The Big Four: Criteria for Community Mask Materials

This deep dive post looks into the "Big Four" criteria evaluated in preliminary assessments of community mask materials: material characteristics, breathability, water-repellence, and disinfection options. More specifically, we focus on nonwoven polypropylene (NWPP), which is commonly used in commercial face masks. Although ideal medical grade NWPP is not currently available for community use, NWPP is commonly available at different weights and grades for other household and/or commercial purposes, such as reusable grocery bags. Here we take a more in depth look at the 4 preliminary criteria considered when evaluating potential sources of NWPP.

Did you know? Spunbond NWP is often categorized based on material density in g/m^2 or gsm or oz/yd^2. (50 gsm = 1.47 oz/yd^2, 100 gsm = 2.95 oz/yd^2). The following link provides a handy conversion tool: https://www.ginifab.com/feeds/ozyd2_gm2/

1. Material Characteristics

MakerMask designs use community-sourced 100% Spunbond Nonwoven Polypropylene. Although medical grade NWPP (20 – 25 gsm) is used in commercial masks and respirators, for ethical reasons these materials are currently reserved for manufacturers that best meet medical, legal, and regulatory standards. Given that these materials are not widely available to the public, the preferred source of spunbond NWPP for use in community masks is reusable grocery bags.[1]

Material Identification: Bags constructed from 100% Spunbond NWPP may be identified by either a tag indicating "100% Polypropylene," or the recycling "#5 PP" indicator.[2] In addition to material composition, it is important to identify the spunbond nonwoven structure of the material. This can be accomplished by looking for the characteristic diamond-shaped dimpled pattern. NOTE: do not use bags that are finished with a laminated waterproof coating or bonded to insulation as these may compromise breathability.

Figure 1. The characteristic diamond-shaped, dimpled pattern seen in spunbond NWPP

TOP CHOICE: Reusable Grocery Bags (typically 70 – 90 gsm): NWPP grocery bags are designed to be in contact with food and have a greater consistency in material properties, manufacturing, and safety than materials used for things like craft projects and

[1] https://pslc.ws/macrog/pp.htm

[2] https://learn.eartheasy.com/articles/plastics-by-the-numbers/

landscaping.[3] Since they are designed to carry food, they have minimal particle shedding, and are designed to withstand washing/disinfection. Although NWPP bags are thicker than many materials, they work well as mask layers (especially outer layers), where they provide a balance of water-repellence, mechanical filtration, and breathability.

NEXT BEST: Conference Bags (typically 60 – 90 gsm): The material weight of conference/promotional bags is more variable than that of reusable grocery bags, and often includes lighter weight and/or softer materials.

Deep Dive: *"Isotactic polypropylene [all the methyl groups are lined up on the same side of the polymer chain] is generally used for commercial purposes due to its high melting point; its ability to withstand heat makes for a better alternative to plastic. This heat-resistant polymer is beneficial for reusable grocery bags, which are expected to carry items of varying temperatures. Polypropylene falls under the category of thermoplastics, meaning it can be softened and molded when it is heated while retaining its structure and durability. Polypropylene naturally repels water, therefore making grocery bags easy to clean. A material that can be easily disinfected is especially important since reusable bags are often exposed to bacteria when carrying raw foods. A review done on the spun bonded process acknowledges isotactic polypropylene as the most economically efficient material, as it is the most cost effective and produces the most fibers per kilogram (Lim 2). Since the order of the fibers doesn't matter, more fabric is yielded as all the material ends up getting pressed together (Kansal 9)."*
http://www.designlife-cycle.com/new-page-93

CAUTION: Safety and usability of NWPP from alternatively sourced materials cannot be assumed. Please review the following cautions:

- **Melt-blown NWPP may pose inhalation risk.** Melt-blown NWPP tears easily, is harder to sterilize, lacks the diamond pattern, and is not used in reusable NWPP grocery bags. Although melt-blown is made from the same raw stock as spunbond NWPP, the structure of the material, and the size of the fibers are different. The individual fibers of melt blown NWPP are both shorter and thinner, which increases the risk of particle inhalation.[4,5] For large-scale commercial mask operations with appropriate manufacturing controls and oversight, these risks can be mitigated, however the use of melt-blown NWPP in DIY masks is not recommended at this time. **Note: MERV HEPA Filter** materials may also contain small fibers that pose an inhalation risk and are not recommended for use in DIY masks at this time.
- **NWPP Interfacing may contain adhesives[6]** and should not be used in DIY masks. In addition, NWPP in interfacing is frequently made using different manufacturing processes and standards than the spunbond NWPP in reusable grocery bags and may not be suitable for use as droplet protection in masks.
- **NWPP from Landscape Cloth and other geotextiles may pose inhalation risk.** The fibers in these materials are prone to shedding and may pose risk of mechanical irritation when inhaled. In addition, preliminary data from particle testing suggests poor filtration performance, and they are not always water resistant. [7]

[3] http://reusablebagsac.org/sites/default/files/Compliant%20Reusable%20Bag%20List%20handout%202016.pdf
[4] Brochocka 2020. https://www.mdpi.com/1996-1944/13/3/712/pdf
[5] https://www.fibre2fashion.com/industry-article/1575/spunbonded-nonwovens-an-overview
[6] https://www.joann.com/fabric/utility-fabric/interfacing/
[7] MakerMask data on file (from preliminary particle testing from NH-based NWPP industrial supplier)

2. Breathability

Breathability is an important factor in facemask design and materials selection. Unfortunately, the materials that most effectively block droplets and particles typically have poor breathability, fit, and usability.[8] Preliminary breathability checks for novel masks/materials frequently begin with qualitative functional assessments from developers and users; however, quantitative analysis of breathability, including tests of the pressure drop across the mask and CO2 accumulation, are important for verifying usability. For masks designs that are not focused on creating a tight seal/fit to the face (e.g. pleated surgical masks), both air and CO2 can leak around the edges of the mask. For 'fit tested' masks with good face seals and submicron particle filtration requirements, these breathability measures become critical for the usability and success of the mask.

Research on the optimal number of NWPP layers is ongoing, however preliminary laboratory data suggest between one and three layers of NWPP provide adequate breathability for fitted and non-fitted mask designs [9],[10] Despite qualitative assessment to the contrary, masks with additional layers began to show decays in performance (e.g., increased pressure differential across the mask and suboptimal CO2 accumulation). The ideal number of layers of NWPP will vary depending on the individual materials used and the trade-off between usability, breathability, particle filtration, and intended duration of use. Optimization and evaluation of prototypes, materials, and designs is ongoing. Particle filtration will be discussed at length in an upcoming post.

Active Question: Do masks made from Halyard H600 Surgical Wrap meet breathability standards? Mask made from H600 are gaining traction in medical communities and the benefits of H600 are indisputable: it has great particle filtration data, is sterilizable, and is commonly available in hospital settings.[11,12] However, uncertainty surrounding quantitative assessments of the breathability and the statements from Halyard disavowing the off-label use in masks suggest a cautious approach may be merited.[13]

CAUTION: DO NOT USE. The following materials do not have sufficient breathability for use in DIY masks: Laminated waterproof bags, Evolon, Vacuum Cleaner Bags, HEPA Filters, microfiber 'Magic Cloth'

Did you know? Without electrostatic treatment, most materials that have 1um or better filtration compromise breathability. This is why the materials with the best particle filtration are often ill-suited for use in DIY masks. The special melt-blown filter materials that are used in N95 masks to get great filtering require special treatments (e.g. Corona Treatment or Electret Treatment) to achieve optimal particle filtration performance. For more information see: https://www.testextextile.com/fighting-the-coronavirus-top-6-knowledge-to-know-before-investing-in-establishing-disposable-medical-mask-production-lines/

[8] Davies A, Thompson KA, Giri K, Kafatos G, Walker J, Bennett A. **Testing the efficacy of homemade masks: would they protect in an influenza pandemic?.** *Disaster Med Public Health Prep*. 2013;7(4):413–418. doi:10.1017/dmp.2013.43. Accessed at https://pubmed.ncbi.nlm.nih.gov/24229526-testing-the-efficacy-of-homemade-masks-would-they-protect-in-an-influenza-pandemic/

[9] Data collected by Ator Labs, initial prototype data on file at MakerMask, additional testing in progress

[10] Preliminary data on file for NWPP MakerMask prototypes including particle penetrance (0.1um, 0.5um, and 1um) from NH-based industrial NWPP supplier. Breathability data for MakerMask NWPP prototypes sourced from re-usable bags conducted by Florida-based Ator Labs.

[11] https://anest.ufl.edu/clinical-divisions/mask-alternative/

[12] https://www.halyardhealth.co.uk/media/17530073/hc465-03-uk_compliance_2015.pdf

[13] https://products.halyardhealth.com/surgical-solutions/sterilization-solutions/sterilization-wraps/halyard-kimguard-one-step-sterilization-wrap.html

3. Fluid Resistance

According to the CDC, droplets >5 µm in size have been implicated in transmission of influenza virus, adenovirus, rhinovirus, and SARS-associated coronavirus (SARS-CoV).[14] For additional information about droplet precautions, see the official CDC guidance: https://www.cdc.gov/infectioncontrol/pdf/droplet-precautions-sign-P.pdf

Droplet resistance is an important feature of the MakerMask designs. Spunbond NWPP is a good choice for droplet protection because it is hydrophobic (water-repellent). This water-resistance creates a barrier to droplets from coughs and sneezes that may contain viruses or other infections agents. A quick qualitative assessment, a 'flick' test, can be performed to see if water beads up on the surface of the material (suggesting it is hydrophobic), or if it saturates into the fabric (suggesting it is hydrophilic).

Although formalized assessments requiring specialized laboratory equipment are preferred for evaluation of fluid penetrance, quantitative assessment of the passage of water through mask materials over a given interval of time (e.g. 60 seconds or 1 hour) can be conducted by mask developers and users (see photo below).[15]

Figure 2. Home test of fluid penetrance, evaluating the amount of water transferred across each fabric over a 60 second time course with 5 ml water applied to each material. Left to Right: Blue Shop Towel (cellulose based; 1.75 ml collected inside jar), Cotton (3.75 ml collected), NWPP shipping bag (midweight; 0 ml collected), and NWPP shopping bag (heavier weight, 0 ml collected). Note the visually observable differences between water atop hydrophilic materials and hydrophobic materials.

4. Disinfection

The fourth key factor for MakerMask designs is whether or not the full mask can be disinfected before use. The current recommendation for home use is to boil masks for 10 minutes prior to use. This factor was established because "boiling is sufficient to kill pathogenic bacteria, viruses and protozoa (WHO, 2015)".[16] The duration maximizes disinfection of all of the mask layers. Boiling as a standardized home disinfection method provides a consistent, maximum temperature well below the melting/deformation point of the 100% spunbond NWPP typically used in reusable grocery bags.

[14] CDC Isolation Protection: https://www.cdc.gov/infectioncontrol/guidelines/isolation/scientific-review.html

[15] Protocol for home testing of fluid penetrance is in development by the MakerMask team

[16] https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water

Deep Dive: The melting point of polypropylene occurs in a range. Spunbond 100% NWPP used in high-quality re-usable grocery bags/conference bags is primarily isotactic polypropylene, which has a melting point between 160 to 166 °C (320 to 331 °F) and is safe to boil (100 °C / 212 °F), steam (121 °C / 250 °F), and/or autoclave.[1] Industry guidance for decorating NWPP tote bags (for groceries/conferences/promotional purposes) suggests that, "bags should not be pressed any higher 275 degrees without experiencing some melting of the fabric. Some transfers that heat at 300 degrees may be used, however some bags may experience minor melting at this temperature." https://blog.transferexpress.com/polypropylene-bags-the-dos-and-donts/

NOTE: The use of pressure cookers for steam sterilizing masks (up to 121C / 250F) has been suggested, but this method of sterilization remains untested/unverified at this time.

Although additional disinfection procedures have been proposed, they have not all been evaluated for this purpose. In general, harsh chemicals (e.g., bleach) are not recommended as residual chemicals in the mask may cause unintended inhalation risks.[17] In addition, oxidizing chemicals may cause the mask materials to degrade more quickly. The longevity of use of community NWPP masks is currently under investigation.

While awaiting more quantitative evaluation, two qualitative indicators indicate reduction of the functional characteristics of the mask: 1) Water-resistance, when water stops beading on the surface during the 'flick' test, the droplet protection is degrading and the mask should be retired, 2) Shedding, when the bonding of the fibers to the mask starts to degrade and the material starts shedding, the mask should be retired from use as dislodged threads could act as lung irritants (NOTE: landscape cloth and other geotextiles typically fail this assessment prior to first use).

CAUTION: NWPP materials used for crafting, sewing, and other purposes may melt even though they are listed as 100% polypropylene because these materials are frequently composed of less crystalline forms of PP with melting points closer to 130 °C (266 °F). Although these materials may be washable, they may deform and/or melt when boiled, ironed, steamed, or autoclaved.

What about 'Oly-fun'? Many sites list 'oly-fun' as 65 gsm 100% NWPP; however, the material grades used for crafting may not be consistent with those used in grocery bags, and preliminary data suggests this material has a low melting point and is unsuitable for proposed disinfection techniques. **What about Olefin?** Olefin is typically a mixture of polypropylene and polyethylene, which significantly lowers the melting point of the material. This material will melt/ shrink when boiled and should not be used in MakerMask designs. **What about Nonwoven Polyethylene?** The melting point for average, commercial, low-density polyethylene is typically 105 to 115 °C (221 to 239 °F), which makes it unsuitable for proposed disinfection procedures.

Final Thoughts

Some of the benefits of NWPP include that it is: commonly available in non-woven grocery bags and conference bags, hypoallergenic, water-resistant, conducive to mechanical filtration, and can be disinfected by boiling. Potential drawbacks of community-sourced NWPP include difficulties identifying suitable materials and variability in NWPP density and structure. These drawbacks can be mitigated by sourcing from more homogenous subsets of NWPP based on use case. For example, reusable grocery bags are designed for the same use (carrying loads of food), have more consistent standards for strength, durability, quality, disinfection, and higher melting points than NWPP from other sources.[18]

[17] https://utrf.tennessee.edu/information-faqs-performance-protection-sterilization-of-face-mask-materials/

[18] http://www.designlife-cycle.com/new-page-93

Additional References/Links:

1. **CDC: Strategies for Optimizing the Supply of N95 Respirators: Crisis/Alternate Strategies, Health Care Provider use of non-NIOSH approved masks or homemade masks**. Accessed at https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/crisis-alternate-strategies.html on March 15, 2020
2. Dato, V. M., Hostler, D., & Hahn, M. E. **(2006). Simple respiratory mask**. *Emerging infectious diseases*, *12*(6), 1033–1034. https://doi.org/10.3201/eid1206.051468. Accessed at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3373043/ and https://wwwnc.cdc.gov/eid/article/12/6/05-1468_article on March 12, 2020 (Figure Below)
3. Rengasamy S, Eimer B, Shaffer RE. **(2010) Simple respiratory protection--**evaluation of the filtration performance of cloth masks and common fabric materials against 20-1000 nm size particles. *Ann Occup Hyg*. **2010**;54(7):789–798. doi:10.1093/annhyg/meq044. Accessed at https://pubmed.ncbi.nlm.nih.gov/20584862-simple-respiratory-protection-evaluation-of-the-filtration-performance-of-cloth-masks-and-common-fabric-materials-against-20-1000-nm-size-particles/ or https://academic.oup.com/annweh/article/54/7/789/202744 on March 12, 2020. "***Fabric materials may provide some level of protection against the transmission of infectious aerosols when used in combination with other protective measures.***"
4. *Institute of Medicine. 2006.* ***Reusability of Facemasks During an Influenza Pandemic: Facing the Flu.*** *Washington, DC: The National Academies Press. https://doi.org/10.17226/11637. Accessed at https://www.nap.edu/read/11637/chapter/6#62 on March 12, 2020*
5. Van der Sande, M., Teunis, P., & Sabel, R. (2008). **Professional and home-made face masks reduce exposure to respiratory infections among the general population**. *PloS one*, *3*(7), e2618. https://doi.org/10.1371/journal.pone.0002618, Accessed at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2440799/
6. Mueller et al (2018). **The effectiveness of respiratory protection** worn by communities to protect from volcanic ash inhalation. Part I: Filtration efficiency tests. International Journal of Hygiene and Environmental Health Volume 221, Issue 6, July 2018, Pages 967-976. Accessed at: https://www.sciencedirect.com/science/article/pii/S1438463917308003
7. Davies A, Thompson KA, Giri K, Kafatos G, Walker J, Bennett A. **Testing the efficacy of homemade masks: would they protect in an influenza pandemic?.** *Disaster Med Public Health Prep*. 2013;7(4):413–418. doi:10.1017/dmp.2013.43 Accessed at https://pubmed.ncbi.nlm.nih.gov/24229526-testing-the-efficacy-of-homemade-masks-would-they-protect-in-an-influenza-pandemic/
8. Adam Burgess Mitsutoshi Horii (2012). **Risk, ritual and health responsibilisation: Japan's 'safety blanket' of surgical face mask-wearing.** Sociology of Health and Illness 34(8) 1184-1198. https://doi.org/10.1111/j.1467-9566.2012.01466.x, Accessed at: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-9566.2012.01466.x

Additional links:

9. **Advice on the use of masks1 in the community setting in Influenza A (H1N1) outbreaks**. https://www.who.int/influenza/preparedness/measures/Adviceusemaskscommunityrevised.pdf
10. **Non-occupational Uses of Respiratory Protection – What Public Health Organizations and Users Need to Know**. https://blogs.cdc.gov/niosh-science-blog/2018/01/04/respirators-public-use/
11. How do respirators actually work? https://www.uvex-safety.com/blog/how-do-respirators-actually-work/
12. Can DIY homemade masks protect us from coronavirus? https://smartairfilters.com/en/blog/diy-homemade-mask-protect-virus-coronavirus/
13. What are the Best Materials for Making a DIY Face Mask? https://smartairfilters.com/en/blog/best-materials-make-diy-face-mask-virus/
14. DIY masks: Is paper towel effective at blocking viruses? https://smartairfilters.com/en/blog/paper-towel-effective-against-viruses-diy-mask/
15. Nonwoven Polypropylene Materials
    a. https://www.superiorfelt.com/products/air-filtration-media/sub-micron/personal-protection/
    b. https://blogs.cdc.gov/niosh-science-blog/2009/10/14/n95/
    c. Medical Face Mask Machine: The Complete Guide for the Medical Masks Production. https://www.testextextile.com/fighting-the-coronavirus-top-6-knowledge-to-know-before-investing-in-establishing-disposable-medical-mask-production-lines/ , *"The core material of medical masks is polypropylene melt blown non-woven fabric after electret treatment. The filtering mechanism of medical masks is Brownian diffusion, entrapment, inertial collision, gravity sedimentation and electrostatic adsorption. The first four are physical factors, that is, the characteristics of the non-woven fabric produced by the melt blown method, the filterability is about 35%; this is not up to the requirements of medical masks, we need to electrotype the material and let the fiber Charged and used static electricity to capture the aerosol where the new coronavirus is located."*
    d. https://www.slideshare.net/muralikrishnan71697092/respiratory-protection-face-masks-and-respirators
16. Non-woven Polypropylene In Masks: Links

These instructions do not guarantee protection against transmission of any diseases. Commercially available masks meet regulatory guidelines, but homemade masks may not and are to be used at your own risk. Due to variability of materials and construction, the mask's safety or effectiveness for personal protection is not proven and cannot be assumed.

a. Example (https://www.nonwovenproductsupplier.com/products/3Ply-Nonwoven-Face-Mask.html): 1st ply: 20g/m2 spun-bond PP, 2nd ply: 25g/m2 melt-blown PP (filter), 3rd ply: 25g/m2 spun-bond
b. Nonwoven polypropylene fabric usages (https://www.pp-nonwoven.com/medical-fabric-use-face-mask_p358.html):
c. https://www.smartbags.co.uk/blog/bag-for-life-fabric-explained-non-woven-polypropylene-nwpp
d. Non-woven: https://www.greatlakesfilters.com/non-woven-textiles/

17. NWPP Sterilization/Disinfection Information
    a. Ozone & Polypropylene: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/sterilization/other-methods.html
    b. https://www.cdc.gov/infectioncontrol/pdf/guidelines/disinfection-guidelines-H.pdf
    c. https://www.hmcpolymers.com/uploads/files/resources/hmc-pp-chemical-resistance.PDF, "Polypropylene offers good resistance to non-oxidizing acids and bases, fats and most organic solvents; The melting point of polypropylene is 160°C / 320°F; Low temperature threshold: polypropylene becomes brittle below 0°C; **NOT compatible with strong oxidants.** According to ASTM D570, its 24 hr water absorption rate is 0.03%. It resists most strong mineral acids and bases, but, like the other polyole-ns, it is subject to attack by oxidizing agents. PP resins are appreciably affected by chlorosulfonic acid and oleum at room temperature, 98% sulfuric acid, 30% hydrochloric acid, and 30% hydrogen peroxide at 100°C (212°F)."
    d. https://www.industrialspec.com/resources/plastics-sterilization-compatibility/, "Steam Sterilization, also known as autoclaving, involves generating or injecting saturated steam into a pressure chamber at a temperature range of 121-148 °C (250-300 °F) at 15psi for a period of time sufficient to provide sterilization.
    e. **Additional References:** Alariqi SAS, Mutair AA, Singh RP (2016) Effect of Different Sterilization Methods on Biodegradation of Biomedical Polypropylene. J Environ Anal Toxicol 6:373. Doi: 10.4172/2161-0525.1000373, https://www.omicsonline.org/open-access/effect-of-different-sterilization-methods-on-biodegradation-of-biomedicalpolypropylene-2161-0525-1000373.php?aid=73845

18. Materials Allergy Proof Bedding (Pore Size 1 to 6 micron, tested in some cases)
    a. "Allergy proof bedding with the smallest pore size will always be all polyester. All cotton allergy-proof bedding will have a larger pore size but will still be an effective allergen barrier. Cotton/polyester blends are in the middle when it comes to pore sizes. Dust mite fecal matter and/or body parts (we don't actually breathe in whole dust mites) are as large as 10 microns. Pet allergen and mold spores are about 3 microns. In order for a microfiber mattress encasing to be effective against dust mites, it needs a pore size of 10 microns or less." https://allergystore.com/blogs/news/what-does-pore-size-mean-in-allergy-proof-bedding
    b. Evaluation of materials used for bedding encasement: Effect of pore size in blocking cat and dust mite allergen. https://www.jacionline.org/article/S0091-6749(99)70495-1/fulltext
    c. 4 Pack Pillow Protectors Standard 20x26" Hypoallergenic 100% Cotton Sateen Tight Weave 3-4 Micron Pore Size High Thread Count 400 Style Zippered White Hotel Quality Non Noisy (4 Pack Standard Zip)
    d. *Opinion:* Evolon is 1um, but has too much impedance to air flow to use as a mask (fails breathability)