A total of 29 mask material types were tested in this study, the product description and material composition of each tested mask material is listed in Table 2.

Application of the NanoAerosol Generator in Efficacy Evaluation of Facial Coverings

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Abstract

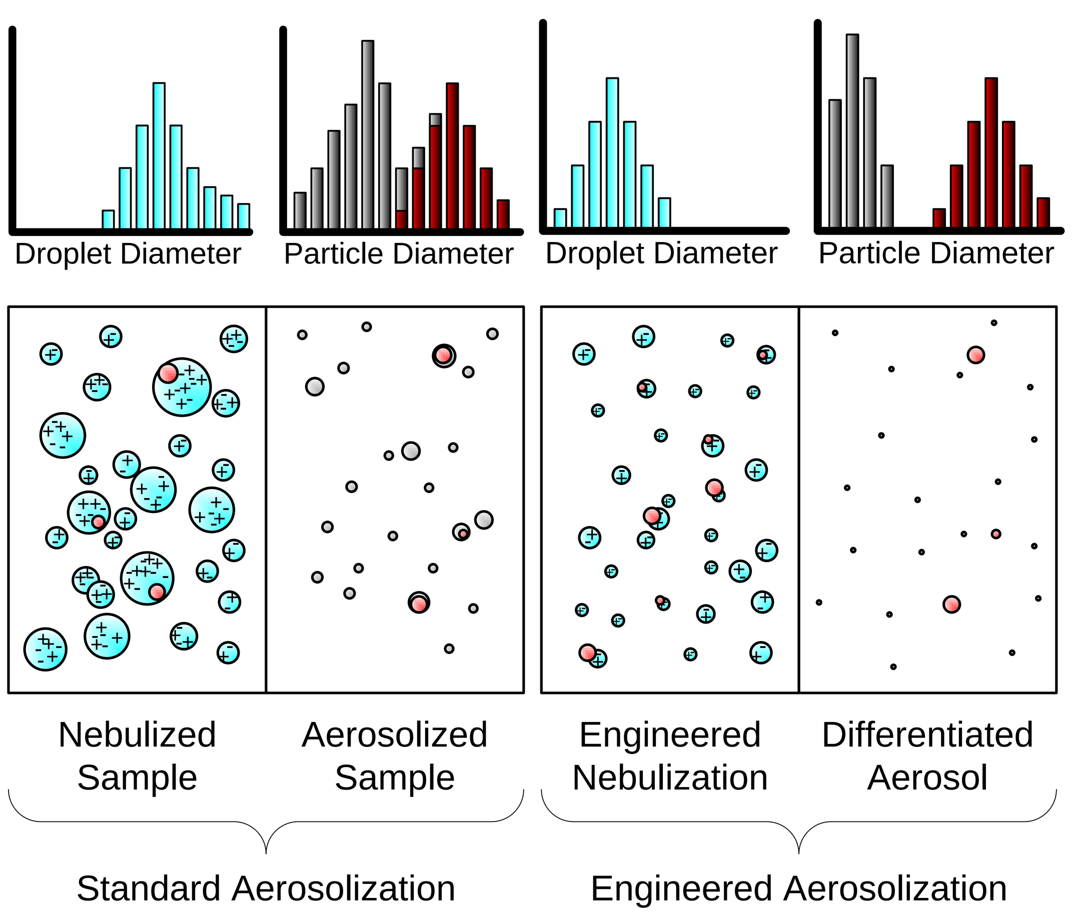
The interest in filtration efficiency characterization tests of face masks and respirators has grown substantially in response to the worldwide spread of Covid-19 and the consequent demand increase of personal protective equipment (PPE) supplies. It is believed the particulate filtration efficiency of the filter material used for manufacturing PPEs primarily affects how effectively they can protect the user against health and safety risks from airborne particles[1]. The filtration efficiency characterization is therefore critically required to evaluate the protection level of a PPE product and guide the proper use of it. Despite the extra size classification step in their generation, monodisperse test particles are usually preferred for testing filters due to the fact that filtration efficiency is a parameter that is primarily size dependent. Substantial information can get lost in a polydisperse test, especially for the applications with a few size(s) of interest in particular, e.g. the Covid-19 related studies.

Unlike other commercially available nebulizers, the Kanomax NanoAerosol Generator (NAG) 3250 can generate a near-monodisperse test aerosol from a NIST-traceable particle standard with its uniquely smaller droplets (nominally 500 nm peak size)[2]. This monodisperse aerosol allows for controlled filter tests without incurring the cost and complexity of using a size classifier. Results from 29 common face mask materials are presented to illustrate the usefulness of the approach.

Introduction

Pneumatic nebulization is the mostly widely used particle generation method and it is also the generation technique recommended in NIOSH standard testing procedure for respirator filtration efficiency evaluation.

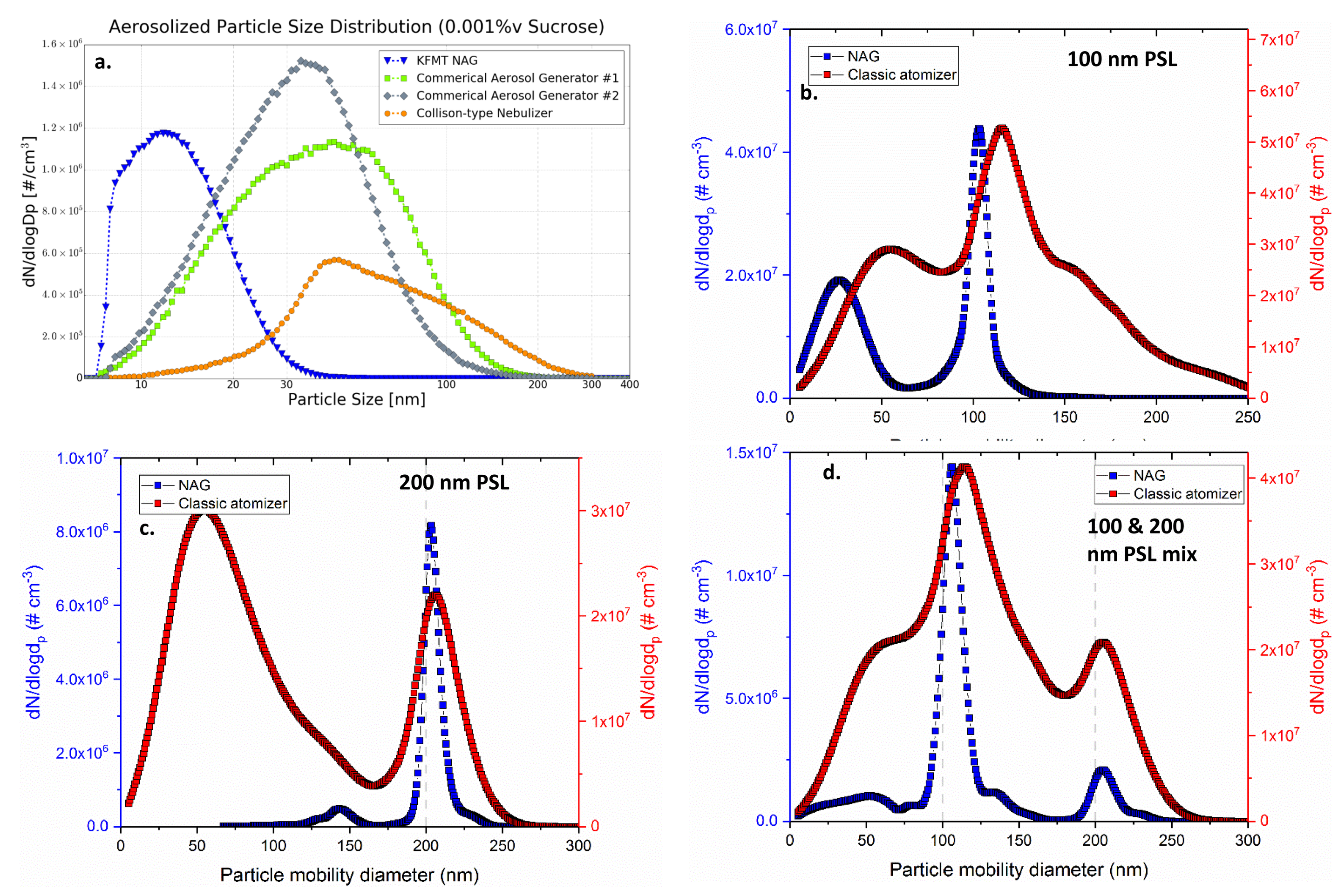
In a typical nebulization-evaporation process, the liquid sample, usually with particles and non-volatile dissolved residue (NVDR) uniformly distributed in an aqueous base, is first dispersed into small droplets which are then dried by evaporating the volatile part. NVDR is undesirable and is to be minimized. The size properties of aerosol particles generated by a nebulization-evaporation process are closely related to the size distribution of the dispersed droplets as well as the concentrations of both NVDR and discrete non-volatile residue.



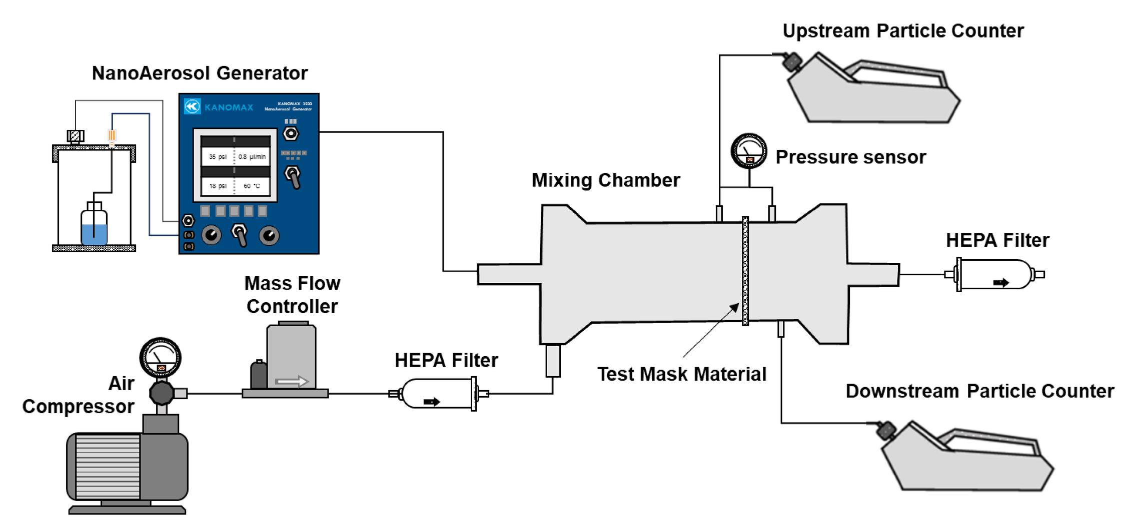
The schematic above shows how smaller droplet sizes yields smaller NVDR particles while at the same time better retain the original size of non-dissolvable particles, e.g. particle standards such as polystyrene latex (PSL) or silica particles. When the above differences are reflected in the generated particle size distribution, which is the mostly concerned parameter for nebulizer users, the particles generated with smaller droplets are better distinguished in NVDR particles (residual peaks) and non-dissolvable particles. This distinct differentiation is particularly preferred in applications where the aerosolization of a particle size standard is needed.

Aerosolization Performance of the NAG

Figures to the right show examples of using the NAG versus a Collison-type nebulizer(s) in dispersing a. sucrose solution, b. 100 nm PSL, c. 200 nm PSL, and d. 100 nm and 200 nm PSL mix. The particles generated by the NAG are not only more monodisperse in terms of smaller GSD values of the size distribution profile, but also their nominal sizes are better retained with less interference from precipitation of the NVDR onto the surface of PSL particles during the evaporation process.



Facial Covering Efficacy Evaluation System



To the left is a schematic of the facial covering efficacy evaluation system. The NAG generates monodisperse PSL particles of 100 or 300 nm at an aerosol flow rate of 1.7 LPM, which mixes with a dilution flow of clean dry air into a 13.15 or 85 LPM total test flow in a 2.87-inch ID aluminum mixing chamber with 12-inch in length.

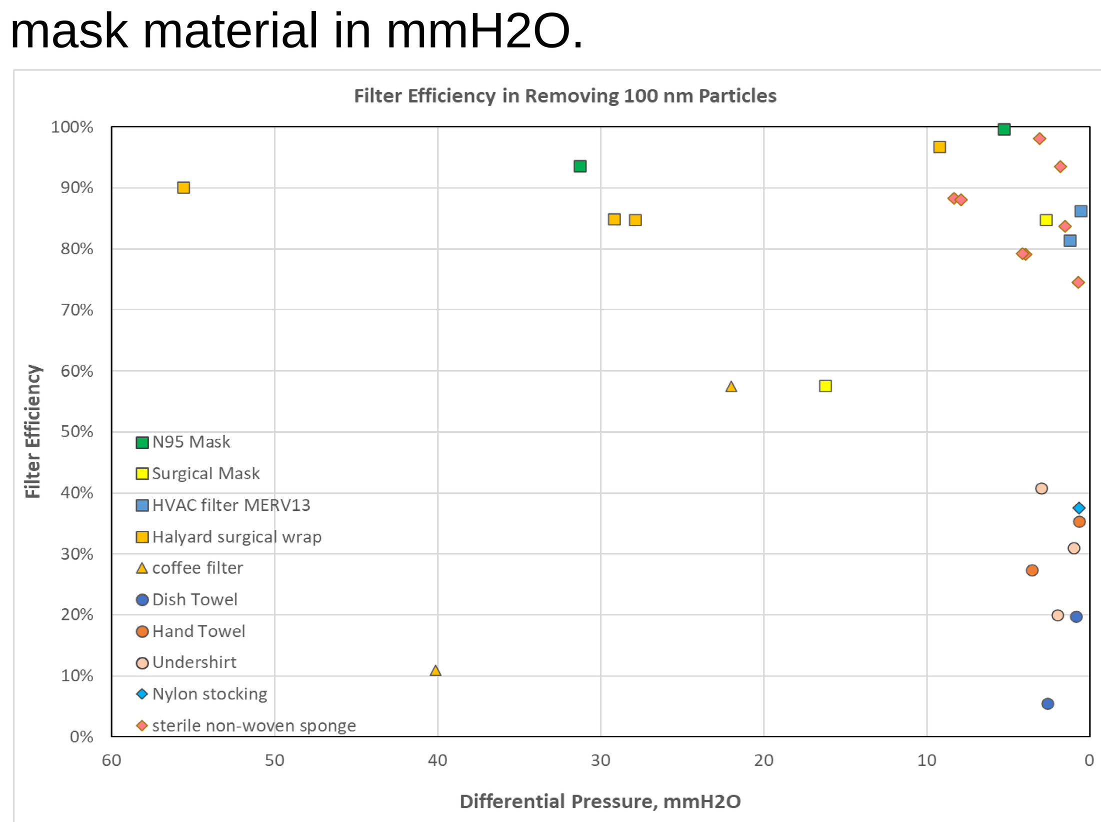
The test mask material embedded in a filter holder is mounted towards the downstream end of the mixing chamber, and the pressure drop across the test material is monitored by a pressure sensor. Two particle counters with 20 nm lower cutoff sizes are used for measuring particle concentrations upstream and downstream of the mask material respectively, and the ratio between the upstream and downstream concentration values yields the corresponding mask filter efficiency.

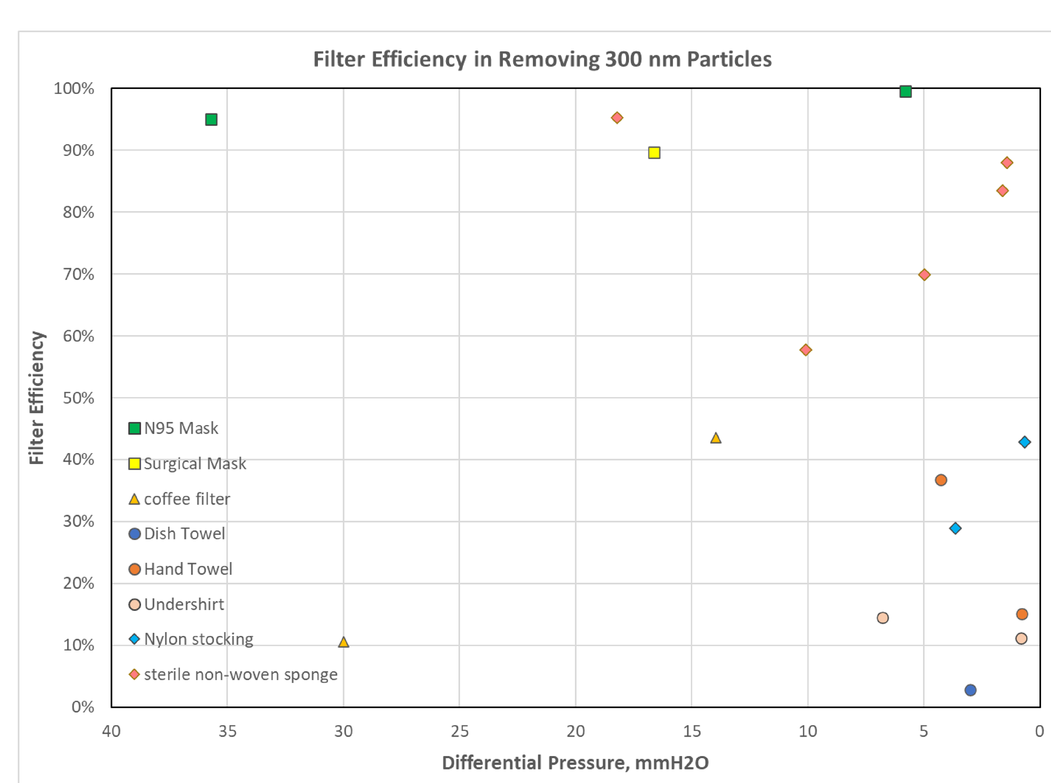
Results

With the benefits of easy-operation and fast-response measurements of using the NAG for size-dependent filtration efficacy evaluation, a total of 29 mask material types were tested in this study, the product description and material composition of each tested mask material is listed in the table to the right.

Material No.	Description	Material Composition	Material Category
1	N95 Mask		baseline
2	Surgical Mask		baseline
3	Monadnock	Monadnock	baseline
4	Sponge (Gauze)		woven cotton
5	Undershirt	Cotton	woven cotton
6	Pillowcase	Cotton	woven cotton
7	Bed sheet	Cotton	woven cotton
8	Hand Towel	Cotton	woven cotton
9	Dish Towel	Cotton	woven cotton
10	sterile non-woven sponge	polyester/rayon non-latex	nonwoven synthetic
11	melt blown polypropylene felt	polypropylene felt, 1.5 lbs./SQ. YD. Density, 1/8" thick	nonwoven synthetic
12	CH Surgical Gown Level III		nonwoven synthetic
13	NSWCPD cloth gaiter		woven synthetic
14	NSWCPD cotton mask	4 layers cotton fabric	woven cotton
15	Polypropylene Scrub Wipes	melt blown polypropylene	nonwoven synthetic
16	Cleanroom wipe	45% polyester / 55% cellulose nonwoven	nonwoven synthetic
17	Halyard surgical wrap		
18	Nylon stocking		woven synthetic
19	coffee filter		paper
20	P100 respirator cartridge		baseline
21	HVAC filter MERV13		filter, other
22	polyester sewing interfacing	melt blown polyester	nonwoven synthetic
23	activated carbon mask insert		filter, other
24	vacuum bag		
25	Buff wrap		
26	bandana	polyester	woven synthetic
27	Pellon fusible fabric interface		nonwoven synthetic
28	Air x MERV 13		filter, other
29	Filti Material	polypropylene/polyester	nonwoven synthetic

Filter efficiency test results for selected mask materials in removing 100 (left) and 300 nm particles (right) are plotted in the figures below respectively, with the y-axes representing average efficiency in % and x-axes representing differential pressure across the test mask material in mmH2O.





The optimal mask material needs to meet two requirements: high performance in filter efficiency and low differential pressure to ensure the user comfort. According to the test results shown above, HVAC filter media, surgical wrap, and sterile non-woven sponge are the best alternatives for face masks among all tested materials.

Conclusion

For particle measurement applications that are interested in obtaining size dependent information of a performance parameter, such as the filter efficiency evaluation for face mask materials, the NanoAerosol Generator (NAG) is a cost-effective alternative to electrical mobility-based size classifiers and it is particularly ideal for applications that are also fond of fast response time in measurements.

References

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