Improving Masks Worn by the General Public

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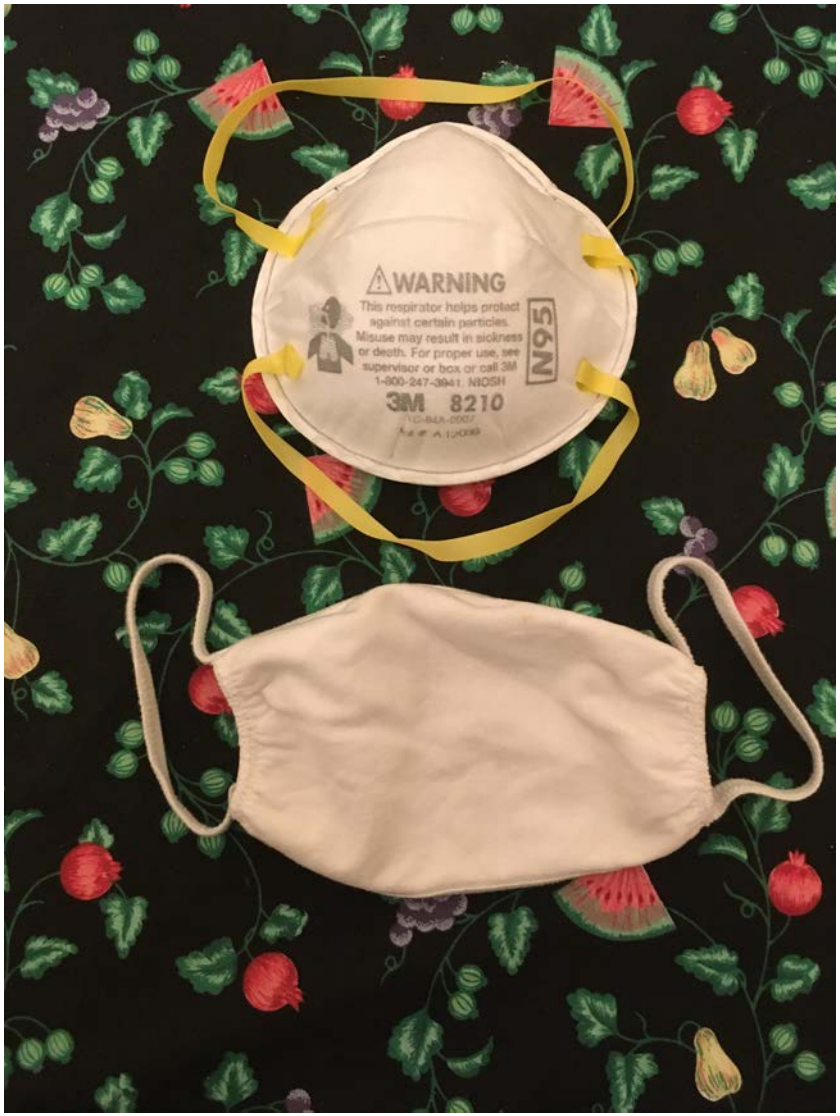
Respiratory Protection

- Any face covering worn for the purpose of reducing the wearer's pollutant exposure is a form of respiratory protection, for example, bandanas, cloth masks, surgical masks, N95 filtering-facepiece respirators (FFRs), etc.

- In workplace settings, bandanas, cloth masks and most surgical masks do not qualify as "respirators" because:

  (1) they permit excessive pollutant penetration

  (2) they are not tested and certified by the National Institute for Occupational Safety and Health (NIOSH)



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Respiratory Protection

- All face coverings do not offer the same level of protection. A well fitting N95 FFR might allow 5% particle penetration, a cloth mask 50%, and a bandana close to 100%.

- I am focusing on cloth masks, because they are type of respiratory protection most frequently being worn by the general public. The same ideas I will discuss pertain to other types of respiratory protection.

- That said …

Recommendation #1

- The manufacturing of N95 FFRs should be substantially increased so that they are available to the general public without causing a shortage in workplace settings.

- N95 FFRs are far superior to cloth masks as respiratory protection for the wearer.

Particulate Pollutants

- My focus is on particles which are removed by filters. Gaseous pollutants can also be of concern, but cloth mask materials remove only particles. Some filtering-facepiece respirators incorporate sorbents that remove certain gases and vapors.

- Particles in ambient air are usually less than 2.5 microns in diameter. Virus carried by particles emitted from the respiratory tract are mostly in particles less than 10 microns in diameter.

- Particles smaller than 10 microns can penetrate down to the end air sacs in the lungs.

Particle Penetration Paths

- For a mask without an exhalation valve, pollutant particles can get inside the mask by two routes:

  (1) through the filter itself

  (2) through gaps around the mask perimeter

- For a mask with an exhalation valve, pollutant particles might also get inside by a third route:

  (3) through a poorly sealed exhalation valve

Filter Efficiency

- Different filter materials allow particles to penetrate to different degrees (= remove particles with different efficiency).
- Some filter materials may be more than 99% efficient in removing 10 micron particles, but only 25% efficient in removing 1 micron particles.
- For any mask, we cannot know its overall filter efficiency unless the filter is tested against a range of particle sizes. Such testing likely has been done for very few cloth masks.

Mask Fit

- Different masks make different fits to the same face, and the same mask makes a different fit to different faces.

- The looser the fit, the more gaps exist around the mask perimeter. In turn, more unfiltered air will enter the mask through these gaps. A mask with two head straps is likely to fit more snugly than a mask with ear loops.

- The fit of a mask to a person's face can be quantitatively measured if we also quantify filter penetration. Such testing has been done for very, very few cloth masks.

Recommendation #2

- A government agency or professional/academic group should formulate standard protocols for testing the filter efficiency and fit (and exhalation valve leakage) of cloth masks.

- If a government agency tested the masks, or funded a group to do the testing, the results should be posted on an open website so consumers can compare mask performance.

- NIOSH is the government agency with the best technical expertise, but evaluating masks for the general public is outside its mandate. The FDA may be a more appropriate agency.

Fit Tests

- Before a N95 FFR is assigned to a worker for use, the worker has to pass a “fit test” to ensure the fit is adequate.

- In fit testing, the FFR wearer is exposed to a challenge aerosol. The N95 filter is very efficient in removing the challenge particles, so if too much aerosol is detected inside the FFR, it is concluded that mask perimeter leakage is excessive.

- Most cloth masks would not pass the fit tests that are used for N95 FFRs, because the masks fit too loosely and/or the filter efficiency against the challenge particles is too low.

Seal Checks

- Every time a successfully fit-tested N95 FFR is donned, the wearer is also required to perform a quick “seal check.” The aim is to subjectively detect excessive air leakage around the mask perimeter should the mask not be seated properly on the face. A challenge aerosol is not involved.

- For a snugly-fitting cloth mask, even though the mask could not be fit tested in the same manner as a N95 FFR, it would be useful to have a point-of-use seal check procedure that can alert the wearer to substantial air leakage around the perimeter.

Recommendation #3

- A government agency or professional/academic group should attempt to devise both a fit test and a seal check procedure that could be used for snugly-fitting cloth masks.

- The materials and equipment involved would need to be easy to use and inexpensive so that the procedures could be employed by the general public.

- I suspect a small minority of cloth mask wearers would be interested but, at a minimum, these wearers would benefit.

Carbon Dioxide

- Some are concerned that cloth masks (or other masks) cause the wearer to inhale dangerous levels of carbon dioxide (CO_2) gas.

- Exhaled air contains 40,000 to 50,000 parts per million (ppm) of CO_2. Exhaled CO_2 gets trapped in the air volume between the mask and the wearer's face (termed the dead space). Upon the next inhalation, this CO_2 is re-inspired.

- Although 40,000 to 50,000 ppm CO_2 can cause dizziness, headache and breathing difficulty, the CO_2 level in the total inhaled air volume is likely 10-fold lower.

Carbon Dioxide

- The inhaled CO_2 level depends on the volume of the mask's dead space and the air volume inhaled per breath, which in turn depends on the wearer's work rate.

- Ballpark estimates are that a cloth mask dead space is 100 mL and the volume inhaled per breath during light exercise is 1,200 mL. For CO_2 = 400 ppm in ambient air and CO_2 = 45,000 ppm in exhaled air, the CO_2 level = 4,100 ppm in the inhaled air volume.

- This is not a dangerous CO_2 level, although it could cause some physiological effects and a decrease in cognitive performance.

Recommendation #4

- A government agency or professional/academic group with government funding should conduct a laboratory study to measure the CO_2 levels inhaled when wearing different masks at different inhaled volumes per breath.

- In a test chamber, place a mask on a breathing mannequin. Control the CO_2 level at 40,000-50,000 ppm in the exhaled air and at 400 ppm in the chamber air. Measure the CO_2 level in the total inhaled air volume.

- Medical experts can determine if the inhaled CO_2 levels would exert health effects of concern.