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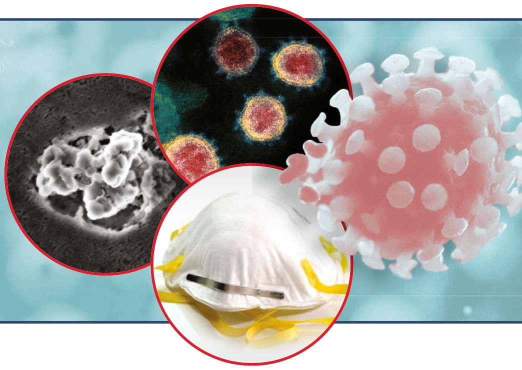
The Materials Genome and COVID-19 Pandemic



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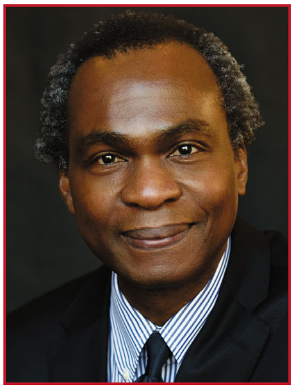

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> *"The current COVID-19 pandemic period seems to be the exact pivot point for what has been learned through the MGI to address human wellbeing and environmental sustainability."*
>
> ***—Oladele A. Ogunseitan***

The Materials Challenge

Near the peak of the COVID-19 outbreak in Wuhan, China, the city generated about 240 metric tons of medical waste per day, nearly six-fold more than before the pandemic, thereby creating the need for flexible and repurposed mobile treatment facilities for managing solid and hazardous waste.[1] In the United States, the shortage of personal protective equipment (PPE), including face masks, gloves, and medical gowns, has added an unforeseen dimension to the population health crisis and unprecedented urgent requests for domestic and international donations to clinics and hospitals. It is unclear if the existing solid waste management facilities for medical waste can meet the rapid increase in demand, and there is an immediate threat that the pandemic impacts will spill over into a crisis of environmental pollution.[2]

Beyond medical facilities, the social distancing policies implemented in response to the pandemic have led to a dramatic surge in demand for face masks and tissue paper throughout the general population.[3] The gap between demand and supply of such products has led to urgent calls for strategies to collect, disinfect, recycle, and reuse masks.[4]

However, there are serious potential risks of infection associated with the reuse of face masks because of the wide range of materials, filtration capacity, and life expectancy of masks designed to protect against exposure to virus particles.[5,6] After the last pandemic flu episode, there were a lot of calls for research to define the parameters for reusing masks, but progress has been slow, probably because of limited research funding after the impact of the pandemic flu abated. Specifically, the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) issued a report on the reusability of facemasks during an Influenza pandemic, and the report's authors advocated for more research.[7]

Lessons from the MGI

The current demand for environmentally sustainable face masks is unprecedented, and it seems to have caught the U.S. manufacturing enterprise by surprise, despite considerable federal investments over the past five years in the Materials Genome Initiative (MGI).[8,9] As a multi-agency initiative, the MGI was designed to support efforts to quickly and affordably "discover, manufacture, and deploy" advanced materials that are critical for economic security and human wellbeing.[10]

The current COVID-19 pandemic period seems to be the exact pivot point for what has been learned through the MGI to address human wellbeing and environmental sustainability. Instead, the federal government invoked the Defense Production Act to compel manufacturers such as 3M to expedite the production of traditional PPE and to restrict exportation to other countries.[11] Simultaneously, the U.S. Environmental Protection Agency issued a temporary policy regarding enforcement of environmental legal obligations during the COVID-19 pandemic, a move that could enlarge the already considerable loopholes in hazardous waste management and materials recycling and reuse.[12]

A Materials Solution?

Protocols currently being explored for reusing face masks include microwave steaming, ultraviolet radiation, and autoclaving; all have serious limitations and uncertainty of their outcomes. Real-time disinfection of PPE is an ideal solution for the challenge of extending its useful lifetime. The idea is not new, but commercial production has not been viable. We now have the opportunity to re-think investments in research on "green" materials that have intrinsic disinfection properties, are long-wearing, and are recyclable. Such materials will save the lives of front-line emergency responders and hospital-based healthcare professionals, while also contributing to the desire to flatten the curve of epidemics when used in concert with policies such as social distancing.

Research and development of nanotechnology-based products brought new prospects for in-use material disinfection. The research on nanomaterials has produced several commercial products, although concerns have been raised about the environmental impacts of nanoparticles released from consumer products embedded with, for example, nanosilver.[13] Results from a study of face masks embedded with nanosilver particles showed that 100 ppm colloidal silver produced antibacterial activity.[14] The limitations of research results so far accumulated are that the studies are usually based on surrogate pathogens, especially bacteria such as laboratory strains of *Escherichia coli*. Very few studies of the disinfecting properties of nanoparticles have been conducted with pathogenic viruses, in part because many such viruses are also sized in the nanometer dimension, and the physical dimensions may reduce the effectiveness of nanosized chemicals embedded in materials that must also have filter-and-hold properties.[15]

The proliferation of medical application of nanosilver has provoked calls for international regulation bases on potential environmental risks associated with their toxicity and discharges in wastewater.[16] However, the concerns about environmental pollution may dissipate with intentional design to make nanoparticle-enhanced PPE that can last longer and is recyclable, thereby reducing the generation of solid waste that requires special management due to risks of infection.

The Icon of a Pandemic

The beaked leather mask is a well-recognized icon of 17th century doctors wearing PPE in response to the epidemic of bubonic plague. In October 1918, during the peak of the pandemic flu that killed millions of people, the city of San Francisco, California, enacted the influenza mask ordinance that required

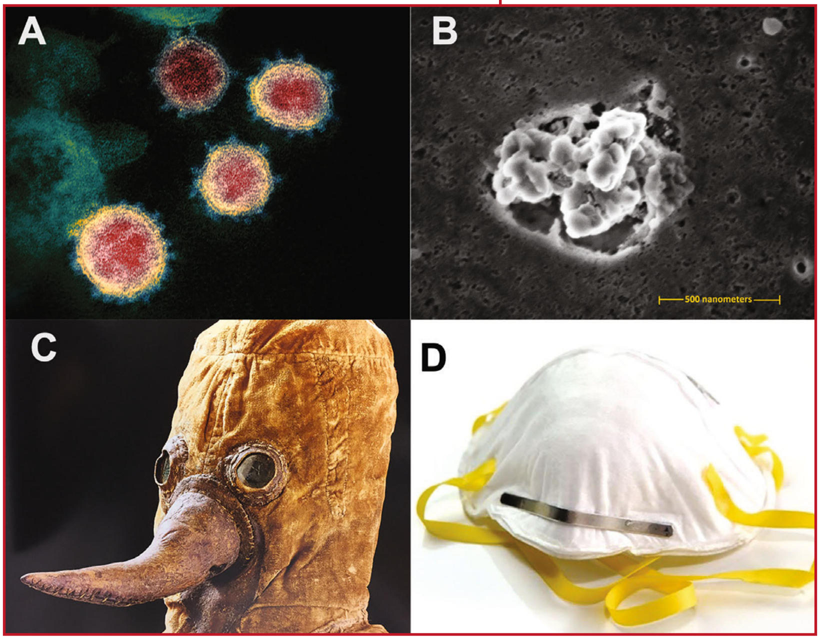

Figure 1.
Panel A: Transmission electron microscope image of SARS-CoV-2, the causative agent of COVID-19 pandemic. Each virus particle is approximately 125 nanometers. (Image courtesy of the National Institute for Allergies and Infectious Diseases-RML.)
Panel B: Scanning electron micrograph showing a cluster of silver nanoparticles with antimicrobial properties that can be embedded in PPE. The diameter of the cluster is about the size of a typical bacterium (~900 nanometers). (Image courtesy of the National Institute of Standards and Technology.)
Panel C: Plague doctors' face masks of the 17th century were made with naturally occurring materials such as leather, cloth, and glass. (Image courtesy of the Minneapolis Institute of Art from original display in Deutsches Historisches Museum.)
Panel D: Modern N95 face mask typically made of synthetic polypropylene fabric. (Image courtesy of the U.S. Food and Drug Administration.)

the population to wear face masks as a prevention strategy. The ordinance led to popular experimentations with all kinds of mask materials.[17]

When the COVID-19 pandemic recedes, there will be several candidate icons to mark the calamity. There is an inkling of hope that the Materials Genome Initiative will produce a candidate icon recognized by advanced sustainable materials for protective masks for the population and PPE for health professionals.

Endnotes

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