The Story of Teamwork and the Birth of the FFP* (Filter Backpack)

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THE STORY OF TEAMWORK AND THE BIRTH OF THE FFP3* (FILTER BACKPACK)

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INTRODUCTION

Soon after the outbreak of the coronavirus crisis in the Czech Republic and the first lockdown (2020), we enthusiastically decided to fight the coronavirus with scientific means. Originally materials engineers, we decided to develop an effective protective respiratory device, which was in short supply at the time. We soon found out; (1) that every textile material (handkerchief 10%) has a certain ability to catch an aerosol particle carrying the corona virus, (2) the slower the aerosol particle (d<300 nm) passes through the filter, the greater the chance it has of being caught, (3) with the thickness of the filter, the amount of passed particles decreases exponentially and breathing resistance increases linearly. On this basis, we decided to experiment with a large-area filter placed on the user's back (it wouldn't fit anywhere else) and commercially available textile filter material.

EXPERIMENTAL SETUP

We chose the filter material from commonly available textile materials. The two candidates included cotton (T-shirt) and polyester knit with a fleece finish (blanket). A filter cartridge with an area of 1200 cm^2 was assembled from both filter materials, which is eight times the area of the respirator. Filter efficiency and pressure drop at an air flow of 95 lpm (hard physical work) were tested for the cartridge set up in this way.

Subsequently, we optimized the size and useful properties of the filter cartridge. We assembled 25 filter cartridges with an area corresponding to (1, 2, 4, 6 and 8 times the size of the mask) with 1, 2, 4, 6 and 8 layers of knit polyester fleece. The selected filter cartridge, which resembled the book "2nd edition Aerosol Technology-W.C.Hinds" in size, was placed in a backpack and connected to a rubber half-mask with hoses. The resulting filter set (Fig. 1) was subjected to a pressure drop test and a 1000 m run.

Fig. 1: A) cartridge frame before wrapping with fleece polyester knit, B) filter set, C) diagram of the filter cartridge in the backpack

RESULTS AND CONCLUSIONS

Already the first assembled filter in April 2020 showed a high filtration efficiency (95%) when using a knit polyester fleece as the filter material. Knit polyester fleece has been shown to have a similar Q factor (ratio of aerosol passed to pressure drop) as nonwovens used for filtration (Zhao et al. 2020, Fraenkl et al. 2022). The results of the filtration efficiency measurements for the 25 cartridges we set up are shown in Fig. 2 (Fraenkl et al. 2022). The optimum for use in the filtration set was a cartridge with an area of 900 cm^2 whose size resolved filtration efficiency can be found in Figure 3 (Fraenkl et al. 2022).

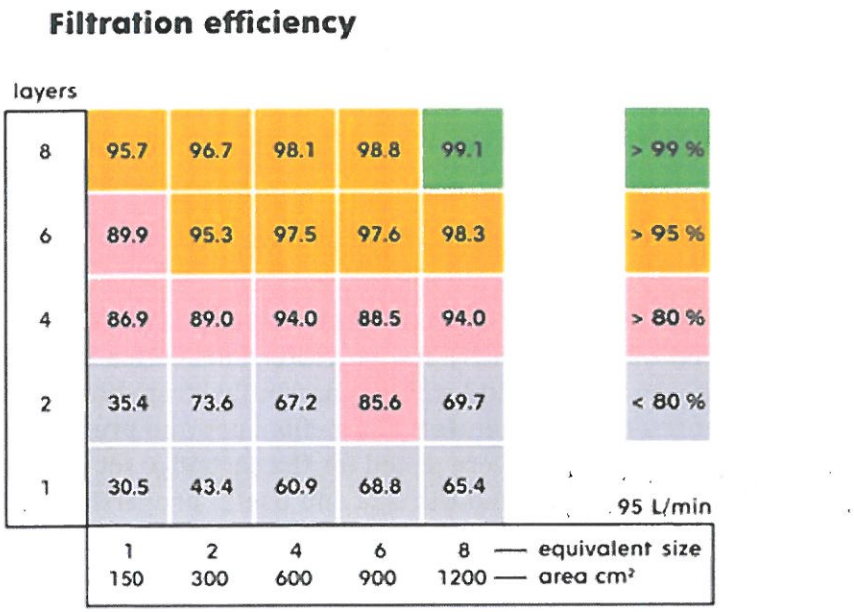

Fig. 2 shows the filtration ability of the PES fabric depending on the filter area, which was varied as multiples of the area of 150 cm^2 (the size of the mask) and the number of layers of filter material (adapted from Fraenkl et al. 2022).

According to a Canadian study, the filtering kit we designed shows better results in terms of pressure loss and filtration efficiency than 41 out of 43 commercially available respirators according to a Canadian study from 2020 (Brochot and Bahloul 2022).

A big advantage of the filtering kit is the "unlimited" lifetime. Fleece knit is a mechanically resistant material. As we have shown, compared to filters made of non-woven fabrics, polyester fleece knit can be regenerated very simply by boiling or washing (at least 10 times) without loss of filtration efficiency (Fraenkl et al. 2022).

Because it can be easily regenerated, our proposed solution has the potential to reduce the environmental impact and simplify access to high-quality respiratory protective devices for health care workers, especially in low-and middle-income countries or in crisis situations.

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REFERENCES

Zhao M, Liao L, Xiao W, Yu X, Wang H, Wang Q, et al. Household Materials Selection for Homemade Cloth Face Coverings and Their Filtration Efficiency Enhancement with Triboelectric Charging. *Nano Lett.*;20: 5544–5552. doi:10.1021/acs.nanolett.0c02211, (2020).

Fraenkl M, Krbal M, Houdek J, Zmrhalova Z, Prokes B, et al. High-quality and easy-to-regenerate personal filter. *PLOS ONE*, (2022).

Brochot C, Bahloul A. Qualitative Knowledge of Filtering Facepiece. J *Int Soc Respir Prot.*;37, No. 2: 94–107, (2020).

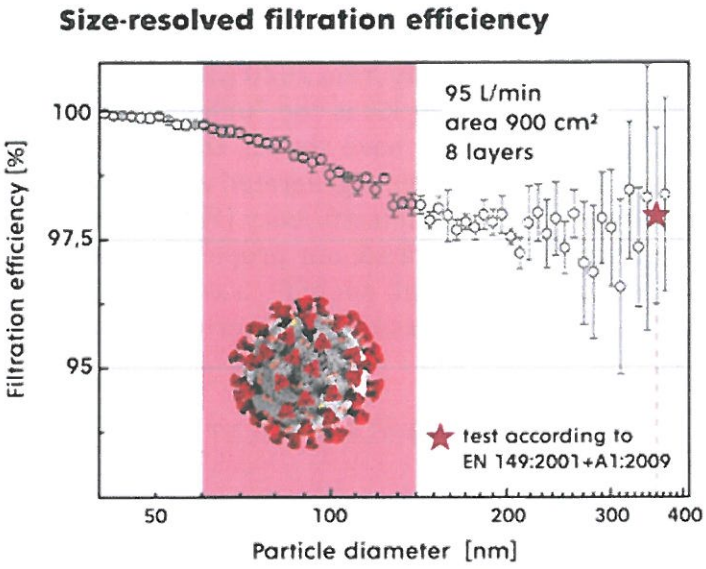
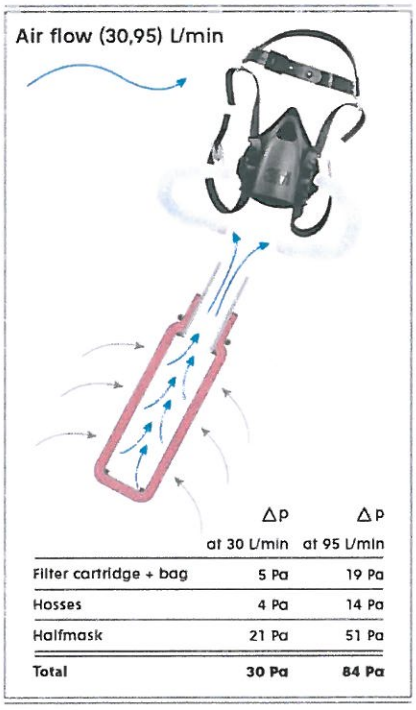


Fig. 3 shows the experimental curve of the filtration efficiency as a function of the particle diameter for the filter cartridge six times the size of a standard mask (900 cm^2) with eight layers of PES fabric. A red star represents a measurement of accredited laboratory VÚBP.

The assembled filter kit shows a low pressure loss of 84 Pa at a flow rate of 95 lpm, while only a quarter of about 19 Pa falls on the filter cartridge, the rest on the hose and half mask (Fig. 4). Low pressure loss means easier breathing and less bypass air.



	ΔP at 30 L/min	ΔP at 95 L/min
Filter cartridge + bag	5 Pa	19 Pa
Hosses	4 Pa	14 Pa
Halfmask	21 Pa	51 Pa
Total	**30 Pa**	**84 Pa**

Fig. 4 shows the pressure drop of the filter kit and its components at volumetric flow rates of 30 and 95 L/min, which correspond to air inhalation during light and heavy physical exercise, respectively. The cross-section of the filter cartridge is shown.