NATIONAL ACADEMIES Sciences Engineering Medicine

Reusable Health Care Textiles for Personal Protective Equipment: A Workshop

March 4th and 5th, 2024

National Academies of Sciences, Engineering, and Medicine
Board on Health Sciences Policy
Link to livestream

NATIONAL ACADEMIES Sciences Engineering Medicine

Reusable Health Care Textiles for Personal Protective Equipment: A Workshop

March 4th and 5th, 2024

Briefing Book Table of Contents

Reusable Health Care Textiles for Personal Protective Equipment: A Workshop

PROJECT STATEMENT OF TASK

A planning committee of the National Academies of Sciences, Engineering, and Medicine will organize a virtual public workshop to examine opportunities to increase the use of reusable health care textiles (HCT) for personal protective equipment (PPE) used in health care settings. This workshop will provide the opportunity to exchange knowledge and ideas among key stakeholders—including technical experts, policy makers, manufacturers, and PPE users in health care—and to explore the potential benefits and feasibility of integrating more reusable HCTs into health care operations.

The workshop will feature invited presentations and discussions to:

- Examine existing recommendations, approaches, and guidelines relating to reusable HCTs to ensure optimal protection of patients and health care workers;
- Discuss issues related to contamination of textiles and fabrics in health care facilities;
- Explore issues associated with current product and technology standards for reusable HCTs, considering input on standards needs from a past National Institute for Occupational Safety and Health (NIOSH) Personal Protective Technologies (PPT) Centers of Excellence Federal Register Notice;
- Examine the comparative performance, comfort, environmental impact, and use issues for disposable and reusable HCTs;
- Highlight similarities and differences between U.S. and European systems for reusable HCT use/maintenance/disposal systems, sustainability, and standards/regulations;
- Explore potential benefits, including potential cost savings, and feasibility issues related to increasing the use of reusable HCTs in crisis and everyday situations and in different health care settings;
- Discuss opportunities and approaches to integrate more reusable HCTs into health care operations where appropriate.

The planning committee will organize the workshop, develop the agenda, select, and invite workshop speakers and discussants, and moderate or identify moderators for the discussions. A *Proceedings of a Workshop* will be published to capture the presentations and discussions at the workshop. This *Proceedings* will be prepared by designated rapporteurs in accordance with National Academies institutional guidelines and will be released to the public.

TIMELINE

The planning committee will meet approximately five times between December 2023 and March 2024 to organize the public workshop, which will be held virtually March 4-5, 2024. The workshop proceedings will be publicly released in Summer 2024.

SPONSOR

National Institute for Occupational Safety and Health's National Personal Protective Technology Laboratory

WEBPAGE

For additional information, please visit the project webpage.

PROJECT STAFF

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NATIONAL ACADEMIES Sciences Engineering Medicine

Planning Committee

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Jacqueline A. Daley, Providence St. Joseph Health

Melissa Dawson, Rochester Institute of Technology

Elizabeth P. Easter, University of Kentucky

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Kelly N. Wright, Cedars-Sinai Medical Center

NATIONAL ACADEMIES Sciences Engineering Medicine

HEALTH AND MEDICINE DIVISION | BOARD ON HEALTH SCIENCES POLICY

Reusable Health Care Textiles for Personal Protective Equipment

Virtual Workshop

WORKSHOP AGENDA

March 4-5, 2024

Workshop Objectives: Workshop discussants and participants will have the opportunity to examine opportunities to increase the use of reusable health care textiles (HCT) for personal protective equipment (PPE) used in health care settings. This workshop will provide the opportunity to exchange knowledge and ideas among key value holders—including technical experts, policy makers, manufacturers, and PPE users in health care—and to explore the potential benefits and feasibility of integrating more reusable HCTs into health care operations.

The public workshop will feature invited presentations and discussions to:

- Examine existing recommendations, approaches, and guidelines relating to reusable HCTs to ensure optimal protection of patients and health care workers;
- Discuss issues related to contamination of textiles and fabrics in health care facilities;
- Explore issues associated with current product and technology standards for reusable HCTs, considering input on standards needs from a past National Institute for Occupational Safety and Health (NIOSH) Personal Protective Technologies (PPT) Centers of Excellence Federal Register Notice;
- Examine the comparative performance, comfort, environmental impact, and use issues for disposable and reusable HCTs;
- Highlight similarities and differences between U.S. and European systems for reusable HCT use/maintenance/disposal systems, sustainability, and standards/regulations;
- Explore potential benefits, including potential cost savings, and feasibility issues related to increasing the use of reusable HCTs in crisis and everyday situations and in different health care settings;
- Discuss opportunities and approaches to integrate more reusable HCTs into health care operations where appropriate.

To watch the livestream, please visit the workshop's event page here.

DAY 1 – MONDAY, MARCH 4, 2024

Welcome and Overview of the Workshop

10:00am **Chair Welcome and Opening Remarks**
Sundaresan Jayaraman, Workshop Chair

10:15am **National Personal Protective Technology Laboratory (NPPTL) Opening Remarks**
Adam Smith, Senior Scientist, NPPTL

Session 1 Level Setting: The US Ecosystem

10:30am **Introduction**
Elizabeth Easter, Professor, University of Kentucky

This panel will lay the foundation of the workshop by defining key terms and concepts. It will describe the current US ecosystems for disposable and reusable healthcare textiles (HCTs) for personal protective equipment (PPE).

10:40am **Panel Presentations**
Elizabeth Easter, Panel Moderator

Overview of Disposable PPE Life Cycle
- *Charlie Merrow, CEO, Merrow Manufacturing*

Overview of Reusable PPE Life Cycle
- *John Wintz,* Group Vice President, Standard Textiles

Sustainability in PPE Manufacturers and Suppliers
- *Dan Glucksman,* Senior Director for Policy, International Safety Equipment Association (ISEA)

Healthcare Worker Perspective on PPE Selection
- *Pamela Falk*, Epidemiologist, Association for Professionals in Infection Control and Epidemiology (APIC)

Audience Q&A *(time permitting)*

11:30am **BREAK**

Session 2 Level Setting: Policies and Standards

11:45am **Introduction**
Elizabeth Beam, Associate Professor, University of Nebraska Medical Center College of Nursing

This panel will lay the foundation of the workshop by defining key terms and concepts. It will describe the current policy and standards that influence the ecosystems for disposable and reusable PPE.

11:50am **Panel Presentations**
Elizabeth Beam, Panel Moderator

Policies and Standards for Manufacturers

- ***PPE Manufacturers:***
  Jeff Stull, President, International Personal Protection; Member, ASTM Committee on Standards for Medical Face Masks and Protective Clothing

- ***Textile Manufacturers:***
  Erika Simmons, Technical Director, American Association of Textile Chemists and Colorists (AATCC)

Policies and Guidance for Use

- ***Federal Perspective:***
  Lynne Sehulster, CDC Division of Healthcare Quality Promotion (ret.)

- ***Healthcare Perspective:***
  Tiffany Wiksten, Associate Director, Standards Interpretation Group, The Joint Commission

- ***Laundry and Reuse Perspective:***
  Liz Remillong, Division Vice President, Crothall Healthcare

Comparison of US and International Policies and Standards

- *Henk Vanhoutte,* Secretary General, European Safety Federation

Audience Q&A *(time permitting)*

1:00pm **BREAK**

Session 3 Environmental Impact

2:00pm **Introduction**
Kelly Wright, Director of Minimally Invasive Gynecological Surgery and Associate Professor of Obstetrics and Gynecology, Cedars-Sinai Medical Center

This session is the first of a series aimed at characterizing the impact associated with the increased adoption of reusable versus disposable HCTs within healthcare settings. Specifically, this session will examine the environmental impact, both risks and benefits, using a life-cycle analysis (LCA).

2:05pm **Presentation**
Environmental Impacts at Each Life Cycle Stage
Michael Overcash, CEO, Environmental Genome Initiative

2:15pm **Case Study**
Environmental Sustainability in Clinical Care
James Marvel, Clinical Assistant Professor, Stanford University School of Medicine

2:25pm **Panel Discussion**
Kelly Wright, Panel Moderator

Production and Use

- ***Biodegradable, Disposable PPE:***
  Gajanan Bhat, Professor, University of Georgia

- ***Reusable PPE:***
  Shelley Petrovskis, Director of Marketing & Regulatory Affairs, Lac-Mac Limited

Transportation of Disposable and Reusable PPE

- *Shawn Gibbs,* Dean, Texas A&M School of Public Health

End-of Life: Disposal and Recycling

- *Melissa Dawson*, Associate Professor, Rochester Institute of Technology

3:10pm **Audience Q&A**

Session 4 Economic Impact

3:15pm **Introduction**
Barbara Strain, Principal, Barbara Strain Consulting, LLC

In this next session of the series, the panel will examine the economic impact of the increasing use of reusable versus disposable HCTs. It will focus on both the short- and long-term infrastructure investments for healthcare facilities and value holders.

3:20pm **Presentation**
Value Analysis 101
Barbara Strain, Principal, Barbara Strain Consulting LLC

3:30pm **Case Study**
Costs Associated with Stockpiling of Reusable Respiratory Protective Devices
Gio Baracco, Professor, University of Miami

3:40pm **Panel Discussion**
Barbara Strain, Panel Moderator

Production, Use, End of Life: Disposable and Reusable PPE

- *Charlie Merrow,* CEO, Merrow Manufacturing

US Trade Policy

- *Laurie-Ann Agama,* Acting Assistant Trade Representative for Textiles, U.S. Trade Representative

Healthcare System Perspective

- *Laura Thurston,* Director Laundry Services, Intermountain Health

4:15pm **Audience Q&A**

Day 1 Wrap-Up

4:20pm	**Chair's Reflection and Preview of Day 2** *Sundaresan Jayaraman*, Workshop Chair
4:30pm	**ADJOURN DAY 1**

DAY 2 – TUESDAY, MARCH 5, 2024

Welcome and Recap of Day 1

10:30am

Chair Welcome and Opening Remarks
Sundaresan Jayaraman, Workshop Chair

Session 5 — Safety & Quality Considerations

10:45am

Introduction
Nicole (Nikki) McCullough, Vice President of Application Engineering and Regulatory, Personal Safety Division, 3M Company

The last session in the series aimed at characterizing the impact associated with increasing the adoption of reusable versus disposable HCTs within healthcare settings, the panel will explore the impact of reusable HCT use on patient and health care worker safety using a risk-based assessment framework.

10:50am

Case Study
Ensuring Reusable Respiratory Protective Devices Were Properly Cleaned/Disinfected During the COVID Pandemic
Hope Waltenbaugh, Vice President of Perioperative Services &
Sara Angelilli, Director - Education & Professional Practice, Allegheny Health Network

11:00am

Panel Discussion
Nicole (Nikki) McCullough, Panel Moderator

Functional Clothing and Textiles

- ***Wearability and Garment-Based Wearable Technology:***
  Lucy Dunne, Professor, University of Minnesota

- ***Performance Comparison and Physiological Stress:***
  Meredith McQuerry, Associate Professor, Florida State University

Healthcare System Level

- *Mark Shirley*, Director - Integrated Resiliency Management, Sutter Health

Healthcare Worker Level

- *Jill Morgan,* Critical Care Nurse, Emory University Hospital

Regulatory Perspective

- *Louise King,* Assistant Professor, Harvard Medical School

11:45am

Audience Q&A

Session 6	Decision Making Support

11:55am

Introduction
Jacqueline Daley, Senior Director - Infection Prevention, Providence St. Joseph

In this session, the panel will consider the elements of a decision-support framework that a healthcare organization might consider when exploring the incorporation of more reusable HCTs into its operations.

12:00pm

Case Study
Decision Process to Incorporate More Reusable Isolation Gowns in Healthcare Operations
Beth Schenk, Executive Director Environmental Stewardship &
Jack Holmberg, Senior Infection Preventionist, Providence Health

12:10pm

Panel Discussion
Jacqueline Daley, Panel Moderator

Healthcare Systems & Organizations Perspective

- ***Large-Scale:***
  Skip Skivington, Vice President of Health Care Continuity and Support Services, Kaiser Permanente

- ***Small-Scale:***
  Barbara DeBaun, Improvement Advisor, Cynosure Health

User Perspective

- *Katherine Townsend,* Professor, Nottingham Trent University

12:55pm

Audience Q&A

1:05pm

BREAK

Session 7	Implementation

1:40pm

Introduction
Sundaresan Jayaraman, Workshop Chair

This final panel will close the workshop by discussing what it would take for a healthcare organization to implement use of more reusable HCTs. In addition to highlighting the implementation strategies and systems and behavior change models each panelist relied on to promote the increased use of reusable HCTs in their healthcare setting, the panel will also address barriers to adoption that were encountered.

1:45pm

Panel Discussion
Sundaresan Jayaraman, Panel Moderator

Healthcare System with Both On- and Off-Site Laundry Services
- *Laura Thurston,* Director Laundry Services, Intermountain Health

Sustainability in Clinical Care
- *Cassandra L. Thiel,* Assistant Professor, NYU Grossman School of Medicine
- *Edward McCauley,* President & CEO, United Hospital Services

Healthcare Worker Level
- *Jill Morgan,* Critical Care Nurse, Emory University Hospital

Intersection of Regulations and Healthcare Worker Safety
- *Louise King,* Assistant Professor, Harvard Medical School

2:30pm **Audience Q&A**

Day 2 Wrap-Up

2:40pm **Sponsor's Reflections**
Maryann D'Alessandro, Director, NPPTL

2:50pm **Closing Remarks**
Sundaresan Jayaraman, Workshop Chair

3:00pm **ADJOURN**

Congress of the United States

Washington, DC 20515

June 27, 2023

The Honorable Xavier Becerra
Secretary
Department of Health and Human Services (HHS)
200 Independence Avenue, S.W.
Washington, D.C. 20201

Dear Secretary Becerra,

We write to request that you examine the feasibility and potential benefits of the increased use of reusable health care textiles (HCT) in hospitals and other medical facilities to protect health care workers, address the rising environmental impact of disposables, prepare for future pandemics, and potentially provide cost savings.

The COVID-19 pandemic revealed pre-existing problems and weaknesses in the health care system. Early in the pandemic, media reports[1] across the country depicted makeshift alternatives to isolation cover gowns and masks, including nurses wearing trash bags and raincoats over their scrubs and using snorkels as facial coverings. This was due to widespread shortages in disposable products, including personal protective equipment (PPE). In the summer of 2020, the American Nursing Association found that 42% of U.S. nurses were experiencing widespread or intermittent PPE shortages, with 68% reusing PPE that was disposable and intended for single use.[2] Patients and providers suffer when the demand for personal protective equipment is not met with enough supply.

In the United States, more than 90% of health care PPE and operating room textiles are single use, even though ample supplies of reusable equivalents are available. By comparison, other countries such as Canada and the United Kingdom maintain inventories of 80% reusable health care textiles.[3] Studies have found that reusable textiles are every bit as safe—if not safer than—their disposable substitutes.[4]

"One and done" disposable textile substitutes contribute significantly to medical waste, which was exacerbated by the COVID-19 pandemic. Between March 2020 and November 2021, approximately 87,000 tons of PPE were shipped worldwide in response to COVID-19.[5] Most of these goods ended up as waste.[6] Alternatively, one reusable gown can replace 75 single-use disposable gowns.[7] Life-cycle assessments show that selecting reusables over disposable substitutes results in significant environmental benefits such as reductions in energy consumption, greenhouse gas emissions, water consumption, and solid waste generation.[8] For example,

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[1] Justine Coleman, March 26, 2020, "Photo shows NY hospital staff using trash bags as protective gear." *The Hill*. https://thehill.com/policy/healthcare/489622-photo-shows-staff-using-trash-bags-as-protective-gear-in-hospital-system/

[2] American Nursing Association. 2020. Update on Nurses and PPE: Survey reveals alarming conditions." https://www.nursingworld.org/~4a558d/globalassets/covid19/ana-ppe-survey-one-pager---final.pdf

[3] 'New Innovations in Reusable OR Textiles' - Encompass Group LLC - 2020

[4] Meredith McQuerry, Elizabeth Easter, and Alex Cao, 2021, "Disposable versus reusable medical gowns: A performance comparison." *American Journal of Infection Control*, https://www.arta1.com/wp-content/uploads/2022/07/Disposable-Versus-Reusable-Medical-Gown-Study-in-American-Journal-of-Infection-Control-2020.pdf.

[5] World Health Organization, February 1, 2022, "Tonnes of COVID-19 health care waste expose urgent need to improve waste management systems." https://www.who.int/news/item/01-02-2022-tonnes-of-covid-19-health-care-waste-expose-urgent-need-to-improve-waste-management-systems

[6] Ibid.

[7] Ronald Reagan UCLA Medical Center. "Reusable Isolation Gowns Practice Greenhealth" https://practicegreenhealth.org/tools-and-resources/ronald-reagan-ucla-medical-center-reusable-isolation-gowns

[8] Michael Overcash. April 2012. "A Comparison of Reusable and Disposable Perioperative Textiles: Sustainability State-of-the-Art

disposables generate far more solid waste than reusables—705 pounds per 1,000 gowns compared with 83 pounds, a 750% margin.[9]

We believe that increasing the use of reusable health care textiles could ensure that the United States is better prepared for future pandemics while reducing environmental impacts of single-use equipment and potentially provide cost savings. We request that the Department of Health and Human Services (HHS) and the National Institute for Occupational Safety and Health conduct a study of the potential benefits and feasibility of increasing the usage of reusable HCTs and any potential savings that would be gained through the use of reusable HCTs. In addition, we are requesting that HHS examine ways to encourage health care facilities to integrate more reusable health care textiles. We ask the results of this review be shared with the undersigned.

Sincerely,

Greg Landsman
Member of Congress

Mike Carey
Member of Congress

Ann McLane Kuster
Member of Congress

Glenn "GT" Thompson
Member of Congress

Max Miller
Member of Congress

2012." Anesthesia and Analgesia.
https://www.researchgate.net/publication/223973613_A_Comparison_of_Reusable_and_Disposable_Perioperative_Textiles_Sustainability_State-of-the-Art_2012

[9] 'New Innovations in Reusable OR Textiles' - Encompass Group LLC - 2020

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
Atlanta GA 30329-4027

October 19, 2023

The Honorable Greg Landsman
U.S. House of Representatives
Washington, DC 20515

Dear Representative Landsman:

Thank you for your letter to Health and Human Services (HHS) Secretary Xavier Becerra regarding the feasibility and potential benefits of the increased use of reusable healthcare textiles (HCTs) in healthcare settings to protect healthcare workers, address the rising environmental impact of disposables, prepare for future pandemics, and potentially provide cost savings. I am responding on behalf of Secretary Becerra.

Healthcare facilities must ensure optimal protection of patients and healthcare workers. The Centers for Disease Control and Prevention (CDC) produces recommendations about the types of personal protective equipment (PPE) that should be used by healthcare personnel when caring for patients with infectious diseases. In most instances, CDC guidance currently allows for disposable and reusable PPE. However, recommended PPE, whether it is disposable or is able to be reprocessed and reused, should meet recommended current, minimum standards.[1,2]

For example, CDC recommends that gowns used to care for patients known or suspected to be infected with certain pathogens meet specific standards for fluid resistance.[3,4,5,6] In addition, masks that are used to protect healthcare personnel against splashes and sprays to their mucous membranes should also meet standards for fluid resistance.

Reusable medical textiles that are used as PPE should have validated reprocessing instructions to ensure that any risks from residual infectious fluids are eliminated and that the reprocessing does not impact safety parameters (e.g., physical and barrier performance of PPE, respiratory or

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[1] U.S. Food and Drug Administration (FDA). Personal Protective Equipment for Infection Control. https://www.fda.gov/medical-devices/general-hospital-devices-and-supplies/personal-protective-equipment-infection-control

[2] U.S. FDA. Personal Protective Equipment for Infection Control: Medical Gowns. https://www.fda.gov/medical-devices/personal-protective-equipment-infection-control/medical-gowns

[3] CDC's Core Infection Prevention and Control Practices for Safe Healthcare Delivery in All Settings. https://www.cdc.gov/infectioncontrol/guidelines/core-practices/index.html

[4] 2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings (Last update: July 2023). https://www.cdc.gov/infectioncontrol/pdf/guidelines/Isolation-guidelines-H.pdf

[5] Guidelines for Environmental Infection Control in Health-Care Facilities (2003) (Last Update: July 2019). https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf

[6] Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Healthcare Settings, Including Procedures for Donning and Doffing PPE. https://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html

dermal reactions due to the residuals from the reprocessing, environmental safety, and processors' health and safety). Outbreaks have occurred related to improperly reprocessed medical textiles (e.g., sheets), including outbreaks of invasive fungal infections among immunocompromised patients related to contamination during the laundry process.[7,8,9] Additionally, the effectiveness of the laundering process depends on multiple factors that can vary between facilities and even facility types.

The environmental impact of disposable PPE can be considerable, and options that reduce waste but still provide protection for healthcare personnel could be valuable. In addition to CDC recommendations,[10,11,12,13] many types of PPE are regulated by other federal agencies (for example, gowns are regulated by the U.S. Food and Drug Administration through a number of pathways), and these agencies would provide regulatory oversight of many of the medical textiles that your letter describes.

As you have noted, an issue of recent concern involves the use of disposable (i.e., single use) versus reusable (i.e., multiple use) surgical attire and fabrics in healthcare settings. Regardless of the material used to manufacture gowns and drapes, these items must be resistant to liquid and microbial penetration. CDC's *Guidelines for Environmental Infection Control in Healthcare Facilities*[14] includes a section on laundry in a healthcare facility.[15] However, this is mainly focused on linens, personal clothing/patient apparel, uniforms, scrub suits, and similar items, and not on reusable PPE beyond surgical gowns.

Within CDC, the National Institute for Occupational Safety and Health (NIOSH) and its National Personal Protective Technology Laboratory are dedicated to addressing all issues concerning PPE, including opportunities for supporting and sustaining the increased use of reusable PPE in healthcare settings.

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[7] Alexander J Sundermann and others, How Clean Is the Linen at My Hospital? The Mucorales on Unclean Linen Discovery Study of Large United States Transplant and Cancer Centers, Clinical Infectious Diseases, Volume 68, Issue 5, 1 March 2019, Pages 850–853, https://doi.org/10.1093/cid/ciy669

[8] Jordan A, James AE, Gold JAW, Wu K, Glowicz J, Wolfe F, Vyas K, Litvintseva A, Gade L, Liverett H, Alverson M, Burgess M, Wilson A, Li R, Benowitz I, Gulley T, Patil N, Chakravorty R, Chu W, Kothari A, Jackson BR, Garner K, Toda M. Investigation of a Prolonged and Large Outbreak of Healthcare-Associated Mucormycosis Cases in an Acute Care Hospital-Arkansas, June 2019-May 2021. Open Forum Infect Dis. 2022 Oct 17;9(10):ofac510. doi: 10.1093/ofid/ofac510

[9] Janet Glowicz, Isaac Benowitz, Matthew J. Arduino, Ruoran Li, Karen Wu, Alexander Jordan, Mitsuru Toda, Kelley Garner, Jeremy A.W. Gold, Keeping health care linens clean: Underrecognized hazards and critical control points to avoid contamination of laundered health care textiles, American Journal of Infection Control, Volume 50, Issue 10,2022, Pages 1178-1181, ISSN 0196-6553, https://doi.org/10.1016/j.ajic.2022.06.026

[10] CDC's Core Infection Prevention and Control Practices for Safe Healthcare Delivery in All Settings. https://www.cdc.gov/infectioncontrol/guidelines/core-practices/index.html

[11] 2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings (Last update: July 2023). https://www.cdc.gov/infectioncontrol/pdf/guidelines/Isolation-guidelines-H.pdf

[12] Guidelines for Environmental Infection Control in Health-Care Facilities (2003) (Last Update: July 2019). https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf

[13] Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Healthcare Settings, Including Procedures for Donning and Doffing PPE. https://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html

[14] https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf

[15] https://www.cdc.gov/infectioncontrol/guidelines/environmental/background/laundry.html

NIOSH previously conducted a study on reusable isolation gowns in which the change in the physical and barrier performance of reusable isolation gowns after multiple processing cycles was studied using standardized laboratory test methods.[16] The findings of this study were reported to the American Society of Testing and Materials (ASTM) International's F23 Committee on Personal Protective Clothing and Equipment and used in the minimum performance requirements of the new isolation gowns standard (ASTM F3352).[17] The study highlighted that multiple reusable isolation gown models on the U.S. market (six of nine models) failed to align with the American National Standards Institute/Association for the Advancement of Medical Instrumentation PB70 requirements for liquid barrier performance at the level specified by the manufacturer after one and multiple laundering cycles.

NIOSH also conducted studies to explore the impact of the decontamination process on multiple PPE items to evaluate the reuse potential of disposable products after decontamination.[18] For example, disposable surgical and isolation gowns, which have been considered for reuse during pandemics and epidemics, and powered air purifying respirator hoods, which are made of disposable materials but generally reused after the decontamination process, were studied in these projects. As a follow-up study, NIOSH started a pilot project that is evaluating the effectiveness of chemical decontamination methods used in healthcare settings for one of the commonly used disposable PPE fabrics, spunbond meltblown spunbond (commonly known as SMS) nonwoven textiles. These fabrics are mostly used in the construction of gowns, head covers, powered air-purifying respirator hood assemblies, and sleeve protectors.

NIOSH will also conduct a study of the potential benefits and feasibility of increasing the usage of reusable HCTs and any potential savings that would be gained through their use. This will include examining ways to encourage healthcare facilities to integrate more reusable HCTs into their activities and commissioning a National Academies Workshop on the topic to be conducted in spring 2024. NIOSH has identified several key issues related to reusable HCTs that will be included in the proposed study. These include the availability of good quality products, the availability of service providers (e.g., cleaning/decontamination services, repairs, quality checks, sizing, stocking), user acceptability, comparative analyses of life cycle costs, thermal comfort, and a rigorous review of studies regarding environmental impact. NIOSH intends to conduct research to further explore each of these issues.

The study's final report describing the feasibility and potential benefits of the increased use of reusable HCTs will consolidate NIOSH research conducted from August 2023-May 2024 to explore the issues described above and report on the pilot research. The report is expected to be completed by August 2024.

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[16] Selcen Kilinc-Balci, and Patrick Yorio, Comparison of Physical and Barrier Performance of Reusable Isolation Gowns, 8th European Conference on Protective Clothing, Porto, Portugal, May 7-9, 2018.
[17] ASTM F3352. Standard Specification for Isolation Gowns Intended for Use in Healthcare Facilities; 2023. West Conshohocken, PA: ASTM International.
[18] Selcen Kilinc-Balci, Zafer Kahveci, Christian Coby, Patrick L. Yorio, How do Disinfecting Wipes Impact the Barrier Performance of Protective Clothing?" 10th European Conference on Protective Clothing, Arnhem, Netherlands, May 9-12, 2023.

I appreciate your letter about this public health issue. If you have further questions, please have your staff contact Jeff Reczek in our CDC Washington Office at (202) 245-0600 or JReczek@cdc.gov.

Sincerely,

Mandy K. Cohen, MD, MPH
Director, CDC
Administrator, Agency for Toxic Substances and Disease Registry

cc:
The Honorable Mike Carey
The Honorable Ann McLane Kuster
The Honorable Max Miller
The Honorable Glenn "GT" Thompson

NATIONAL ACADEMIES Sciences Engineering Medicine

Workshop On Reusable Health Care Textiles for Personal Protective Equipment

Planning Committee Biographies

Committee Chair

Sundaresan Jayaraman, Ph.D., is a Professor in the School of Materials Science and Engineering at the Georgia Institute of Technology. He is also the Founding Director of the Kolon Center for Lifestyle Innovation at Georgia Tech. A pioneer in bringing about convergence between textiles and computing, Professor Jayaraman's research has led to the paradigm of "Fabric is the Computer." He is a leader in studying and defining the roles of engineering design, manufacturing and materials technologies in public policy for the nation. Professor Jayaraman and his research students have made significant contributions in the following areas: (i) Smart Textile-based Wearable Systems; (ii) Computer-aided Manufacturing, Automation and Enterprise Architecture Modeling; (iii) Engineering Design and Analysis of Intelligent Textile Structures and Processes; (iv) Design and Development of Knowledge Based Systems (KBS) for textiles and apparel; and (v) Design and Development of Respiratory Protection Systems. Professor Jayaraman is a recipient of the 1989 Presidential Young Investigator Award from NSF for his research in the area of computer aided manufacturing and enterprise architecture. In September 1994, he was elected a Fellow of the Textile Institute, (UK). His publications include a textbook on computer-aided problem solving published by McGraw-Hill in 1991 and eleven U.S. patents. As Principal Investigator, he has received over $16 Million in research funding from a variety of sources including NSF, DARPA, DoD, NIST, CDC, and industry. Dr. Jayaraman served as Technical Editor, Information Technology, for ATI Magazine (now Textile World) from 1995-2003. From May 2000 to October 2004, he was an Editor of the Journal of the Textile Institute and is currently on the Editorial Advisory Board. Professor Jayaraman is a founding member of the IOM Standing Committee on Personal Protective Equipment in the Workplace (2005-2013) and is currently serving on it. From December 2008 to February 2011, he served on the Board on Manufacturing and Engineering Design of the National Academies. In February 2011, he became a founding member of the National Materials and Manufacturing Board of the National Academies. He has also served on nine NASEM Study Committees. He is also a founding member of the IEEE Technical Committee on Biomedical Wearable Systems (2004 –2008). In October 2000, Professor Jayaraman received the Georgia Technology Research Leader Award from the State of Georgia. He received The 2018 Textile Institute Research Publication Award for the most outstanding paper published in 2018 in the Journal of the Textile Institute. In December 2019, he received the Inaugural Distinguished Alumni Award from A.C. College of Technology, Chennai, India. In 2020, he once again received The 2020 Textile Institute Research Publication Award. In 2023, he received the National Academy of Medicine Catalyst Award in the Global Healthy Longevity Challenge (https://bit.ly/47P5d3Y).

Committee Members

Elizabeth L. Beam, Ph.D., is an associate professor at the University of Nebraska Medical Center (UNMC) College of Nursing. She has worked on an emergency preparedness grant called HEROES at the college of nursing since 2005. In that role, she became a member of the Nebraska biocontainment unit leadership team and was the director for education in 2014 when Ebola virus disease was treated in the United States. She worked with that team to create and publish the personal protective equipment (PPE) ensemble used by the care team at Nebraska Medicine for this Category A illness. In 2018, the team won the American Industrial Hygiene Association's (AIHA) Edward J. Baier Technical Achievement Award which is a lifetime achievement award in the field of industrial hygiene. Beam has gone on to do further research on healthcare worker behaviors in PPE for transmission-based precautions with an emphasis on respiratory protection for situations like the COVID-19 pandemic. Her infection control behavior studies specifically used reusable isolation gowns as they were the product used by Nebraska Medicine at the time. She currently serves on the National Emerging Special Pathogen Training and Education Center (NETEC) PPE working group.

Gajanan S. Bhat, Ph.D., earned his doctorate from Georgia Tech in textile and polymer engineering and worked for industry making carpets from recycled plastic bottles. Bhat joined the University of Tennessee, Knoxville in August 1990, where his research covered nonwovens - melt blown, spunbonded and biodegradable; plastics recycling; nanotechnology; sustainable materials; and high-performance fibers. As the director of UTNRL he demonstrated successful production of nanofibers from thermoplastic polymers by meltblowing. In July 2016, he joined the University of Georia (UGA) as the head of the Department of Textiles, Merchandising, and Interiors. He has served as the president of the Fiber Society and is also an active member of the Association of the Nonwoven Fabrics Industry (INDA) and the Technical Association of the Pulp & Paper Industry (TAPPI). Some of the awards/recognitions he has received include: Outstanding Young Engineering Alumni by Georgia Tech; Distinguished Achievement Award from the Fiber Society; Fellow of the Textile Institute; and TAPPI NET division Technical Achievement Award. He has published more than 250 research papers and made over 300 presentations.

Jacqueline A. Daley, is the Senior Director, Infection Prevention at Providence St. Joseph Health in Irvine, California and an infection prevention consultant, a certified Infection Preventionist and an APIC Fellow with over 35 years of experience working in hospitals and ambulatory care settings. Jacqueline is a member of Association for the Advancement of Medical Instrumentation (AAMI) sitting on a number of working groups including Protective Barriers. She is a member of the American Society for Testing and Materials (ASTM) Personal Protective Clothing and Equipment Committee and was the former sub-vice chair for the Biological Hazards Subcommittee. She was a former member of the California Department of Public Health, Healthcare-Associated Infections Advisory Committee. Jacqueline presents at local, national and international conferences and meetings on various Infection Prevention topics including reprocessing of endoscopes, sterilization and disinfection and prevention of

surgical site infections. She has a number of collaborative published articles on prevention of surgical site infections and has authored a chapter on Central Service Leaders and Infection Prevention in the Central Service Leadership Manual published by the International Association of Healthcare Central Services Materiel Management. Jacqueline is a member of APIC, AORN, SHEA, SGNA and Healthcare Sterile Processing (HSPA). She was also named one of the 50 experts leading the field of patient safety by Becker's Hospital's in 2015.

Melissa Dawson, M.S., is an Associate Professor and Program Director of Industrial Design at Rochester Institute of Technology in Rochester, NY. Before transitioning back to academia, Dawson spent eight years in the textiles and apparel industry as a textile and soft product designer. Working for a manufacturer, vendor, and retailer allowed her to learn and experience the textile and soft product design industry from all sides. She has spent both her professional design and academic careers espousing the technological complexities of successful soft product design. Her primary research focuses center on the reclamation and reuse of post-consumer textile waste into new nonwoven composite materials, as well as the Clear Mask Project which emphasizes creating accessible and equitable personal protective equipment (PPE) for underserved populations. Dawson is on the Fulbright Specialist roster and is an active member of Technical Association of the Pulp & Paper Industry (TAPPI); NYSAR3 Textile Council; and W4R: Women for Reduction, Reuse, Recycling, and Rethinking Strategies for Managing Materials. She received her B.S. in Textiles and Apparel from Cornell University and her M.S. in Textile Design from Philadelphia University. She is currently pursuing her Ph.D. in Textile Engineering and Sciences at Thomas Jefferson University.

Elizabeth P. Easter, Ph.D., received her M.S. and Ph.D. in Textile Science from the University of Tennessee-Knoxville. She teaches Textiles for Consumers and Research Methods. Her research in textile science is applied research focusing on protective clothing, laundry fundamentals, and quality evaluations of textile and apparel products. In 1988, Easter established the Textile Testing Laboratory. The laboratory has provided contractual fee-based services to more than fifty corporations and organizations for testing textiles during product development, performance, and durability evaluations. A grant contract with the Association of Linen Management (ALM), the professional organization of facility and laundry managers of healthcare and hospitality laundries, has generated $1,019,855.00 over the past 36 years.

Nicole (Nikki) V. McCullough, Ph.D., CIH, is the Vice President of Application Engineering and Regulatory in the Personal Safety Division of 3M Company based in St. Paul, MN. She has been with 3M's Personal Safety Division for over 26 years working in product development, technical outreach, and regulatory affairs. In her role she has engaged with the occupational health and safety communities regarding the use of personal protective equipment (PPE) in Latin America, Europe, and Asia as well as the US and Canada. Nikki is a Certified Industrial Hygienist and has a PhD from the University of Minnesota in Environmental Health with a focus in Industrial Hygiene where she studied control of airborne infectious diseases using respiratory protection. She has engaged in many forums regarding infectious outbreak and pandemic planning response, published numerous articles, and participated in many conferences focused on improving worker health and safety as well as contributed to standards development activities.

Barbara Strain, M.A., is an independent healthcare value consultant. She is retired from University of Virgina (UVA) Health, where she held various positions including: manager of clinical microbiology, director of value management, director of supply chain operations, director of linen operations, director of surgical supply, and member of the sustainability and safety and security committees. Strain's expertise spans microbiology, virology, disinfection, sterilization, textiles selection and contracting, sustainability assessments, supply chain, and value analysis. She is also a member of the Association of Healthcare Value Analysis Professionals, Healthcare Surfaces Institute (board member), American College of Healthcare Executives, Association of Healthcare Resource & Material Managers, and Bellwether League Foundation (chairman). She has been honored with numerous awards including the Brooke Berson Founder's Award-AHVAP and the Hall of Fame Class of 2021-Bellwether League Foundation.

Kelly N. Wright, M.D., is the Director of the Division of Minimally Invasive Gynecologic Surgery and an Associate Professor of Obstetrics and Gynecology at Cedars-Sinai Medical Center in Los Angeles. She currently serves Cedars-Sinai in several capacities by promoting cost-effectiveness and sustainability in healthcare, implementing enhanced recovery after surgery, increasing telehealth utilization, and decreasing hospital waste production. She serves on Cedars-Sinai's executive sustainability committee and has consulted with medical device companies on reusable equipment and sustainability initiatives. She has given more than 25 keynote talks and grand rounds on healthcare's impact on climate change, pollution, and waste. She lives the reality of medical waste and operating room supply chain processes as a high-volume surgeon. She currently is a Fellow of the American Congress of Obstetricians and Gynecologists and of the American College of Surgeons. She serves as a board member of AAGL and is a member of the Society of Gynecologic Surgeons (SGS). She received a BS in Biomedical Engineering and an MD from Texas A&M University, graduating both programs with honors. She did her residency at the Brigham and Women's and Massachusetts General Hospital combined program in obstetrics and gynecology and her fellowship in minimally invasive gynecologic surgery at Newton-Wellesley Hospital in Massachusetts.

Project Staff

Autumn Downey, Ph.D., is a Senior Program Officer with the Board on Health Sciences Policy. She joined the National Academies of Sciences, Engineering, and Medicine in 2012 and, in addition to the current study, she directs the Standing Committee on Personal Protective Equipment for Workplace Safety and Health. She was formerly the director of the Standing Committee on Medical and Epidemiological Aspects of Air Pollution on U.S. Government Employees and Their Families. Other National Academies studies she has worked on include Meeting the Challenge of Caring for Persons Living with Dementia and Their Care Partners and Caregivers; Evidence-Based Practice for Public Health Emergency Preparedness and Response; Return of Individual-Specific Research Results Generated in Research Laboratories; Preventing Cognitive Decline and Dementia; A National Trauma Care System; Healthy, Resilient, and Sustainable Communities After Disasters; BioWatch PCR Assays; and Advancing Workforce Health at the Department of Homeland Security. Dr. Downey received her Ph.D. in molecular microbiology and immunology from the Johns Hopkins Bloomberg School of Public Health, where she also completed a postdoctoral fellowship at the school's National Center for the Study of Preparedness and Catastrophic Event Response. Prior to

joining the National Academies, she was a National Research Council postdoctoral fellow at the National Institute of Standards and Technology, where she worked on environmental sampling for biothreat agents and the indoor microbiome.

Kelsey R. Babik, M.P.H., is an Associate Program Officer in the Health Medicine Division at the National Academies of Sciences, Engineering, and Medicine. In addition to this workshop, she works on projects initiated by the Committee on Personal Protective Equipment for Workplace Safety and Health. This is a standing committee at the National Academies of Sciences, Engineering, and Medicine sponsored by the National Personal Protective Technology Laboratory of the National Institute for Occupational Safety and Health, to provide a forum for discussion of scientific and technical issues relevant to the development, certification, deployment, and use of personal protective equipment, standards, and related systems to ensure workplace safety and health. Previously, at the Risk Sciences and Public Policy Institute of the Johns Hopkins Bloomberg School of Public Health, she worked on occupational health risk assessments for first responders. She has a B.S. in molecular biology from the University of Pittsburgh, an M.P.H. from the University of Maryland, and is currently pursuing a doctorate of public health (Dr.P.H.) at the University of Illinois Chicago.

Ashley Bologna, M.S, is a Senior Program Assistant in the Health Medicine Division at the National Academies of Sciences, Engineering, and Medicine. In addition to this workshop, she works on projects initiated by the Committee on Personal Protective Equipment for Workplace Safety and Health. This is a standing committee at the National Academies of Sciences, Engineering, and Medicine sponsored by the National Personal Protective Technology Laboratory of the National Institute for Occupational Safety and Health, to provide a forum for discussion of scientific and technical issues relevant to the development, certification, deployment, and use of personal protective equipment, standards, and related systems to ensure workplace safety and health She earned her Master of Science in global health at Georgetown University. She also has a B.A. in international relations and political science from Virginia Wesleyan University.

Laura Runnels, MPH, is the founder of LARC. Prior to founding LARC, Laura was a Senior Program Analyst at the National Association of County and City Health Officials. Laura was born on a mountaintop in Tennessee, raised in a small-town in Mississippi, and educated in Connecticut, California, and Missouri. She has over fifteen years of experience working with local, state, and federal clients. As a convening specialist, she is known for designing and facilitating highly collaborative, efficient, and productive meetings. As a strategist, she guides individuals, organizations, and coalitions through technical and adaptive challenges. Laura earned her Masters Degree in Public Health, Behavioral Science and Health Education from Saint Louis University and earned her Bachelor of Arts in American Studies from Yale University.

Amy Schlotthauer, MPH, is the owner of AES Consulting Firm and collaborator to LARC. She has a Master's Degree in Public Health from the Rollins School of Public Health at Emory University and a Bachelor's Degree in Anthropology from University of Wisconsin-Madison. Amy has over eighteen years' experience in project management, grant writing, program evaluation, qualitative and quantitative research methods and data analysis, group facilitation and consensus building, and using these skills to help clients work collaboratively to answer a pressing public health question. Amy is a member of the American Evaluation Association, Safe States, Milwaukee Evaluation, and Wisconsin Public Health Association. She also serves on the Menomonee Falls

Public Library Board and is a member of the Menomonee Falls Collective Impact project in her hometown of Menomonee Falls, WI.

NATIONAL ACADEMIES Sciences Engineering Medicine

Reusable Health Care Textiles for Personal Protective Equipment – A Workshop

Speaker and Panelist Biographies

LAURIE-ANN AGAMA, M.S., PH.D., is the Acting Assistant U.S. Trade Representative for Textiles, responsible for advising the U.S. Trade Representative on textile and apparel trade policy matters, conducting negotiations affecting textile and apparel products, and working to expand the industry's access to foreign markets. Dr. Agama has served as the Deputy Assistant U.S. Trade Representative for Economic Affairs in the Office of Trade Policy and Economics since 2012, where she has led USTR's strategic planning processes and provided economic analysis and advice for U.S. trade policy development and implementation, trade negotiations, dispute settlement cases and to resolve trade policy and investment-related issues. She joined USTR in 2004 as Director in the Office of African Affairs, where she supported the development of initiatives to enhance U.S. trade and investment relations with the countries in sub-Saharan Africa, including the implementation of the African Growth and Opportunity Act (AGOA). Dr. Agama holds Masters and Doctorate degrees in Economics from McGill University, is an International Career Advancement Program (ICAP) Fellow.

SARA ANGELILLI, DNP, M.S., RN, is the Director of Nursing Education and Professional Practice for Perioperative, Procedural, and Para-Professional Education at Allegheny Health Network. She has 16 years of nursing experience with 7 years in education and professional development. Sara graduated with her doctorate in Nursing Practice with a concentration in nursing administration from Capella University. Sara received dual master's degrees in industrial and organizational psychology and nursing education and leadership. She is dual-certified in perioperative nursing (CNOR) and in nursing professional development (NPD-BC). She participated as a co-investigator on the federally funded grant to explore preferred uses and best practices for EHMR in the healthcare setting and is co-author on several related papers.

GIO BARACCO, M.D., is an adult infectious disease specialist and hospital epidemiologist in Miami, Florida. He is a Professor of Clinical Medicine in the Division of Infectious Diseases at the University of Miami Miller School of Medicine. He is the Associate Chief of Staff for Hospital Epidemiology and Occupational Health at the Miami Veterans Affairs (VA) Healthcare System and serves as Senior Advisor for Emerging Infections to the VA Under Secretary for Health in Washington, D.C. Baracco has a long-standing interest in healthcare epidemiology and healthcare preparedness and response to high consequence infections. He has authored multiple

papers on emergency stockpiles, including tools to understand cost implications of reusable PPE and stockpiling priorities.

BARBARA DEBAUN, M.S.N., RN, CIC, has over 40 years of experience in the fields of infection prevention, patient safety and quality improvement. She provides coaching and team facilitation to healthcare facilities of all sizes from large academic medical centers to critical access hospitals. Barbara earned her Bachelor of Science in Nursing degree from Pace University in New York and her Master of Science Nursing degree from San Francisco State University. Barbara's infection prevention career has been bookended by two pandemics. She was a pioneer in the early days of HIV/AIDS who championed healthcare worker safety and protection from bloodborne pathogen exposures. She has extensive experience navigating the challenges the COVID-19 pandemic posed on personal protective equipment availability and efficacy.

LUCY E. DUNNE, PH.D., is a professor in the Department of Design, Housing, and Apparel in the College of Design at the University of Minnesota. She is also co-director of the Wearable Technology Lab. Dr. Dunne is a co-author (with Susan Watkins) of "Functional Apparel Design: From Sportswear to Space Suits" (Fairchild Books, 2015). Her research is focused on wearability and garment-based wearable technology, and explores new functionality in apparel, human-device interfaces, production and manufacture, and human factors of wearable products. Dunne has received the National Science Foundation's CAREER award and the NASA Silver Achievement Medal for her work with functional clothing and wearable technology.

PAMELA FALK, M.P.H., CIC, FSHEA, FAPIC, has worked in the infection control field for more than 40 years, and is currently the President of Pamela S Falk Consulting. She is a fellow of Association for Professionals in Infection Control and Epidemiology (APIC) and Society for Healthcare Epidemiology of America (SHEA). She has experience in university and community acute care and ambulatory healthcare settings. She holds a Master of Public Health in Infectious Diseases Epidemiology from the University of Michigan and is certified in Infection Control. She has authored many papers, and presented nationally at APIC, SHEA, and the American Medical Association (AMA). Falk was the APIC representative during the creation of the Centers for Disease Control and Prevention (CDC)/Johns Hopkins instructional video for donning and doffing for Ebola, edited the voice over copy, and is seen in sections of the video. She edits sections of the The Joint Commission/Occupational Safety and Health Administration Course Review and Updates for Elsevier publishing. Falk is an APIC Consultant and is the past Education Chair of the Atlanta APIC chapter. She is the creator of The Don and Doff Fashion Show at the 2015 and 2016 National APIC Live show and created Battles of the IP (Jeopardy) game at the 2017 and 2018 National APIC Live show. She also created the section of the APIC skills lab "Outpatient Infection Prevention." Falk is a past member of the APIC National Education Committee. Most recently she has been working with acute care facilities, long term care facilities and ambulatory care sites on issues related to COVID-19. Her focus has been on hand hygiene, proper use of personal protection equipment (PPE), including extended use of PPE, and cleaning and disinfection of the environment. Pam currently lends her experience of COVID-19 to the national APIC COVID-19 task force. Falk has lent her epidemiology experience to many legionella projects

in several institutions including investigating legionella outbreaks, creating a water management plans, and developing a water testing program. She attends the CDC Healthcare Infection Control Practices Advisory Committee (HICPAC) committee meeting on a regular basis to keep up with the most recent guidelines.

SHAWN G. GIBBS, Ph.D., M.B.A., CIH, is Dean of the Texas A&M University School of Public Health. Shawn has over a hundred articles in industrial hygiene focusing on disrupting transmission of high consequence infectious diseases. He is a member of the Board of Directors of Global Environmental Health and Safety (EHS) Credentialing and Clinical Laboratory Improvement Advisory Committee Biosafety Working Group. He was a Member of the U.S. Environmental Protection Agency (EPA) Board of Scientific Counselors for Homeland Security and the Southeastern Conference Medical Task Force. He was a U.S. Faculty Fulbright Scholar to Egypt and primary investigation of three Fulbright Faculty Development Programs. At Nebraska Biocontainment Unit, he led and performed aeromedical evacuation, waste handling, and safety and risk reduction involved in the treatment of confirmed and under investigation patients with Ebola virus disease in Nebraska and the United States. His research helped determine national policies, procedure, and best practices for response to Ebola virus disease, COVID-19, and other high consequence infectious diseases.

DAN GLUCKSMAN, is the Public Affairs Director at the International Safety Equipment Association (ISEA). He is known as a strategic and goal-oriented association professional, who has taken ISEA's government relations programs to new levels. He provides ISEA member companies with actionable insights on federal policies allowing these employers to grow revenue and minimize risk. He has led several Congressional and regulatory visits for manufacturing executives to achieve strategic objectives. His event management and planning skills have led to successful annual meetings and executive summits. In addition, his team-oriented approach has led to successful events. He has expanded stakeholder engagement through coalition participation and direct outreach. These activities have led to strategic alliances that move the association forward.

JACK HOLMBERG, RN, is an Infection Preventionist at Providence Willamette Falls Medical Center (PWFMC), practicing as a Registered Nurse in the Emergency Department for nearly 10 years before transitioning to Infection Prevention and Control. He holds a Bachelor of Science in Environmental Studies and a genuine interest in sustainability, environmental health, and Infection Prevention. Holmberg believes there is much opportunity to improve sustainable practices in the health care field. Contrary to widespread belief, he thinks Infection Prevention can play a pivotal role in identifying new sustainable practices. He is Co-chair of the Green Team at PWFMC and enjoys collaborating with a multidisciplinary team to solve complicated problems while looking for ways to keep patients safe and reducing Providence's carbon footprint. In his free time, he enjoys spending time with his family, being outdoors, and playing music.

LOUISE KING, M.D., J.D., is an Assistant Professor of Obstetrics, Gynecology and Reproductive Biology at Harvard Medical School and a Surgeon within the Division of Minimally Invasive

Gynecologic Surgery at Brigham and Women's. Dr. King completed her juris doctorate at Tulane Law School before attending medical school at University of Texas Southwestern Medical Center. She completed her residency in obstetrics and gynecology at Parkland Hospital in Dallas Texas and her fellowship in Minimally Invasive Surgery with Dr. Camran Nezhat at Stanford University. Her areas of interest in medical ethics focus on questions of informed decision making and assisted reproduction as well as equitable access to advanced gynecologic surgery.

MARYANN D'ALESSANDRO, PH.D., has served as the Director of the National Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) since March 2012. She also served as the Associate Director for Science for NPPTL from 2003-2012. Maryann provides leadership to the NIOSH Personal Protective Technology (PPT) Core and Specialty Program and the Public Safety Program where she serves as the Manager leading the effort to align PPT initiatives with user needs across all workplace industry sectors. Within the PPT Program, Maryann has served as the catalyst for aligning surveillance, research, standards, certification, outreach and intervention activities to improve workplace safety and health. She has played a key role in the COVID-19 response including leading personal protective equipment research, respirator conformity assessment, combatting counterfeit and substandard PPE, and addressing respiratory protection needs for the general public.

JAMES MARVEL, M.D., is a Clinical Assistant Professor of Emergency Medicine at Stanford University. His clinical focus is on emergency and wilderness medicine. Dr. Marvel is also a member of the Wu Tsai Human Performance Alliance. Dr. Marvel earned his MD from Columbia University College of Physicians and Surgeons and completed a fellowship at Stanford University Emergency Medicine.

EDWARD MCCAULEY, M.B.A., has been in the laundry business for nearly 40 years. He started in 1983 with AraTex Uniform in Bethlehem, PA then moved on to Hospital Central Services Cooperative Laundry in Allentown, PA. At the Hospital Services Cooperative Laundry he held several mid-level management positions and finally moved to United Hospital Services in Indianapolis where he has been for the past 22 years as the COO and CEO. Ed has spent time on several industry related boards including the International Association of Healthcare Textile Managers (IAHTM), the American Reusable Textiles Association (ARTA), the Healthcare Laundry Accreditation Council (HLAC) in addition to the Make-A-Wish Foundation of Ohio, Kentucky, and Indiana. Mr. McCauley has a BS from Penn State University and an MBA from Wilkes University.

MEREDITH MCQUERRY, Ph.D., is the Carol E. Avery Associate Professor of textile science in the Jim Moran College of Entrepreneurship at Florida State University. She directs the ThermaNOLE Comfort Lab® and Textile Testing Laboratory where her research focuses on engineering better performing personal protective clothing and equipment for multiple end user applications. Her work focuses primarily on reusable personal protective equipment (PPE) for healthcare workers, first responders, soldiers, and athletes. She has received nearly $4 million in research funding including a $1.5M grant from Federal Emergency Management Agency (FEMA) to continue to explore the development of better fitting female firefighting gear. Work led by Dr. McQuerry on

disposable versus reusable medical gown performance has been recognized internationally as it identifies the advantages of reusable gowns in a primarily disposable market. In total, Dr. McQuerry's work has been published through more than 30 journal articles and more than 80 presentations.

CHARLIE MERROW, is the Chief Executive Officer and Managing Director at The Merrow Group Companies. Mr. Merrow is also on the Southcoast President's Council at Southcoast Health, the Academic Center for Entrepreneurship Advisory Committee at Bristol Community College, and the Advisory Board Member Charlton College of Business at University of Massachusetts Darthmouth. Mr. Merrow attended DePauw University and Cheltenham College.

JILL MORGAN, B.S., is a nurse with over thirty-five years of bedside experience in emergency and critical care medicine. She is on Emory's biocontainment team and cared for Emory's viral hemorrhagic fever patients. She now serves as the site manager for the Emory biocontainment unit and has worked to validate the unit's protocols, including the inactivation of Category A waste and the safe doffing of complex personal protective equipment (PPE) ensembles. She is a PPE subject matter expert and co-lead of the PPE Working Group for National Emerging Special Pathogens Training and Education Center (NETEC), the National Emerging Special Pathogens Training and Education Center, an Administration for Strategic Preparedness and Response (ASPR) funded organization charged with improving the readiness of the US healthcare system for infectious pathogens. For NETEC, she helps create and deliver frontline education, evaluate ensembles, protocols, and plans, and assess the readiness of healthcare facilities. She is a member of ASTM, Association for the Advancement of Medical Instrumentation (AAMI), and Association for Professionals in Infection Control and Epidemiology (APIC).

MICHAEL OVERCASH, PH.D., is the Executive Director of the Environmental Genome Initiative which has one of the largest chemical life cycle databases. He has set the standards for the quality control and peer review of all the environmental genome elements to date (about 1,600 chemical plant analyses). He is on the Board of Directors and is helping to develop the various utilization communities that will develop analytics for the open-source environmental genome database. Dr. Overcash served as a Professor in Chemical Engineering and in Biological and Agricultural Engineering at North Carolina State University. Recently he served as the Sam Bloomfield Chair in Sustainable Engineered Systems at Wichita State University. His life cycle research work has focused on healthcare, reusable textile technology, recycling of chemicals, and prevention of hospital acquired infections. He received his Ph.D. from the University of Minnesota in Chemical Engineering.

SHELLEY PETROVSKIS, is the Director of Marketing and Regulatory Affairs for Lac-Mac Limited, a manufacturer of high-performance personal protective equipment (PPE) for Health Care and other industrial markets. With over 42 years' experience marketing and promoting the environmental merits of reusable health care textile products, she has a deep understanding of the many benefits reusables can deliver. She has a wide range of experience with the complexity of manufacturing reusable technical PPE, and the standards and compliances to meet regulatory requirements which govern medical devices. Shelley is an active member of American Reusable

Textile Association (ARTA), Textile Rental Services Association (TRSA), American Linen Management (ALM) and supports International Association for Healthcare Textile Management (IAHTM). She has an understanding around the challenges presented and the rewards observed when converting from a disposable program. Her expertise around technical barrier products, provides a solid foundation for supporting customers through their journey to more sustainable products.

LIZ REMILLONG, BSBA, is currently a VP for Core Linen Services (formally Crothall Laundry Services) with over 40 years commercial healthcare laundry management experience. Liz has provided hospital linen rental services or linen processing services to health systems across the country, including Alaska and Hawaii. Liz has provided management services to numerous healthcare cooperative laundries as well as consulting services to Health Systems and Laundries looking for improvements. Liz's vast and varied experience in the commercial healthcare laundry space enables her to be considered a subject matter expert in this space. Additionally, Liz is a Board Member for TRSA (Textile Rental Services Association), on the Advisory Board for TRSA's Hygienically Clean certification, a member of ALM (Association for Linen Management), ARTA (American Reusable Textile Association) and numerous other healthcare related organizations and associations.

ELIZABETH SCHENK, Ph.D., RN, FAAN, serves as Chief Environmental Stewardship Officer for Providence, one of the nation's largest non-profit health systems. Schenk and team lead Providence's efforts through strategy and innovation, efficiency of practices and processes, and research, education, and engagement, built on her experience decreasing the environmental impacts of health care for over 30 years. She is an assistant research professor at Washington State University College of Nursing. She led the development of CHANT: Climate and Health Tool, measuring health professionals' awareness and engagement with climate change and health. CHANT has been translated to several languages and used in over 40 nations. She developed the WE ACT Framework (Waste, Energy/water, Agriculture/food, Chemicals, Transportation) to organize the extensive range of environmental stewardship, while motivating action. She is active at national, state, and local levels, serving on the Expert Panel on Environmental and Public Health for the American Academy of Nursing. She is treasurer for the state organization Montana Health Professionals for a Healthy Climate, and board chair for the local organization Climate Smart Missoula. She hosts the Nurses for Healthy Environments Podcast, now in its sixth season.

LYNNE SEHULSTER, PH.D., was previously part of the Division of Healthcare Quality Promotion National Center for Infectious Diseases at the Centers for Disease Control and Prevention.

MARK SHIRLEY, M.S., is the Director of Integrated Resiliency Management in the Office of the General Counsel at Sutter Health. He provides corporate-level leadership and guidance across a broad range of environmental health, safety and emergency management operations in support of risk mitigation, regulatory compliance and organizational resiliency. Mr. Shirley received his Master's Degree in Environmental Management from the University of San Francisco in 2000 and has been a Board Certified Safety Professional since 2006. He currently serves as a member of the

California Department of Public Health's Joint Advisory Committee on Public Health Preparedness, the California Hospital Association's Emergency Management Advisory Committee, and the Hospital Incident Command System National Advisory Executive Committee.

ERIKA SIMMONS, M.B.A., is the Technical Director at the American Association of Textile Chemists and Colorists (AATCC) where she is accountable for AATCC standards development, research committees and testing materials support. Prior to AATCC, she worked for a branded apparel company where she held various roles in product development, International Standards Organization (ISO) 17025 lab accreditation management and customer compliance. She received her M.B.A. from Wake Forest University and an undergraduate degree in Textile Engineering from N.C. State University.

SKIP SKIVINGTON, M.B.A., is the Vice President, Health Care Continuity and Support Services at Kaiser Permanente. Skivington concurrently served as the Interim Vice President of Supply Chain during the period of 2005 to 2009, and from 2015 to 2017 led Kaiser's security services program. Since 2000, he has been responsible for the implementation of a formal healthcare continuity management program throughout Kaiser Permanente. In addition to directing this formal planning and response process, and immediately following the anthrax attacks in October 2001, he formed and now directs Kaiser Permanente's threat assessment program consisting of an executive oversight council, and functional working groups in the disciplines of clinical (physicians, nursing, pharmacy, mental health and lab), facilities, community linkages, people, legal, communications, training, supply chain and public policy. He serves as Kaiser Permanente's National Incident Manager during wide scale events such as the Ebola crisis from 2014 to 2015 and the California Wildfires in 2017. Following Hurricanes Katrina and Rita, Skivington led two Kaiser Permanente volunteer medical response teams consisting of physicians, nurses and mental health providers to the Gulf Region at the specific request of the US Surgeon General and was part of the largest medical volunteer response program in the history of the country. Skivington holds both a Bachelor of Science Degree in Business Administration, and an MBA.

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methodologies, towards emotional durability, social and sustainable design. Dr. Townsend has collaborated with different groups of 'overlooked wearers', including older women (Emotional Fit, 2017-2020) homeless and vulnerable people (NTU X Emmanuel House, 2020-2023). Her AHRC-funded project, Redesigning PPE: enhancing the comfort and safety of healthcare workers wearing isolation gowns to treat patients with COVID-19 (2021-2023) resulted in a Circular Gown System informed by user and environment-centred approaches. Related research is focused on developing PPE repurposing solutions, and menopause-aware workwear to mitigate the discomfort - particularly heat stress - experienced by women working in the healthcare sector. Dr. Townsend is lead editor of Crafting Anatomies (Bloomsbury, 2020) and the journal of Craft Research (Intellect).

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Updated June 7, 2018

Key Terms

Term	Definition
• Circular Economy/Circularity	A system where materials never become waste, the life of the product is extended, and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources.
• Healthcare Setting	Places where a broad array of healthcare services occurs, including acute care hospitals, urgent care centers, rehabilitation centers, nursing homes and other long-term care facilities, specialized outpatient services, and outpatient surgery centers.
• Healthcare Textiles (HCTs)	Fabric-based products that touch patients and employees directly or indirectly on a daily basis in a healthcare setting.
○ Disposable HCT	Generally, serve only as single-use products in healthcare facilities and many other institutional protective clothing applications for a given length of time. After usage, these have to be immediately discarded as hazardous materials.
○ Reusable HCT	Can be repeatedly used in healthcare facilities. After each usage, the textiles should be laundered following the CDC's guidelines (CDC, 1997, 2001). When laundered, the used textiles are not only cleaned but also disinfected with bleaching agents such as diluted sodium hypochlorite solution or concentrated hydrogen peroxide solution.
• Healthcare Worker	Any individuals working within a healthcare setting who would need to use healthcare PPE or come into direct contact with healthcare PPE.
• Life-Cycle Analysis (LCA)	A systematic analysis of environmental impact over the course of the entire life cycle of a product, material, process, or other measurable activity. LCA models the environmental implications of the many interacting systems that make up industrial production.
• Life Span	Time interval from when a product is sold to when it is discarded

Key Terms

Term	Definition
• Personal Protective Equipment (PPE)	Equipment worn to minimize exposure to a variety of hazards. Examples include gloves, foot protection, face and eye protection, protective hearing devices (earplugs, muffs) hard hats, respirators, and full body suits.
○ Healthcare PPE	PPE designed to protect the wearer from injury or the spread of infection or illness. Examples include gloves, face and eye protection, gowns, respirators, and full body suits.
○ Disposable PPE	PPE designed to be used only one time and by one person prior to disposal.
○ Reusable PPE	PPE designed to be reused and able to withstand numerous cleanings, decontaminations, launderings, and sterilizations. For the purposes of this workshop, the Planning Committee considered the following items to be included in as reusable PPE for health care: isolation gowns, surgical gowns, reusable elastomeric half-mask respirators (EHMRs).
• Standards Organizations	Organizations whose primary function is developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise contributing to the usefulness of technical standards.
○ AAMI	Association for the Advancement of Medical Instrumentation
○ AATCC	American Association of Textile Chemists and Colorists
○ ANSI	American National Standards Institute
○ ASTM	American Society for Testing and Materials
• Value Analysis	Evidenced-based, systematic approach to review healthcare products, equipment, technology and services. Using recognized practices, organizational resources collaborate to evaluate clinical efficacy, appropriate use and safety for the greatest financial value.
• Value Chain	An analytical way to disaggregate a company into its strategically relevant activities in order to focus on the sources of competitive advantage, that is, the specific activities that result in higher prices or lower costs.

NOTE: These definitions/descriptions were complied for the purposes of this workshop. In some cases, the Planning Committee clarified or expanded on them. However, every effort was made to be consistent with existing definitions/descriptions from standards organizations and regulatory agencies.

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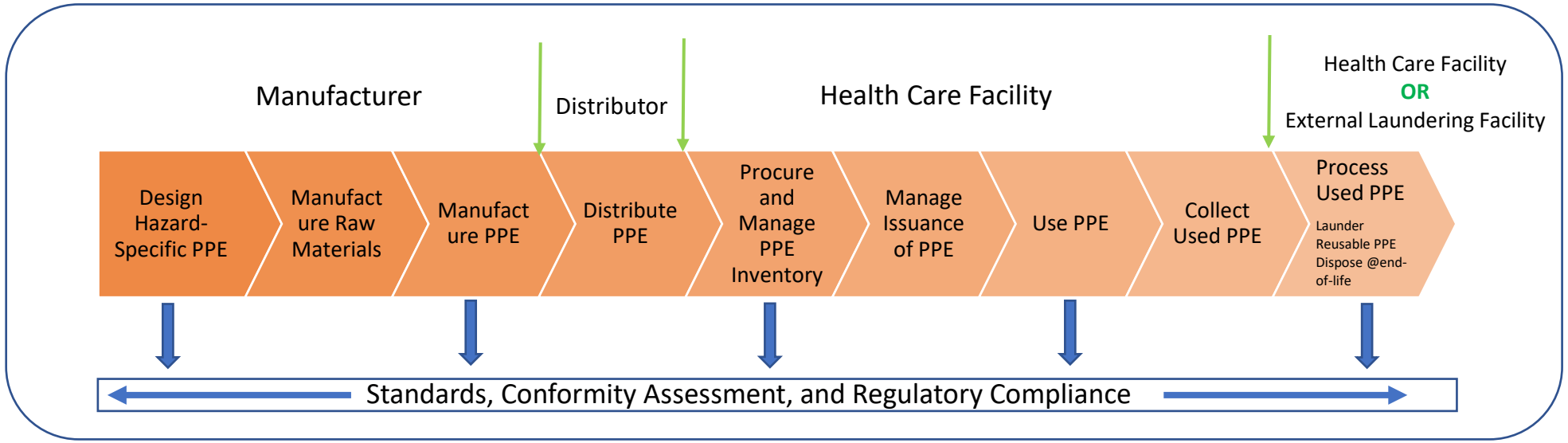
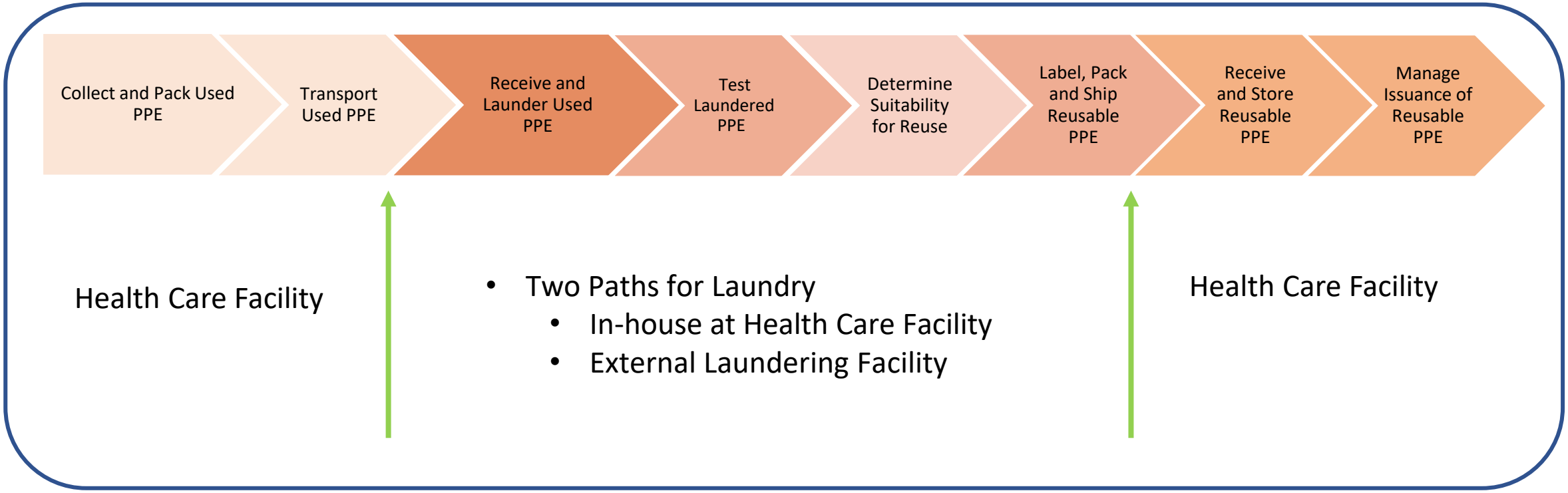
The PPE Ecosystem: Design to Reuse / Disposal



This figure shows the major operations in the PPE Ecosystem.

Figure courtesy of Sundaresan Jayaraman, Beth Beam, Jacqueline Daley, Melissa Dawson, Elizabeth Easter

Reusable HCT Laundry Process: The Unit Operations



This figure shows the unit operations in the decontamination process of **Reusable HCTs**.
Note: The washing process for reusable elastomeric respirators are not shown here.

Figure courtesy of Sundaresan Jayaraman, Beth Beam, Jacqueline Daley, Melissa Dawson, Elizabeth Easter

Relevant AAMI Standards for Isolation and Surgical Gowns

Purpose	Description	Test Method	Test Name	Parameters Evaluated	Metrics for Passing
AAMI Level 1	Used for MINIMAL-risk situations. *Example:* basic care	AATCC 42	Test Method for Water Resistance: Impact Penetration	Minimal water resistance (some resistance to water spray)	<4.5g
AAMI Level 2	Used in LOW-risk situations. *Example:* vein blood draws, pathology labs	AATCC 42	Test Method for Water Resistance: Impact Penetration	Low water resistance (resistance to water spray)	< 1.0g
		AATCC 127	Test Method for Water Resistance: Hydrostatic Pressure		> 20 cm
AAMI Level 3	Used for MODERATE-risk situations. *Example:* arterial blood draws, ER/trauma departments	AATCC 42	Test Method for Water Resistance: Impact Penetration	Moderate water resistance (resistance to water spray)	< 1.0g
		AATCC 127	Test Method for Water Resistance: Hydrostatic Pressure		> 50 cm
AAMI Level 4	Used for HIGH-risk situations. *Example:* pathogen and infectious disease (non-aerosolized)	ASTM F 1670	Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Synthetic Blood	Blood and viral penetration resistance	Pass (at 2 psi)
		ASTM F 1671	Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood-Borne Pathogens Using Phi-X174 Bacteriophage Penetration as a Test System		Pass (at 2 psi)
Laundering	Laundering	AAMI/ANSI ST65:2000	Processing of Reusable Surgical Textiles for Use in Health Care Facilities	• design criteria for all applicable work areas • staff qualifications • transporting, receiving, handling, storage • laundry processing (loading, washing, drying) • inspection, testing, and maintenance of laundered textiles • preparation and packaging of laundered textiles • installation, operation, care, maintenance of laundry equipment • quality control measures, procedures, and practices • medical device regulatory considerations	

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Reusable Health Care Textiles for Personal Protective Equipment: A Workshop

Selected Readings

Background – Medical Gowns and Healthcare Laundry

An Evaluation of the Barrier and Durability Performance of Reusable Level 2 Isolation Gowns Over Their Promoted Service Life | Easter et al, 2023

Medical Gowns | FDA, 2024

Understanding AAMI: 5 Things to Know About Protection in The Operating Room | Halyard, 2019

Healthcare Laundry Accreditation Council (HLAC): Accreditation Standards | HLAC, 2023

Disposable versus reusable medical gowns: A performance comparison | McQuerry et al, 2020

Choosing isolation gowns: How to know the right barrier protection | Medline, 2022

Considerations for Selecting Protective Clothing used in Healthcare for Protection against Microorganisms in Blood and Body Fluids | NIOSH, 2020

Human Factors

Clinical Challenges in Isolation Care | Beam et al, 2015

Method for investigating nursing behaviors related to isolation care | Beam et al, 2014

Out of isolation: Designing reusable PPE gowns based on an understanding of healthcare workers' lived experiences | Townsend, et al, 2022

User experience of wearing comfort of reusable versus disposable surgical gowns and environmental perspectives: A cross-sectional survey | van Nieuwenhuizen et al, 2023

International Perspectives

European Safety Federation (ESF) reflections on sustainability of PPE | ESF, 2020

Reusable PPE in Canadian healthcare: Safe, secure, and sustainable | Varangu et al, 2023

Transforming Our World: The 2030 Agenda for Sustainable Development | United Nations, 2015

Global Analysis of Health Care Waste in the Context of COVID-19 | WHO, 2022

Lessons Learned from Surge Use

COVID-19 Solutions Are Climate Solutions: Lessons From Reusable Gowns | Baker et al, 2020

Comparative Cost of Stockpiling Various Types of Respiratory Protective Devices to Protect the Health Care Workforce During an Influenza Pandemic | Baracco, 2015

Pandemic Operating Room Supply Shortage and Surgical Site Infection: Considerations as We Emerge from the Coronavirus Disease 2019 Pandemic | Malhotra, 2022

THREADS: Innovation for healthcare textiles & EVS – Helping healthcare recover together | Medline, 2020

Sustainability - Environmental and Economic

Reusable versus Disposable PPE | Agency for Healthcare Research and Quality (AHRQ), 2020

How medicine becomes trash: disposability in health care | Greene et al, 2022

Reusable and Disposable Incontinence Underpads: Environmental Footprints as a Route for Decision Making to Decarbonize Health Care | Griffing et al, 2023

Environmental footprints of disposable and reusable personal protective equipment – a product life cycle approach for body coveralls | Hiloidhari et al, 2023

End-User Preferences for Sustainability in PPE and Safety Equipment | International Safety Equipment Association, 2023

Sustainable Personal Protective Clothing for Healthcare Applications: A Review | Karim et al, 2020

The impact of switching from single-use to reusable healthcare products: a transparency checklist and systematic review of life-cycle assessments | Keil et al, 2023

National Economic and Environmental Benefit of Reusable Textiles in Cleanroom Industry | Overcash et al, 2022

The University of Maryland Medical Center: Reusable Textiles in the OR | Practice Greenhealth, 2013

An Environmental Analysis of Reusable and Disposable Surgical Gowns | Vozzola et al, 2020

Environmental considerations in the selection of isolation gowns: A life cycle assessment of reusable and disposable alternatives | Vozzola et al, 2018

Please contact project staff if you run into access issues.

ESF reflections on sustainability of PPE

Date : 23/10/2020

The COVID crisis has put PPE, at least some types, in the spotlight of a more general public than usual. Given the huge amounts of disposable PPE being used during the crisis, the amount of waste generated by these PPE creates concerns.

There is no reason for the PPE sector not to contribute to the ‘green deal’ and ‘digital economy’ efforts made by the EU Commission, and the suppliers are certainly willing to do so.

In our view, there are different aspects to the issue :

- The product itself
- The packaging
- The printed user instructions
- The logistics

All those aspects create waste and other environmental burden (such as global climate change or use of natural resources) and should be considered when discussing sustainability.

Product itself

In order to be able to offer more sustainable solutions, manufacturers are engaged in research activities on materials, designs and maintenance (cleaning / decontamination / disinfection). Also the application of the PPE is an important factor (e.g. contaminated with chemical or biological agents requires specific treatment, also for the waste).

Many types of PPE are re-usable. But there are indeed also a number of PPE items (and specifically those mostly used in healthcare) that are single use for different reasons. One reason is certainly economical : re-usable solutions are often more expensive to produce and purchase. However, it is of course important to consider the total cost of ownership (TCO). Calculating TCO is often quite complicated and therefor it is not done or not correctly done. Efforts from authorities and standardisers to facilitate the calculation of TCO would certainly be helpful.

Another reason is practical : for PPE that require cleaning, decontamination or disinfection after each use, a logistical system has to be set up to get the used PPE to the relevant specialists for treatment and then back to the users. This is often seen as to big a burden for all concerned parties, especially at the users where separated collection systems (per type of PPE and/or per type of contamination) are needed

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close to the wearers of the PPE. Such logistical systems also require some volume to be economically viable. A good example of an well-functioning, existing system is the textile services sector, which has a huge experience in workwear, including protective clothing.

There is certainly a role for public purchases / tenders where typically the purchase cost is an important consideration and where the product purchase is separated from the necessary services linked to those products.

Packaging

The choice of the packaging material, the design of the packaging but also the amount of PPE per packaging will have an important impact on the environmental burden created by the packaging. All concerned parties need to take these aspects into consideration when producing/ordering/using PPE. Cooperation between the different stakeholders can certainly lead to more sustainable solutions.

Packaging is protecting the product, enabling its transportation and often informing the user about its functionality, and this in line with the legislative framework.

Design, amount and material of packaging importantly affect the environmental footprint of products and supply chains as well as effective waste management.

It is therefore critical for PPE manufacturers to make the right packaging choices within the framework of the European and national legislation.

Examples of choices with positive impacts are: use of recycled materials, responsible source materials, change towards fully recyclable material, choice of mono-material for packaging component facilitating recycling, additional customer guidance on recycling, reduction of plastic use or removal of unnecessary packaging.

Examples of key burdens PPE manufacturers face in reducing packaging waste are the current need for large quantity of printed mandatory information on products and product packaging or printed user instructions (see also specific part of this paper related to printed user instructions).

While a lot of the choices towards more sustainable packaging can be made by each individual PPE manufacturer, a collaboration with the European Commission as well as national authorities is required when it comes to driving reduction of packaging waste through adaptations of the legislative framework to facilitate positive environmental footprint while safeguarding the end user rights and protection.

Printed user instructions

The PPE Regulation (EU)2016/425 obliges manufacturers to provide information for the user in the appropriate language with each PPE (or the smallest commercial packaging). The guidance to this Regulation stipulates that these need to be in printed form. ESF has already shared concerns about the environmental impact of this obligation in the past.

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The primary purpose of the user instructions is to inform the wearer of the PPE about the protection offered and give instructions/warnings for the correct, safe use of the PPE. To attain this purpose, it is essential to keep the instructions as clear as possible. Which also means, only give the information that is crucial for the wearer of the product. Any other information should be kept separately in order to prevent that wearers are not reading the instructions for reasons of information overload.

Currently, the guide on the PPE Regulation 2016/425 obliges the manufacturer to include the instructions in printed form with each PPE (or the smallest commercial packaging). Looking at the amount of information most (harmonised) standards require to be included in the instructions and the type of information (mostly information necessary for specialists to be able to correctly select or maintain the PPE), it is no wonder that the wearers are not reading this information. Hence the main purpose of the instructions is lost.

It has to be noted that in most cases, the user instructions are added with the PPE in the packaging. However, for some types of PPE, it is common to have the instructions printed on the packaging.

Calculating the environmental footprint of the user instructions supplied in paper format with each PPE is as good as impossible seen the wide variety of products. However, we did make some estimations :

- Number of smallest commercial packaging units of PPE in the EU per year : 700.000.000
- Average weight of the current user instructions : 15 g (for complex PPE available all over the EU, we see instruction books of 700+ g)
- This results in 10.500 tonnes of paper per year
- Based on an estimation that 24 trees are necessary to produce 1 tonne of paper, this means 250.000 trees per year. With an average of 400 trees per ha, this means 630 ha or the equivalent of about 950 football fields per year.
- 10.500 tonnes of paper represents about 19.000 m^3 of volume to be transported, meaning about 625 containers.
- Taking into account the complete supply chain, we estimate that the paper for the user instruction travels on average 10.000 km (from paper mill to printer to PPE manufacturer production site to importer to distributors to users to paper recycling mill or waste disposal site).

For purpose of the discussion, we divide the PPE wearers in two distinct segments :

a) Professional users (B2B): in this case, the wearer does not purchase his/her own PPE nor makes own decisions about its selection. The purchase is realized by his employer. In this case, EU Directive 89/656 (use of PPE in the workplace) obliges the employer to make the necessary risk assessment, select and provide the correct PPE and provide mandatory training to his employees, i.e. PPE wearers.
   It is to be noted that most of the professional wearers use the same type of PPE repetitively over a longer period of time.
   In this case, it is most important to provide the employer all the necessary information before the purchase and support the employer with the information

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needed to best comply with his/her obligation (e.g. training) as per the above Directive 89/656.

b) Consumers (B2C): in this case, the wearer purchases the PPE on his/her own and makes his/her own risk assessment and choice.
In this case, it is most important that the necessary information to make a correct choice is made available before the purchase to avoid health and safety risks.

Observed practices and needs :

For professional wearers :

- The employer receives the PPE, stores and prepares (e.g. pre-wash of clothing; 'vending machine' for internal distribution at employer's site (see e.g ESF Q&A 0069)) for internal distribution of the correct PPE to the wearers in line with the employees' tasks and assessed risks and protection needs.
- The obligation for information and training lies on the employer, in line with the Directive 89/656 mentioned above.
- It is therefore important for the PPE manufacturers to ensure the employers are duly informed on the use of the product and have all necessary information available from the PPE manufacturers to perform their employer obligations towards the wearers.
- It is our conviction that if a wearer would like to access the PPE manufacturer's information, the best way would be in electronic format (e.g. accessible via a QR code). This also allows for the employer to make the instructions available in the languages of his/her employees and/or include company specific instructions and information (e.g. video made in own workplaces, were to deposit PPE that need cleaning, …).
- It also needs to be remarked that once an industrial wearer is trained and used to work with a specific type of PPE, he does not need the instructions with each new piece of PPE. We have to take into account that for different types of PPE (not only single use PPE), the wearer will use several pieces of the exact same PPE (e.g. he will have several pairs of safety shoes, of protective garments – this to allow for timely cleaning).
- In reality the vast majority of printed instructions is thrown in the trash without reading.

For consumers :

- If the wearer is making his/her own decision of the use of the PPE for private use, we endorse the need to inform the wearer about the product and help guide him/her to make the correct choice for own health and safety. However, this information needs to be available before the purchase and at the point of purchase (or online as many consumers do some research online before buying products). If available in the instructions included inside the packaging, the necessary information is not available at the right moment.
- In reality, we notice that vast majority of wearers of PPE do not read the supplied user instructions. One of the reasons being that, certainly younger generations, are not willing to read lengthy explanations. This can cause health and safety issues by lack of correctly informed wearers.
- Also for consumers, having the instructions available in electronic format is an advantage as they can access them before the purchase on the one hand,

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they only have to look at the information in their own language, which makes it a shorter document than a booklet with several languages included, and the manufacturer can easily include video or other media to show correct use.

Recital 18 of the PPE Regulation 2016/425 reads : “Efforts should be made by economic operators to ensure that all relevant documentation, such as the user's instructions, whilst ensuring precise and comprehensible information, are easily understandable, take into account technological developments and changes to end-user behaviour, and are as up to date as possible. When PPE is made available on the market in packages containing multiple units, the instructions and information should accompany each smallest commercially available unit.”.
Footnote 99 with paragraph 3.1 of the Blue Guide, also allows for electronic format for the instructions.

Taking into account the above, ESF suggests allowing manufacturers the following alternatives for the printed instructions, which can be introduced without decreasing safety/protection while improving the environmental impact :

For the professional use, where the employer is responsible for the PPE selection, purchase and care and maintenance, we propose the following :

- Transition from printed to electronic version of the instructions entirely. This makes it possible to include visual instructions such as video.
- Provide additional information to the specialists, mainly the Health and Safety Officers of organizations, to help them make the correct choices for the PPE.
- For professional wearers, the employer can organise the instructions on the internal network (which is in fact already done by some employers anyway as the printed instructions are thrown away when unboxing the PPE) and make them available for their employees in a simple structured way (and in the language of the employee, which is not necessarily the language of the country where he/she works).
- Moreover, through direct (e.g. via QR code) electronic links to the product information and the video material, also the professional wearer will have easier access to relevant product information in the desired language as opposed to 30+ technical language information available today which mostly doesn’t reach the professional wearer at all.

This way the health and safety of the industrial wearers will be maintained, perhaps even increased through improved access to more tailor-made information and at the same time we will secure an important positive environmental impact.

For the consumers, where the individual wearer makes the PPE selection and purchase, we propose the following:

- In principle, we also suggest allowing the PPE manufacturers to make the instructions available in electronic format, indicating with each PPE a simple way to get access to the instructions (e.g. link via QR code).
- Collaboration within the supply chain to evaluate the means for fair access of consumers to the information as well as the optimized and practically useful type (and amount) of information that will help the wearers make the right PPE choices. This includes information available before purchase, in the language

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of the consumer, possibility for the instructions to be printed at point of sales, …

- This way, the wearer would always have the instructions available in his own language.
- The vast majority of EU citizens are used to working with electronically available instructions, as is the case for e.g. electric/electronic consumer devices (at best a 'quick start' guide is available in printed form with the product – detailed instructions are only electronically available) so we have no reasons to believe that such type of access would not work for those individual PPE wearers.
- For consumers, the distributor can also offer to print the instructions on request, but then only in the language required by the consumer. This is a simple, quick way to decrease the environmental burden without jeopardising the safety of the users.

Lastly, the pandemic times have offered a precedence in the approach to the discussed topic. We have observed the millions of disposable masks, disposable gloves and other products such as face shields, not delivered with the user instructions as required by the Regulation, in the interest of sheer availability. We have also observed that this has not caused any additional problems. Therefore, this is an aspect to further take into consideration while keeping the wearers' safety in mind at all times.

Logistics

The COVID crisis showed the risks related to the production of PPE which was far from the market where they will be used. At the same time a lot of PPE were transported by air instead of by boat or other means (e.g. train). This has an important impact on the environment. All concerned parties need to take this aspect into consideration when taking decisions. Support on how to calculate the environmental footprint of the logistics of PPE is needed to make this easier for stakeholders.

It also has to be noted that logistic solutions must be developed when cleaning/decontamination of PPE is possible (see e.g. textile service systems already in place for protective clothing and workwear), and also for recycling of PPE. These aspects need to be taken into account by employers or authorities when tendering PPE.

Conclusion

There is clearly a need to work on the sustainability of PPE. A "quick win" is to allow manufacturers to provide the instructions in electronic format instead of only in paper format.

For other aspects, further cooperation and research might be necessary and for that the PPE supply chain needs support from authorities in order to be able to speed up the work. To coordinate this we suggest to set up a 'task force' with representatives of all involved stakeholders (authorities, industry, service providers, users, …) so that the complete supply chain is covered.

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	0069	Question related to PPE Regulation 2016/425
	If the PPE are distributed in a vending machine at the employers plant, must the user instructions/Declaration of Conformity be supplied with each individual product ?	
	ESF answer - version 20180219	Disclaimer – www.eu-esf.org

In practice, vending machines are used as a means of internal distributing the PPE close to the work place of the employees and also makes the PPE available 24/7/365. To be able to do this efficiently the PPE are offered per piece to the employees, which in most cases means that the packaging of the manufacturer (or importer or distributor) has been opened to make this possible.

This is typically used for PPE that are regularly used by the employees (e.g. gloves that need to be changed often) and for which the employees have been trained before and are used to wear.

The practical approach is that the user instructions are available for the employer. According to the PPE use Directive (89/656), the employer has the obligation to both provide the instructions for use and training so that the employee is aware of which PPE and for what uses they are available in the vending machine. When the instructions are available at the vending machine (printed or easily accessible electronically), the employee can consult them whenever he deems necessary and at any time.

The employer certainly has the obligation to provide the necessary training to his employees to make sure that they can use the appropriate PPE in the correct way.

Q&A 0066 can also be taken into account

Topic Brief: Reusable versus Disposable PPE

Date: 6/15/2020

Nomination Number: 0903

Purpose:

This document summarizes the information addressing a nomination submitted on April 27, 2020 through the Effective Health Care (EHC) Website. This information was used to inform the Evidence-based Practice Center (EPC) Program decisions about whether to produce an evidence report on the topic, and if so, what type of evidence report would be most suitable.

Issue:

Personal protective equipment (PPE) is a specialized clothing or equipment, such as medical masks, respirators, gloves, gowns, and eye protection worn by healthcare personnel to prevent infection[1, 2]. The Coronavirus Disease 2019 (COVID-19) pandemic created a shift from reusable to disposable PPE due to its perceived greater effectiveness at preventing infection[3]. Also, global shortages of PPE supplies called for alternative solutions involving extended use and reprocessing of PPE[4-6]. There is limited evidence regarding the comparative effectiveness of disposable versus reusable PPE, as well as the efficacy and safety of different methods of PPE reprocessing. Additionally, recent studies[7, 8] have raised concerns regarding a greater environmental and public health burden associated with less sustainable forms of PPE.

Program Decision:

Key Questions (KQs) 1, 2, and 2a pertaining to the effectiveness of disposable, reusable and reprocessed PPE were adequately addressed by a total of 24 published and in-progress evidence reviews. Three of these reviews also partially covered a part of KQ 1a pertaining to strategies for optimizing the use of limited PPE supply during the pandemic. The remainder of KQ 1a pertaining to broader aspects of PPE supply chain management and the nominator's concerns related to environmental and public health impacts of different forms of PPE are outside the scope of the AHRQ EHC Program which focuses on developing evidence reviews to inform decision-making about healthcare interventions or care delivery. Because the nomination questions are either sufficiently addressed by the existing reviews or are outside the scope of the EHC Program, AHRQ will not develop a new evidence review.

Key Findings

We found eight systematic reviews[9-16], including one Cochrane review[11], and eight rapid reviews[17-24] (including one rapid review update[24]) which assessed the effectiveness and comparative effectiveness of reusable and disposable PPE in preventing infection transmission within healthcare settings (KQ 1). Two systematic reviews[15, 16] and one rapid review[19] assessed strategies to optimize the limited supplies of PPE (KQ 1a).

Three systematic reviews[9, 14, 25] and five rapid reviews[19, 23, 26-28] assessed the effectiveness of extended use and reprocessing/reuse of PPE compared to standard use (KQ 2). Five published systematic[9, 25, 29-31] and two rapid reviews[27, 32] in addition to five protocols[33-37] for in-development systematic reviews, examined the safety and efficacy of different methods of PPE reprocessing and reuse (KQ2a).

Background

PPE is a critical component of infection prevention and control strategies in healthcare and community settings. Safe and effective use of PPE is essential to protect healthcare workers and transmission within healthcare settings and in the community. Effective use of PPE is particularly important during the COVID-19 pandemic because of the high prevalence of the coronavirus disease (SARS-CoV-2) (3,296,599 confirmed SARS-CoV-2 cases reported in the U.S. according to July 13, 2020 CDC report[38]) and high rates of asymptomatic infection transmission[39].

PPE can be effective only if the equipment can form a barrier between healthcare workers and infectious pathogens. All manufactured PPE must meet strict technical standards, and its use in healthcare settings is regulated by infection prevention and control guidelines. Recent widespread shortages of PPE and the need to conserve limited reserves necessitated temporary solutions involving extended use, reuse and reprocessing of PPE. The World Health Organization (WHO)[2], the Centers for Disease Control and Prevention (CDC)[1] and other authorities issued guidelines on rational use of PPE and recommendations for alternative methods of PPE use. However, there is uncertainty regarding the effectiveness, comparative effectiveness and risks associated with PPE reprocessing and reuse resulting in inconsistent recommendations across different guidelines. Additionally, the recent shift towards a greater use of disposable and less reusable PPE raised additional concerns regarding environmental, economic, and public health impacts[40] associated with manufacturing, use and disposal of less environmentally sustainable healthcare equipment[8].

Nomination Summary

This research topic was nominated by a group of Harvard and Yale physician climate leaders interested in the environmental sustainability of healthcare services. They are interested in a comprehensive evidence review assessing (1) the benefits and harms of reusable compared to disposable compared to reprocessed PPE for infection control and prevention in healthcare settings and (2) the environmental and public health impacts associated with the manufacturing, use, and disposal of different types of PPE by the healthcare industry. Though assessment of environmental impacts is outside the scope of AHRQ and the EHC Program, in the course of our evidence literature search we identified a few relevant studies that may be of interest to the nominator. These are included under Related Resources.

Scope

1. What is the effectiveness and comparative effectiveness of different types of disposable and reusable PPE (in addition to standard precautions) for infection prevention and control in healthcare settings?
   (a) What are the costs of acquisition, utilization, disposal, and supply-availability related considerations of disposable and reusable PPE?

2. What is the effectiveness and comparative effectiveness of extended use and the reprocessing followed by reuse of PPE compared to standard use (i.e. guideline mandated frequency and duration) for infection prevention and control in healthcare settings?
   (a) What is the efficacy and safety of different methods for PPE reprocessing?

Table 1. Questions and PICOS (population, intervention, comparator, outcome, and setting)

Questions	1. Effectiveness and comparative effectiveness of reusable and disposable PPE to prevent infection transmission (a) Costs and supply availability considerations for reusable and disposable PPE	2. Effectiveness and comparative effectiveness of extended use and reuse of PPE compared to standard use (a) Efficacy and safety of different methods of PPE reprocessing
Population	Healthcare workers (physicians, nurses, other healthcare staff), other healthcare services personal (environmental services employees, janitorial staff, etc.)	Healthcare workers (physicians, nurses, other healthcare staff), other healthcare services personal (environmental services employees, janitorial staff, etc.)
Interventions	Below PPE types, used individually or in combination: Disposable PPE Facial/Respiratory protection • Medical/surgical facemasks • N-95 and FFP2 respirators Eye protection • Face shields Contact isolation equipment • Isolation gowns • Surgical gowns • Isolation aprons • Lab coats • Protective full body suits Gloves (nonsterile) Reusable PPE • Powered air purifying respirators (PAPR) • Elastomeric facepiece respirators (EFR) • Goggles • Fabric isolation gowns	Extended use (i.e. wearing the same facemask for repeated close contact encounters with several different patients, without removing the facemask between patient encounters.) Reprocessing/reuse (i.e. repeat use after decontamination, disinfection and/or sterilization process) using one or more of the following (or other) methods: • Ultraviolet germicidal irradiation • Microwave and heat-based decontamination • Dry heat inactivation • Autoclave sterilization • Chemical disinfection (i.e. chlorine dioxide, hydrogen perchloride, ethylene oxide, etc.)
Comparators	One type of PPE (used individually or in combination) compared to other type	Standard use (duration and frequency) compared to extended use compared to reprocessing (i.e. use following decontamination)
Outcomes	KQ1: Effectiveness at preventing infection: • Transmission to healthcare workers • Transmission to patients KQ 1a: Supply availability: • Risk of supply-chain interruptions • Supply shortages KQ 1a: Costs: • Acquisition per unit cost • Storage, reprocessing and disposal related costs	KQ 2: Effectiveness at preventing infection: • Transmission to healthcare workers • Transmission to patients KQ 2a: Efficacy of reprocessing methods: • Reduction in viral/bacterial load KQ 2-2a: Performance post-reprocessing: • Aerosol penetration • Airflow resistance • Fit/structural integrity • Physical appearance • Residual odor/chemical residues KQ 2-2a: Usability and comfort:

		• Donning and doffing ease • Wearing comfort
Setting	Inpatient and outpatient healthcare settings, nursing homes, long-term care facilities, etc.	Inpatient and outpatient healthcare settings, nursing homes, long-term care facilities, etc.

Abbreviations: NA=not applicable; PPE=personal protective equipment; PAPR=Powered Air Purifying Respirator. EFR= Elastomeric Faceplates Respirator

Assessment Methods

See Appendix A.

Summary of Literature Findings

Our search identified eight systematic reviews[9-16] and eight rapid reviews[17-24] pertaining to KQ1 (effectiveness of reusable and disposable PPE). Fifteen of the sixteen reviews have been published since March 2020 in response to the COVID-19 pandemic, and thus have overlapping questions and evidence. Fifteen reviews, including seven systematic reviews[9, 10, 12-16] and eight rapid reviews[18-21, 23, 24, 26, 28] compared the effectiveness of medical and surgical facemasks and N95 respirators. Three systematic reviews[9, 10, 13] and one living rapid review[19] (including a rapid review update[24]) evaluated the effectiveness of cloth facemasks. One systematic review[11] and one preprint rapid review[23] directly compared reusable and disposable facepiece respirators (N95 versus elastomeric facepiece respirators (EFRs) and powered air purifying respirators (PAPRs)). Four systematic reviews[9, 11, 15, 16] and two rapid reviews[20, 23] (one preprint) included studies of eye protection (goggles, face shields and eye protection integrated with PAPRs). One additional Cochrane review[11] assessed the effectiveness of full body suits, isolation gowns and aprons at preventing contact-based infection transmission; they found one study comparing reusable fabric gowns to disposable gowns.

Two systematic reviews[15, 16] and one rapid review[19] considered methods to optimize the use of limited PPE supplies in the context of the COVID-19 pandemic (KQ1a). No evidence reviews and only one primary economic modeling study[41] addressed the remainder of KQ1a, pertaining to costs associated with the acquisition, storage, use and disposal of reusable, disposable, and reprocessed respiratory PPE (i.e. filtering facemasks and powered air purifying respirators)

We found three systematic reviews[9, 14, 25], five rapid reviews[19, 23, 26-28] (two pre-prints) pertaining to KQ2. These reviews assessed the comparative effectiveness of extended use and reuse/reprocessing of PPE compared to standard use. Four published systematic[9, 25, 29, 31] and two rapid reviews[27, 32] in addition to five protocols[33-37] for upcoming systematic reviews assessed the efficacy and safety of different reprocessing methods (decontamination, disinfection and sterilization) for facemasks and N95 respirators (KQ2a). One systematic review[25] compared the efficacy of different reprocessing methods for surgical facemasks. One rapid review[26] synthesized the existing evidence for extended use of N95 respirators. Four upcoming reviews[33-35, 37] will assess the comparative efficacy and safety of different methods of reprocessing for medical facemasks and N95 respirators. One upcoming living systematic review[36] will specifically examine how different methods of reprocessing of N95 respirators impact their function and performance.

See Appendix Tables C1 and C2 for descriptions of the evidence reviews.

Table 2. Literature identified for the nomination question

Question	Systematic reviews (6/2017-6/2020)
1. Effectiveness and comparative effectiveness of reusable and disposable PPE	Total reviews: 16[9-24, 42, 43] Total systematic reviews – 8[9-16] • Cochrane – 1[11] Total rapid reviews – 8[17-24] • Pre-print – 1[23] • Rapid review update – 1[24]
1(a). Costs and supply availability factors	Total reviews: 3[15, 16, 19] Total systematic reviews – 2[15, 16] Total rapid reviews – 1[19]
2. Effectiveness and comparative effectiveness of extended use, reprocessing/reuse vs standard use of PPE	Total reviews: 8[9, 14, 19, 23, 25-28] Total systematic reviews – 3[9, 14, 25] Total rapid reviews – 5[19, 23, 26-28] • Pre-print – 2[23, 27]
2(a). Efficacy and safety of PPE reprocessing methods	Total reviews: 8[9, 25, 27, 29-32] Total systematic reviews – 5[9, 25, 29-31] • Pre-print – 3[30, 31] Total rapid reviews – 2[27, 32] • Pre-print – 1[27] • In-progress – 1[32] Systematic review protocols – 5[33-37]

Abbreviations: NA=not applicable; PPE=personal protective equipment.

See Appendix B for detailed assessments of all EPC selection criteria.

Summary of Selection Criteria Assessment

For this nomination, KQs 1, 2 and 2a were sufficiently addressed by existing reviews. For KQ1a, we found two systematic reviews[15, 16] and one rapid review[23] that considered certain aspects of optimizing the use of limited PPE supply but did not address the entire question.
Please see Appendix B for detailed assessments of individual EPC Program selection criteria.

Related Resources

We identified additional information in the course of our assessment that may be useful to the nominator. One economic modeling study[41] examined the financial expenditures associated with utilization of different types of PPE (an assessment relevant to KQ 1a). Another primary study provided an environmental lifecycle assessment of reusable and disposable medical isolation gowns, addressing the environmental and public health impacts of reusable, disposable, and reprocessed PPE.

In addition, the Emergency Care Research Institute (ECRI) has produced reviews of environmental footprints of the healthcare industry. ECRI's recent guidance report developed in conjunction with the U.S. Environmental Protection Agency that discusses environmentally preferable purchasing and other methods of reducing energy consumption by the healthcare industry can be found on their website[44].

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Appendix A: Methods

We assessed nomination for priority for a systematic review or other AHRQ Effective Health Care report with a hierarchical process using established selection criteria. Assessment of each criteria determined the need to evaluate the next one. See Appendix B for detailed description of the criteria.

Appropriateness and Importance

We assessed the nomination for appropriateness and importance.

Desirability of New Review/Absence of Duplication

We searched for high-quality, completed or in-process evidence reviews published in the last three years on May 8, 2020 followed by a repeat search on June 12, 2020 on the questions of the nomination from these sources:

- AHRQ: Evidence reports and technology assessments
    - AHRQ Evidence Reports https://www.ahrq.gov/research/findings/evidence-based-reports/index.html
    - EHC Program https://effectivehealthcare.ahrq.gov/
    - US Preventive Services Task Force https://www.uspreventiveservicestaskforce.org/
    - AHRQ Technology Assessment Program https://www.ahrq.gov/research/findings/ta/index.html
- US Department of Veterans Affairs Products publications
    - Evidence Synthesis Program https://www.hsrd.research.va.gov/publications/esp/
    - VA/Department of Defense Evidence-Based Clinical Practice Guideline Program https://www.healthquality.va.gov/
- Cochrane Systematic Reviews https://www.cochranelibrary.com/
- Cochrane COVID Rapid Reviews: https://covidrapidreviews.cochrane.org/
- CEBM Oxford COVID-19 Evidence Service https://www.cebm.net/oxford-covid-19-evidence-service/
- University of York Centre for Reviews and Dissemination database https://www.crd.york.ac.uk/CRDWeb/
- PROSPERO Database (international prospective register of systematic reviews and protocols) http://www.crd.york.ac.uk/prospero/
- PubMed https://www.ncbi.nlm.nih.gov/pubmed/
- Campbell Collaboration http://www.campbellcollaboration.org/
- McMaster Health System Evidence https://www.healthsystemsevidence.org/
- WHO Health Evidence Network http://www.euro.who.int/en/data-and-evidence/evidence-informed-policy-making/health-evidence-network-hen

Impact of a New Evidence Review

The impact of a new evidence review was qualitatively assessed by analyzing the current standard of care, the existence of potential knowledge gaps, and practice variation. We considered whether it was possible for this review to influence the current state of practice through various dissemination pathways (practice recommendation, clinical guidelines, etc.).

Feasibility of New Evidence Review

We conducted a limited literature search in Ovid MEDLINE for the last five years from 7/12/2015 to 7/12/2020. We reviewed all titles and abstracts of the identified studies for inclusion. We classified identified studies by question and study design to estimate the size and scope of a potential evidence review.

Search strategy

Ovid MEDLINE(R) ALL 1946 to June 11, 2020 Date searched: June 12, 2020
1 Personal Protective Equipment/ or Protective Clothing/ or Masks/ or Respiratory Protective Devices/ (12335)
2 ("personal protective equipment" or PPE or cap or caps or aprons or capes or coveralls or "elastomeric respirator*" or facemask* or facepiece* or gowns or hat or hats or headwear or masks or N95 or "protective clothing" or (respiratory adj2 (device* or protect*)) or wrap or wraps).ti,ab,kf. (83857)
3 or/1-2 (91868)
4 Equipment Reuse/ (2868)
5 (reusab* or reuse or reusing or sustainability).ti,ab,kf. (44320)
6 or/4-5 (46032)
7 and/3,6 (455)
8 limit 7 to english language (426)
9 limit 8 to yr="2015 -Current" (206)
10 randomized controlled trials as topic/ or random allocation/ or double-blind method/ or single-blind method/ or exp clinical trial as topic/ or placebos/ or research design/ or comparative study/ or exp evaluation studies/ or follow up studies/ or prospective studies/ (3444646)
11 ("randomized controlled trial" or "controlled clinical trial" or "clinical trial").pt. (837812)
12 ((clin* adj25 trial*) or ((single* or doubl* or trebl* or tripl*) adj25 (blind* or mask*)) or control* or placebo* or prospective* or random* or volunteer*).ti,ab. (5248803)
13 or/10-12 (7526603)
14 animals/ not humans/ (4673354)
15 13 not 14 (6247396)
16 and/9,15 (67)
17 exp cohort studies/ or exp epidemiologic studies/ or exp clinical trial/ or exp evaluation studies as topic/ or exp statistics as topic/ (5533571)
18 ((control and (group* or study)) or (time and factors) or program or survey* or ci or cohort or comparative stud* or evaluation studies or follow-up*).mp. (7280615)
19 or/17-18 (9574715)
20 (animals/ not humans/) or comment/ or editorial/ or exp review/ or meta analysis/ or consensus/ or exp guideline/ (8427530
21 hi.fs. or case report.mp. (610364)
22 or/20-21 (8957471)
23 19 not 22 (7390151)
24 and/9,23 (73)

25 or/16,24 (102) 26 9 not 25 (104)
EBM Reviews - Cochrane Central Register of Controlled Trials May 2020 Date searched: June 12, 2020
Date searched: June 12, 2020 1 ("personal protective equipment" or PPE or cap or caps or aprons or capes or coveralls or "elastomeric respirator*" or facemask* or facepiece* or gloves or gowns or hat or hats or headwear or masks or N95 or "protective clothing" or (respiratory adj2 (device* or protect*)) or tyvek or wrap or wraps).ti,ab. (8261) 2 (reusab* or reuse or reusing or sustainability).ti,ab. (2643) 3 and/1-2 (55) 4 limit 3 to yr="2015 -Current" (27)

Appendix B. Selection Criteria Assessment

Selection Criteria	Assessment
1. Appropriateness	
1a. Does the nomination represent a health care drug, intervention, device, technology, or health care system/setting available (or soon to be available) in the United States?	Yes. The CDC requires disposable and reusable PPE in all healthcare settings in the U.S. for infection control and prevention re. KQs 1, 2 and 2a pertain to comparative effectiveness of different types of PPE. KQs 1a relates to PPE costs and supply chain management.
1b. Is the nomination a request for an evidence report?	Yes.
1c. Is the focus on effectiveness or comparative effectiveness?	Yes.
1d. Is the nomination focus supported by a logic model or biologic plausibility? Is it consistent or coherent with what is known about the topic?	Yes.
2. Importance	
2a. Represents a significant disease burden; large proportion of the population	Yes as of July 13, 2020, the CDC reported over 3 million of confirmed COVID-19 cases in the U.S.[38]. Healthcare workers are at increased risk for contracting COVID-19 and care organizations are required to protect them by providing guideline mandated PPE Recent review[45] revealed high prevalence rates of confirmed COVID-19 infection in healthcare workers (between 1.12% and 18.6%) and noted a strong association between PPE use and decreased infection risk. As such, effective use of PPE is important to protect people in healthcare and community settings.
2b. Is of high public interest; affects health care decision making, outcomes, or costs for a large proportion of the U.S. population or for a vulnerable population	According to the July 2, 2020 Congressional Budget Office report, the COVID-19 pandemic will cost the U.S. economy an estimated $7.9 trillion[46] over the next decade. This includes an estimated 56 billion to 556 billion in healthcare costs over the next two years. High costs of care will disproportionately affect over 30 million of uninsured Americans who may be expected to cover an expected average of $73,300 for a COVID-19 related hospital stay compared to approximately a half of that amount (an estimated $38,221) when it is covered by insurance[47].
2c. Incorporates issues around both clinical benefits and potential clinical harms	Yes. This topic concerns comparative effectiveness of different forms of PPE and efficacy and safety of procedures for PPE reprocessing.
2d. Represents high costs due to common use, high unit costs, or high associated costs to consumers, to patients, to health care systems, or to payers	Yes. The April 7, 2020 report by the Society for Healthcare Organization Procurement Professionals (SHOPP)[48] calculated the daily costs of PPE for healthcare worker according to the current CDC guidelines. The SHOPP reported a 1084% increase in PPE costs per one healthcare worker from pre-COVID-19 pricing.
3. Desirability of a New Evidence Review/Absence of Duplication	
3. A recent high-quality systematic review or other evidence review is not available on this topic	KQs 1, 2 and 2a were sufficiently addressed by published reviews. We found 16 reviews [9-24, 42, 43]

	relevant to KQ1, eight reviews [9, 14, 19, 23, 25-28] for KQ2 and eight reviews[9, 25, 27, 29-32] and five protocols[33-37] for upcoming systematic reviews for KQ2a. Three reviews[15, 16, 19] partially addressed a part of KQ1a regarding the supply availability of different PPE types.
4. Impact of a New Evidence Review	
4a. Is the standard of care unclear (guidelines not available or guidelines inconsistent, indicating an information gap that may be addressed by a new evidence review)?	Yes. The CDC[49], FDA[50], and other regulatory agencies issued recent guidance on optimizing the use of PPE. However, this guidance focuses mainly on compliance with hospital infection control standards and does not consider environmental harms of healthcare services. There is little guidance regarding the environmental and public health impacts[7] of different types of PPE to help healthcare organizations make environmentally conscious supply purchasing decisions.
4b. Is there practice variation (guideline inconsistent with current practice, indicating a potential implementation gap and not best addressed by a new evidence review)?	Yes. Most healthcare organizations purchase their supplies, including PPE based on cost and patient and employee safety considerations and without considering their environmental sustainability.
5. Primary Research	
5. Effectively utilizes existing research and knowledge by considering: - Adequacy (type and volume) of research for conducting a systematic review - Newly available evidence (particularly for updates or new technologies)	We found only one primary study[41] that addressed a part of KQ1a related to costs of stockpiling of PPE.

Abbreviations: AHRQ=Agency for Healthcare Research and Quality; CDC=Centers for Disease Control and Prevention; COVID-19=coronavirus disease 2019; FDA=Food and Drug Administration; KQ=key question; PPE=personal protective equipment.

Appendix C. Summary of Included Systematic Reviews

Table C1. Published Systematic Reviews

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Garcia Godoy et al.[9], 2020 **USA** **Scoping Review** **n=67 (48 peer-reviewed studies and 19 gray literature articles)**	Healthcare workers (nurses, doctors, co-medical personnel), healthy volunteers (for laboratory/ controlled studies) Patient care settings (inpatient and outpatient), experimental/laboratory settings	The following PPE types, used alone or in combination were compared to one another: • Medical facemasks • Surgical facemasks • Fabric (non-medical grade) facemasks • N-95 respirators • Other respirators (KF94, KF80) • Face shields Continuous vs targeted use of medical and surgical facemasks and N95 respirators Efficacy of PPE preprocessing strategies, including but not limited to the following decontamination methods: • Ultraviolent germicidal irradiation (UVGI) • Microwave irradiation • Microwave generated steam and moist heat incubation • Chemical decontamination (i.e. hydrogen peroxide gas plasma, 70% isopropyl alcohol etc.)	Self-reported (based on symptoms) or laboratory confirmed viral (e.g., SARS-CoV-2, influenza A/B etc.) or bacterial (E. Coli etc.) upper respiratory infection Efficacy of different PPE decontamination methods: • Fractional penetration by viral particles • Resistance of SARS coronavirus to temperature and UV irradiation • Face fit • Changes in physical appearance, odor, and filtration performance	Compared to surgical facemasks, N95 respirators performed better in laboratory settings, may provide superior protection in inpatient settings and are equivocal in outpatient settings. Conserving surgical mask and N95 respirator supplies through extended use, reuse, or decontamination may result in inferior protection. Alternative forms of facial protection (non-medical grade facemasks) offer inferior protection.

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Liang et al., 2020[10] **China** **Systematic Review and Meta-Analysis** **n=21 (13 case control, 6 cluster RCTs, 2 cohort)**	Healthcare workers (12 studies) Nonhealthcare professional populations (8 studies) Healthcare workers and patient contacts (1 study) Patient care and community settings	The following PPE types, used alone or in combination, compared to one another: • Medical facemasks • Surgical facemasks • Fabric (paper or cotton) facemasks • N-95 respirators	Self-reported (based on symptoms) or laboratory confirmed viral respiratory infection. Prevention of respiratory viral infection transmission.	Wearing facemasks and N95 respirators was effective for protecting healthcare workers from SARS infection in a hospital setting. However, gowns and gloves did not show a measurable protective effect. Fit tested and non-fit tested N95 respirators were not significantly different in their performance.
Verbeek et al., 2020[11] **Finland** **Cochrane Systematic Review** **n=24 (14 RCT, 1 quasi-RCT, 9 nonrandomized trials)**	Healthcare workers and ancillary hospital staff, non-healthcare laboratory staff Patient care settings, experimental/laboratory settings	Powered air purifying respirator (PAPR) plus coverall vs N95 respirator plus isolation gown Modified (more protective) PPE vs standard PPE: • Gowns with sealed gown-glove interface • Gowns with improved fit around the neck, wrists, and hands • Added grab tabs to facilitate doffing of masks or gloves Gowns vs aprons for preventing infectious exposures from contact with contaminated body fluids Different types of full body PPE compared to another PPE type for preventing infectious exposures from contact with contaminated body fluids.	Contamination of body cites (skin surface and PPE) using visible florescence marker Contamination with viral or bacterial pathogen, quantity of viral or bacterial contamination PPE usability as assessed by the users (comfort, ease of donning and doffing, satisfaction with use etc.) Donning and doffing compliance; donning and doffing time.	Covering more of the body leads to better protection but is associated with increased difficulty related to putting on and removing PPE. Respirators worn with coveralls may protect better than a mask worn with a gown but are more difficult to put on. More breathable types of PPE may have similar surface contamination rates but are associated with greater user satisfaction.

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
		Different types of methods of PPE donning and doffing compared to one another Water repellent vs breathable PPE fabric (1 study)		
Bartoszko et al, 2020[12] **Canada** **Systematic Review and Meta-Analysis** **n=4 RCTs**	Healthcare workers Patient care settings, including inpatient (emergency department, wards) and outpatient (outpatient primary care and dental clinics etc.)	Medical and surgical facemasks compared to N95 respirators and FFP2 respirators	Laboratory confirmed viral respiratory infection Serology confirmed viral infection Laboratory confirmed coronavirus infection Laboratory confirmed influenza Influenza -like illness Clinical respiratory illness Workplace absenteeism.	Low certainty evidence suggests that medical masks and N95 respirators offer similar protection against respiratory viral infections (including with coronavirus) to healthcare workers engaged in direct patient care (without performing aerosol generating procedures).
Offeddu et al., 2017[13] **UK** **Systematic Review and Meta-Analysis** **n=29 (6 RCT and 23 observational studies)**	Healthcare workers Healthcare settings, including inpatient and outpatient settings	Medical facemasks vs N95 respirators (fit tested or non-fit tested) Continuous or targeted use of N95 respirators versus medical facemasks Surgical facemasks vs N95 respirators (including continuous vs targeted use of each) Nonmedical grade cotton facemasks: double layered versus single layered Any surgical facemask compared to another compared to N95 respirator	Self-reported (based on symptoms) or laboratory confirmed upper respiratory while or bacterial infection	Compared to medical and surgical facemasks, N95 respirators conferred superior protection against clinical respiratory illness and laboratory confirmed bacterial, but not viral infections. Wearing multilayered cotton masks is not associated with protection from SARS infection

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Long et al., 2020[14] **China** **Systematic Review and Meta-Analysis** **n=6 RCTs**	Healthcare workers (5 studies), household members of a laboratory confirmed SARS infected case (1 study) Healthcare settings (inpatient and outpatient) (5 studies), community setting (1 study)	Targeted use of surgical facemasks vs fit-tested N95 respirators Continual use of surgical facemasks vs non-fit tested N95 respirators Continual use of fit tested vs non-fit tested N95 respirators compared to continual use of surgical facemasks Continual use of fit tested N95 respirators vs targeted use of fit test N95 respirators compared to continual use of surgical facemasks Targeted use of fit tested N95 respirators compared to targeted use of medical facemasks	Self-reported (based on symptoms) or laboratory confirmed respiratory viral infection (Influenza A/B, RSV, coronavirus) Workplace absenteeism	The use of N95 respirators compared to surgical facemasks is not associated with lower rates of laboratory confirmed influenza. This suggests that N95 respirators should not be recommended for general public and healthcare workers without direct contact with patients with confirmed or suspected influenza infection.
Chu et al., 2020[15] **Canada** **Systematic Review and Meta-Analysis** **n=172 observational studies included in SR, 44 studies in meta-analysis)**	Healthcare workers, non-healthcare workers Healthcare (inpatient and outpatient) settings and community settings	Medical or surgical facemasks or 12-16-layer cotton masks compared to no facemasks Medical or surgical facemasks compared to N95 respirators Eye protection (eye goggles or face shields) compared to no eye protection 2 qualitative and 2 cross-sectional studies reported on data related to the cost PPE	Risk of transmission (defined confirmed or probable COVID-19, SARS, or MERS) from noninfected to infected individuals COVID-19, SARS, or MERS infection related hospitalizations COVID-19, SARS, or MERS infection related intensive care unit admissions	The use of medical or surgical facemasks could lead to a larger reduction in infection risk. N95 and similar facepiece respirators showed stronger associations with reduced infection compared to disposable surgical or similar facemasks (i.e. reusable 12-16-layer cotton masks). Using eye protection was also associated with less infection

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
		and resource use in the management of SARS (2 studies), MERS (1 study) and SARS-CoV-2 (1 study)		compared with not using eye protection.
Jessop et al, 2020[16] **UK** **Systematic Review** **n=95 studies**	Healthcare (surgical wards and operating room) settings	Types of PPE reviewed: • Surgical facemasks • FFP2 and FFP3 masks • N95 respirators • Eye protection • Surgical gowns • Disposable aprons • Gloves The review also considered ethical aspects of rationing PPE due to supply shortages and touched on a number of innovative solutions to meeting the PPE demand during the times of pandemic.	Risk of infection transmission during surgical procedures with different types of PPE Sources of transmission of infection during surgical procedures	The review provides practical advice on all aspects of PPE use in surgical practice
Iannone et al., 2020[18] **Italy** **Rapid Review** **n=5 studies (1 RCT and 4 cluster studies)**	Healthcare workers (4 studies) and community dwelling adults (1 study) Healthcare (inpatient wards, emergency departments, outpatient clinics) setting (4 studies) and community setting (1 study)	Surgical facemasks vs N95 respirators Surgical facemasks vs FFP-2 masks Medical facemasks vs N95 respirators Medical facemasks vs fit-tested and non-fit-tested N95 respirators	Laboratory confirmed respiratory viral infections Laboratory confirmed bacterial colonization Clinical respiratory infection Influenza -like illness	Wearing N95 respirators can prevent approx. 75 more respiratory viral infections per 1000 healthcare workers compared to surgical facemasks. N95 respirators were more effective than surgical facemasks at protecting against laboratory confirmed respiratory bacterial and viral infections. There was no direct high-quality evidence to show whether N95 respirators were also superior to surgical facemasks for

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
				protecting against SARS-CoV-2 infection.
Chou et al, 2020[19] **USA** **Living Rapid Review** **n=39**	Healthcare workers and healthcare workers, community dwelling adults Healthcare settings, community settings	N95 respirators or equivalent, medical and surgical facemasks, cloth masks, surgical paper masks and P2 masks One type of mask versus another type of mask, mask single use versus reuse, mask use versus non-use.	Laboratory confirmed infection Clinical respiratory illness Influenza -like illness Infection with SARS-CoV-2, SARS-CoV-1, or MERS-CoV-1 Harms of mask usage	Evidence for the effectiveness of masks to prevent respiratory infections is stronger in healthcare compared to community settings. N95 respirators may result in greater reduction of SARS-CoV-1 infection risk in healthcare settings compared to surgical masks, but the applicability to SARS-CoV-2 is uncertain.
Chou et al., 2020[24] **USA** **Living Rapid Review Update** **n=1**	Household contacts of laboratory confirmed COVID-19 cases Healthcare and community settings	N95 respirator vs surgical facemask N95 respirator vs surgical facemask vs cloth mask Surgical facemask vs cloth mask N95 respirator or surgical facemask vs cloth mask	SARS-CoV-2 infection SARS-CoV-1 or MERS-CoV infection Influenza infection influenza -like illness Other respiratory illness (excluding pandemic coronaviruses)	There was no association between mask use after illness onset in the index case and risk for SARS-CoV-2 infection among family members. Although the new study provides evidence for effectiveness of mask use in community settings to prevent SARS-CoV-2 infection, the strength of evidence is insufficient.
Greenhalgh et al., 2020[21] **UK** **Rapid Review** **n=1**	Healthcare workers Healthcare setting	Shoe protective equipment (shoe covers) as a component of healthcare worker PPE	Outcomes related to reducing infection transmission	The review found no relevant trials and only one observational study related to the use of protective shoe covers by healthcare workers. More research is needed to determine whether shoe covers should be included as a part of PPE.
Greenhalgh et al., 2020[22] **UK**	Healthcare workers Healthcare setting	N95 respirators compared to fluid resistant surgical facemasks (FRSM)	Laboratory confirmed influenza Laboratory confirmed respiratory infection Influenza like illness	Included studies provide cautious support for the use of surgical facemasks to protect from respiratory viral infections

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Rapid Review **n=17**			Confirmed bacterial colonization	when proving patient care (without performing aerosol generating procedures)
NSW Health. COVID-19 Critical Intelligence Unit, 2020[20] **Australia** **Rapid Review**	Healthcare workers Healthcare setting	This review examined current guidelines on the use of PPE and the evidence behind the guidelines. The following PPE types reviewed: Medical/surgical facemasks Eye protection N95/FFP2 or equivalent respirators Gloves and gowns	Respiratory virus transmission Functional respirator performance characteristics	The review evaluated contemporary guidance on the use of PPE in healthcare settings to prevent SARS-CoV-2 infection and examined the evidence base underlying the guidelines' recommendations.
Zorko et al., 2020[25] **Canada** **Systematic Review** **n=7**	Experimental/laboratory settings	Surgical facemasks Reprocessing methods for surgical facemasks including the following: • Dry heat • Moist heat (autoclave) • Chemical disinfection (70% ethanol, isopropyl, sodium hypochlorite)	Mask performance (i.e. filtration efficiency and airflow resistance) Reduction in pathogen load In-vivo infection rates following use of the contaminated masks Changes in physical appearance (i.e. mask appearance or physical degradation) User experience (i.e. skin irritation) Feasibility of the intervention (i.e. time, cost, resource utilization)	Mask performance was best preserved with using dry heat-based decontamination. There is limited evidence on the safety or efficacy of other techniques to decontaminate surgical facemasks.
NSW Health. COVID-19 Critical Intelligence Unit, 2020[26] **Australia** **Rapid Review**	Healthcare workers Healthcare settings	Surgical facemasks compared to N95 respirators	Laboratory confirmed influenza Laboratory confirmed respiratory viral infection Laboratory confirmed respiratory infection Influenza like illness	The review found one meta-analysis based on six RCTs and no primary studies comparing the effectiveness of surgical facemasks and N95 respirators. The meta-analysis showed no statistically significant difference

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
				in efficacy of surgical facemasks and N95 respirators to prevent laboratory confirmed viral illness
MacIntyre et al., 2020[28] **Australia** **Rapid Review** **n=19 RCTs**	Healthcare workers, community dwelling adults Healthcare settings, community settings	Medical facemasks, P2 masks Medical facemasks vs targeted use of N95 respirators Medical facemasks vs fit tested N95 respirators vs non-fit tested N95 respirators Medical facemasks vs continuous use of N95 respirators vs targeted use of N95 respirators	Respiratory infection transmission related outcomes	RCT data supports continuous use of facepiece respirators during patient care shifts to prevent infection in healthcare workers. The same data suggests that community mask use by well people would also be beneficial, particularly to prevent COVID-19 transmission from pre-symptomatic individuals.
O'Hearn et al., 2020[35] **Canada** **Systematic Review** **n=5**	Experimental/laboratory setting	Effectiveness of ultraviolet germicidal irradiation to decontaminate N95 and SN95 respirators	Particle penetration and airflow resistance Germicidal impact (reduction of viral/bacterial pathogens) Physical characteristics (physical appearance, odor, fit, texture, chemical residues)	Ultraviolet germicidal irradiation was effective at decontaminating N95 respirators as they consistently maintained certification standards following UVGI.

Table 4. Pre-published and in-progress systematic reviews

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Burton et al, 2020[23] **UK** **Rapid Review** **n=38 studies**	Healthcare workers and experimental/laboratory setting	Filtering facepiece respirator (FFP) vs elastomeric facepiece respirator (EFR) vs fluid resistance surgical mask (FRSM) Filtering facepiece respirator (FFP) vs powered air purifying	Respirator fit User comfort/usability Ease-of-use during clinical activities Intubation time Speech intelligibility Headaches associated with mask use	Training on proper respirator use and ensuring adequate fit are essential for safe respirator use and failures result in reduced protection. All types of respirators may cause discomfort and interfere with users' communication, which

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
		respirator (PAPR) vs elastomeric facepiece respirator (EFR) Powered air purifying respirator (PAPR) vs elastomeric facepiece respirator (EFR) Filtering facepiece respirator (FFP) vs powered air purifying respirator (PAPR)		may limit their safe use if worn for prolonged periods of time. Studies suggest that respirator use has little negative impact on healthcare providers' work performance in the short term.
Gertsman et al., 2020[31] **Canada** **Systematic Review**	Experimental/laboratory setting	Reprocessing strategies for N95 respirators, including: • Microwave irradiation and heat • Autoclaving	Reduction in viral/bacterial load after decontamination interventions Aerosol penetration Airflow resistance Physical changes (fit, odor, degradation)	Microwave irradiation coupled with heat was safe and effective for decontaminating N95 respirators. However, autoclave-based disinfection had negative effect on fit and functional parameters of respirators and is not recommended.
O'Hearn et al., 2020[30] **Canada** **Systematic Review** **n=13 studies**	Experimental/laboratory setting	Different decontamination strategies for the processing of N95 and SN95 respirators: chemical disinfectants (sodium hypochlorite, ethanol, isopropyl alcohol)	Viral/bacterial load reduction following disinfection Aerosol penetration Airflow resistance Fit/comfort Physical appearance Residual odor User safety/skin irritation	N95 respirator sterilization using vaporized hydrogen peroxide was successful to ensure adequate decontamination. However, chemical decontamination with other disinfectants negatively affected respirator function and fit and is not recommended.
Toomey et al., 2020[27] **Ireland** **Rapid Review** **n=4 SRs**	Experimental/laboratory setting	Re-use, extended use or reprocessing of medical and surgical facemasks and N95 respirators • Microwave and heat-based disinfection • Decontamination using chemical disinfectants	Decontamination effectiveness Respirator performance and appearance: • filtration efficiency • airflow resistance • physical integrity • fit • user comfort and safety	There is limited evidence regarding the impact of extended use and reuse of surgical facemasks and respirators on their effectiveness for infection prevention.

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
		• Ultraviolent germicidal irradiation • Disinfectant wipes • Gamma irradiation		
Gupta et al., 2020[33] **India** **Systematic Review Protocol**	Review of laboratory-based experimental studies assessing different methods of reprocessing or decontamination of PPE	Reprocessing methods for N95 respirators, including but not limited to: • Ultraviolet germicidal irradiation • Steam exposure • Dry heat exposure • Gaseous or liquid chemical disinfectants	Effectiveness of reprocessed N95 respirators, including: • Physical durability • User acceptability • Filter efficiency • Respirator fit • Microbicidal efficacy • Presence of chemical residues	This in-development systematic review will assess the efficacy of different methods of reprocessing of N95 respirators
McNally et al., 2020[29] **Canada** **Systematic Review Protocol**	Healthcare workers Healthcare setting, experimental/laboratory settings	Reprocessing methods for N95 respirators, including but not limited to: • Microwave radiation • Microwave generated steam • Microwave radiation plus extraneous water • Dry heat • Moist heat • Autoclave serialization	Percent filter aerosol penetration following microwave radiation/heat treatment Airflow resistance Viral or bacterial contamination on mask surface Fit/ wearability post disinfection Physical degradation Residual odor	This in-development systematic review will answer the question of whether various decontamination strategies can be safely and effectively used to reprocess N95 respirators.
McNally et al., 2020 **Canada** **Systematic Review Protocol**	Experimental/laboratory settings	Methods of reprocessing of N95 respirators, including decontamination with the following types of disinfectants: • Hydrogen peroxide • Bleach (sodium hypochlorite) • Ethanol • Isopropyl alcohol • Ethylene oxide	N95 mask performance after disinfection, including: Filter aerosol penetration airflow resistance Fit Safety Residual odor Chemical skin irritation User comfort Bacterial decontamination	This in-development systematic review will assess efficacy and safety of using different chemical disinfectants to decontaminate N95 and SN95 facepiece respirators
Rajaee et al., 2020[36] **USA**	Experimental/laboratory settings	Any methods of sterilization of N95 respirators and their	Reduction of bacterial/viral load Gross changes including changes in texture, pliability,	This in-development systematic review will assess different sterilizations methods for N95

Author, Year, Country, Study Type, n of included studies	Population and Setting	Intervention vs Comparator	Relevant Outcomes	Results
Living Systematic Review Protocol		analogs (FFP2 or KN95, PS2, DS)	order, structural integrity etc. compared to baseline Filter aerosol penetration after decontamination compared to baseline Filter aerosol resistance after decontamination compared to baseline Fit testing	respirators and how they affect respirator fit and functional performance
Said Abbas et al., 2020[37] **Egypt** **Systematic Review and Meta-Analysis Protocol**	Healthcare and experimental/laboratory settings	Different methods of disinfection and sterilization of medical facemasks and N95 respirators	The following outcomes after disinfection: • Biocidal efficacy • Filtration performance • Residual toxicity • Maintenance of fit	This in-development systematic review will assess the efficacy of different disinfection and sterilization techniques used to reprocess medical facemasks and N95 respirators.
Carr et al., 2020[32] **Canada** **Rapid Review**	Healthcare workers Healthcare setting (community health clinics, emergency department, inpatient wards, long-term care)	Methods of reprocessing N95 respirators	Outcome metrics related to germicidal efficiency and effectiveness of use after decontamination	This in-development rapid review will assess the efficacy of different disinfection techniques procedures for reprocessing of N95 respirators.