

What Not to Wear: Evaluation of Particle Penetration through Candidate DIY Mask Materials

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Since the CDC's recommendation that all residents of the United States wear cloth masks in public, what to wear during the COVID-19 pandemic has become much more than a fashion statement. While there is little doubt that high quality N95 respirators are an effective protective measure, there is a shortage of N95 respirators, with the current supply falling short of what is needed for health care workers, let alone the public. In this situation people around the world have started making their own face masks from ordinary materials. However, many people question the effectiveness of a DIY cloth mask in blocking transmission of the SARS-CoV-2 virus known to cause COVID-19. Here in Dr. Sarah Brooks' laboratory in the Department of Atmospheric Sciences, Texas A&M University, we are conducting a study evaluating a wide range of household materials as resources for constructing DIY face masks. Effective face protection must fit snugly around the mouth and nose, and must be made of appropriate materials. Our results show that while a standard bandana provides some protection, certain household materials, including room air filters and vacuum bags, are vastly more effective protection against COVID-19. In summary, make your cloth masks, but stitch a layer of either of these into its lining, and you will have far greater protection against transmission of the virus.

The details of how SARS-CoV-2 is transmitted are still under study. The virus can be released from an infected person through coughing, sneezing, spitting, and regular respiration. Some medical procedures for treating COVID-19 patients could also generate aerosols that contain viruses. SARS-CoV-2 is transmitted in both droplets which are relatively large (like fog) and the tiny virus itself (with a diameter similar to strand of horse hair). Since the majority of the droplets will be caught by a cloth mask, even a simple cloth mask provides some protection. However, a high percentage of the tiny viruses will pass through most cloth. For this reason, N95 filter materials, which by definition eliminate $\geq 95\%$ of all 300 nm diameter particles, provide far better protection against any free-floating viruses. Fortunately, certain common materials compare well to N95, though others perform much worse.

We have tested a wide range of materials and the results vary, meaning your choice of material largely determines the quality of your mask. Our results are summarized in the Table 1 below. Specifically, room air filters designed for furnace, HVAC (heating, ventilation and air conditioning) or central heating and cooling systems performed as well as the N95 material in removing the 300 nanometer diameter particles under the conditions tested in this study. In addition, the Eureka vacuum bag performed nearly as well, removing 94% of the particles removed by N95 material. The vacuum bag outperformed the standard surgical mask, which removed particles only 72% of the particles removed by the N95, making the vacuum bag our second-choice household item. Note that vacuum bags that are designed to remove odors contain agents that make breathing through them unpleasant and therefore we advise against using them. Unfortunately, the cloth samples tested in this study performed relatively poorly, with the standard bandana donned by many eliminating only 28% of what the N95 removed. To put this into practical terms, inserting one layer of a vacuum bag between layers of a bandana will greatly improve the filter performance of a cloth bandana. Include one layer of room air filter material (available at major hardware and DIY stores), and it may protect you as well as an N95

respirator. We encourage you to use the highest quality material you have available. Meanwhile, our study continues as we expand the list of possible material choices.

Note that in addition to filtering efficiency one needs to consider breathability when selecting a filtering material. For example, HEPA can provide excellent filtering efficiency but be very difficult to breathe through for some people. If the mask is being worn to protect oneself, one must ensure the mask fits properly, i.e. creates a seal wherein air entering the lungs must first pass through the filter. If the purpose of the mask is to prevent one from potentially spreading a disease that is transmitted by droplets, e.g. saliva, coughing, sneezing, etc., then filtering efficiency is not as critical.

Table 1 shows the relative efficiency of each filter sample material at removing 300 nm particles compared with the mean percentage removed by the N95 mask samples included in this study (i.e., the Suzhou Sanical Protective Mask and the 3M Particulate Respirator).

Table 1: Relative efficiency of removal of 300 nm particles relative to N95 mask materials.

Sample Description	Number of Layers	Particle Removal Relative to N95
N95 Test Material #1 (Suzhou Sanical Protective N95, P/N: MS 8265)	1 layer	100
N95 Test Material #1 (Particulate respirator, 3M N95 8200/07023)	1 layer	100
Room air purifier filter #1 (3M Filtrete 1900, MERV 13)	4 layers	100
Room air purifier filter #2, (3M Filtrete Premium Allergen and Ultrafine Particles, D Filter Size, True HEPA, Model #1150099)	1 layer	100
Prototype 3D Printed Respirator Test Material	MERV 13, 4 layers, cloth covering, 2 layers	100
Vacuum bag, (Eureka, Style RR bag)	1 layer	94
Engine Filter (FRAM EXTRA GUARD, 2x Engine protection, CA 9895)	1 layer	82
Bra cup (Wire-free Ultra Soft Blissful Benefits by Warner's, Style RM1691W)	1 layer	83
Surgical mask (FluidBloq)	N/A	72
Pillowcase #1 (California Design Den, 100% Extra Long Staple Cotton, 600 thread count sateen weave)	2 layers	56
Landscaping Fabric (Sta-Green Ultimate Weed Barrier Level 3)	1 layer	55
Shower curtain (water-repellant, embossed, 100% polyester)	1 layer	55

Pillowcase #2 (Bare Home Premium Ultra Microfiber, 1800 thread count)	2 layers	39
Bandana (Levi's Men's printed bandana, 100% cotton)	2 layers	28
Coffee filter (Walmart Great Value filter)	1 layer	25

Note: This is a preliminary report and essentially a 'living document', i.e. new materials are being added to the queue almost daily and tests are still ongoing. Please check back regularly for the latest results, findings, and recommendations.

Disclaimer: The filtering materials used in these tests and mask designs are items that we identified as household materials that have been considered for DIY mask type respirators. Our results are strictly related to mask fit and filtering ability. We have not tested the safety of the filter material itself for use as a mask. Manufacturers have insisted that the products are only to be used as intended on the packaging and should not be used as face masks. Many filtering materials are dangerous, and the composition and safety of them must be considered before using.