CUSTOMER REPORT

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Filtration Efficiency and Breathing Resistance of Community Face Coverings

Confidentiality: Confidential

Report's title

Filtration Efficiency and Breathing Resistance of Community Face Coverings

Customer, contact person, address	**Order reference**
Turvallisuus- ja kemikaalivirasto (Tukes) Yliopistonkatu 38 FI-33100 Tampere FINLAND	Confirmation of order VTT-CRM-170160-20
Project name	**Project number/Short name**
Hengityksensuojainten tutkimus	128621

Summary

The purpose of the commission was to determine the filtration efficiency and breathing resistance of the community face coverings.

The filtration efficiency was determined according to the CEN Workshop Agreement CWA 17553:2020 (E) using measurement method defined in EN 13274-7. The filtration efficiency was measured with DEHS (di-ethyl-hexyl-sebacate) test aerosol in accordance with CWA 17553 (E) (Annex D). The efficiency was determined by measuring particle concentrations alternately from the downstream and upstream of the face covering. The air flow rate through the face covering was 28,3 l/min. The particle size in the test was 3 µm. Measurements were done with an optical particle size analyser. The breathing resistance was determined according to the CEN Workshop Agreement CWA 17553:2020 (E) using measurement method defined in the standard EN 14683:2019 + AC:2019, Annex C (Medical face masks. Requirements and test methods). The air flow rate through the face covering according to the standard EN 14683 was 8 l/min.

According to the measurement results the breathing resistance of the products "1" and "20" exceeded considerably the requirement (≤ 70 Pa/cm^2) of the CWA 17553. The breathing resistance of other tested products fulfilled the requirement of CWA 17553.

Only one (5%) of all the twenty reusable community face coverings fulfilled the higher (≥90%) filtration efficiency requirement of CWA 17553. Seven (35%) of the twenty face coverings fulfilled the lower (≥70%) filtration efficiency requirement of CWA 17553.

Two disposable community face coverings were included in the study. Both of them were in accordance with the requirements of CWA 17553.

Tampere 11.12.2020

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1. Description and objectives

The objective of the commission was to determine the filtration efficiency to particles and breathing resistance of the community face coverings. The inspected community face coverings are presented in Table 1. The commission was performed to the samples delivered to VTT Technical Research Centre of Finland by the customer on September 30th 2020.

Table 1. The inspected community face coverings.

Product	Material information	Model
1	Weaved fabric (outer surface) + nonwoven fabric (inner surface), no material information	Cup mask, seam in the middle, washable
2	Knitted fabric (outer surface) + nonwoven fabric (inner surface), both 100% polyester	Pleated mask, washable
3	Nonwoven fabric, 3 layers, no material information	Pleated mask, disposable
4	Nonwoven fabric, 3 layers, synthetic fibers, no exact material information	Pleated mask, disposable
5	Knitted fabric, 3 layers (100% polyester (outer surface) / 100% cotton (inner surface), antimikrobial)	Pleated mask, washable
6	Hydrophilic polyurethane, 1 layer, antimikrobial material	Cup mask, seam in the middle, washable
7	Knitted fabric, 2 layers (100% polyester, antimikrobial material, includes silver ions)	Cup mask, seam in the middle, washable
8	Knitted fabric, 2 layers (100% polyester), water and dirt repellent treatment	Pleated mask, washable
9	Knitted fabric, 1 layer (100% polypropylene), ergonomically knitted into shape	Cup mask, no seam in the middle, washable
10	Neoprene mask with a hole, neoprene layer's outer and inner surface include knitted fabric	Cup mask, seam and hole in the middle, washable
11	Sequin mask (outer surface, 100% polyester), weaved fabric (inner surface, 97% cotton / 3% elastane)	Cup mask, seam in the middle, washable
12	Knitted fabric, 1 layer (95% polyester + 5% elastane)	Cup mask, seam in the middle, washable
13	Weaved fabric, 2 layers (100% linen)	Pleated mask, washable
14	Knitted fabric, 2 layers (100% cotton, organic)	Cup mask, seam in the middle, washable
15	Weaved fabric, 1 layer (50% Tencel + 50% polyester)	Pleated mask, washable
16	Knitted fabric, 2 layers (97% polyamide + 3% elastane), contains silver chloride	Straight mask, washable
17	Knitted fabric, 2 layers (95% cotton+ 5% elastane, antimikrobial and liquid-repellent surface treatment)	Straight mask, washable
18	Weaved fabric (chiffon), 2 layers (100% polyester)	Scarf mask, washable
19	Knitted fabric (100% polyester) / nonwoven fabric (100% polypropylene + nanofiber) / weaved fabric (100% polyester), 3 layers	Cup mask, no seam in the middle, washable
20	Weaved fabric (88% polyester + 12% elastane, liquid-repellent surface treatment) / Knitted fabric (100% polyester, antimikrobial treatment), 2 layers	Cup mask, seam in the middle, washable
21	Weaved fabric (100% cotton, outer surfaces) / nonwoven fabric (100% polypropylene, inner surface), 3 layers	Pleated mask, washable
22	Knitted fabric, 2 layers (100% cotton)	Pleated mask, washable

2. Methods and realisation

The filtration efficiency and breathing resistance was determined according to the CEN Workshop Agreement CWA 17553:2020 (E).

2.1 Filtration efficiency

The filtration efficiency was determined in accordance with the CEN Workshop Agreement CWA 17553:2020 (E) (Community face coverings - Guide to minimum requirements, methods of testing and use) using measurement method defined in EN 13274-7 (Respiratory protective devices. Methods of test. Part 7: Determination of particle filter penetration). The surface area of the sample was the whole face covering that was attached to the adapter as shown in Figure 1.

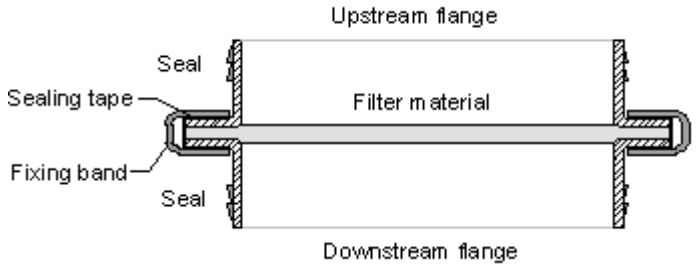

Figure 1. Principle of the sample adapter.

The airflow through the material was adjusted with an orifice plate ASME 17/34 mm complying with standard ASME MFC-14M-2001, and the pressure drop was measured with a DPM TT570SV micromanometer. The flow rate through the community face covering was 28,3 l/min thus that the air speed calculated according to the minimum area of the sample holder was 6 (±1) cm/s, as recommended in CWA 17553:2020 (E) (Annex D).

The filtration efficiency was determined by utilizing the flow-through method (Figure 2). It was measured with DEHS (di-ethyl-hexyl-sebacate) test aerosol recommended in CWA 17553:2020 (E) (Annex D) generated with a pneumatic aerosol nebulizer. The test aerosol was evenly mixed into HEPA filtered supply air. The efficiency was determined by measuring particle concentrations and size distribution alternately before (unfiltered air) and after the sample (filtered air). The filtration efficiency of the community face covering was measured with an optical particle size analyser PMS LAS-X2 in the size range of 0,1…5 µm. The result is presented according to the particle size 3 µm according to the CWA 17553:2020 (E) (Annex D).

Departing from the standard EN 13274-7, one sample was measured from the product. The filtration efficiency of the sample was measured with six consecutive repetitions. The filtration efficiency results' statistical analysis utilized Student's t-distribution. According to that the 95% reliability limits (an upper limit and lower limit) were calculated from the sample standard deviation using a coefficient 2,015 (5 freedom degrees). An average, standard deviation and reliability limits of the obtained result were reported. With a 95% probability the filtration efficiency is greater than the obtained lower limit value excluding products with a lower limit that was smaller than a zero. In these cases with a 95% probability the filtration efficiency is smaller than the value of the upper limit that has been received. The filtration efficiency is placed between the reliability limits on a 90% probability.

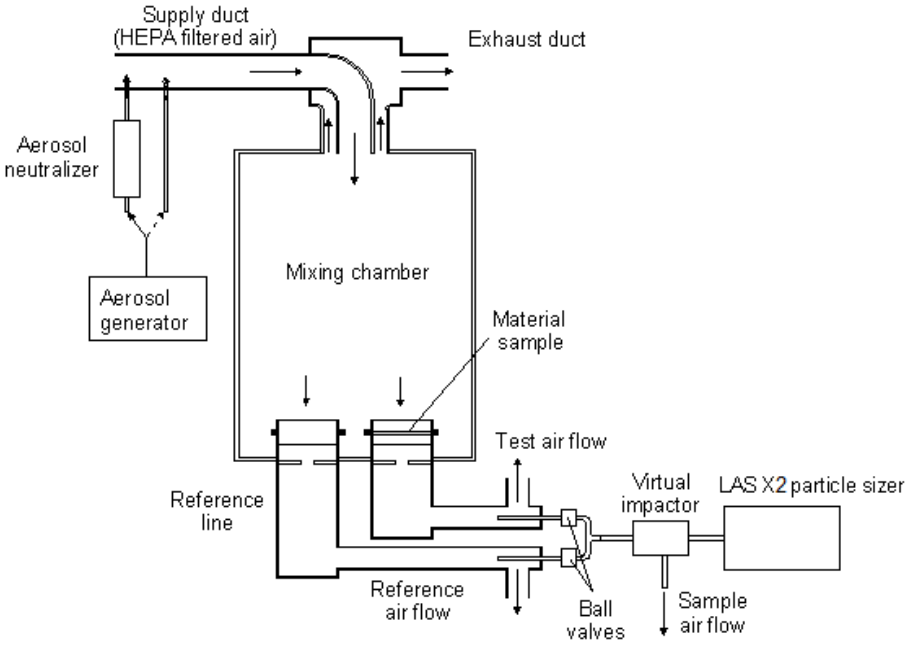

Figure 2. Principle of the test system.

2.2 Breathing resistance

The breathing resistance (differential pressure) of the community face covering was determined according to CWA 17553:2020 (E) (Community face coverings - Guide to minimum requirements, methods of testing and use) using the measurement method defined in EN 14683:2019 + AC:2019, Annex C (Medical face masks. Requirements and test methods).

The airflow through the material was adjusted with a mass flow meter Bronkhorst EL-flow F-201CB-20K-AAD-00-K, and the pressure drop was measured with a DPM TT570SV micromanometer. The air flow rate through the face mask was 8 l/min in accordance with EN 14683:2019 + AC:2019 (Medical face masks. Requirements and test methods). The diameter of the test area was 25 mm. Departing from the standard SFS-EN 14683, the samples were not conditioned at 85 % relative humidity before the measurements.

Departing from the standard EN 14683, one sample was measured from the product. The filtration efficiency of the sample was measured from five test areas so, that all variations in the construction of the mask were incorporated representatively in the test. The filtration efficiency results' statistical analysis utilized Student's t-distribution. The 95% reliability limits (an upper limit and lower limit) were calculated from the sample standard deviation using a coefficient 2,132 (4 freedom degrees). An average, standard deviation and reliability limits of the obtained result were reported. With a 95% probability the breathing resistance is smaller than the obtained upper limit value and it is placed between the reliability limits on a 90% probability.

3. Results

The measurements were made in the laboratory of the VTT Technical Research Centre of Finland on 20. - 29.10.2020. The filtration efficiencies of the community face coverings are presented in Table 2 and Figures 3 and 4. The results of the breathing resistance are presented in Table 3 and Figure 5.

Table 2. The filtration efficiency of the community face coverings.

Product	FILTRATION EFFICIENCY, 3 µm [%]			
	Average	Standard deviation	95% lower reliability limit	95% upper reliability limit
1	100.0	0.0	100.0	100.0
2	37.8	4.2	29.3	46.3
3	100.0	0.0	100.0	100.0
4	99.2	0.2	98.8	99.6
5	57.6	3.8	49.9	65.3
6	8.4	10.1	0.0 *)	28.8
7	23.3	2.5	18.2	28.4
8	36.6	5.8	24.8	48.4
9	21.7	6.2	9.2	34.1
10	3.9	3.8	0.0 *)	11.6
11	26.3	8.0	10.1	42.4
12	40.2	6.0	28.0	52.4
13	23.2	7.7	7.8	38.7
14	75.8	3.4	69.0	82.6
15	78.5	3.1	72.3	84.7
16	92.0	1.0	89.9	94.1
17	78.4	3.1	72.1	84.6
18	1.0	4.9	0.0 *)	10.9
19	80.2	3.2	73.8	86.6
20	97.0	0.8	95.4	98.7
21	76.8	4.0	68.8	84.8
22	85.0	2.1	80.8	89.1

*) computationally negative

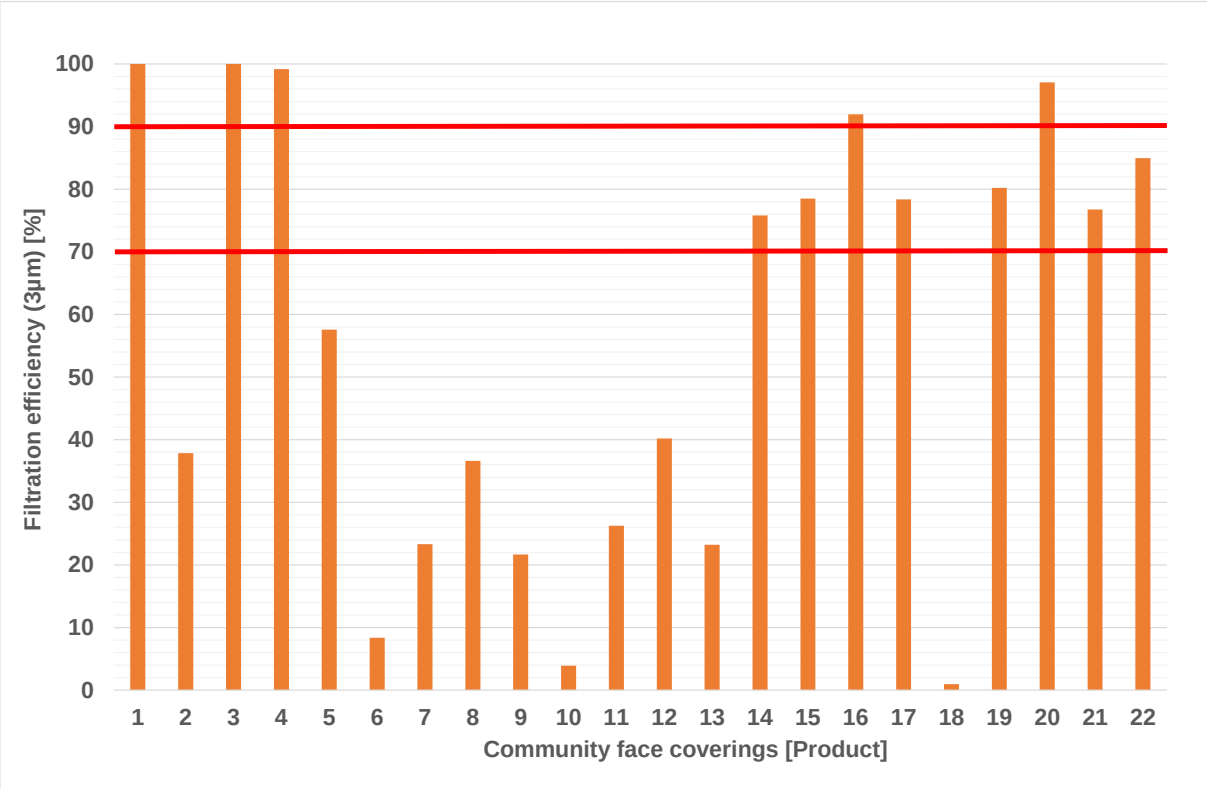

Figure 3. The filtration efficiency of the community face coverings (average, particle size 3 µm).

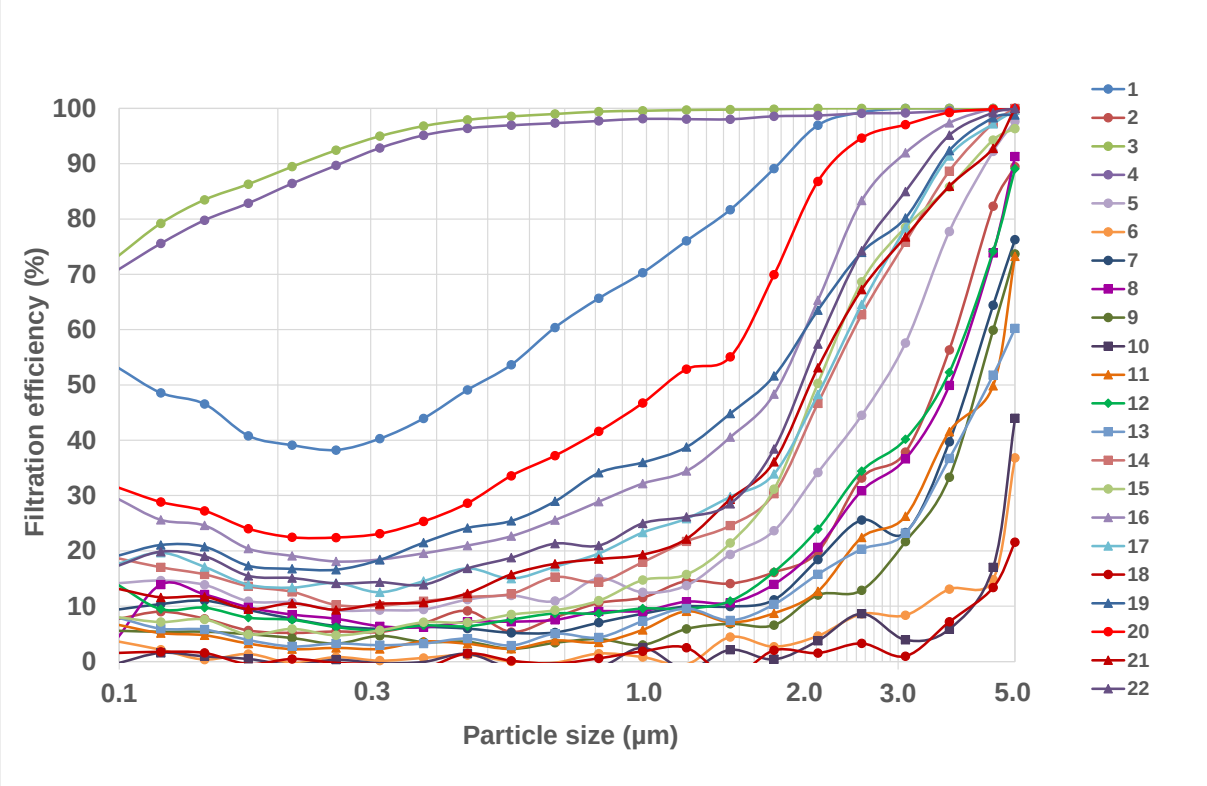

Figure 4. The filtration efficiency as a function of the particle size range of the community face coverings.

Table 3. The breathing resistance of the community face coverings.

Product	BREATHING RESISTANCE (Differential pressure), Δp [Pa/cm^2]								
	1	2	3	4	5	Average	Standard deviation	95% lower reliability limit	95% upper reliability limit
1	118.2	107.1	103.1	103.5	108.7	108.1	5.5	96.5	119.7
2	8.2	11.3	13.3	6.8	8.7	9.7	2.3	4.7	14.6
3	34.8	37.9	34.9	34.4	38.5	36.1	1.7	32.4	39.8
4	39.4	39.0	40.9	38.9	39.3	39.5	0.7	38.0	41.1
5	12.2	15.2	15.7	15.7	12.8	14.3	1.5	11.1	17.5
6	1.3	1.3	1.3	1.3	1.3	1.3	0.0	1.2	1.4
7	5.5	5.5	5.0	5.0	5.0	5.2	0.2	4.7	5.7
8	5.7	5.9	6.1	6.4	6.1	6.0	0.2	5.5	6.6
9	9.0	8.9	9.9	9.1	7.5	8.9	0.8	7.2	10.5
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	7.9	8.3	8.6	7.9	7.6	8.1	0.3	7.3	8.8
12	12.0	11.3	12.3	12.1	12.2	12.0	0.3	11.3	12.7
13	8.4	8.3	10.1	10.1	9.6	9.3	0.8	7.6	11.0
14	33.2	39.9	40.5	39.7	44.0	39.5	3.5	32.0	46.9
15	55.9	52.9	49.8	61.6	54.3	54.9	3.9	46.6	63.2
16	41.1	43.6	41.3	43.2	43.8	42.6	1.2	40.1	45.1
17	33.5	42.1	39.4	43.2	40.7	39.8	3.4	32.6	47.0
18	0.9	0.9	0.9	1.0	1.0	0.9	0.0	0.9	1.0
19	47.0	46.1	48.3	46.6	46.7	47.0	0.8	45.3	48.6
20	91.8	116.6	103.9	103.5	101.7	103.5	7.9	86.7	120.3
21	23.2	19.2	32.2	31.2	20.4	25.2	5.4	13.6	36.9
22	30.6	25.8	32.6	30.8	27.3	29.4	2.5	24.1	34.8

Note. The breathing resistance of the tested product “10” was either 0 or >1000 Pa/cm^2, depending on the test area. The design of the product included a large hole made to facilitate breathing.

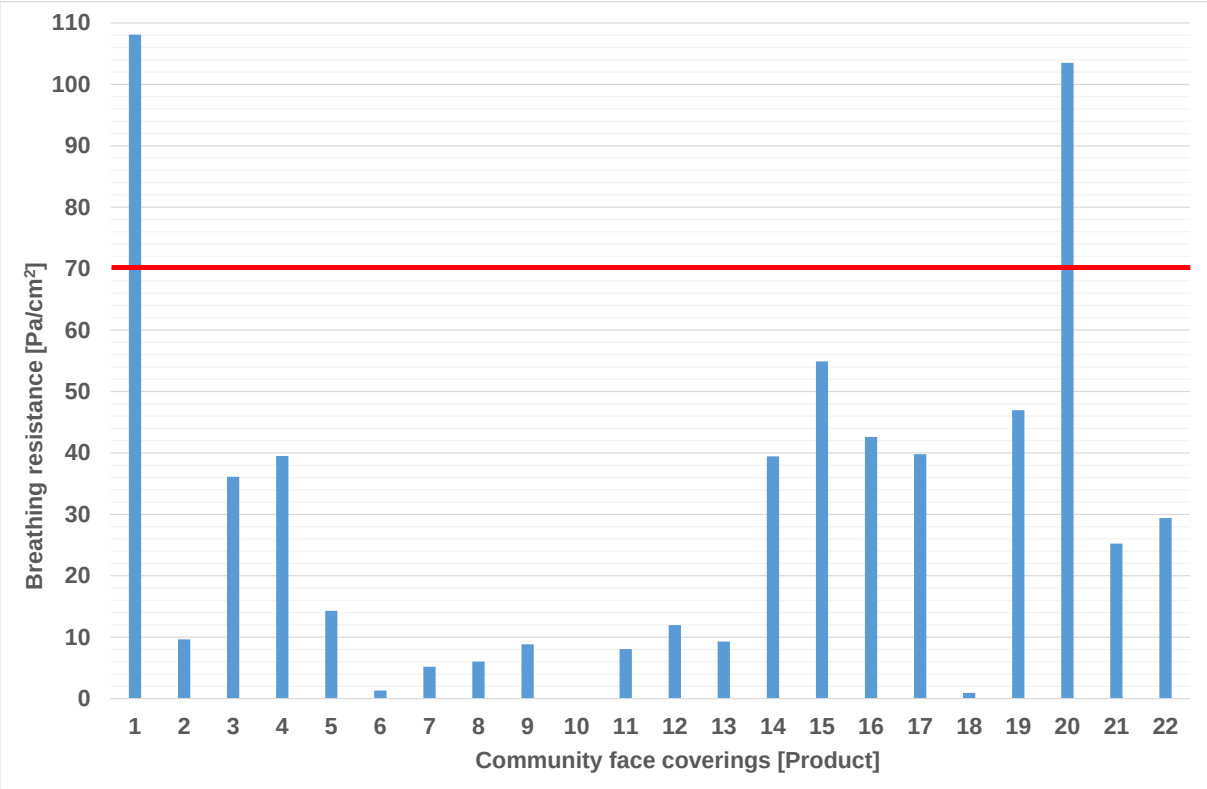

Figure 5. The breathing resistance of the community face coverings.

4. Conclusions and summary

The results of the community face coverings are summarised in Figure 6.

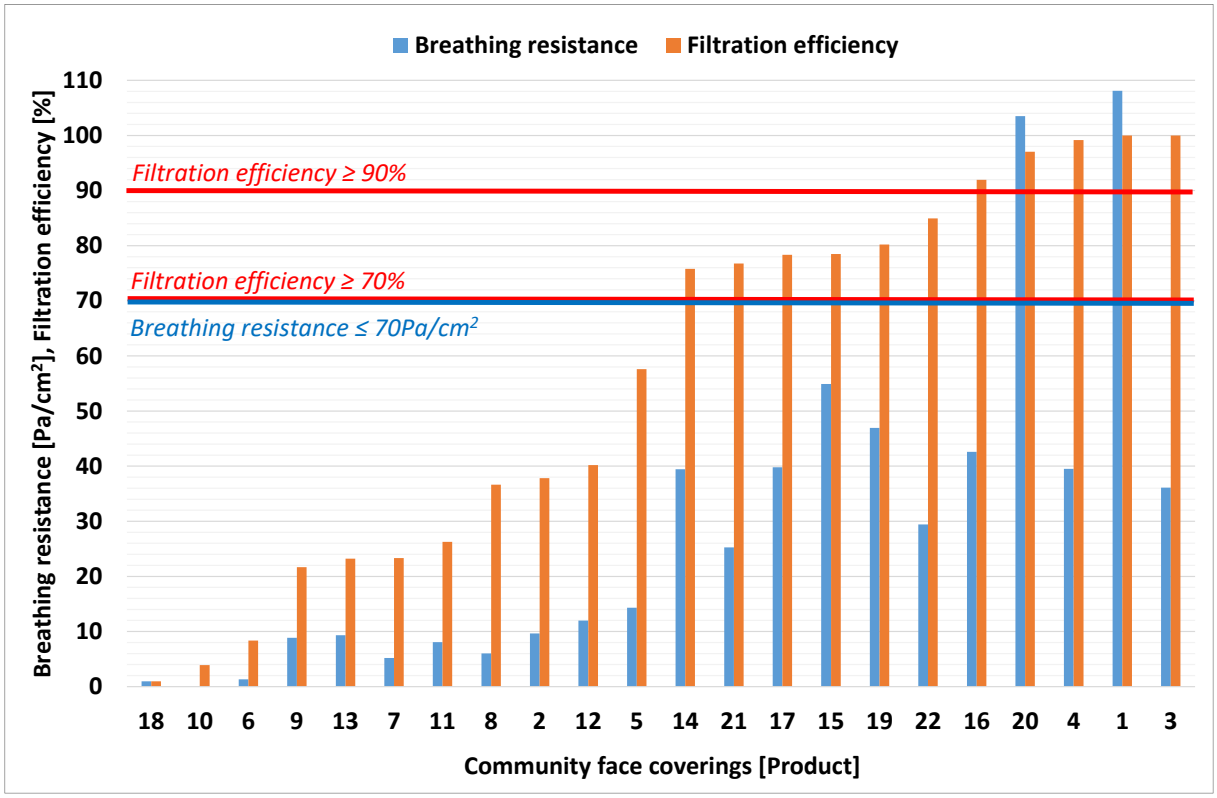

Figure 6. Summary of the test results.

According to the CEN Workshop Agreement CWA 17553:2020 (E) the breathing resistance should be ≤ 70 Pa/cm^2. Two levels of community face coverings are considered according to their filtration efficiency to particles around 3 (±0.5) µm:

- Level 70%: ≥ 70 %
- Level 90%: ≥ 90 %.

According to the measurement results the breathing resistance of the products “1” and “20” exceeded considerably the requirement of the CWA 17553. The breathing resistance of other tested products fulfilled the requirement of CWA 17553.

Only one (5%) of all the twenty reusable community face coverings fulfilled the higher (≥90%) filtration efficiency requirement of CWA 17553. Seven (35%) of the twenty face coverings fulfilled the lower (≥70%) filtration efficiency requirement of CWA 17553.

Three of the seven masks that fulfilled the lower requirement for filtration efficiency given in the CWA 17553 were made from synthetic fibers, three from natural fibers and one from both synthetic and natural fibers. Therefore, it cannot be concluded from the results that the use of synthetic or natural fibers hade influence to the filtration efficiency. Fifteen (75%) community face coverings of all the reusable community face coverings included in the study contained synthetic fiber and seven (35%) natural fiber.

The only reusable community face covering that met the requirement for higher filtration efficiency was a synthetic fiber knit with antimicrobial treatment. Six masks (30%) of all the reusable products tested were antimicrobial. The other five of antimicrobial face coverings did

not meet the requirements of CWA 17553. The structure of the fabric used in the reusable community face coverings included in the study was in 55% of the coverings knitted (11 pieces) and in 25% of the coverings weaved (5 pieces) and in 15% of the coverings both knitted and weaved (3 pieces). Two reusable community face coverings (10%) included in the study represented other structure than knitted or weaved fabric.

Four (20%) of all the reusable community face coverings contained a nonwoven structure. Two of these coverings passed the requirements of the CWA 17553.

A total of six community face coverings for children were included in the study, five of which were reusable. Five of the six masks met the breathing resistance requirement and one reusable children's face covering clearly exceeded the maximum limit. Two of the childrens' reusable face coverings met also the lower (≥ 70%) filtration efficiency requirement of the CWA 17553, but none met the upper (≥ 90%) filtration efficiency requirement.

The design of the product "10" included a large hole made to facilitate breathing, as a result of which the product did not cause breathing resistance and its filtration efficiency was zero. Due to the design, the product may cause a direct disadvantage by delivering the splashes generated by sneezing through the hole farther than without using the product.

Two disposable community face coverings were included in the study. Both of them were in accordance with the requirements of CWA 17553.