Spunbond Polypropylene's suitability for high-filtration masks that can be made on sewing machines.

Author: Paul Hammant
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Abstract

Given SARS-COV-2 is predominantly airborne (transmitted in aerosols via breathing, talking or sneezing) and that N95 grade disposable respirators are desired personal protective equipment, we decided to test particle filtration of masks made on a sewing machine using fairly common spunbond polypropylene (SBPP).

Unlike melt-blown polypropylene, SBPP is known to be washable and dryable as there are multiple garment-industry uses already. In addition to the filtration effectiveness measured after masks were completed, we wanted to test the filtration effectiveness after cycles of washing and drying as that may happen in real-world use.

Health care professionals and citizens should seek the best respirators or masks they can, but in the event of there being none available and a desperate need, sewing machine made items might be the only choice, and this study hopes to provide useful data towards such decisions.

Method

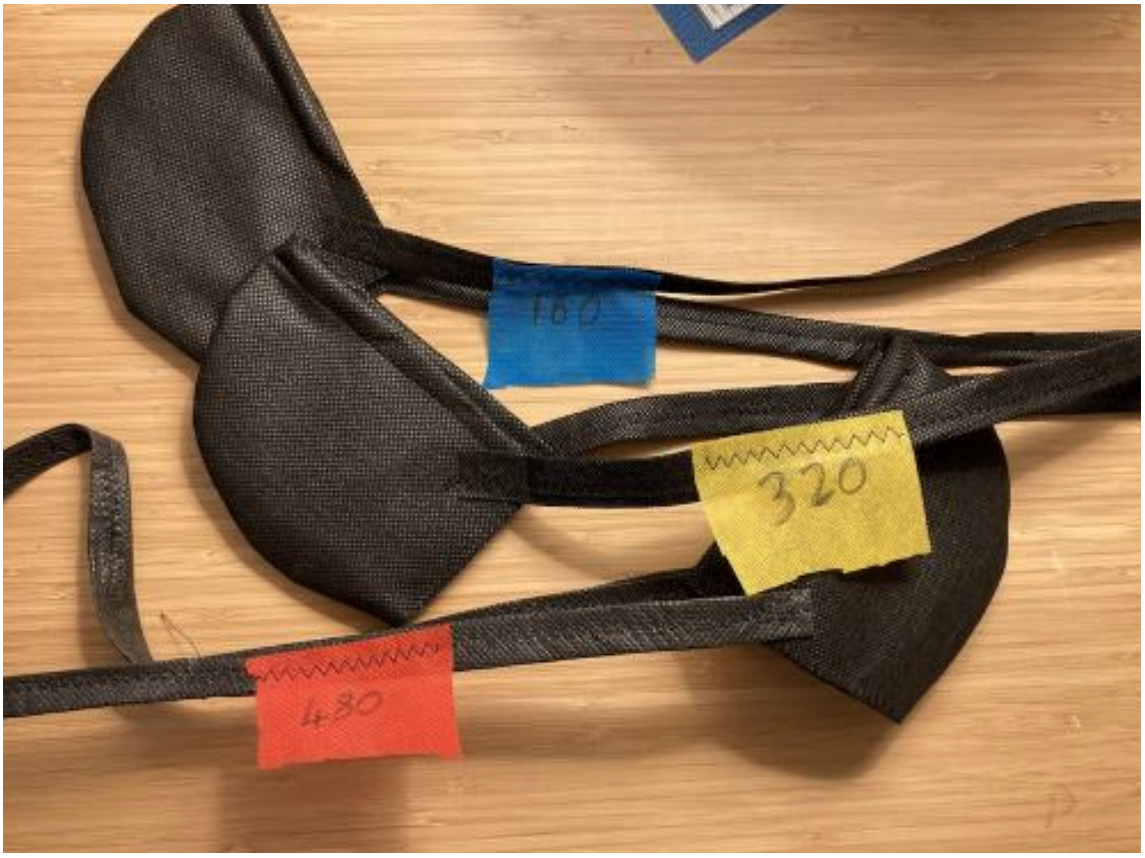
A prototype msk was constructed of 130 cm^2 of SBPP with a design focused on simulating typical industrial respirators including a design to ensure a tight seal to the face, filter media that stays away from the mouth during inhalation and head straps to ensure good face sealing pressure. This mask is termed the “Rag Mask Max” and can be made easily on a typical sewing machine (see Supplemental Section). The strapped nature of the mask makes for a better fit versus masks with elasticated ear loops. Higher spec respirators often come with elastic that goes around the wearer’s head, leading to a tighter fit than ear loops. Tight fit means less leaks at the edges of the respirator. The straps for the mask of this study are sewn and tied in a bow, rather than elasticated.

Masks for our tests here were made with “Black Polypropylene Weed control fabric” SBPP that was purchased from a garden center. Specifically a roll purchased in the United Kingdom from the B&Q home improvement chain[1] at their “Verve” brand. Measured weight was confirmed to be 80 GSM, as labelled. The product is a generic item made in China and labelled differently for other chains. The masks made were SBPP only - no cotton, polyester or other fabrics. Depending on the layer count the time to make each mask is 10 - 12 minutes for someone with modest sewing machine experience.

The Rag Mask Max design allows for the fabric layering to be achieved as a first step through simple folding. Two layers of 80 GSM SBPP would be 160, and masks to that specification were

[1] “Verve Black Polypropylene Weed control fabric, (L)10m (W)1m“ - https://www.diy.com/departments/verve-black-polypropylene-weed-control-fabric-l-10m-w-1m/1849805_BQ.prd

made for the tests. Masks at 320 GSM (four layers) and 480 (six layers) were also made. To make it clear which was which, labels were sewn into the mask straps and the GSM number was sharpied on. The Rag Mask Max has a central vertical seam which provides a rudimentary mechanism to retain a 3D cupping of the fabric to hold it away from the face on each breath in. For the sake of the testing a two-strapped version was made that suits people with a “high nose bridge”. It should be noted that many people would want a four strapped version for additional stability while wearing it.



The masks tested, before mailing from the UK to Thailand

The masks were affixed to a steel plate for a particle counter at Rajamangala University of Technology Lanna (RMUTL) in Thailand. Their TSI Inc “Nano Water-Based Condensation Particle Counter” (CPC) model 3788 was used for all the tests. The team doing the testing was from the Research Unit of Applied Electric In Engineering (RUEE) under Associate Professor Panich Intra. Instructions for NIOSH respirator testing were the general guide to testing.

Filtration testing

The following four combinations of particle size and flow rate were tested:

Particle size (nanometers)	Flow rate (liters per minute)
100	28.3
100	85
300	28.3
300	85

This section is provided by Associate Professor Panich Intra or RUEE/RMUTL.

The TSI 3788 testing process results in a particle filtration efficiency and an indication of breathability. Fig. 1 shows the experimental setup for evaluating the filtration efficiency and breathability of SBPP masks. An aerosol atomizer, filtered air supply, aerosol neutralizer, concentration adjustment valves, a high efficiency particulate-free air (HEPA) filter, a diffusion dryer, a flow meter, a vacuum pump, a test chamber, a mixing chamber, an electrostatic classifier, and an ultrafine condensation particle counter (UCPC) were all included in the setup. The NaCl polydisperse particles was generated by atomizing a NaCl solution (w/w 0.1% in water) with an aerosol atomizer (Model 3076, TSI Inc., St. Paul, MN, USA) and a filtered air supply (Model 3074B, TSI Inc., St. Paul, MN, USA). The wet NaCl polydisperse particles that came out of the aerosol atomizer were dried in the diffusion dryer (Model 3062, TSI Inc., St. Paul, MN, USA) to a relative humidity of less than around 30%RH. The generated NaCl polydisperse particles have some level of electric charge. Therefore, unless the electrostatic effect on tube walls and other surfaces in the system was neutralized, there may have been some particle losses. The soft X-ray aerosol neutralizer (Model 3088, TSI Inc., St. Paul, MN, USA) was used to neutralize the particles and brought the particles to the Boltzman charge equilibrium. In this system, number concentration of particles could be changed by adjusting the concentration adjustment valves and a HEPA capsule filter (Model 1602051, TSI Inc., St. Paul, MN, USA). As shown in Fig. 2, the mean diameter, number concentration and geometric standard deviation of the generated NaCl particles were 98.8 nm, 1.74×10^3 particles/cm^3 and 2.0, respectively. NaCl polydisperse particles were then classified according to their electrical mobility by the studied classifier at aerosol flow rate of about 1.5 l/min and sheath flow rate of about 3.0 l/min. At a given voltage, the particles exiting the examined classifier were almost singly charged, 100nm and 300 nm monodisperse NaCl particles. The NaCl monodisperse particle flow was introduced into the soft X-ray aerosol neutralizer (Model 3088, TSI Inc., St. Paul, MN, USA) was used to neutralize the particles and brought the particles to the Boltzman charge equilibrium. After the aerosol neutralizer, the NaCl monodisperse particles were mixed with the clean air to allow testing flow rate in the range between 28.3 L/min and 85L/min. 100

nm or 300 nm NaCl monodisperse particles were then entered into the test chamber that the SBPP masks inside. Isokinetic sampling was used to extract the upstream and downstream particles with the particle sampling probe in this study. In order to measure the particle size distribution and particle number concentration at upstream and downstream of the studied SBPP masks, the scanning mobility particle sizer (SMPS) which included the aerosol neutralizer, the electrostatic classifier (Model 3082, TSI Inc., St. Paul, MN, USA) with a long-differential mobility analyzer, long DMA (model 3081, TSI Inc., St. Paul, MN, USA) with a sheath air flow of 3.0 L/min and the UCPC (Model 3788, TSI Inc., St. Paul, MN, USA), allowing for a mobility diameter selection from 100 to 300 nm. In this study, the pressure drop inside the test chamber during filtration efficiency test was measured by the manometer (Model 8380, TSI Inc., St. Paul, MN, USA) The particle filtration efficiency, $\eta_{\exp}$, can be calculated by the following equation:

$$\eta_{\exp} = \frac{c_{\text{inlet}} - c_{\text{outlet}}}{c_{\text{inlet}}} \times 100$$

Where c_{inlet} and c_{outlet} are the particle number concentration at upstream and downstream, respectively.

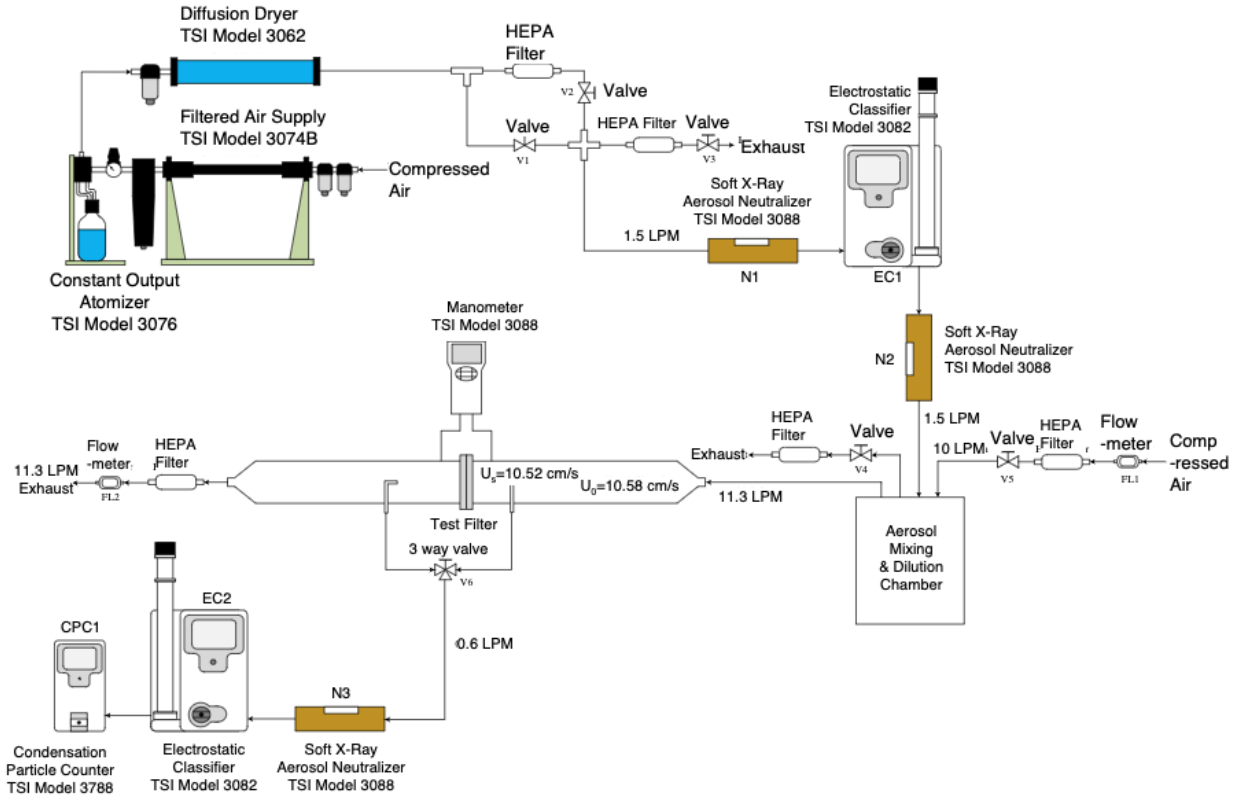


Fig. 1 Experimental setup for evaluating the filtration efficiency and breathability of SBPP masks.

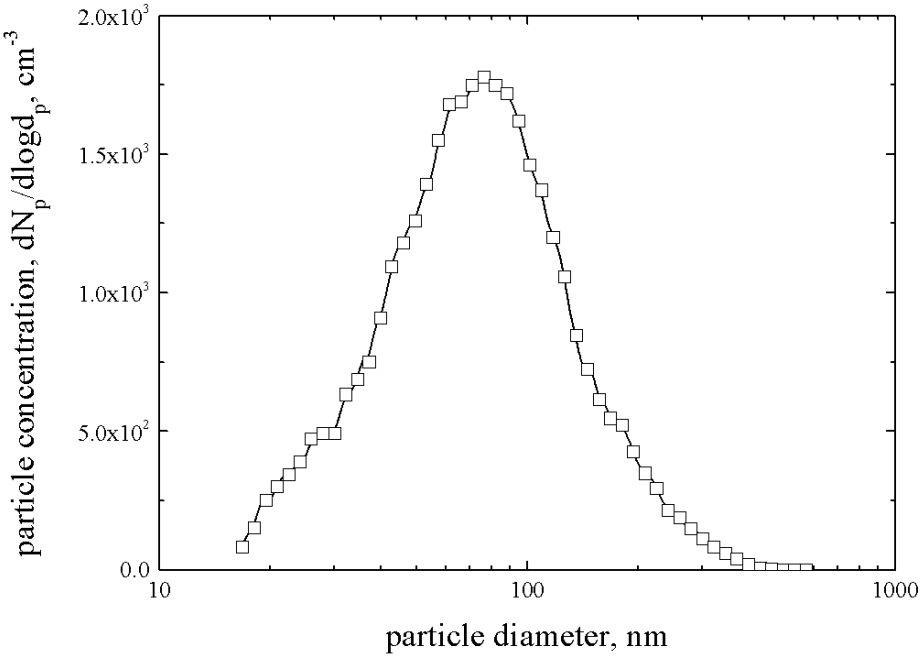


Fig.2 Particle concentration and size distribution of sodium chloride particles generated from an atomizer.

Cleaning SBPP masks.

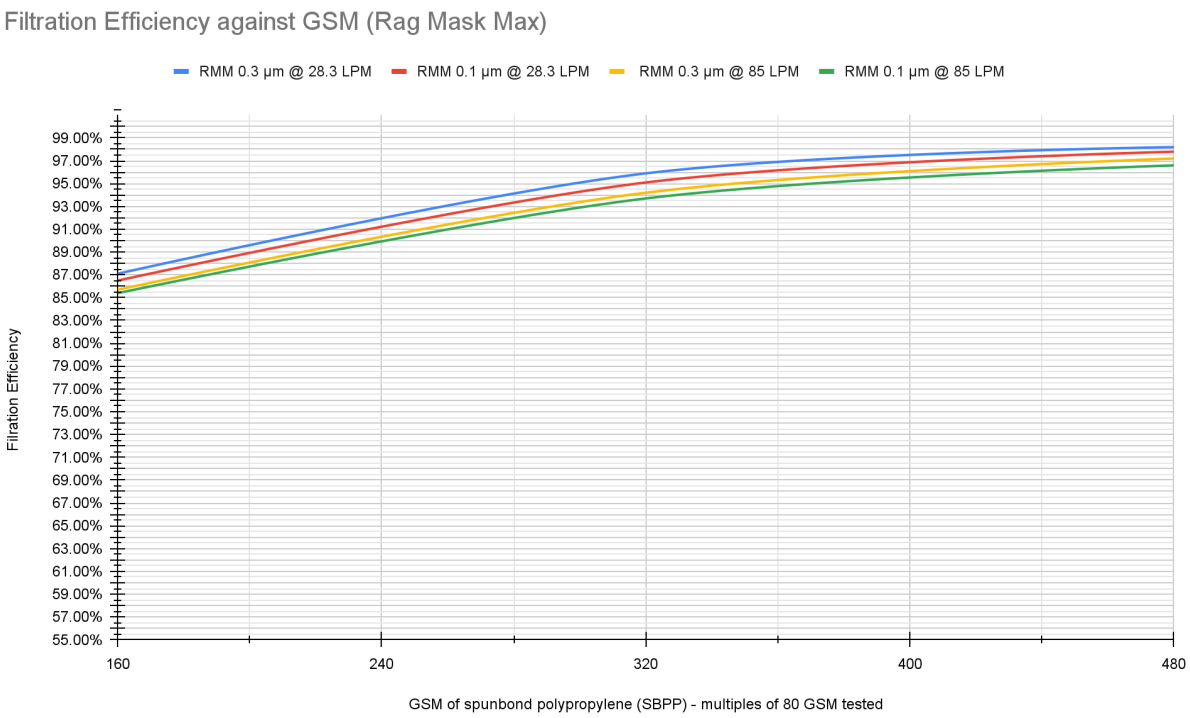
Different masks at 160, 320 and 480 GSM (two each) were run through protocols for cleaning by team members in Thailand. Ten cleanings and one hundred cleanings were performed on different masks.

- Dry heat in a rice cooker then cooling before the next iteration.
- Washing with warm soap water and air-drying.
- Boiling in water then air drying
- Steaming then air drying

Mask with the desired number of iterations was taken to the TSI 3788 filtration testing step for measurements there. Masks were not removed from the TSI 3788 apparatus for subsequent cleanings - all masks were essentially discarded after filtration testng.

Initial Filtration Results

Filtration



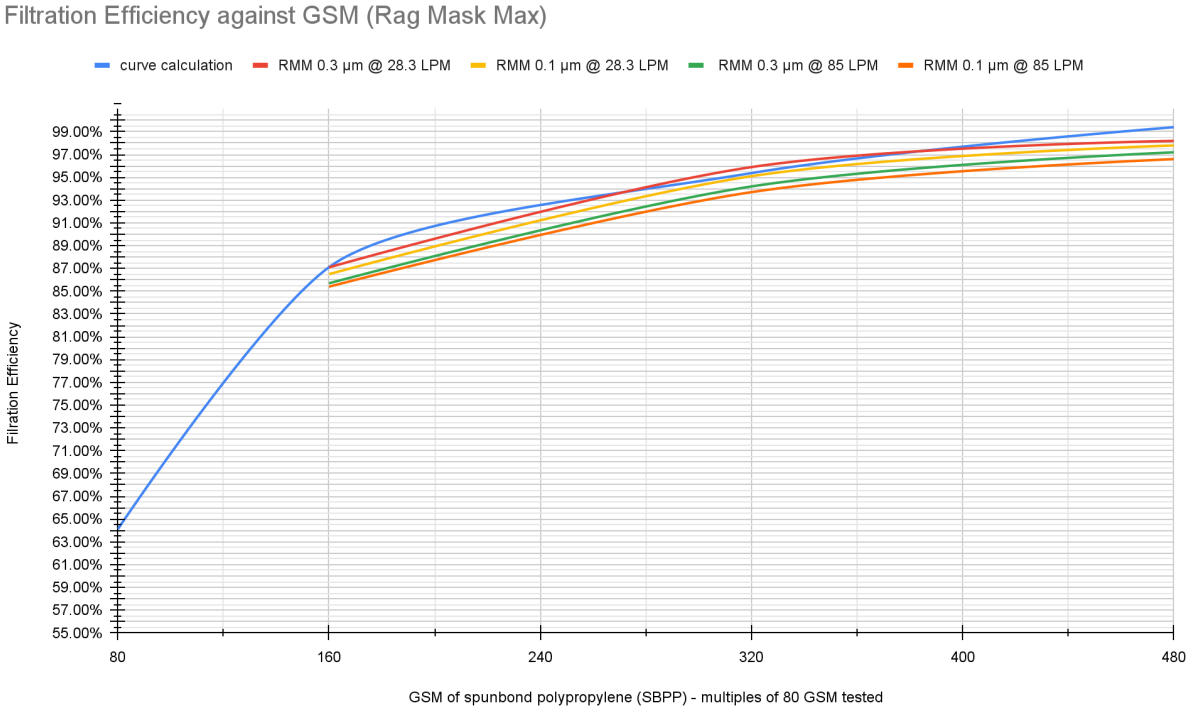
Curves shown are as estimated by Google's spreadsheet application. In the case of our 80 GSM fabric layers, it gives a rough indication of what 240 and 400 GSM would deliver in terms of PFE.

The 480 GSM masks regardless of particle size and flow rate performed better than the 320 GSM masks which similarly performed better than the 160 GSM masks. For each mask, 85 LPM flow rate lowered the filtration versus 28.3. Similarly, 100 nm tests showed lower filtration than 300 nm.

Curve fitting Attempts predicting untested GSM

Using the formula[2] for filtration from layers of the same fabric, we can attempt to make a curve fit the results:

[2] $1-(1-p)n$ where 'n' is layers of fabric, and each layer filters out a 'p' (0.0 - 1.0) proportion of the particles. Via https://math.stackexchange.com/questions/3698080/math-for-predicting-fabric-filter-effectiveness



The blue line above is the attempt to reverse engineer a PFE for 80 GSM (one layer of this was not tested) then see the curve formula applied to see how that corresponds to measured 160, 320 and 480 GSM. **The curve does not fit.** This is really indicated on the right hand side (480 GSM). The filtration should have been higher if the layering formula was a perfect prediction for PFE. Most likely there is leakage from the stitching and other imperceptible gaps.

Breathability

Figures for masks of known grades:

Grade	**<u>Typical</u> Breathability - Delta P**
ASTM Level 1	Less than 4 mm H2O/cm^2
ASTM Level 2	Less than 5 mm H2O/cm^2
ASTM Level 3	Less than 5 mm H2O/cm^2
N95	Greater than 5 mm H2O/cm^2

Actual masks and respirators measured from commercial manufacturers will vary, hence the less-than more-than language.

For the masks in this study:

GSM	**Measured Breathability - Delta P**
160	1.04 mm H2O/cm^2
320	1.56 mm H2O/cm^2
480	3.11 mm H2O/cm^2

The Delta P test was performed to determine the breathability of test articles by measuring the differential air pressure on either side of the test article, using a manometer, at a constant flow rate. The area of the test was 4.9 cm^2. The Delta P flow Rate was 8 liters per minute.

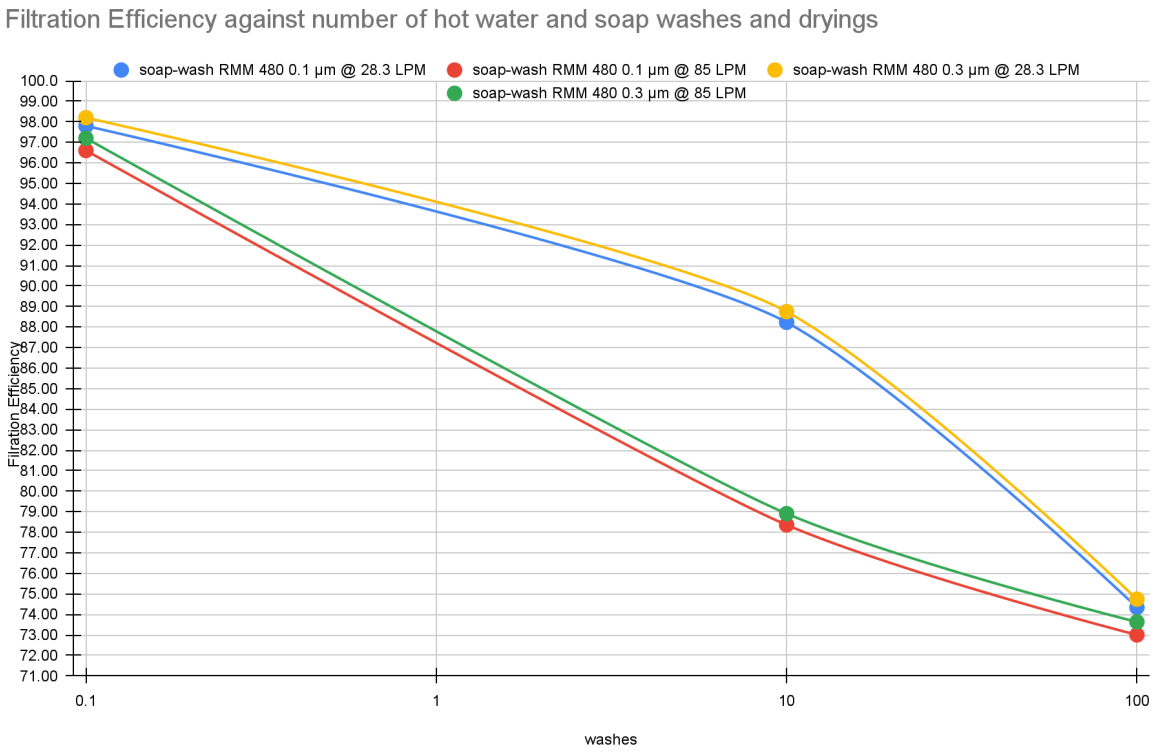
All three masks sewn are very breathable, and within the guidelines of the formal standards listed above.

Results after cleaning masks

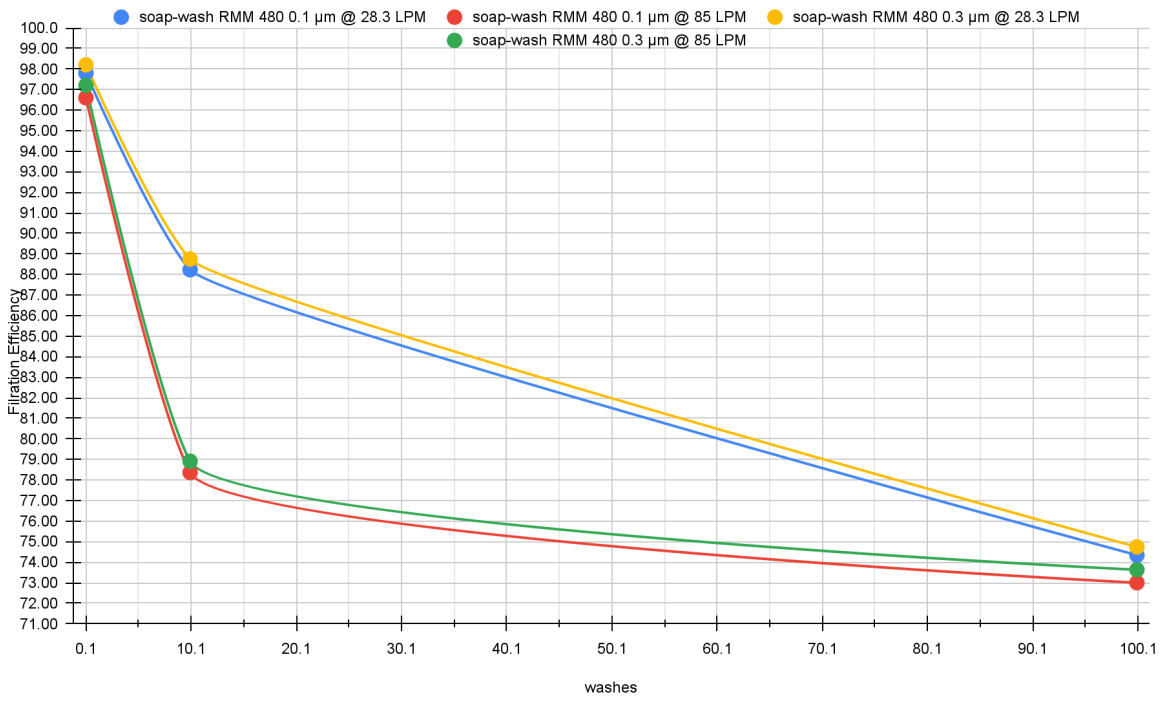
Dry heat attempts were too error prone to continue with - in experimentation we found that the masks could not be held at the desired temperature. They would too easily rise to the melting temperature of polypropylene, ruining the mask.

Hot soapy water washing

Washes with hot soapy water then drying: One 480 GSM mask with ten washes, then the PFE tests with the TSI machine, Another identical one with 100 washed then the PFE tests. Graph below.



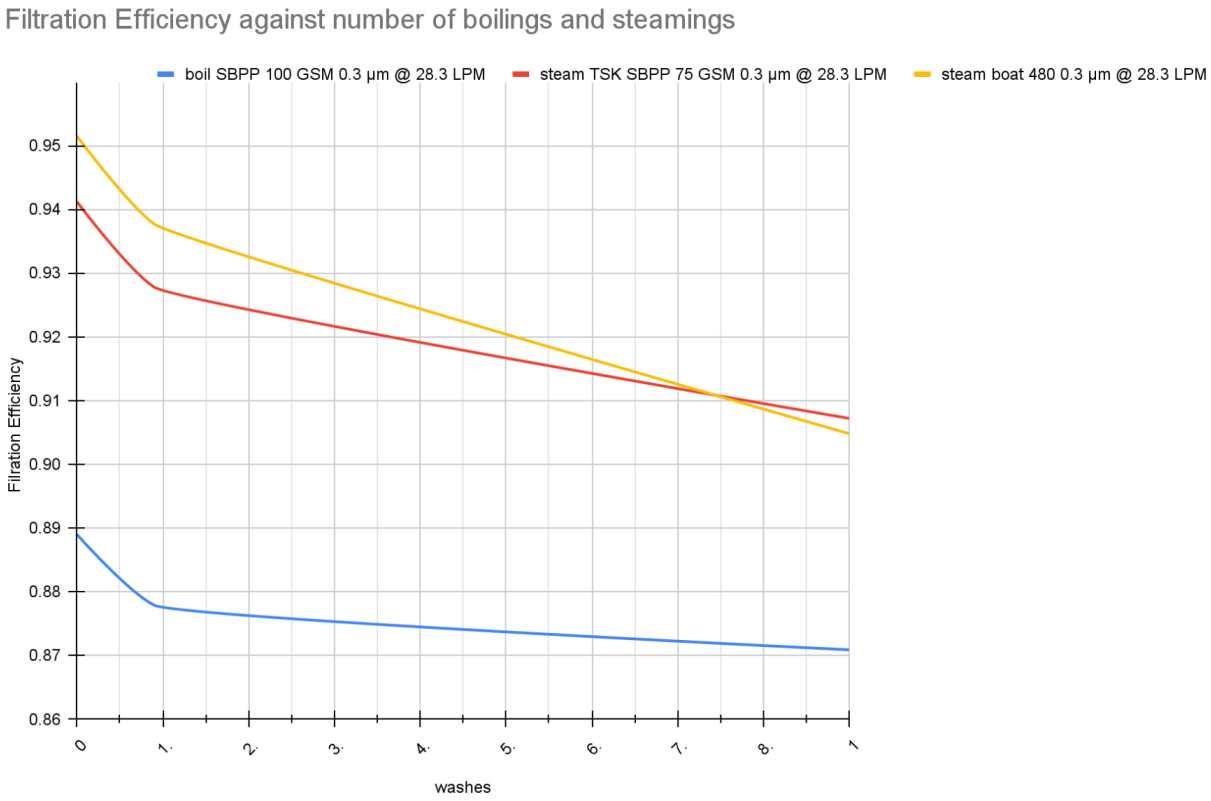
The above chart is logarithmic for the cleaning count. Here's the same as linear:



Filtration effectiveness drops off for both 100 nm and 300 nm particle sizes. 300 nm does better than 100 nm up to ten washes, but then starts to converge. By 200 washes, the graph could show the lines crossing, but we did no't test that. It seems moot, as it is unlikely that the owner of a mask would ever get to 100 washes before disposing of it. Besides, the filtration drop off with washing for this 80 GSM SBPP fabric, means you wouldn't count on it remaining high filtration. Masks with 320 and 160 GSM were not tested in the same 10 and 100 washes.

Boiling and Steaming

Boiling without soap and steaming all worked, with results shown here:



This chart isn't logarithmic, as 100 cleanings were not performed for neither boil & air dry nor steam and air dry. The filtration still drops off a 1 and 10 cleanings. Perhaps not as aggressively as soapy hot water and air dry. It is also important to note that three different sources of SBPP were tested here. Only the top yellow line was the same multiple of 80 GSM SBPP. And in the case of this test not a Rag Mask Max as used for the soapy hot water cleanings, But a boat design which has a slightly smaller breathable surface area, but roughly the same amount of stitching in the breathable area.

Conclusion

Masks made from SBPP can hit very high filtration levels and be very breathable. This is **without** the electrostatic properties of melt blown polypropylene that N95-grade respirators use. Clearly the item is thicker without the fabric savings with melt-blown layers. We are confident that SBPP can perform a particle filtration duty similar to melt blown when layers are sewn into a finished product that is substantially thicker. We are also confident that household sewing machines can produce these helping to solve a manufacturing bottleneck[3] given spunbond polypropylene is easier to manufacture than its melt blown counterpart. Though melt blown polypropylene respirators are always preferable, spunbond PP of sufficiently high GSM could be considered a contingency domestically-producible high filtration mask in a hypothetical COVID-19 elimination quest.

That said, until subsequent experimentation turns up a cleaning protocol that does not lower filtration significantly, you perhaps should **not wash SBPP masks**. Instead, label each SBPP mask for an individual to eliminate accidental sharing. Then use each for some time before disposing of it. Polypropylene is not going to provide a surface for biofilms (your own saliva for example) to multiply on, and your own exhaled breath potentially containing bacteria and viruses is not going to infect you more than you have been infected with the same already. Those pathogens would infect someone else, so masks not being sterilized should not be shared. While it would be desirable for a mask to last for three months before replacement, it is possible that each should be replaced after (say) one month, as it is not being cleaned.

Given the goals of the SBPP industry are not certification for mask use, only the purchaser of a roll would grade the material for mask use. Anyone producing these for an extended period of time, should continually test PFE rather than just once up front.

Acknowledgements

Associate Professor **Panich intra** and the team in the RUEE lab at RMUTL in Thailand have done an incredible amount of mask and respirator testing in the pandemic so far. This includes all the enthusiastic testing for this study. Their facebook page chronicles only some of their huge work: https://www.facebook.com/ruee.rmutl

The **ZeroCovid team in Thailand** did much of the organization of the testing of the SBPP masks of this study. This as part of a larger evaluation exercise for similar masks, dissimilar ones, and regular respirators in the quest for an inexpensive mass-market mask that could be used in a bigger push to protect Thailand and other countries. The team is multiple individuals presently, and is working anonymously in a Discord.com server towards their goals. Their

[3] https://www.forbes.com/sites/brucelee/2021/01/18/why-mask-gown-ppe-shortages-persist-even-though-manufacturers-want-to-help/

Facebook page is one key place their work and advocacy is detailed: https://www.facebook.com/zerocovidthailand

Aaron Collins, provided input to the project during the experiment phase and has been a reviewer of this report, and gave feedback on prototype mask designs in the run up to this study. Aaron's extensive solo work on mask testing in the pandemic is detailed on his Youtube channel: https://www.youtube.com/channel/UC3fF_rzkmZD0ufN685YE7Ig

Many Professors, PhD, MDs and enthusiasts from #TeamAirborne tested prototypes and gave feedback on those ahead of the study. They deserve many thanks for that and their tireless pushing of the airborne message when the WHO and other political/health bodies that have not.

Future Studies

Other high GSM home-sewn mask designs

We have sewn three-fold boat style masks, too. The same layering of the same SBPP after an initial step of simple folding. The ones we made had elastic ear loops, which are a much bigger challenge to getting very high particle filtrations, and the smaller amount of tests we did showed that. A team could pick a range of SBPP-only three-fold boat designs that are above 450 GSM to see how high filtration can be reliably made. But rather than affix the masks to a bed in the style of NIOSH tests, use a live human setup for the CPC testing. This change to specifically look for the contribution of edge leaks

Washability of other sources of SBPP

We do not know the washability of the SBPP at a given GSM made by other manufacturers. Most likely there is wide variance worldwide as thousands of manufacturers are involved in making rolls of the generic product. Washing with soapy hot water is the most accessible cleaning regime, but to what extent does the soap cause clumping of fibers in other makes sources of SBPP. Indeed, a study to determine the nature of the clumping, would be good. if clumping is the cause of the loss of filtration.

PFE for other sources of SBPP

With this study, we also don't know if spunbond polyester fabric at the same GSM from other sources performs in terms of filtration or breathability. A study to discover how wide the variance of filtration is for a given GSM of SBPP. Results might inform whether that is a guide alone in the purchasing of the material for home high filtration mask making.

Other cleaning protocols

As mentioned, **washing with soap and water** then air drying is the most practical for consumers. Unfortunately, we noted a loss of PFE for the SBPP we used. Other cleaning agents in hot water might fare better than soap.

Steaming of the same SBPP was covered (no soap involved), and the loss of filtration was reduced. More experiments on protocols involving steam would be good.

Future teams may try to work out if there is a practical way of utilizing **dry heat** for sterilization that doesn't come close to the melting point of Polypropylene. A study "Dry Heat as a Decontamination Method for N95 Respirator Reuse"[4] (Oh, Araud, Puthussery, Bai, Clark, Wang, Verma, Nguyen; July 2020) laid the foundational work, and maybe practical protocols for households could be derived from that for home made pure SBPP masks.

The pure **pressure cooking** function of a "insta pot" class cooker, can be utilized. The setup would be the standard 1 cup (236 ml) of water, the trivet that comes with the cooker, a cotton face towel for protection, then the SBPP masks resting on that. Many consumer grade pressure cookers hit 15 PSI (103.4 kilopascal), then drop the pressure to normalize at 10 - 11.5 PSI (68.9 - 79.2 kilopascal). That in turn means a temperature of 116-117°C (239 to 243°F) at sea level[5]. We have only done one informal test - achieving desired pressure for two minutes, then letting the pressure drop to normal without venting. The masks emerge fine - no visible signs of deterioration, but another team should test for PFE after 1, 10 and 100 cycles of that.

[4] https://pubs.acs.org/doi/full/10.1021/acs.estlett.0c00534
[5] https://www.hippressurecooking.com/pressure-cooker-psi-faq-the-stuff-you-didnt-think-to-ask/

Initial test data - 480 GSM

TEST 0.1 um 28.3L | TEST 0.1 um 85L | TEST 0.3 um 28.3L | **TEST 0.3um 85L** | DATA

Test result sheet

Name :
Addres
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0211**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3930.00	112.00	97.15	
SBPP 480	2	17.8	3950.00	110.00	97.22	
	3	17.8	3920.00	116.00	97.04	
	4	17.8	3940.00	98.00	97.51	
	5	17.8	3910.00	114.00	97.08	
Average			3930.00	110.00	97.20	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.60	15.24	3.11
SBPP 480	2	4.9	0.60	15.24	3.11
	3	4.9	0.60	15.24	3.11
	4	4.9	0.60	15.24	3.11
	5	4.9	0.60	15.24	3.11
Average			0.60	15.24	3.11

TEST 0.1 um 28.3L | TEST 0.1 um 85L | **TEST 0.3 um 28.3L** | TEST 0.3um 85L | DATA

Test result sheet

Name :
Addres
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0211**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3930.00	68.00	98.27	
SBPP 480	2	17.8	3950.00	70.00	98.23	
	3	17.8	3970.00	76.00	98.09	
	4	17.8	3920.00	69.00	98.24	
	5	17.8	3910.00	77.00	98.03	
Average			3936.00	72.00	98.17	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.60	15.24	3.11
SBPP 480	2	4.9	0.60	15.24	3.11
	3	4.9	0.60	15.24	3.11
	4	4.9	0.60	15.24	3.11
	5	4.9	0.60	15.24	3.11
Average			0.60	15.24	3.11

TEST 0.1 um 28.3L | **TEST 0.1 um 85L** | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name :
Addres
Date : 27 July 2021
Contact :
Particle size : 0.1 um | Sample floe rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0211**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4330.00	136.00	96.86	
SBPP 480	2	17.8	4360.00	145.00	96.67	
	3	17.8	4410.00	149.00	96.62	
	4	17.8	4000.00	133.00	96.68	
	5	17.8	4390.00	150.00	96.58	
Average			4298.00	142.60	96.68	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.60	15.24	3.11
SBPP 480	2	4.9	0.60	15.24	3.11
	3	4.9	0.60	15.24	3.11
	4	4.9	0.60	15.24	3.11
	5	4.9	0.60	15.24	3.11
Average			0.60	15.24	3.11

TEST 0.1 um 28.3L | TEST 0.1 um 85L | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name :
Addres
Date : 27 July 2021
Contact :
Particle size : 0.1 um | Sample floe rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0211**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4390.00	103.00	97.65	
SBPP 480	2	17.8	4330.00	88.10	97.97	
	3	17.8	4300.00	87.30	97.97	
	4	17.8	4380.00	95.00	97.83	
	5	17.8	4410.00	99.00	97.76	
Average			4362.00	94.48	97.84	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.60	15.24	3.11
SBPP 480	2	4.9	0.60	15.24	3.11
	3	4.9	0.60	15.24	3.11
	4	4.9	0.60	15.24	3.11
	5	4.9	0.60	15.24	3.11
Average			0.60	15.24	3.11

Initial test data - 320 GSM

TEST 0.1 um 28.3L | TEST 0.1um 85L | TEST 0.3 um 28.3L | **TEST 0.3um 85L** | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0209**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3990.00	226.00	94.34	
SBPP 320	2	17.8	3960.00	230.00	94.19	
	3	17.8	3930.00	233.00	94.07	
	4	17.8	3950.00	220.00	94.43	
	5	17.8	3920.00	224.00	94.29	
Average			3950.00	226.60	94.26	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.30	7.62	1.56
SBPP 320	2	4.9	0.30	7.62	1.56
	3	4.9	0.30	7.62	1.56
	4	4.9	0.30	7.62	1.56
	5	4.9	0.30	7.62	1.56
Average			0.30	7.62	1.56

TEST 0.1 um 28.3L | TEST 0.1um 85L | **TEST 0.3 um 28.3L** | TEST 0.3um 85L | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0209**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3980.00	160.00	95.98	
SBPP 320	2	17.8	3930.00	158.00	95.98	
	3	17.8	3910.00	159.00	95.93	
	4	17.8	3950.00	166.00	95.80	
	5	17.8	3940.00	158.00	95.99	
Average			3942.00	160.20	95.94	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.30	7.62	1.56
SBPP 320	2	4.9	0.30	7.62	1.56
	3	4.9	0.30	7.62	1.56
	4	4.9	0.30	7.62	1.56
	5	4.9	0.30	7.62	1.56
Average			0.30	7.62	1.56

TEST 0.1 um 28.3L | **TEST 0.1um 85L** | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.1 um | Sample flow rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0209**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4340.00	267.00	93.85	
SBPP 320	2	17.8	4430.00	270.00	93.91	
	3	17.8	4380.00	276.00	93.70	
	4	17.8	4470.00	281.00	93.71	
	5	17.8	4340.00	279.00	93.57	
Average			4392.00	274.60	93.75	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.30	7.62	1.56
SBPP 320	2	4.9	0.30	7.62	1.56
	3	4.9	0.30	7.62	1.56
	4	4.9	0.30	7.62	1.56
	5	4.9	0.30	7.62	1.56
Average			0.30	7.62	1.56

TEST 0.1 um 28.3L | TEST 0.1um 85L | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name
Addre
Date :
Contact :
Particle size : 0.1 um | Sample flow rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0209**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4350.00	197.00	95.47	
SBPP 320	2	17.8	4420.00	215.00	95.14	
	3	17.8	4460.00	220.00	95.07	
	4	17.8	4390.00	218.00	95.03	
	5	17.8	4330.00	193.00	95.54	
Average			4390.00	208.60	95.25	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.30	7.62	1.56
SBPP 320	2	4.9	0.30	7.62	1.56
	3	4.9	0.30	7.62	1.56
	4	4.9	0.30	7.62	1.56
	5	4.9	0.30	7.62	1.56
Average			0.30	7.62	1.56

Initial test data - 160 GSM

TEST 0.1 um 28.3L | TEST 0.1um 85L | TEST 0.3 um 28.3L | **TEST 0.3um 85L** | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0208**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3960.00	559.00	85.88	
SBPP 160	2	17.8	3950.00	560.00	85.82	
	3	17.8	3930.00	573.00	85.42	
	4	17.8	3990.00	561.00	85.94	
	5	17.8	3910.00	553.00	85.86	
Average			3948.00	561.20	85.78	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.20	5.08	1.04
SBPP 160	2	4.9	0.20	5.08	1.04
	3	4.9	0.20	5.08	1.04
	4	4.9	0.20	5.08	1.04
	5	4.9	0.20	5.08	1.04
Average			0.20	5.08	1.04

TEST 0.1 um 28.3L | TEST 0.1um 85L | **TEST 0.3 um 28.3L** | TEST 0.3um 85L | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.3 um | Sample flow rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0208**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	3930.00	509.00	87.05	
SBPP 160	2	17.8	3950.00	511.00	87.06	
	3	17.8	3910.00	499.00	87.24	
	4	17.8	3960.00	513.00	87.05	
	5	17.8	3980.00	517.00	87.01	
Average			3946.00	509.80	87.08	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.20	5.08	1.04
SBPP 160	2	4.9	0.20	5.08	1.04
	3	4.9	0.20	5.08	1.04
	4	4.9	0.20	5.08	1.04
	5	4.9	0.20	5.08	1.04
Average			0.20	5.08	1.04

TEST 0.1 um 28.3L | TEST 0.1um 85L | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.1 um | Sample flow rate : 28.3 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0208**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4360.00	599.00	86.26	
SBPP 160	2	17.8	4390.00	589.00	86.58	
	3	17.8	4430.00	594.00	86.59	
	4	17.8	4410.00	580.00	86.85	
	5	17.8	4450.00	591.00	86.72	
Average			4408.00	590.60	86.60	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.20	5.08	1.04
SBPP 160	2	4.9	0.20	5.08	1.04
	3	4.9	0.20	5.08	1.04
	4	4.9	0.20	5.08	1.04
	5	4.9	0.20	5.08	1.04
Average			0.20	5.08	1.04

TEST 0.1 um 28.3L | **TEST 0.1um 85L** | TEST 0.3 um 28.3L | TEST 0.3um 85L | DATA

Test result sheet

Name :
Address
Date : 27 July 2021
Contact :
Particle size : 0.1 um | Sample flow rate : 85 Liter/min
Apparatus : CPC, TSI Incorporated Model 3788, Dwyer SLACK TUBE

Sample code **64-0208**

Figure

PFE

Sample name	Sample Number	Test Area	Up stream (particles /)	Down stream (particles /)	Efficiency (%)	หมายเหตุ
	1	17.8	4330.00	645.00	85.10	
SBPP 160	2	17.8	4390.00	642.00	85.38	
	3	17.8	4430.00	639.00	85.58	
	4	17.8	4410.00	640.00	85.49	
	5	17.8	4370.00	635.00	85.47	
Average			4386.00	640.20	85.40	

DELTA P

Sample name	Sample Number	Test Area	P	P	P
	1	4.9	0.20	5.08	1.04
SBPP 160	2	4.9	0.20	5.08	1.04
	3	4.9	0.20	5.08	1.04
	4	4.9	0.20	5.08	1.04
	5	4.9	0.20	5.08	1.04
Average			0.20	5.08	1.04

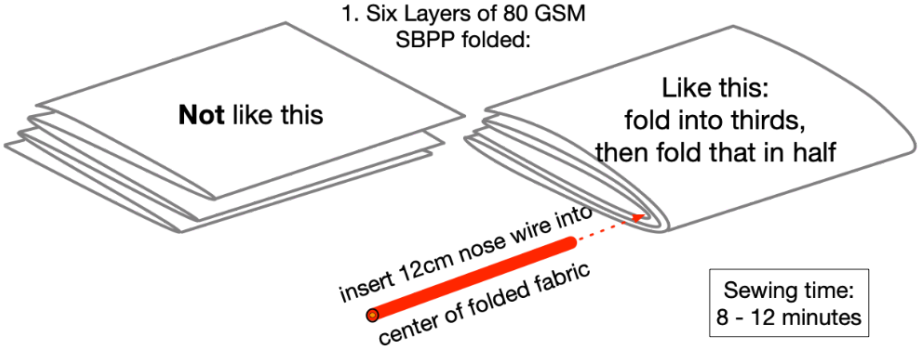
PFE Data In Table Form

GSM	Particle size µm	LPM	Mean PFE	Max PFE	Min PFE	Measured PFE
480	0.3	85				0.9715
480	0.3	85				0.9722
480	0.3	85				0.9704
480	0.3	85				0.9751
480	0.3	85				0.9708
480	0.3	85	0.972	0.9751	0.9704	
480	0.3	28.3				0.9827
480	0.3	28.3				0.9823
480	0.3	28.3				0.9809
480	0.3	28.3				0.9824
480	0.3	28.3				0.9803
480	0.3	28.3	0.98172	0.9827	0.9803	
480	0.1	85				0.9686
480	0.1	85				0.9667
480	0.1	85				0.9662
480	0.1	85				0.9668
480	0.1	85				0.9658
480	0.1	85	0.96682	0.9686	0.9658	
480	0.1	28.3				0.9765
480	0.1	28.3				0.9797
480	0.1	28.3				0.9797
480	0.1	28.3				0.9783
480	0.1	28.3				0.9776
480	0.1	28.3	0.97836	0.9797	0.9765	
320	0.3	85				0.9434
320	0.3	85				0.9419
320	0.3	85				0.9407
320	0.3	85				0.9443
320	0.3	85				0.9429
320	0.3	85	0.94264	0.9443	0.9407	
320	0.3	28.3				0.9598
320	0.3	28.3				0.9598
320	0.3	28.3				0.9593
320	0.3	28.3				0.958
320	0.3	28.3				0.9599

320	0.3	28.3	0.95936	0.9599	0.958	
320	0.1	85				0.9385
320	0.1	85				0.9391
320	0.1	85				0.937
320	0.1	85				0.9371
320	0.1	85				0.9357
320	0.1	85	0.93748	0.9391	0.9357	
320	0.1	28.3				0.9547
320	0.1	28.3				0.9514
320	0.1	28.3				0.9507
320	0.1	28.3				0.9503
320	0.1	28.3				0.9554
320	0.1	28.3	0.9525	0.9554	0.9503	
160	0.3	85				0.8588
160	0.3	85				0.8582
160	0.3	85				0.8542
160	0.3	85				0.8594
160	0.3	85				0.8586
160	0.3	85	0.85784	0.8594	0.8542	
160	0.3	28.3				0.8707
160	0.3	28.3				0.8706
160	0.3	28.3				0.8724
160	0.3	28.3				0.8705
160	0.3	28.3				0.8701
160	0.3	28.3	0.87086	0.8724	0.8701	
160	0.1	85				0.851
160	0.1	85				0.8538
160	0.1	85				0.8558
160	0.1	85				0.8549
160	0.1	85				0.8547
160	0.1	85	0.85404	0.8558	0.851	
160	0.1	28.3				0.8626
160	0.1	28.3				0.8658
160	0.1	28.3				0.8659
160	0.1	28.3				0.8685
160	0.1	28.3				0.8672
160	0.1	28.3	0.866	0.8685	0.8626	

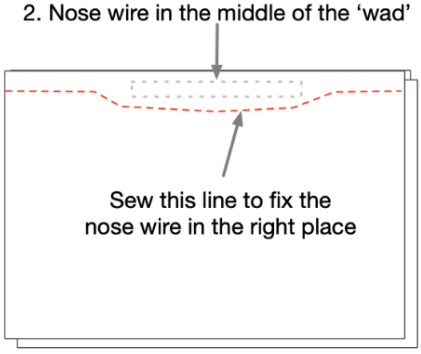
Rag Mask Max Sewing Guide

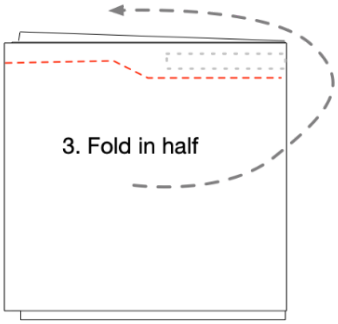
1. Six Layers of 80 GSM SBPP folded:

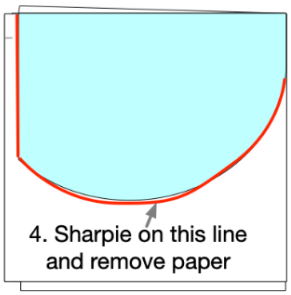


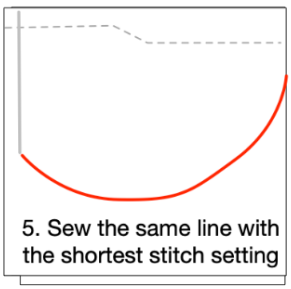
Sewing time:
8 - 12 minutes

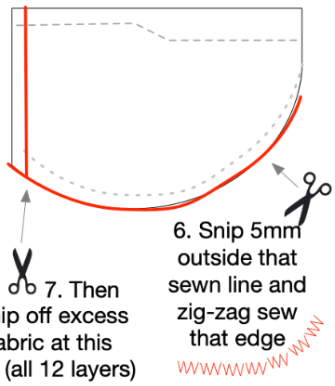
2. Nose wire in the middle of the 'wad'

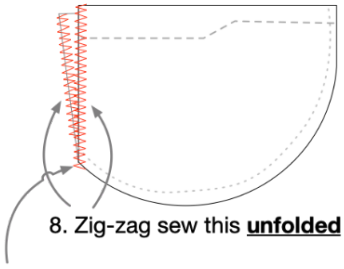






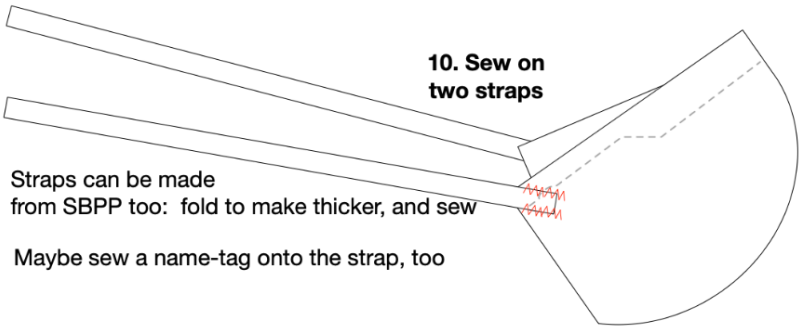






Be careful through the center that is already stitched and the layers are thicker there.

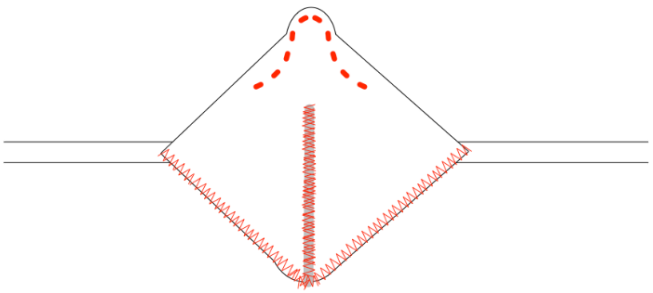
9. Then carefully turn the mask inside out



To wear this mask

(3D shape looking from the back into the inside of the mask depicted)

First shape the nose wire for your nose

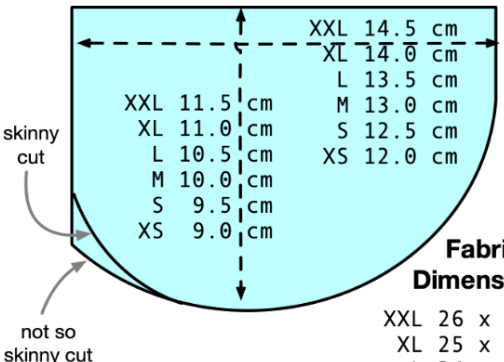


Then, with your chin down on your chest, place it over your nose and mouth and tie the straps behind your head below your ears

Lastly, lift your head up to face forward to tighten the mask slightly.

Throughly practice positioning the mask on your face before you enter a potentially contaminated area for the first time. Also practice taking it off after use while **minimally touching** the outside of the mask

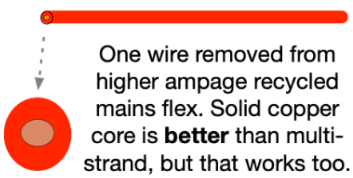
Paper template



Fabric Dimensions

XXL 26 x 99 cm
XL 25 x 96 cm
L 24 x 93 cm
M 23 x 90 cm
S 22 x 87 cm
XS 21 x 84 cm

Nose Wire



One wire removed from higher ampage recycled mains flex. Solid copper core is **better** than multi-strand, but that works too.