Researchers collaboratively test mask effectiveness to fight spread of COVID-19

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This decontamination chamber is one of the tools being used to sterilize masks. Credit: Texas Tech University

In the early weeks of the coronavirus pandemic, masks were in such short supply they were nearly impossible to find. As a result, people began creating substitute masks out of anything possible—scarves, repurposed old T-shirts, even vacuum bags.

For researchers at Texas Tech University and the Texas Tech University Health Sciences Center (TTUHSC), this posed vitally important questions: Were such masks effective? Were they even safe?

As part of the newly established West Texas 3-D COVID-19 Relief Consortium—a collaborative group using innovative methods to produce personal protective equipment (PPE), ventilators and ventilator components for hospitals and health care systems throughout West Texas—these researchers began the task of evaluating different types of masks suggested by the public as well as new prototypes being developed by other members of the consortium.

"I set up the mask testing and design group to evaluate fit and protection," said Al Sacco Jr., dean of the Edward E. Whitacre Jr. College of Engineering who assembled the testing team. "First a mask must be worn properly—a mask configuration must be properly fitted to an individual's face or it does no good at all.

"If the mask can be made to seal around one's face, then the material the mask is made of is sent to a group to test it for protection. We set this group up to evaluate how efficiently these materials filter particles and, if they have efficiency greater than 95%, how they can be cleaned. We also have individuals characterizing all materials tested to better understand how they work, to verify the particle challenge results and to help us design better masks for the future."

The researchers come from a variety of disciplines and, accordingly, they test the masks in a variety of ways specific to their individual expertise.

Brandon Weeks, a professor of chemical engineering and associate dean of research and graduate programs in the College of Engineering, and his wife, Louisa Hope-Weeks, a professor in the Department of Chemistry & Biochemistry, are testing the fit, seal and breathability of assembled masks.

Karin Ardon-Dryer, an assistant professor of atmospheric science in the Department of Geosciences who studies the health effects of aerosols—tiny particles in the air—and analytical chemist Jon Thompson, an associate professor in chemistry and biochemistry who studies the chemical and optical properties of atmospheric aerosols, are examining how well different mask materials can filter such particles.

Sharilyn Almodovar, an assistant professor in the TTUHSC Department of Immunology and Molecular Microbiology, is exposing the materials to different decontamination methods to see how they respond. In the meantime, Min Kang, TTUHSC interim senior vice president for research; Justin White, senior director in the TTUHSC President's Office; and Dr. Jnev Biros, a research associate in the engineering dean's office, are studying how well those materials can be sterilized for reuse.

Juliusz Warzywoda and Rumeysa Tekin, in the Materials Characterization Center, are imaging and analyzing the materials' particle and fiber size distribution to learn more about them.

"There are so many components," Ardon-Dryer said. "It's a really big team and everyone contributes to one aspect of it, or to several. But, it's all a crucial part of the puzzle."

"One piece only is not enough to determine which mask or filter is better," Tekin agreed. "That's why each team member is working on different things to understand the mask performance."

Together, the team hopes to be able to provide a useful recommendation for those who so badly need masks for protection.

"We have put together a wonderful, innovative group of caring professionals," Sacco said. "This is a cross-disciplinary, integrated effort to inform health care professionals, first responders and groups like the police how to wear masks and what mask is best for their applications."

Fit, seal and breathability

Because most of the masks to be tested arrive already fabricated, the group tests the assembled masks before deconstructing them to test their materials.

As the first step in testing, Weeks and Hope-Weeks examine how well each mask fits the wearer's face, whether it creates an effective seal around the outer edges and how well the wearer can breathe in it.

"We use a device that measures the concentration of particles inside the mask vs. outside the mask," Weeks said. "It has two tubes, one is outside the mask and the other inside. The efficiency of the mask is the ratio of these two numbers. For example, an N95 mask would remove 95% of the particles 300 nanometers or larger."

In order to directly compare masks to one another without having to account for issues between different wearers, all masks are being tested on one subject: Hope-Weeks.

"We do the mask testing in a closer-to-real-world setting to make sure the entire mask is efficient, from the nose bridge to the ties to hold it on," Weeks said. "We worked with a nurse, Molly Bates, who was sewing, and actually using in the emergency room, masks that she made. The first ones we had, there were challenges to get it to seal around the nose and cheeks. By using some of our information, she was able to move the placement of the ties and change the nose bridge wire and we got a much better seal."

Particle filtration

Ardon-Dryer now has an elaborate setup she designed for the sole purpose of testing how well different mask materials are able to stop particles in the air from being inhaled.

In her lab, Ardon-Dryer uses her instruments to generate and count spherical particles which are 250 nanometers in size. The particles are evenly divided into two groups. One group is funneled directly into what's effectively a counting instrument. The other group must pass through a sample of the mask material being tested on its way to an identical counter instrument.

By comparing the number of potential particles and the number of particles the mask stopped, the material can be graded on its effectiveness. The particle size is also important because, while 250 nanometers is significantly larger than the size of the coronavirus particles, it is smaller than the 300 nanometers that N95 masks are supposed to block. This means her setup can determine the effectiveness of the tested materials in comparison to those comprising N95s.

In her testing, Ardon-Dryer tried to account for additional factors that can influence the material efficiency, such as air flow rate and time.

"At rest, you're breathing seven or eight liters per minute, but when you're active it's considerably higher and it can result in more particles being inhaled," she said. "Also, how long is this material going to be used for? Is it good for one hour or can a health worker do a whole shift of 12 hours with it? We can't test all the possible combinations, but we've run three-hour-long experiments at multiple flow rates to see if it's actually going to work or if we see a decrease in efficiency."

So far, Ardon-Dryer has examined a wide variety of mask materials, including N95s, KN95s from China, HEPA filters, cotton fabrics and more.

"Whatever we can put our hands on and test, that helps us to understand how efficient the material is and how can we make it better."

Materials characterization

Warzywoda and Tekin are using the technology available in the Materials Characterization Center (MCC) to image and analyze specific features of the different materials, such as particle and fiber size distribution.

"I think the MCC is key in this effort," Tekin said. "In the MCC, we have advanced instruments such as a scanning electron microscope, infrared spectrometer, Raman microscope spectrometer, etc."

The scanning electron microscope, for instance, is used to examine the materials through which particles have been passed. With the microscope, the researchers can see how well the various fabrics captured the particles.

She emphasized that any one tool—or indeed any one approach—cannot by itself give an accurate determination of which material is the best. That, she said, is why it's so important to be part of a large team all working together to answer the question from as many perspectives as possible—because at the heart of it all is the health and safety of the people working to ensure the health and safety of everyone else.

"We are hoping to measure the performance of the new mask materials which will protect first responders—our heroes—in the battle against COVID-19," Tekin said. "We are thrilled to be able to contribute to these projects."

Mask sterilization

Almodovar and Biros are using a real-world approach to testing the mask materials: exposing them to a virus and then examining both how well they can be sterilized and what method of sterilization is most effective.

Because of the stringent testing restrictions for labs actually using SARS-CoV-2, the virus that causes COVID-19, Almodovar is running the experiments with a different virus that's similar in structure.

"That will provide us with a proof of concept for eliminating pathogens with certain decontamination methods," Biros said.

The testing allows the researchers to evaluate not only how the materials respond to various cleaning methods, but also how often they can be used safely, Sacco said.

One such method, with which Kang and collaborators at The Institute of Environmental and Human Health are decontaminating PPE for regional health care institutions, uses a special chamber filled with wire shelves. Up to 10,000 masks can be placed inside at a time, which are then exposed to a special vapor for 15 minutes before being allowed to aerate for four to five hours. Bioindicator cards containing hard-to-kill bacteria are put in the chamber with the masks to indicate that the decontamination process is complete.

While the coronavirus pandemic has presented challenges to researchers from many backgrounds, it's also presented an opportunity for them to pull together to face the threat, Biros said.

"This has been such a bewildering experience for us all over past weeks," Biros said. "And yet our team put forth not only fast-paced innovation, but also our unparalleled sense of community dedication. We have faculty, staff, students and community partners from an unthinkable scope of disciplines across West Texas to make sure we do our best to provide the needed support for our fellow health care workers in their good fight of sacrifice and determination."

Why it matters

The point, Weeks said, is that PPE is needed for many more people than are on the front lines of the coronavirus fight.

"People need to remember that most of the medical community is not directly working with COVID-19 patients," Weeks said. "They, too, need PPE to safely do their jobs. When we found out there are doctors and nurses making and using their own masks because the high-quality PPE was used for COVID-19 patients, it really sunk in how this impacts people all over the medical community. Even if we can't make a mask that meets the N95 standard, it is nice to know that we are helping others do their job as safely as possible.

"Doing nothing is not an option."

One reason the group's work is so important is to counteract misinformation.

"The elemental objective of this project is to provide authorities and even concerned citizens with evidence-based recommendations in their decision-making process for the use of mask material and patterns," Biros said. "We hope to provide recommendations on mask-making procedures backed up with solid scientific evidence that will guide the mask users through many materials that are falsely assumed to be effective in protection."

To put it bluntly, that means helping people realize they're wasting their time, and putting themselves and others in danger, by making masks out of ineffective materials.

"About the time we started, an article came out on how blue shop towels were the best material for masks available," Weeks said. "The internet was blowing up about this because they were cheap and simple. However, we found they were terrible and not effective at all. We were able to get people locally to stop sewing these masks pretty quickly."

In such cases, discovering the materials that don't work is just as important as finding those that do.

"If we know the materials that are not good, we know not to recommend them," Ardon-Dryer said. "If we know that there are some materials that are better, we can move to the next step and test them more. So, it's a piece of the puzzle, really, and we're trying to go over every piece. If we're missing one piece, we don't answer all the questions, and we must, because this involves people's lives."

All the researchers expressed a sense of pride at being involved in the consortium's work and, above all, a desire to make a difference for the good of the community.

"I've never done anything like this," Weeks said, "but we work with a bunch of smart people. When people put their knowledge behind things collaboratively, it is possible to make big impacts rather quickly."

Provided by Texas Tech University

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