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TEST REPORT

A Comparison of Particle Filter Efficiency Measurements for Protective Masks using Particle Counters with Different Flow Rates

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Testing Location	
Name of Testing Laboratory:	Delft University of Technology - Department of Biomechanical Engineering
Address:	Faculty of Mechanical, Maritime and Materials Engineering (3mE), Building 34, Delft University of Technology
Test Specification	
Test Specification:	See Appendix
Test Description:	More information about the test setup can be found on: http://resolver.tudelft.nl/uuid:604ed9c2-c218-45e8-8c62-7d669865056c
Test Item	
Test Item Description:	J&C KN95 FACE MASK
Manufacturer:	Huizhou Hengda Innovation Communication Equipment Co., Ltd.
Model/Type Reference:	KN95
Number of Samples:	2
Other	
Other Remarks:	Samples tested on 30 April 2020, 13:05.

TEST RESULTS

Benchmarking

Test Item Description:	J&C KN95 FACE MASK
Flow:	1F^3
Measurement time:	1 min

Particle size:	0,3mu	0,5mu	1,0mu	3,0mu	5,0mu
Environment Particles 1	705252	116584	24347	1416	951
Environment Particles 2	713737	117310	24694	1523	1074
Average	709494,5	116947	24520,5	1469,5	1012,5

Particles Counted

Particle size:	0,3mu	0,5mu	1,0mu	3,0mu	5,0mu
Sample #1	9502	722	100	0	0
Sample #2	9928	824	102	1	0
Average	9715,0	773,0	101,0	0,5	0,0

Percentage particles filtered in %

BFE:		Type 2			
Particle size:	0,3mu	0,5mu	1,0mu	3,0mu	5,0mu
Sample #1	99	99	100	100	100
Sample #2	99	99	100	100	100
Average	98,6	99,3	99,6	100,0	100,0

Place / Date: De Meeren / 06-05-2020	
Test results approved by:	Majid El Mortadi (Director GreenCycl)
Signature / Stamp:	A.M. el Mortadi Director

A Comparison of Particle Filter Efficiency Measurements for Protective Masks using Particle Counters with Different Flow Rates

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A Comparison of Particle Filter Efficiency Measurements for Protective Masks using Particle Counters with Different Flow Rates.

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Background

The Covid-19 pandemic can cause imminent local shortages of personal protective equipment such as face masks, in hospitals and other healthcare facilities. In preparation for that scarcity hospitals may obtain masks from other parties than their regular suppliers or consider re-use of masks after sterilization. To evaluate the safety of these masks extensive testing according to standardized norms is required. However, as these testing facilities are not readily available we and other institutes initiated the use of basic particle filtering measurements to quickly get insight in the minimal required filtering performance of a mask. Here we study the robustness of these measurement approaches as well as their sensitivity to differences in the flow rates used by various particle counters.

Aim

The filtration efficiencies of protective masks are evaluated with use of several different types of airborne particle counters from Lighthouse Benelux (www.lighthousetest.com). These particle counters are intended for clean room validation and enable the measurement of filter integrity for particle sizes between 0.3 and 25 µm. All have an internal closed-loop controlled vacuum pump for generating a constant inlet flow. However, the flow rate delivered by these devices can differ (range 0.1- 2.0 cfm; cubic feet per minute) which may affect the robustness of the measurements. In this study we test filters in equal environmental conditions with flow rates of 0.1 cfm and 1.0 cfm to determine to what extent different flow rates affect the outcomes of the filter efficiency measurements of protective masks.

Apparatus

Lighthouse Solair 3100, Particle size: 0.3 - 25.0µm, Flow rate: 1.0 cfm
Lighthouse Handheld 3016, Particle size: 0.3 - 25.0µm, Flow rate: 0.1 cfm
Lighthouse Handheld 2016, Particle size: 0.2 µm - 2 µm, Flow rate: 0.1 cfm

Data format particle counters

The data format is either Raw (RAW) or Normalized (NORM). Raw data pertains to the actual number of particles counted. Normalized data shows particle concentrations calculated from the raw data (based on the settings chosen in ft3 or m3).

Volume of Air = Sample time (minutes) x FlowRate (CFM)
Normalized Data = Number of Particles/Volume of Air

Thus, depending on the flow rate and sample time a certain volume of air is collected by the particle counter. The Normalized data on the number of particles counted output is presented relative to this volume.

Hardware & Test setup

To ensure correct comparison between filter capacity of different mouth masks it is important to measure on a standardized area of the mask. This area should be large enough to guarantee sufficient airflow through the filter material that matches the specifications of the particle counter device. Figure 1 shows a particle chamber that allows researchers to use a particle counter as a device that measures the filter efficiency of a mask. The design of the setup can be downloaded here https://surfdrive.surf.nl/files/index.php/s/EVtnsfPUz7FOzAJ. Figure 1-middle shows the lid and chamber of the device that are designed such that easy install of a mask with minimum risk of contamination of the filter surface is possible. Furthermore, the lid compresses the mask material on a quad ring in the chamber that facilitates a constant distributed force (Figure 1-right) around the chamber rim. This minimizing the risk of false air inflow due to folds in the material. The lid height with respect to the chamber top can be adjusted to facilitate different filters with various filter thicknesses. The particle chamber has an internal diameter of 40 mm and is 40 mm deep. The outer diameter measures 50mm. Especially for the low flow particle counters it is important to keep the tube between particle chamber and counter as short as possible to minimize the influence of the trapped environmental air (after filter placement) on the measurement results. Figure 2 shows how adapters can be made to fit differ tubes of filters and tubes on the particle counter

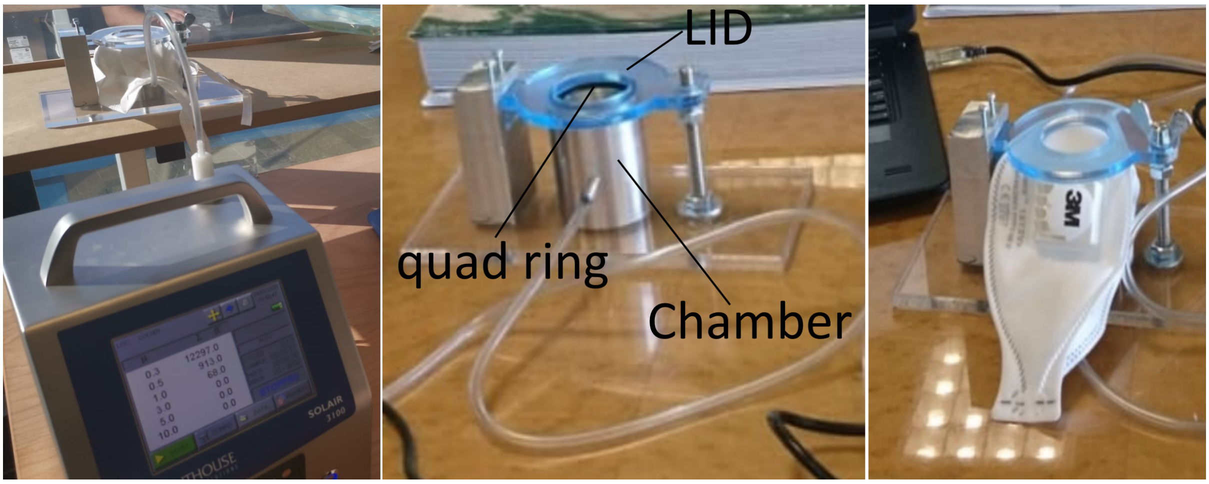

Figure 1, Filter testing setup. Left, Solar 3100 connected with a tube to the Particle Chamber. Middle, Particle chamber components. Right Mouth piece installed in particle chamber.

Figure 2, Filter testing setup. Left, adapter made to test respiratory filter for ventilation. Right, adapter made for connection of the particle chamber.

Procedure

For each particle counter the number of free floating airborne particles of sizes 0.3, 0.5 and 5.0 µm were measured in an enclosed room for 1 minute at a the flow rate as a baseline measurement. Next, a mask was firmly installed on the particle chamber that was connected to the inlet tube of the particle counter. Subsequent measurements reveal a reduction of particles counted due to the filtering of the environmental air that enters the inlet tube. Filtering efficiency was expressed as the percentage particle reduction relative to the baseline measurement for that particular particle counter.

Results

Table 1 shows the results of particle measurements for 2 mask samples from polish origin (supposedly of class FFP2). Each mask was measured for 3 times on different locations on the mask. These masks were also sterilised once using steam sterilization by means at 121 ^{o}C in combination with permeable laminate bags, Halyard type CLFP150X300WI-S20. Both Lighthouse hand-held devices show similar particle filter capacity. The filter capacity of the samples measured with the 3100 version are much lower when compared with the hand-held version.

Table 2, comparison between 3 different particle counters with different flow rates

3016	counted particles [mu]			percentage filtered particles [%]		
New FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	2767,00	246	0	97,8	97,5	100,0
sample 1b	2580,00	213	0	97,9	97,8	100,0
sample 1c	2722,00	255	0	97,8	97,4	100,0
1x steam sterilized FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	11041,00	929	0	91,1	90,5	100,0
sample 1b	10494,00	867	1	91,5	91,1	97,7
sample 1c	9155,00	766	1	92,6	92,2	97,7
2016	**counted particles [mu]**			**percentage filtered particles [%]**		
New FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	5467,00	752	1,0	94,1	94,6	100,0
sample 1b	5137,00	837	0,0	94,5	94,0	100,0
sample 1c	5970,00	837	0,0	93,6	94,0	100,0
1x steam sterilized FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	8553,00	1229	0,0	90,8	91,2	100,0
sample 1b	7324,00	1229	0,0	92,1	91,2	100,0
sample 1c	8867,00	1301	0,0	90,5	90,7	100,0
3100	**counted particles [mu]**			**percentage filtered particles [%]**		
New FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	131628,00	7623	14	83,4	94,7	98,5
sample 1b	132777,00	7721	2	83,3	94,6	99,8
sample 1c	130644,00	7597	2	83,6	94,7	99,8
1x steam sterilized FFP2 polish mask FFP2 class	**0.3**	**0.5**	**5**	**0.3**	**0.5**	**5**
sample 1a	259412,00	22322	17	67,4	84,4	98,1
sample 1b	244549,00	21353	7	69,2	85,1	99,2
sample 1c	259258,00	21931	39	67,4	84,7	95,7

Comments

The particle filtering efficiency was only tested with dry particles that are present in the environmental air. Additional aerosol testing (NaCl test, Paraffin oil) is needed to evaluate the filtering efficiency of aerosols.

The breathability of the material has not been tested. Pressure drop tests need to be performed to evaluate whether the ability to breathe through the masks is not affected.
Also, no FIT test has been performed to determine whether the mask properly fits on to the face of the user and whether air bypasses the mask along the face of the wearer.

Take home message
We tested whether the data obtained for particle counters having different specifications, in particular using different flow rates, results in different outcomes and therefore different estimates of the filter efficiency of a mask.

The results obtained with all individual particle counters are robust and reproducible. This suggests that all counters are suitable for direct comparisons between masks (for instance to compare effects of sterilization or direct comparisons between different types of masks). However, testing at a low flow rate (0.1 cfm) results in higher overall estimates of the filter efficiency than testing at a high flow rate (1.0 cfm). Therefore, tests performed at low flow rates may overestimate the actual filter efficiency and cannot directly show whether a mask reaches the requirements for certain types of masks such as FFP1 and FFP2 without benchmark testing.