that involves chromatographic analysis, which is one of the most important and frequently applied part of analytical chemistry worldwide and this field has a great consumption of volatile organic solvents. For instance, in liquid chromatographic (LC) separation acetonitrile (AcN, exposure limit = 20 ppm, 34 mg/m^3), methanol (MeOH, exposure limit = 250 ppm, 328 mg/m^3), isopropyl alcohol (IPA, exposure limit = 400 ppm, 980 mg/m^3) and tetrahydofuran (THF exposure limit = 200 ppm, 590 mg/m^3) are generally used in high volume and the effluent is directed in to waste containers. The vapor of organic solvent must be ventilated into the air or adsorbed if the vapor is in a closed system; otherwise they pollute the laboratory where experts are working on daily basis.

Exhaust filters are generally used to avoid the present of organic solvent vapor in the air. Exhaust filters are attached to the waste containers and adsorb the vapor. These filters are packed with active charcoal, but different manufacturers include other substances among the active charcoal as well in order to extend the lifetime and adoption capacity of filters. It is commonly known that the specific surface area has a strong influence on filter capacity. Generally, bigger particle size of packaging material (1 mm – 4 mm) is used in the filters. This size has a great advantageous for industrial filters since the pressure drop strongly depends on the particle size, however in LC practice the bigger particle size is not as important. Considerably, the appropriate function between particle size and capacity of exhaust filters has not

thoroughly been studied so far. The aim of our study therefore was to (i) test different competitors' exhaust filters suitable for HPLC solvent vapor adoption, (ii) investigate the capacity of filters containing sorbents with various particle sizes and finally (iii) examine the lifetime of filters that can be in strong relation with the sorbent bed.

2. Experimental

Solvents were of HPLC grade and purchased from MolarChem. Acetonitrile – water (70/30, v/v) mixture was transferred from a plastic reservoir into another one equipped with exhaust filter using ECOM Kappa HPLC pump. The system was closed, so the vapor could only leave the container through the filter. Containers were saturated with vapor and the stationer condition was continuously held by solvent feed (**Fig. 1**). The laboratory conditions were as average laboratory temperature between 21 °C and 23 °C and the relative humidity was approximately 30%. The flow rate was 2 mL/min and the pump was in continuous operation (24 h per day) for a month. Based on manufacturing recommendation, these filters have 6-month lifetime during standard operation. It means 8 hours shift over 5 working days per week and maintaining a 1 mL/min flow rate. Commonly, the lifetime of exhaust filters lasts for a half year under these conditions. Hence, the reason for applying faster and longer pumping condition was to demonstrate 6-month long loading on the filters. In continuous operation (24 hours per day) with flow rate of 2 mL/min over 30 days, the amount of vapor left the system through the filters are equal to 6-month period.

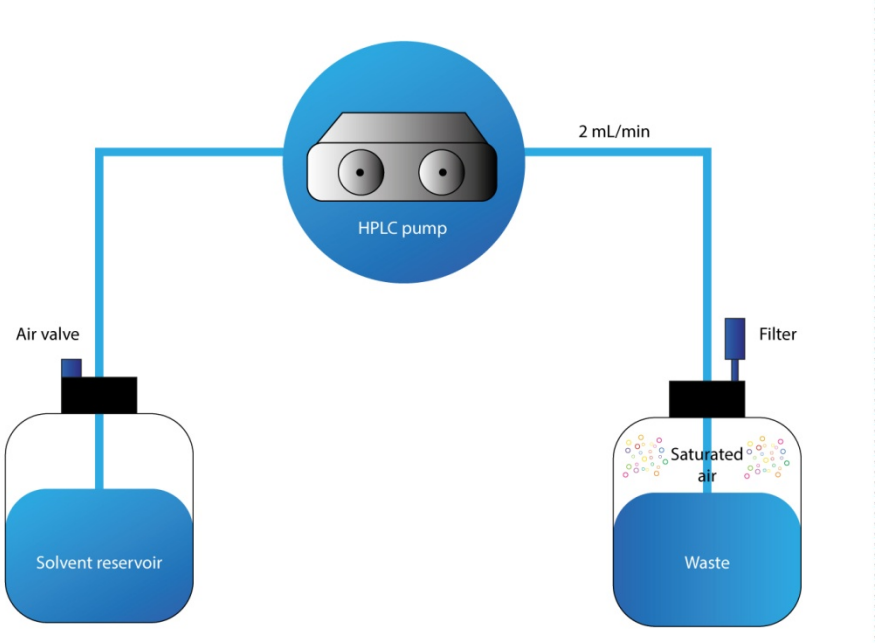

Fig. 1: Sematic figure of the investigation.

Five commercially available filters packed with approximately 50 g adsorbent were simultaneously tested in total. Filters originated from two different competitors and from Vision. Filters are recommended to be used up to 6 months under standard conditions according to manufacturers. Competitor#1 filter was packed with 2 mm – 4 mm adsorbent (specific surface ~ 1200 g/m^2), parallel measurement was performed. Competitor#2 filter contained 1 – 2 mm packaging material (specific surface not known), single measurement was carried out. Vision filter contained a not discussed mixture of different adsorbents with particles of 0.05 mm – 0.20 mm distribution (specific surface of the base activated charcoal 1050 g/m^2). The composition of sorbents of competitors is not known.

Each day the mass of filters was weighed on a Demandy AJCS laboratory scale 1000g/0.01 g balance at the same time and the mass increase of filters were recorded and plotted against the days. Five days long interval means one-month long period due to the 2 mL/min flow and continuous operation.

3. Results and discussion

Such adsorption of vapor is generally performed in columns packed with various materials depending on the character of VOC. In LC practice the filter's sorbent bed consists of active charcoal with big specific surface (~ 1200 g/m^2), on which the vapor/solution can adsorb depending on the quality and physical-chemical parameters of the adsorbent. Also, the adsorption depends on the composition of vapor and the working conditions. If we plot the ratio of outlet concentration to inlet concentration of vapor versus time, we will obtain the breakthrough curves. In our study, however, we measured the weight increase of filters at the same time each day. In a closed system the vapor can only leave the container through filters, so we can conclude that the mass of vapor adsorbed on the filter is constant as long as the sorbent does not reach the breakpoint. At the breakpoint the sorbent cannot adsorb all the feed entered the filter and a part of the vapor breaks through the sorbent bed and starts to pollute the air. At the saturation point the sorbent cannot adsorb the vapor anymore.

In the present investigation we tested different exhaust filters containing different particle size of packaging materials to find correlation between particle size and the capacity of filters. For this purpose, five commercially available exhaust filters were continuously loaded with vapor containing a general HPLC solvent composition of acetonitrile – water (70/30, v/v) mixture. Our hypothesis was that adsorption capacity

links not only to the specific surface area, but it is also influenced by the pore structure and particle size.

Fig. 2 shows the mass increase on filters expressed in percentage over 30 days (equal to 6-months period). The highest mass increase (%) can be seen on Vision filters containing packaging materials with particle size of 0.05 mm – 0.2 mm distribution and the lowest specific surface. It means that not only the specific surface, but also the particle size and the porous structure have impact on capacity of filters. **Fig. 3** shows the parallel measurement on Competitor#1's filter. The reproducibility of adsorption was fit-for-purpose.

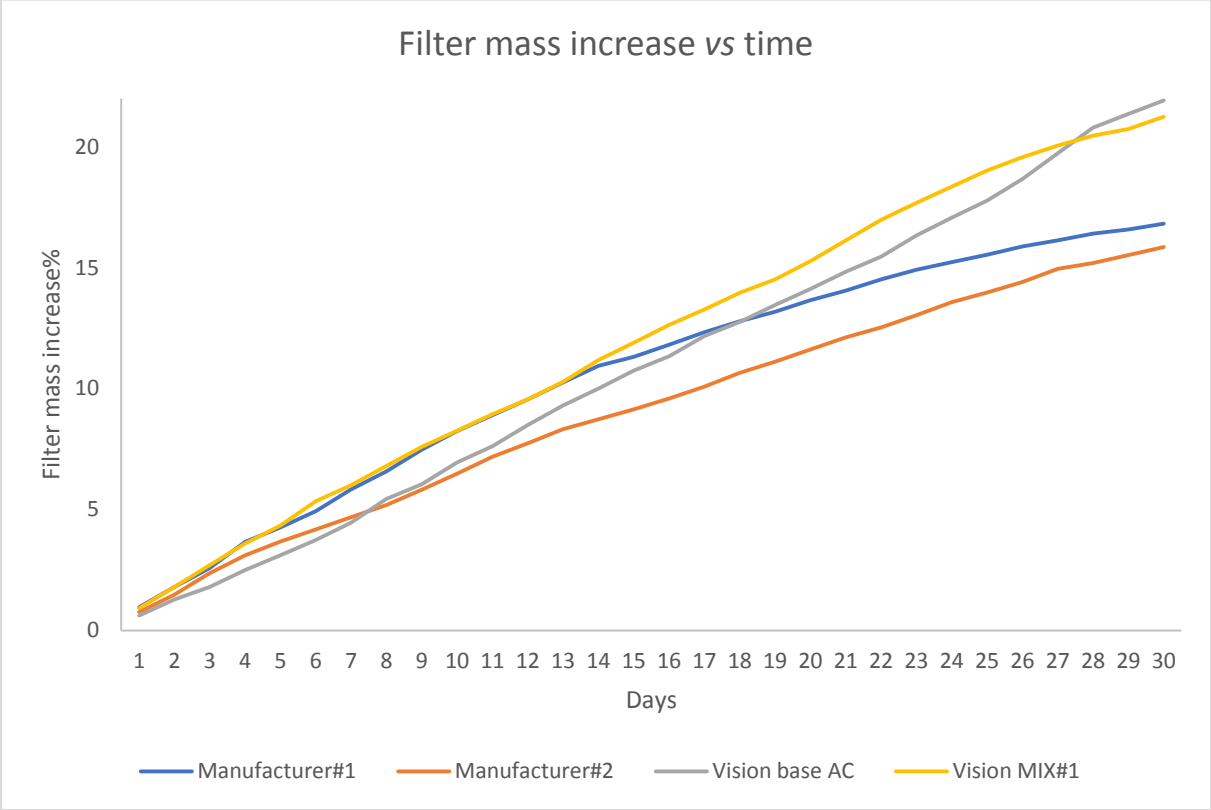

Fig. 2: Filter mass increase on competitors' filters packed with different particle size versus time.

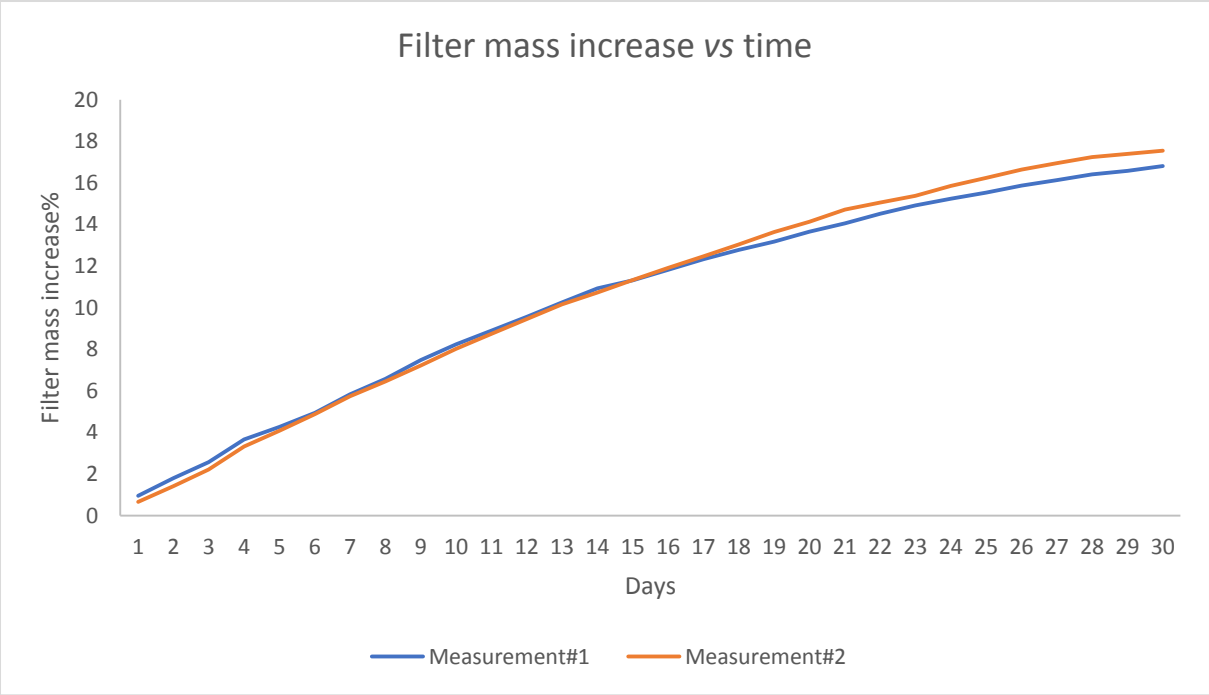

Fig. 3: Filter mass increase on competitor#1's filters. Parallel measurements were also done.

4. Conclusion

In this study, we tested commercially available exhaust filters for the first time. The outcome of the investigation indicates that all filters are usable up to 6-months in line with the manufacturers' recommendations. In contrast to those publications not based on appropriate experimental section, the exhaust filters packed with smaller particle size of packaging material were found to be as good as those filters containing adsorbents with bigger particle size. Therefore, we can conclude that not only the specific surface influences the adsorption, but also the particle size and pore structure have important role in the vapor adsorption. The differences in adsorption among Competitors' filters are negligible and can be the reason of measurement uncertainty. Finally, this experiment is a good basis of testing other filters packed with various composition of adsorbents (i.e. particle size, specific surface area, pore structure, etc.).