Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages

Interim guidance
6 April 2020

Background

This document summarizes WHO’s recommendations for the rational use of personal protective equipment (PPE) in health care and home care settings, as well as during the handling of cargo; it also assesses the current disruption of the global supply chain and considerations for decision making during severe shortages of PPE.

This document does not include recommendations for members of the general community. See here for more information about WHO advice of use of masks in the general community.

In this context, PPE includes gloves, medical/surgical face masks - hereafter referred as “medical masks”, goggles, face shield, and gowns, as well as items for specific procedures-filtering facepiece respirators (i.e. N95 or FFP2 or FFP3 standard or equivalent) - hereafter referred to as “respirators” - and aprons. This document is intended for those involved in distributing and managing PPE, as well as public health authorities and individuals in health care and home care settings involved in decisions about PPE use and prioritization; it provides information about when PPE use is most appropriate, including in the context of cargo handling.

This document has been updated to address key considerations for decision making processes during severe shortages of PPE.

Preventive measures for COVID-19 disease

Based on current evidence, the COVID-19 virus is transmitted between people through close contact and droplets. Airborne transmission may occur during aerosol-generating procedures and support treatments (e.g. tracheal intubation, non-invasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy); thus, WHO recommends airborne precautions for these procedures.

For all, the most effective preventive measures include:

- maintaining physical distance (a minimum of 1 metre) from other individuals;
- performing hand hygiene frequently with an alcohol-based hand rub if available and if your hands are not visibly dirty or with soap and water if hands are dirty;
- avoiding touching your eyes, nose, and mouth;
- practicing respiratory hygiene by coughing or sneezing into a bent elbow or tissue and then immediately disposing of the tissue;
- wearing a medical mask if you have respiratory symptoms and performing hand hygiene after disposing of the mask;
- routine cleaning and disinfection of environmental and other frequently touched surfaces.

In health care settings, the main infection prevention and control (IPC) strategies to prevent or limit COVID-19 transmission include the following:

1. ensuring triage, early recognition, and source control (isolating suspected and confirmed COVID-19 patients);
2. applying standard precautions for all patients and including diligent hand hygiene;
3. implementing empiric additional precautions (droplet and contact and, wherever applicable for aerosol-generating procedures and support treatments, airborne precautions) for suspected and confirmed cases of COVID-19;
4. implementing administrative controls;
5. using environmental and engineering controls.

Standard precautions are meant to reduce the risk of transmission of bloodborne and other pathogens from both recognized and unrecognized sources. They are the basic level of infection control precautions to be used, as a minimum, in the care of all patients.

Additional transmission-based precautions are required by health care workers to protect themselves and prevent transmission in the health care setting. Contact and droplets precautions should be implemented by health workers caring for patients with COVID-19 at all times. Airborne precautions should be applied for aerosol-generating procedures and support treatments.

Although use of PPE is the most visible control used to prevent the spread of infection, it is only one of the IPC measures and should not be relied on as a primary prevention strategy. In the absence of effective administrative and engineering controls, PPE has limited benefit, as described in WHO’s Infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care. These controls are summarized here.
• **Administrative controls** include ensuring resources for infection prevention and control (IPC measures, such as appropriate infrastructure, the development of clear IPC policies, facilitated access to laboratory testing, appropriate triage and placement of patients, including separate waiting areas/rooms dedicated to patients with respiratory symptoms, and adequate staff-to-patient ratios, and training of staff. In the case of COVID-19, consideration should be given, wherever possible, to establish differentiated care pathways that minimize mixing of known or suspected COVID-19 patients with other patients (e.g. through separate health facilities, wards, waiting, and triage areas).

• **Environmental and engineering controls** aim at reducing the spread of pathogens and the contamination of surfaces and inanimate objects. They include providing adequate space to allow social distance of at least 1 m to be maintained between patients and health care workers and ensuring the availability of well-ventilated isolation rooms for patients with suspected or confirmed COVID-19, as well as adequate environmental cleaning and disinfection.  

Coveralls, double gloves, or head covers (hood) that cover the head and neck used in the context of filovirus disease outbreaks (e.g. Ebola virus) are not required when managing COVID-19 patients.

**Recommendations for optimizing the availability of PPE**

The protection of our frontline health workers is paramount and PPE, including medical masks, respirators, gloves, gowns, and eye protection, must be prioritized for health care workers and others caring for COVID-19 patients.

In view of the global PPE shortage, strategies that can facilitate optimal PPE availability include minimizing the need for PPE in health care settings, ensuring rational and appropriate use of PPE, and coordinating PPE supply chain management mechanisms (Figure 1).

**Figure 1. Strategies to optimize the availability of personal protective equipment (PPE)**

1. **Minimize the need for PPE in health care settings**

The following interventions can minimize the use and need for PPE while ensuring that the protection health care workers and others from exposure to the COVID-19 virus in health care settings is not compromised.

• Wherever feasible, use telemedicine and telephone hotlines to initially evaluate suspected cases of COVID-19, thus minimizing the need for these persons to go to health care facilities for evaluation.

• Use physical barriers to reduce exposure to the COVID-19 virus, such as glass or plastic windows. This approach can be implemented in areas of the health care setting where patients will first present, such as triage and screening areas, the registration desk at the emergency department, or at the pharmacy window where medication is collected.

• Postpone elective, non-urgent procedure, and hospitalizations, reduce frequency of visits for chronic patients, apply telemedicine and telephone solutions where possible so that health care workers, wards, and PPE can be redistributed to services in which COVID-19 patients receive care.

• Cohort confirmed COVID-19 patients without co-infection with other transmissible microorganisms in the same room in order to streamline the workflow and facilitate extended use of PPE (see below).

• Designate dedicated health care workers/teams only for COVID-19 patient care so that they can use PPE for longer periods of time (extended use of PPE), if necessary (see considerations section below for details).

• Restrict the number of health care workers from entering the rooms of COVID-19 patients if they are not involved in providing direct care. Streamline the workflow and reduce to a safe level care that requires face-to-face interaction between health worker and patient. To do so, consider bundling activities to minimize the number of times a room is entered (e.g. check vital signs during medication administration or have food delivered by health care workers while they are performing other care) and plan which activities will be performed at the bedside.

• Consider using specific PPE only if in direct close contact with the patient or when touching the environment (e.g. wearing a medical mask and face shield, not using gloves or gown over the scrub suit, if entering the patient’s room only to ask questions or make visual checks).

• Visitors should not be allowed to visit confirmed or probable COVID-19 patients, but if strictly necessary, restrict the number of visitors and the time allowed; provide clear instructions about what PPE is required to be used during the visit, about how to put on and remove PPE, and perform hand hygiene to ensure that visitors avoid exposure.

2. **Ensure rational and appropriate use of PPE**

PPE should be used in combination with administrative and engineering controls. The indications for PPE should be
Based on the setting, target audience, risk of exposure (e.g., type of activity) and the transmission dynamics of the pathogen (e.g., contact, droplet, or aerosol). The overuse or misuse of PPE will have a further impact on supply shortages. Observing the following recommendations will ensure rational use of PPE:

- The type of PPE used when caring for COVID-19 patients will vary according to the setting, type of personnel, and activity (Table 1).
- Health care workers involved in the direct care of patients should use PPE according to indications (Table 1).
- Specifically, for aerosol-generating procedures and support treatments (tracheal intubation, non-invasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation, and bronchoscopy) health care workers should use respirators, eye protection, gloves and gowns; aprons should also be used if gowns are not fluid-resistant.
- Among the general public, persons with symptoms suggestive of COVID-19 or those caring for COVID-19 patients at home should receive medical masks and instructions on their use. For additional information, see Home care for patients with COVID-19 presenting with mild symptoms and management of their contacts.
- For additional information, see Advice on the use of masks in the community, during home care, and in health care settings in the context of COVID-19.

### 3. Coordinate PPE supply chain management mechanisms.

The management of PPE should be coordinated through essential national and international supply chain management mechanisms that include but are not restricted to:

- Using PPE forecasts based on rational quantification models to ensure the rationalization of requested supplies;
- Monitoring and controlling PPE requests from countries and large responders;
- Promoting a centralized request management approach to avoid duplication of stock and ensuring strict adherence to essential stock management rules to limit wastage, overstock, and stock ruptures;
- Monitoring the end-to-end distribution of PPE;
- Monitoring and controlling the distribution of PPE from medical facilities stores.

### Handling cargo from affected countries

An experimental study conducted in a laboratory evaluated the survival of the COVID-19 virus on different surfaces and reported that the virus can remain viable up to 72 hours on plastic and stainless steel, up to four hours on copper, and up to 24 hours on cardboard. To date, there are no data to suggest that contact with goods or products shipped from countries affected by the COVID-19 outbreak have been the source of COVID-19 infection in humans. WHO will continue to closely monitor the evolution of the COVID-19 outbreak and will update recommendations as needed.

The rationalized use and distribution of PPE when handling cargo from and to countries affected by the COVID-19 outbreak includes the following recommendations:

- Wearing a mask of any type is not recommended when handling cargo from an affected country.
- Gloves are not required unless they are used for protection against mechanical hazards, such as when manipulating rough surfaces.
- Importantly, the use of gloves does not replace the need for appropriate hand hygiene, which should be performed frequently, as described above.
- When disinfecting supplies or pallets, no additional PPE is required beyond what is routinely recommended.
- Hand hygiene should be practiced.
Table 1. Recommended PPE during the outbreak of COVID-19 outbreak, according to the setting, personnel, and type of activity

<table>
<thead>
<tr>
<th>Setting</th>
<th>Target personnel or patients</th>
<th>Activity</th>
<th>Type of PPE or procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health care facilities</td>
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<tr>
<td>Inpatient facilities</td>
<td></td>
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<tr>
<td>Screening(^1)</td>
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<tr>
<td>Clinical triage for prioritization of care according to severity (e.g., Manchester classification) should be performed in separate area for individuals with symptoms and signs</td>
<td>Health care workers</td>
<td>Preliminary screening not involving direct contact(^2).</td>
<td>Maintain physical distance of at least 1 metre.</td>
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<td></td>
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<td></td>
<td>Ideally, build glass/plastic screens to create a barrier between health care workers and patients</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>No PPE required.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>When physical distance is not feasible and yet no patient contact, use mask and eye protection.</td>
</tr>
<tr>
<td></td>
<td>Patients with symptoms suggestive of COVID-19</td>
<td>Any</td>
<td>Maintain physical distance of at least 1 metre.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Provide medical mask if tolerated by patient.</td>
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<td></td>
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<td></td>
<td>Immediately move the patient to an isolation room or separate area away from others; if this is not feasible, ensure spatial distance of at least 1 metre from other patients.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene and have the patient perform hand hygiene.</td>
</tr>
<tr>
<td></td>
<td>Patients without symptoms suggestive of COVID-19</td>
<td>Any</td>
<td>No PPE required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene and have the patient perform hand hygiene.</td>
</tr>
<tr>
<td>Patient room/ward</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Health care workers</td>
<td>Providing direct care to COVID-19 patients, in the absence of aerosol-generating procedures</td>
<td>Medical mask.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Gown.</td>
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<td></td>
<td></td>
<td></td>
<td>Gloves.</td>
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<td></td>
<td></td>
<td></td>
<td>Eye protection (goggles or face shield).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene.</td>
</tr>
<tr>
<td></td>
<td>Health care workers</td>
<td>Providing direct care to COVID-19 patients in settings where aerosol-generating procedures are frequently in place(^3)</td>
<td>Respirator N95 or FFP2 or FFP3 standard, or equivalent.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Gown.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Gloves.</td>
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<td></td>
<td></td>
<td></td>
<td>Eye protection.</td>
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<td></td>
<td></td>
<td></td>
<td>Apron.</td>
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<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene.</td>
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<tr>
<td></td>
<td>Cleaners</td>
<td>Entering the room of COVID-19 patients</td>
<td>Medical mask.</td>
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<td></td>
<td></td>
<td></td>
<td>Gown.</td>
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<td></td>
<td></td>
<td></td>
<td>Heavy-duty gloves.</td>
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<td></td>
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<td>Eye protection (if risk of splash from organic material or chemicals is anticipated)</td>
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<td></td>
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<td></td>
<td>Closed work shoes.</td>
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<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene.</td>
</tr>
<tr>
<td></td>
<td>Visitors(^b)</td>
<td>Entering the room of a COVID-19 patient</td>
<td>Maintain physical distance of at least 1 metre.</td>
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<td></td>
<td></td>
<td></td>
<td>Medical mask.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Gown.</td>
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<td></td>
<td></td>
<td></td>
<td>Gloves.</td>
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<td></td>
<td></td>
<td></td>
<td>Perform hand hygiene.</td>
</tr>
</tbody>
</table>

\(^1\) The screening procedure refers to prompt identification of patients with signs and symptoms of COVID-19.

\(^2\) AGP: tracheal intubation, non-invasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy.
| Areas of transit where patients are not allowed (e.g. cafeteria, corridors) | All staff, including health care workers. | Any activity that does not involve contact with COVID-19 patients | • Maintain physical distance of at least 1 metre  
• No PPE required  
• Perform hand hygiene |
|---|---|---|---|
| Laboratory | Lab technician | Manipulation of respiratory samples Specimen handling for molecular testing would require BSL-2 or equivalent facilities. Handling and processing of specimens from cases with suspected or confirmed COVID-19 infection that are intended for additional laboratory tests, such as haematology or blood gas analysis, should apply standard precautions<sup>9</sup> | • Maintain physical distance of at least 1 metre  
• Medical mask  
• Eye protection  
• Gown  
• Gloves  
• Perform hand hygiene |
| Administrative areas | All staff, including health care workers. | Administrative tasks that do not involve contact with COVID-19 patients. | • Maintain physical distance of at least 1 metre  
• No PPE required  
• Perform hand hygiene |

### Outpatient facilities

| Screening/ triage | Health care workers | Preliminary screening not involving direct contact<sup>6</sup> | • Maintain physical distance of at least 1 metre.  
• Ideally, build a glass/plastic screen to create a barrier between health care workers and patients  
• No PPE required  
• When physical distance is not feasible and yet no patient contact, use mask and eye protection.  
• Perform hand hygiene |
|---|---|---|---|
| Patients with symptoms suggestive of COVID-19 | Any | | • Maintain spatial distance of at least 1 metre.  
• Provide medical mask if tolerated.  
• Perform hand hygiene |
| Patients without symptoms suggestive of COVID-19 | Any | | • No PPE required  
• Perform hand hygiene |
| Waiting room | Patients with symptoms suggestive of COVID-19 | Any | • Provide medical mask if tolerated.  
• Immediately move the patient to an isolation room or separate area away from others; if this is not feasible, ensure spatial distance of at least 1 metre from other patients.  
• Have the patient perform hand hygiene |
| Patients without respiratory symptoms | Any | | • No PPE required  
• Have the patient perform hand hygiene |
| Consultation room | Health care workers | Physical examination of patient with symptoms suggestive of COVID-19 | • Medical mask  
• Gown  
• Gloves  
• Eye protection  
• Perform hand hygiene |
| Health care workers | Physical examination of patients without symptoms suggestive of COVID-19 | | • PPE according to standard precautions and risk assessment.  
• Perform hand hygiene |
| Patients with symptoms suggestive of COVID-19 | Any | | • Provide medical mask if tolerated.  
• Hand hygiene and respiratory etiquette |
### Patients without symptoms suggestive of COVID-19

*Any*

- No PPE required
- Have the patient perform hand hygiene

### Cleaners

After and between consultations with patients with respiratory symptoms.

- Medical mask
- Gown
- Heavy-duty gloves
- Eye protection (if risk of splash from organic material or chemicals)
- Closed work shoes
- Perform hand hygiene

### Administrative areas

All staff, including health care workers

#### Administrative tasks

- Maintain physical distance of at least 1 metre between staff
- No PPE required
- Perform hand hygiene

### Home care

#### Home

Patients with symptoms suggestive of COVID-19

*Any*

- Maintain physical distance of at least 1 metre.
- Provide medical mask if tolerated, except when sleeping.
- Hand and respiratory hygiene

Caregiver

Entering the patient’s room, but not providing direct care or assistance

- Maintain physical distance of at least 1 metre
- Medical mask
- Perform hand hygiene

Caregiver

Providing direct care or when handling stool, urine, or waste from COVID-19 patient being cared for at home

- Gloves
- Medical mask
- Apron (if risk of splash is anticipated)
- Perform hand hygiene

Health care workers

Providing direct care or assistance to a COVID-19 patient at home

- Medical mask
- Gown
- Gloves
- Eye protection

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### Points of entry at airports, ports and ground crossing as applicable

#### Administrative areas

All staff

*Any*

- No PPE required

**Screening area**

Staff

First screening (temperature measurement) not involving direct contact:

- Maintain physical distance of at least 1 metre.
- Ideally, build a glass/plastic screen to create a barrier between health care workers and patients
- No PPE required
- When physical distance is not feasible, yet no patient contact, use mask and eye protection.
- Perform hand hygiene

Staff

Second screening (i.e. interviewing passengers with fever for clinical symptoms suggestive of COVID-19 disease and travel history)

- Maintain physical distance of at least 1 metre.
- Medical mask
- Gloves
- Perform hand hygiene

Cleaners

Cleaning the area where passengers with fever are being screened

- Medical mask
- Gown
- Heavy duty gloves
- Eye protection (if risk of splash from organic material or chemicals)
- Boots or closed work shoes
- Perform hand hygiene

### Temporary isolation area

Staff

Entering the isolation area, but not providing direct assistance

- Maintain physical distance of at least 1 metre.
- Medical mask
<table>
<thead>
<tr>
<th>Role</th>
<th>Task Description</th>
<th>Equipment/Precautions</th>
</tr>
</thead>
</table>
| Staff, health care workers  | Assisting or caring for passenger being transported to a health care facility as a suspected COVID-19 cases | • Gloves  
• Medical mask  
• Gown  
• Gloves  
• Eye protection  
• Perform hand hygiene |
| Cleaners                    | Cleaning isolation area                                                           | • Maintain physical distance of at least 1 metre.  
• Medical mask  
• Gown  
• Heavy duty gloves  
• Eye protection (if risk of splash from organic material or chemicals).  
• Closed work shoes  
• Perform hand hygiene |
| Ambulance or transfer vehicle | Health care workers Transporting suspected COVID-19 patients to the referral health care facility | • Medical mask  
• Gowns  
• Gloves  
• Eye protection  
• Perform hand hygiene |
| Driver                      | Involved only in driving the patient with suspected COVID-19 disease and the driver's compartment is separated from the COVID-19 patient | • Maintain physical distance of at least 1 metre.  
• No PPE required  
• Perform hand hygiene |
| Patient with suspected COVID-19. | Transport to the referral health care facility. | • Medical mask if tolerated  
• Have the patient perform hand hygiene |
| Cleaners                    | Cleaning after and between transport of patients with suspected COVID-19 to the referral health care facility. | • Medical mask  
• Gown  
• Heavy duty gloves  
• Eye protection (if risk of splash from organic material or chemicals).  
• Boots or closed work shoes  
• Perform hand hygiene |

### Special considerations for rapid-response teams assisting with public health investigations

<table>
<thead>
<tr>
<th>Location</th>
<th>Team</th>
<th>Task Description</th>
<th>Equipment/Precautions</th>
</tr>
</thead>
</table>
| Anywhere | Rapid-response team investigators | Remote interview of suspected or confirmed COVID-19 patients or their contacts. | • No PPE if done remotely (e.g. by telephone or video conference).  
• Remote interview is the preferred method. |
|          |      | In-person interview of suspected or confirmed COVID-19 patients or contacts without direct contact | • Medical mask  
• Maintain physical distance of at least 1 metre.  
• The interview should be conducted outside the house or outdoors, and confirmed or suspected COVID-19 patients should wear a medical mask if tolerated.  
• Perform hand hygiene |
Disruptions in the global supply chain of PPE

The current global stockpile of PPE is insufficient, particularly for medical masks and respirators, and the supply of gowns, goggles, and face shields is now insufficient to satisfy the global demand. Surging global demand—driven not only by the number of COVID-19 cases but also by misinformation, panic buying, and stockpiling—has resulted in further shortages of PPE globally. The capacity to expand PPE production is limited, and the current demand for respirators and masks cannot be met, especially if widespread inappropriate use of PPE continues.

However, with manufacturing companies in some of the main exporting countries restarting their production, and an established global coordination mechanism that WHO anticipates will contribute to addressing the global shortage. Dedicated assistance and international solidarity mechanisms are required to meet the needs of the most vulnerable countries, which may face affordability issues in a context of rising prices determined by an unprecedented surge in demand, coupled with supply and distribution disruptions.

Members States and large responders can forecast their supply needs using the Essential Supplies forecasting tool.

Considerations for decision making processes during severe shortages of PPE

In the context of severe PPE shortages despite application of the above-mentioned strategies, it is crucial to ensure a “whole of society” response and to protect frontline health care workers. This includes advocating for the urgent increased production of PPE, including, if needed, through advance market commitments, public-sector mandated scale up of production by the private sector, pursuing donation options, international solidarity through financial support of PPE purchase and distribution for the needs of the most vulnerable countries, and engaging with the general public to prevent irrational use of PPE at community level, among other strategies.

Any alternative approach to find temporary solutions to mitigate critical shortages of PPE should be based on scientific evidence, the principles of safe care delivery and health care safety, workload minimization for health care workers, and avoiding a false sense of security.

Based on current evidence, in consultation with international experts and other agencies in the field of IPC, WHO carefully considered last-resort temporary measures in crisis situations to be adopted only where there might be serious shortages of PPE or in areas where PPE may not be available.

WHO stresses that these temporary measures should be avoided as much as possible when caring for severe or critically ill COVID-19 patients, and for patients with known co-infections of multi-drug resistant or other organisms transmitted by contact (e.g. Klebsiella pneumoniae) or droplets (e.g. influenza virus).

The following temporary measures could be considered independently or in combination, depending on the local situation:

1. PPE extended use (using for longer periods of time than normal according to standards);
2. Reprocessing followed by reuse (after cleaning or decontamination/sterilization) of either reusable or disposable PPE;
3. Considering alternative items compared with the standards recommended by WHO.

An additional consideration is the use of PPE beyond the manufacturer-designated shelf life or expiration date for a limited time. The items should be inspected before use to be sure they are in good condition with no degradation, tears, or wear that could affect performance. N95 respirators that are past their designated shelf life are no longer NIOSH-approved, as all manufacturer-designated conditions of use must be met to maintain the NIOSH approval. An expired respirator can still be effective at protecting health care provider if the straps are intact, there are no visible signs of damage, and they can be fit-tested. Health care providers should inspect the mask and perform a seal check before use.

The reuse of any item without a reprocessing/decontamination process is considered inadequate and unsafe. The reprocessing should be performed by trained staff in the sterile services department of a health care facility or at bigger scale under controlled and standardized conditions. Many medical devices are designed to be reusable, hence their compatibility with decontamination methods; this is not the case for face shields, medical masks, and respirators. Normally, for any reprocessing methods, cleaning before disinfection and sterilization is required. This is a problem for masks and respirators because they cannot be cleaned without losing their proprieties.

Methods for reprocessing masks or respirators are not well established nor standardized, and therefore should be considered only when there is critical PPE shortage or lack of PPE. Issues to take into consideration when reprocessing include:
1. efficacy of the process to guarantee disinfection or sterilization
2. reprocessing method not resulting in residual toxicity for health care workers
3. maintenance of functional integrity and shape of item. Further, when considering reprocessing and reuse, manufacturers’ instructions for reprocessing should be followed, if available. In addition, systems should be put in place to routinely inspect, repair (if applicable) and dispose of reused PPE when necessary (e.g. damaged, no longer suitable for reuse).

In the current exceptional crisis scenario of the COVID-19 pandemic, reprocessing of disposable PPE is an evolving area where research and development is ongoing and urgently needed. In this document, only methods that have been tested and either published in peer-reviewed journals or commissioned by the US Food and Drug Administration (FDA) are reported. However, WHO is aware of ongoing studies that are testing promising approaches (e.g. steam or heat sterilization of medical masks if performed in standardized conditions). As more evidence becomes available, WHO will update these considerations accordingly and hence this document should be considered interim guidance.

Alternative materials
As of the date of publication, the replacement of standard PPE with items produced with materials not having the necessary requirements (e.g. cotton cloth masks to replace medical masks or respirators) has not been proven to be effective and is discouraged (see below). If production of any PPE for use in health care settings is proposed locally in situations of shortage or stock out, a local authority should assess the proposed PPE according to specific minimum standards and technical specifications.

Each of these measures carries significant risks and limitations and thus should be considered only as a last resort when all other strategies for rational and appropriate use and procurement of PPE (see Figure 1) have been exhausted.

Summary of temporary measures in the context of severe PPE shortage
Table 2 summarizes temporary measures in the context of severe PPE shortage or stock-out. For each option, there is a description of how the measure should be used, what the limitations are, criteria for PPE removal and precautions, and feasibility. The latter mainly takes into consideration costs and local capacity (e.g. infrastructures, equipment, human resources) to undertake the measure in the safest and most standardized conditions possible, and it refers to feasibility for high-income countries (HIC) vs low and middle-income countries (LMIC).

Irrespective of the measure implemented, health care workers must have the required IPC education and training about the correct use of PPE and other IPC precautions, including demonstration of competency in appropriate procedures for putting on and removing PPE required for direct care of patients with COVID-19 and other tasks - see: WHO | How to put on and take off Personal Protective Equipment (PPE).
Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance

### Table 2. Options for temporary measures due to the shortage of Personal Protective Equipment (PPE): extended use, reprocessing, or use of alternative PPE

<table>
<thead>
<tr>
<th>Type of PPE</th>
<th>Measure</th>
<th>Description</th>
<th>Limitations/risks/removal criteria</th>
<th>Feasibility considerations</th>
</tr>
</thead>
</table>
| Medical mask use by health workers| 1) Extended use  | The use without removing for up to 6h, when caring for a cohort of COVID-19 patients | **Risks:**  
- Extended use of medical mask may increase risk of contamination of the mask with COVID-19 virus and other pathogens  
- Wearing the mask for a prolonged period may increase the chance of the health care worker touching the mask or having inadvertent under-mask touches; if the mask is touched/adjusted, hand hygiene must be performed immediately  
- Damage to or reactions of face skin tissue may occur with prolonged use of medical masks  
- Filtration media of the medical mask may become clogged, thereby increasing breathing resistance and the risk of breathing unfiltered ambient air from the sides of the medical mask  
- Extended periods of time in active patient wards required for health care workers  

**Removal criteria and precautions:**  
- If the mask becomes wet, soiled, or damaged, or if it becomes difficult to breathe through  
- If the mask is exposed to splash of chemicals, infectious substances, or body fluids  
- If the mask is displaced from face for any reason.  
- If the front of the mask is touched to adjust it  
- Follow the safe procedure for removal and do not touch the front of the mask  
- The mask needs to be removed whenever providing care outside a designated cohort of COVID-19 patients  
- Follow the safe procedure for removal and do not touch the front of the mask  
- Use of the same medical mask by a health care worker between a patient with COVID-19 and a patient who does not have COVID-19 is not recommended owing to the risk of transmission to another patient who would be susceptible to COVID-19 |
|                                   |                  |                                                                             |                                                                                                    | Feasible in all countries  
Minimum requirements include definition of standard procedure, training and follow up to ensure good practices |

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<table>
<thead>
<tr>
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<th>Description</th>
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<th>Feasibility considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2) Reprocessing</td>
<td>No quality evidence is available to date on medical mask reprocessing and is not advised</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>3) Alternative items in absence of medical masks</td>
<td>i) FFP1 respirator</td>
<td>Removal criteria and precautions:</td>
<td>Feasible in HIC and LMIC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If the mask becomes wet, soiled, or damaged, or if it becomes difficult to breathe through</td>
<td>Risks:</td>
<td>Potential of local production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If the mask is exposed to splash of chemicals, infectious substances, or body fluids</td>
<td>Protective against direct direct exposure of mouth, nose and eyes to droplets; however depends on the design and on the positioning of HCW in relation to the patient</td>
<td>Minimum requirements include definition of standard procedure, training, and follow up to ensure good practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If the mask is displaced from face for any reason</td>
<td>Removal criteria:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If the front of the mask is touched to adjust it</td>
<td>• If face shield is contaminated by splash of chemicals, infectious substances, or body fluids</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>• The mask needs to be removed whenever providing care outside of designated cohort of COVID-19 patients</td>
<td>• If face shield obstructs health care worker safety or visibility of health care environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Follow the safe procedure for removal and do not touch the front of the mask</td>
<td>• Follow the safe procedure for removal and do not touch the front of the face shield</td>
<td></td>
</tr>
<tr>
<td>Respirators (FFP2, FFP3 or N95)</td>
<td>1) Extended use</td>
<td>The use without removing up to 6h, when caring for a cohort of COVID-19 patients.</td>
<td>Risks:</td>
<td>Feasible in HIC and LMIC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Extended use of respirators may increase risk of contamination with COVID-19 virus and other pathogens</td>
<td>Extended use of respirators may increase risk of contamination with COVID-19 virus and other pathogens</td>
<td>Minimum requirements include definition of standard procedure, training and follow up to ensure good practices</td>
</tr>
</tbody>
</table>
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<tr>
<th>Type of PPE</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Facial dermatitis, respirator-induced acne, respiratory fatigue, impaired work capacity, increased oxygen debt, early exhaustion at lighter workloads, elevated levels of CO₂, increased nasal resistance, and increased non-compliance with best practices while wearing a respirator (adjustments, mask or face touches, under-the-respirator touches, and eye touches), have been reported after prolonged use of respirators.</strong></td>
<td><strong>Feasible in HIC</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Extended use may clog the filtration media, leading to increased breathing resistance</strong></td>
<td><strong>Potentially feasible in LMIC; Human resources, equipment installation, procurement of consumables, health care worker safety during the reprocessing should be considered.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Removal criteria and precautions:</strong></td>
<td><strong>Minimum requirements include defining a standard operating procedure, training, and follow up to ensure good practices</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• If respirator becomes wet, soiled, damaged, or difficult to breathe through.</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>• If exposed to splash of chemicals, infectious substances, or body fluids</td>
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<td>• If displaced from the face for any reason.</td>
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<td>• If the front of the respirator is touched to adjust it</td>
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<td></td>
<td></td>
<td></td>
<td>• Follow the safe procedure for removal and do not touch the front of the respirator</td>
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<td></td>
<td></td>
<td></td>
<td>• Use of the same respirator by a health care worker between a patient with COVID-19 and a patient who does not have COVID-19 is not recommended owing to the risk of transmission to another patient who would be susceptible to COVID-19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Reprocessing</td>
<td>Process to decontaminate a respirator using disinfection or sterilization methods.</td>
<td><strong>Limitations/ Risks:</strong></td>
<td><strong>Feasible in HIC</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methods (not validated) for respirator reprocessing (see Annex 1):</td>
<td>• Reprocessing methods have not been validated by substantial research and there are currently no standardized methods or protocols for ensuring the effectiveness nor integrity of the respirators after reprocessing</td>
<td><strong>Potentially feasible in LMIC;</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• vapor of hydrogen peroxide</td>
<td>• Shelf-life of reprocessed respirators is unknown; however, degradation of the filtration media or elastic strap after one or more sterilization cycles affects the fit of a respirator to the face</td>
<td><strong>Human resources, equipment installation, procurement of consumables, health care worker safety during the reprocessing should be considered.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ethylene oxide</td>
<td>• Damage to the shape of respirators due to the reprocessing may affect fit and protection properties</td>
<td><strong>Minimum requirements include defining a standard operating procedure, training, and follow up to ensure good practices</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• UV radiation lamp</td>
<td>• Number of reprocessing cycles highly variable, depending on the reprocessing method used and the respirator brand/model</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Disposal criteria and precautions:</strong></td>
<td><strong>Feasible in HIC</strong></td>
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<tr>
<td></td>
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<td></td>
<td>• After a pre-defined number of reuses the respirator should be discarded in appropriate contained waste receptacle according to local guidance/policy</td>
<td><strong>Potentially feasible in LMIC;</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Human resources, equipment installation, procurement of consumables, health care worker safety during the reprocessing should be considered.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Minimum requirements include defining a standard operating procedure, training, and follow up to ensure good practices</strong></td>
</tr>
<tr>
<td>Type of PPE</td>
<td>Measure</td>
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</tr>
<tr>
<td>Gowns used by health workers</td>
<td>1) Extended use</td>
<td>The use without removing, when providing care of a cohort of patients with COVID-19. Not applicable if the patient has multidrug resistant microorganisms or other type of disease requiring contact precautions. In such case, the gowns should be changed between patients</td>
<td>• When a respirator is removed from the face, it should be immediately placed in a designated container for reprocessing and labeled with the original wearer’s name. • The respirator should be returned to original wearer after reprocessing cycle.</td>
<td>Feasible in HIC and LMIC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risks</td>
<td>• Extended use of gowns may increase risk of contamination with COVID-19 virus • The extended use of gowns may increase the risk of transmission of other pathogens between patients</td>
<td>Minimum requirements include definition of standard procedure, training, and follow up to ensure good practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removal criteria and precautions:</td>
<td>• If gown becomes wet, soiled, or damaged • If gown is exposed to splash of chemicals, infectious substances, or body fluids • When providing care outside designated cohort of COVID-19 patients • Follow the safe procedure for removal of gowns to prevent contamination of environment • Use of the same gown by a health care worker between a patient with COVID-19 and a patient who does not have COVID-19 is not recommended due to the risk of transmission to another patient who would be susceptible to COVID-19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Reprocessing</td>
<td>Process to decontaminate a cotton gown by washing and disinfection methods. Reprocessing can be done with cotton gowns. Wash and disinfect cotton gowns: washing by machine with warm water (60-90°C) and laundry detergent is recommended for reprocessing of the gown. If machine washing is not possible, linen can be soaked in hot water and soap in a large drum, using a stick to</td>
<td>• In hot and humid weather, the cotton gown can lead to discomfort and sweating</td>
<td>Feasible in HIC and LMIC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removal criteria:</td>
<td>• If gown becomes wet, soiled, or damaged</td>
<td>Requires additional support staff, gown reprocessing inventory; laundry equipped with hot water or manual washing with water and soap, followed by soaking in disinfectant</td>
</tr>
<tr>
<td>Type of PPE</td>
<td>Measure</td>
<td>Description</td>
<td>Limitations/risks/removal criteria</td>
<td>Feasibility considerations</td>
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<td></td>
<td>stir, avoiding splashing. Then soak linen in 0.05% chlorine for approximately 30 minutes. Finally, rinse with clean water and let it dry fully in the sunlight</td>
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</tbody>
</table>
| 3) Alternatives | i) Disposable laboratory coats | Only for brief contact with the patients; should not be used for prolonged contact or when performing aerosol-generating procedures and support treatments | **Risks:**  
- Disposable laboratory coats are less durable than gowns, so there is a risk of damage during the patient care  
**Removal criteria and precautions:**  
- If disposable alternatives to gowns become wet, soiled, or damaged  
- If alternative to gown is exposed to splash of chemicals, infectious substances, or body fluids  
- Follow the safe procedure for removal of laboratory coat to prevent contamination of environment  
- Use of the same laboratory coat by a health care worker between a patient with COVID-19 and a patient who does not have COVID-19 is not recommended due to the risk of transmission to another patient who would be susceptible to COVID-19 | Feasible in HIC and LMIC |
| | ii) Disposable impermeable plastic aprons | Should be avoided when performing aerosol-generating procedures and support treatments | **Risks:**  
- Plastic aprons do not protect arms and the back of the torso, which can be exposed to splashes  
**Removal criteria and precautions:**  
- If disposable alternatives to gowns become wet, soiled, or damaged  
- If alternative to gown is exposed to splash of chemicals, infectious substances, or body fluids  
- Follow the safe procedure for removal of apron to prevent contamination of environment | Potentially feasible in HIC and LMIC  
Requires procurement of aprons with proper design for health care |
| | iii) Reusable (washable) patient gowns, reusable (washable) laboratory coats | (see above recommendations for laundry of gowns) | **Risk:**  
- Design and thickness may not be compatible with the full protection of the torso or arms  
**Removal criteria:** | Potentially feasible in HIC and LMIC  
Requires additional support staff, gown reprocessing inventory; laundry equipped with hot water or manual washing with water and soap, followed by soaking in disinfectant |
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<tr>
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<th>Limitations/risks/removal criteria</th>
<th>Feasibility considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goggles or safety glasses used by health workers</td>
<td>1) Extended use</td>
<td>The use without removing during the shift period, when caring for a cohort of COVID-19 patients.</td>
<td>• If gown or coat becomes wet, soiled, or damaged</td>
<td></td>
</tr>
</tbody>
</table>
| | | | **Risks:**  
  • Extended use of goggles may increase the discomfort and fatigue of health care workers  
  • Skin tissue damage may occur to face with prolonged goggle use |
| | | **Removal criteria and precautions:**  
  • If goggles are contaminated by splash of chemicals, infectious substances, or body fluids  
  • If goggles obstruct health care worker safety or visibility of health care environment or become loose  
  • Follow the safe procedure for removal of goggles to prevent contamination of eyes  
  • Use of the same goggles by a health care worker between a patient with COVID-19 and a patient who does not have COVID-19 is not recommended due to the risk of transmission to another patient who would be susceptible to COVID-19 |
| | | **Feasibility:** Feasible in both HIC and LMIC |
| | 2) Reprocessing | Clean goggles with soap/detergent and water followed by disinfection using either sodium hypochlorite 0.1% (followed by rinsing with clean water) or 70% alcohol wipes. Goggles may be cleaned immediately after removal and hand hygiene is performed OR placed in designated closed container for later cleaning and disinfection. | **Risks:**  
  • Residual toxicity of sodium hypochlorite can occur if not thoroughly rinsed after disinfection.  
  • Increases health care worker workload (limitation) |
| | | **Removal criteria:**  
  • If contaminated by splash of chemicals, infectious substances, or body fluids  
  • If goggles obstruct health care worker safety or visibility of health care environment |
| | | **Feasibility:** Potentially feasible in HIC and LMIC  
  Requires procurement of disinfectants and adequate clean space for the procedure |
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</tr>
</thead>
</table>
|                      |                    | Ensure cleaning of goggles takes place on a clean surface by disinfecting the surface before cleaning of goggles. Appropriate contact time with disinfectant (e.g. 10 minutes when using sodium hypochlorite 0.1%) should be adhered to before reuse of goggles. After cleaning and disinfection, they must be stored in a clean area to avoid recontamination | Removal criteria and precautions:  
• If contaminated by splash of chemicals, infectious substances, or body fluids  
• If goggles obstruct health care worker safety or visibility of health care environment  
Removal criteria and precautions:  
• If contaminated by splash of chemicals, infectious substances, or body fluids  
• If goggles obstruct health care worker safety or visibility of health care environment | Feasible in HIC and LIMC  
Minimal requirements include definition of standard procedure, training and follow up to ensure good practices |
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</tr>
</thead>
</table>
|            | 2) Reprocessing | Cleaning with soap/detergent and water and disinfection with 70% alcohol or sodium hypochlorite 0.1%; finally rinsing with clean water if sodium hypochlorite used after contact time of 10 min. Face shield may be cleaned immediately after appropriate doffing and hand hygiene is performed OR placed in designated closed container for later cleaning and disinfection. Ensure cleaning of face shield takes place on surface without contamination. Disinfection of surface for cleaning of face shield is advised. Appropriate contact time with disinfectant should be adhered to before reuse of face shield. After cleaning and disinfection, they must be stored in a clean area to avoid recontamination. | Limitations/Risks:  
- Damage to plastic, resulting in reduced visibility and integrity  
- Residual toxicity of the sodium hypochlorite can occur if not thoroughly rinsed after disinfection.  
Removal criteria and precautions:  
- If contaminated by splash of chemicals, infectious substances, or body fluids  
- If face shield obstructs health care worker safety or visibility of healthcare environment  
- Follow the safe procedure for removal of goggles to prevent contamination of the face and eyes | Feasible in both HIC and LMIC  
Minimal requirements include definition of standard procedure, training and follow up to ensure good practices  
Human resource requirements, equipment installation, procurement of consumables, HCW safety during the chemical manipulation should be considered. |
|            | 3) Alternative | Local production of face shield | Limitations/Risks:  
- Suboptimal quality, including inadequate shape to ensure face protection  
Removal criteria:  
- If contaminated by splash of chemicals, infectious substances, or body fluids  
- If face shield obstructs health care worker safety or visibility of healthcare environment | Minimal requirements include definition of standard procedure, availability of material, human resource requirements, training, and follow up to ensure good practices |
Options not recommended by WHO: What WHO does and does NOT recommend:

1. Gloves: gloves should be worn when providing direct care for a COVID-19 case and then removed, followed by hand hygiene between COVID-19 patients. Using the same gloves for a cohort of COVID-19 cases (extended use) must not be done. Changing gloves between dirty and clean tasks during care to a patient and when moving from a patient to another, accompanied by hand hygiene, is absolutely necessary. Double gloving is not recommended, except for surgical procedures that carry a high risk of rupture.

2. The reuse of masks, gowns, or eye protection without appropriate decontamination/sterilization is strongly discouraged. The removal, storage, re-donning, and reuse of the same, potentially contaminated PPE items without adequate reprocessing is one of the principal sources of risk to health care workers.

3. The use of cotton cloth masks as an alternative to medical masks or respirators is not considered appropriate for protection of health care workers. Fabric thickness and weaving standards vary widely; hence, the barrier (filtration efficiency) against microorganisms passing through the fabric is unknown. In addition, cotton cloth masks are not fluid-resistant and thus may retain moisture, become contaminated, and act as a potential source of infection. Although some studies have been carried out for cloth masks using synthetic, hydrophobic materials on the outer layer, there is no current evidence to show that these perform adequately as PPE for health settings. As for other PPE items, if production of masks for use in health care settings is proposed locally in situations of shortage or stock out, a local authority should assess the proposed PPE according to specific minimum standards and technical specifications. As evidence becomes available WHO will update these considerations accordingly.
Annex 1: Studies on medical masks and respirators reprocessing methods

Table 1 presents a summary of studies on reprocessing options for respirators; only one study testing medical masks was found. This study, from 1978, used ethylene oxide sterilizer (EtO) with a single warm cycle (55°C and 725 mg/l 100% EtO gas) with exposure for 1 hour followed by 4 hours of aeration time.\textsuperscript{11} The study was however performed with restricted sampling of nonwoven masks, and it therefore not generalizable.

When considering whether to adopt described methods, the handling of masks and respirators for the decontamination procedure is a critical step; excessive manipulation must be avoided. In addition, systems should be in place to carefully inspect the items before every reprocessing cycle to check their integrity and shape maintenance; if damaged or not suitable for reuse, they should be immediately disposed of. The key aspects to be considered for considering a reprocessing method as acceptable are: 1) the efficacy of the method to disinfect/sterilize the equipment; 2) the preservation of the respirator’s filtration; 3) the preservation of the respirator’s shape and thus, of its fit; and 4) the safety for the person wearing the respirator (e.g. toxic effect after reprocessing).

Some methods should be avoided due to the damage to the mask, toxicity, or loss of filtration efficiency: washing, steam sterilization at 134°C, disinfection with bleach/sodium hypochlorite or alcohol, or microwave oven irradiation.\textsuperscript{14} Microwave ovens have shown some biocidal effect when combined with moisture to combine radiation with steam heat; however, problems that require careful consideration include: i) a lack of substantial review of standard microwave oven radiation capacities with respirator disinfection, ii) an inability to ensure controls for uniform distribution of steam, and iii) concern that the metal noseband of respirators may combust.\textsuperscript{15,16} Although gamma irradiation demonstrated experimental efficacy against emerging virus, this method was not evaluated specifically for masks or respirators.\textsuperscript{17}

Both vapor of hydrogen peroxide\textsuperscript{14,18,19} and ethylene oxide were favorable in some studies but limited by the models of respirators evaluated. The use of UV radiation can be a potential alternative; however, the low penetration power of UV light may not reach inner materials of respirator or penetrate through pleats or folds.\textsuperscript{20} The parameters of disinfection by using UVC light is not yet fully standardized for the purpose of reprocessing masks and respirators; this requires a validation procedure to ensure that all surfaces inside and outside masks are reached by the UVC light with appropriate irradiation time.\textsuperscript{20,21} Comparison among studies regarding methods is limited owing to different outcomes and evaluation methods. Further, the implications for practical considerations must include the feasibility of the control of all parameters of the methods.

Table 1. Studies on medical mask and respirators reprocessing methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment Parameters</th>
<th>Medical/ Respirator - Test method/Outcome Evaluated</th>
<th>Author, year</th>
<th>Limitations/Considerations</th>
<th>Pertinent Study Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Peroxide Vaporized</td>
<td>STERRAD NX100 Express cycle - Vaporized hydrogen peroxide low pressure gas sterilization Chamber temperature &lt;55 °C. Hydrogen Peroxide concentration 26.1mg/L. 6-minute sterilant exposure time. Total dose of 157 (mg/L x exposure time). 24 minutes</td>
<td>• FFP2 (3M) - Sodium chloride ‘fit test’ for total inward leakage used after each reprocessing cycle</td>
<td>RIVM, 2020 \textsuperscript{19}</td>
<td>• Not to be used with any material containing celluloses. • Soiled respirators were not used in this study. • Shelf life of reprocessed respirators not determined.</td>
<td>Filtration efficacy for an unused respirator is retained after 2 sterilization cycles</td>
</tr>
<tr>
<td>Hydrogen Peroxide Vaporized</td>
<td>Room Bio-Decontamination Service (RBDS™, BIOQUELL UK Ltd, Andover, UK), Clarus® R hydrogen peroxide vapor generator utilizing 30% H2O2</td>
<td>• N95 (six models)</td>
<td>Bergman, et al, 2010\textsuperscript{24}</td>
<td>• No observable physical changes</td>
<td>Control and decontamination treatment groups, had mean % penetration (P) &lt;</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment/Procedure</th>
<th>Recommendations</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Peroxide Gas plasma</td>
<td>STERRAD 100S Gas Plasma Sterilizer 55 minutes standard cycle</td>
<td>N95 and P100 - Automated Filter Tester used to measure initial filter aerosol penetration post-decontamination.</td>
<td>Viscusi et al, 2009 14 • Not to be used with any material containing cellulosates.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8130 Automated fit test (NaCl aerosol) - Filter air flow resistance</td>
<td>Standardized sterilization cycle performed at commercial facility, not by primary researcher</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control group: 4-hour 3x submersion in deionized water</td>
<td>If cotton is present in head straps or mask layers; they may absorb hydrogen peroxide and cause the STERRAD cycle to abort due to low hydrogen peroxide vapor concentration.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soiled respirators were not used in this study</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Did not significantly affect the aerosol penetration or filter airflow resistance.</td>
</tr>
<tr>
<td>Hydrogen Peroxide Vaporized</td>
<td>Bioquell Clarus C hydrogen peroxide vapor generator Generator was used in a closed chamber built for the experiment. Cycle: 10 min conditioning phase, 20 min gassing phase at 2 g/min, 150 min dwell phase at 0.5 g/min, 300 min aeration phase. Total cycle duration of 480 min (8 hr).</td>
<td>N95 (3M) - Decontamination efficacy after inoculation of Geobacillus stearothermophilus droplets; 50 repeated aerosol inoculation/decontamination cycles</td>
<td>Batelle, 201618 • Some degradation in elastic respirator straps noted following 30 cycles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Study showed performance of N95 FFR (respirator) continued to exceed 95% efficiency after 50 repeated inoculation and decontamination cycles. Approach allowed &gt;50 respirators to be decontaminated simultaneously</td>
</tr>
<tr>
<td>Hydrogen Peroxide gas plasma</td>
<td>3 cycles</td>
<td>STERRAD® 100S H2O2 Gas Plasma Sterilizer (Advanced Sterilization Products, Irvine, CA)</td>
<td>• N95 (six models)</td>
</tr>
<tr>
<td>Ethylene Oxide</td>
<td>Steri-Vac 5XL sterilizer</td>
<td>55 °C; 1-hour exposure</td>
<td>• N95 and P100 - Automated Filter Tester (AFT) used to measure initial filter aerosol penetration post-decontamination.</td>
</tr>
<tr>
<td>Ethylene Oxide</td>
<td>Gas concentration of 800 mg/L</td>
<td>60 °C; 4 hours sterilization; 1-hour aeration</td>
<td>• Medical mask (2 commercial nonwovens; 3 cotton gauze masks (3 layers); 1 gauze mask) - % of Bacterial Efficiency Filtration was measured for aerosol of bacteria (Staphylococcus aureus and Serratia marcescens)</td>
</tr>
<tr>
<td>Ethylene Oxide</td>
<td>Amsco® Eagle® 3017</td>
<td>55°C; 1-hour exposure (736.4 mg/L) followed by 12-hour aeration.</td>
<td>• N95 (six models)</td>
</tr>
</tbody>
</table>

Samples were packaged in Steris Vis-U-Tyvek®/polypropylene-polyethylene

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### Ultraviolet irradiation

<table>
<thead>
<tr>
<th>Method</th>
<th>Details</th>
<th>Final Dose</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultraviolet irradiation</strong></td>
<td>SterilGARD III model SG403A (low-pressure mercury arc lamp, 5.5 mg Hg; lamp type, TUV 36TS 4P SE; lamp voltage, 94 Volts; lamp wattage, 40 Watts; wavelength, 253.7 nm)</td>
<td>5-hour irradiation time</td>
<td>Final doses: 4.32-5.76 J/cm² Low: 5-hour irradiation time Final doses:</td>
</tr>
<tr>
<td><strong>Ultraviolet irradiation</strong></td>
<td>Sterilgard III laminar flow cabinet (The Baker Company, Sanford, ME, USA) fitted with a 40-W UV-C light (average UV intensity experimentally measured to range from 0.18 to 0.20 mW cm²). Fifteen-minute exposure to each side (outer and inner)</td>
<td>15-minute exposure to each side of FFR.</td>
<td>Final doses: 176–181 mJ/cm² exposure to each side of FFR.</td>
</tr>
<tr>
<td><strong>Ultraviolet irradiation</strong></td>
<td>A 120-cm, 80-W UV-C (254 nm, nanometer) lamp was adjusted to a height of 25 cm. The range of UV to which the FFR was exposed varied from 1.6 mW/cm² to 2.2 mW/cm² (Joules per square centimeter)</td>
<td>15 Minutes</td>
<td>Filter air flow resistance Control group: 4-hour 3x submersion in deionized water</td>
</tr>
</tbody>
</table>

- **Filter air flow resistance**
- **Control group:** 4-hour 3x submersion in deionized water
- **N95 (Honeywell)**
- Respirator masks uniformly loaded with nebulized MS2 droplets generated with six-jet Collison nebulizer. Coupons were cut from respirator masks for viral detection.
- **N95 (3M)**
- Quantitative real-time polymerase chain reaction (qRT-PCR) for decontamination efficiency of H5N1 virus NaCl penetration with 0.3µm particle size
- **N95**
- Laboratory applied H1N1 added to exterior surface of respirator. Circular coupons were cut from respirator and placed in medium to detect viable H1N1 in TCID₅₀ assay.

- **Vo et al, 2009**
- Author mentions potential limitation of pleats or folds in the respirator for UV light penetration
- Efficacy demonstrated only for decontamination of single virus (MS2) in study

- **Viscusi et al, 2009**
- Limited by the available working surface area of a biosafety cabinet equipped with a UV-C source or other area being irradiated by a UV source.
- the treatment did not affect the filter aerosol penetration, filter airflow resistance, or physical appearance of the FFRs.

- **Lore et al, 2012**
- Study did not examine decontamination effect on the straps or nose clip of the two respirators
- qRT-PCR indicated decontamination resulted in lower levels of detectable viral RNA compared with other two methods (microwave-generated steam and moist heat)
- Filtration efficiency was maintained with <5% penetration of NaCl

- **Heimbuch et al, 2011**
- Two instances in which viable virus were recovered in study can possibly be attributed to mask shielding
- Authors note that hundreds of FFR models exist but only 6 FFR were tested in study; other FFRs may perform differently
- Efficacy demonstrated for decontamination of single virus (H1N1) in study

- **Average log reduction of 4.69, virus reduced to values below the detection limit with no obvious signs of deterioration or deformation.**

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- **Ultraviolet irradiation**
  - SterilGARD III model SG403A (low-pressure mercury arc lamp, 5.5 mg Hg; lamp type, TUV 36TS 4P SE; lamp voltage, 94 Volts; lamp wattage, 40 Watts; wavelength, 253.7 nm) 5-hour irradiation time
  - 4.32-5.76 J/cm² Final doses: Low: 5-hour irradiation time
  - 7.20 J/cm² Final doses: High: 5-hour irradiation time
  - No detectable MS2 virus in this study.

- **Ultraviolet irradiation**
  - Sterilgard III laminar flow cabinet (The Baker Company, Sanford, ME, USA) fitted with a 40-W UV-C light (average UV intensity experimentally measured to range from 0.18 to 0.20 mW cm²). Fifteen-minute exposure to each side (outer and inner).
  - 176–181 mJ/cm² Final doses: 15-minute exposure to each side of FFR.

- **Ultraviolet irradiation**
  - A 120-cm, 80-W UV-C (254 nm, nanometer) lamp was adjusted to a height of 25 cm. The range of UV to which the FFR was exposed varied from 1.6 mW/cm² to 2.2 mW/cm² (Joules per square centimeter).
  - 1.8 J/cm² Final dose: 15 Minutes
### Ultraviolet irradiation (UV)

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
</table>
| **FFRs were placed on a laboratory stand inside a Sterilgard III laminar flow cabinet, fitted with a 40 W UV-C bulb.** Intensity 1.8 mW/cm² measured with a UVX Digital Radiometer with model UVX-25 sensor (254 nm filter). 15 min exposure to outer side of FFR. Final dose; 1.6-2.0 mW/cm² | - Surgical N95 (fluid resistance N95): 3M 1860, 3M 1870, KC PFR95-270 (46767)  
  - Respirator fit AND face seal leakage were measured with 10 participants using PORTACOUNT® Plus Model 8020A Respirator Fit Tester with an N95 Companion™ Model 8095 accessory.  
  - Bergman et al., 2011²⁵  
  - Study use an abbreviated fit-test protocol, only three FFR models, and a small group (n = 10) of respirator test subjects per FFR model.  
  - Subjects wore their FFRs for a shorter total test time of ~5 min (which includes the 3-min acclimatization period) using the modified protocol compared with the standard OSHA-accepted protocol (~12 min)  
  - Respirator fit was maintained throughout three decontamination cycles alternating with four donning/doffing cycles. Face seal leakage value was maintained at below 1% |
| **Custom UV device made of polished aluminum measuring 40-in L × 16-in W × 13-in H with a tunnel extension measuring 18-in L × 8-in W × 6-in H.** Eight 32-in 254-nm UV-C bulbs with an irradiance of 0.39 W/cm² at 1 m to deliver a UV dose of 1 J/cm² in ~1 minute. A sliding wire mesh rack was used to position the FFR during UV treatment. Air circulation system with high-airflow fans. Mean UV dose per FFR 1.1 ± 0.1 J/cm², mean temperature 21°C ± 2°C, mean relative humidity 48% ± 6% within the UV device. | - N95 (3M, Alpha Protech, Gerson Kimberly-Clark Moldex, Precept Prestige Ameritech, Sperian, U.S. Safety)  
  - Study artificially contaminated N95 with H1N1 influenza. Artificial saliva (mucin buffer) and artificial skin oil (sebum) were applied directly over influenza contamination. Coupons cut from mask for viral detection.  
  - Mills, et al., 2018²²  
  - Study conducted at 100x theoretical highest real-world respirator viral contamination levels estimated in other studies.  
  - Mean log reduction ranged from 1.25-4.64 log TCID₅₀ for sebum-soiled facepieces and 0.08-4.40 log TCID₅₀ for sebum-soiled straps. |
| **Ultraviolet light with a primary wavelength of 254 nm (UV-C).** Custom-made chamber of 91 cm × 31 cm × 64 cm high chamber. Two 15-Watt T-150 254 nm UV-C lamps in a reflective housing lined with black felt. UV doses from 120–950 J/cm² (coupons) and 590-2360 J/cm² (straps) | - Four models of N95 (3M, Gerson, Middleboro, Kimberly & Clark)  
  - 37mm coupons were punched + 2 straps from each respirator  
  - Determination of filter penetration and flow resistance before and after exposure to UV  
  - Lindsley, et al., 2015²¹  
  - Study found dramatic differences in the bursting strength of the layered materials that make up the respirator  
  - Study tested exterior of respirators, not interior but estimates this would require a high dose UV to penetrate to inside layers and would require testing the specific respirator used  
  - UV exposure led to small increase in particle penetration (1.25%) at UV doses from 120–950 J/cm² with little to no effect on flow resistance.  
  - Some degradation of the elastic straps used in different respirator designs when exposed to higher UV levels. |
| Ultraviolet irradiation (UV) | Mineralight® XX-20S 20-W UV bench lamp | • N95 – 15 models (3M, Kimberly Clark, Moldex, Precept, Gerson, Sperian, US Safety, Alpha Protect, Prestige Ameritech) - Influenza; MERS-CoV, SARS-CoV-1. Presence of either artificial saliva or artificial skin oil 50% tissue culture infectious dose per mL (TCID50/mL) | Heimbuch, 2019 | • Decontamination the presence of soiling agents on N95 can be effective but is dependent on the material being treated. • The shapes of respirators, their materials, and UV light arrangement can significantly affect decontamination efficacy | UV dose of 1 J/cm² was found to be the minimum dose providing maximum disinfection. Up to 20 cycles of UV treatment (approximately 1 J/cm² per cycle) does not have a meaningfully significant effect on, fit, air flow resistance, or particle |
| --- | --- | --- | --- | --- |
| Ultraviolet irradiation (UV) | UV Bench Lamp (UV-C, 254 nm, 40 W), Model XX-40S (UVP, LLC, Upland, CA). The UV intensity; mean of 27 measurements over the rectangular area used at the surface of the hood using a UVX Digital Radiometer with a model UVX-25 Sensor (254 nm filter) 45-min exposure at intensity 1.8 mW/cm² (UVP, LLC, Upland, CA). | • N95 (six models) • Study evaluated physical appearance, odour, and laboratory filtration performance. • 8130 Automated fit test (NaCl aerosol) • Filter air flow resistance | Bergman et al, 2010 | • No observable physical changes | Control and decontamination treatment groups, had mean %P < 4.01%, which is similar to penetration levels found in untreated |
| Ultraviolet irradiation (UV) | Sterigard cabinet flow cabinet (The Baker Company, Sanford, Maine fitte with 40 W UV-C Bulb, intensity 1.8mW/cm², 245nm Total exposure 30min (15 min each FFR side) | • FFR (6 model, 3M, Moldex, Kimberly Clark) - Phase 1: fit test to identify fit factor Phase 2: Physically examined for degradation and smell | Viscusi et al, 2011 | • Each FFR model is constructed uniquely, which may affect the impact that decontamination has on that model. • No physical damage • One subject reported strong odour • The MDFF were lower than the control depending on the model | No significant changes in fit, odour detection, comfort, or donning difficulty with each of the six models. |
Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance

| Moist heat incubation | Caron model 6010 laboratory incubator (Marietta, OH) 30-min incubation at 60°C, 80% relative humidity Following the first incubation, the samples were removed from the incubator and air-dried overnight. Following the second and third incubations, samples were removed from the incubator and air-dried for 30 min with the aid of a fan. | Multidonning fit-test procedure – metal nose bridge was return to the original position – multidonning fit factor (MDFF) 10 subjects x 6 FFR models x 4 treatment Subjective questionnaires Standard visual analog scale | Bergman et al, 2010<sup>24</sup> Some samples to experience partial separation of the inner foam nose cushion from the FFR Possible sparking during microwave heating caused by the metallic FFR nose bands. Control and decontamination treatment groups, had mean %P < 4.01%, which is similar to penetration levels found in untreated | • N95 (six models) • Study evaluated physical appearance, odour, and laboratory filtration performance. • 8130 Automated fit test (NaCl aerosol) • Filter air flow resistance Control group: 4-hour 3x submersion in deionized water |
| Moist Heat Incubation | 15 min incubation at 60 °C (upper temp. limit), 80% relative humidity in a Caron model 6010 laboratory incubator | • Surgical N95 (fluid resistance N95): 3M 1860, 3M 1870, KC PFR95-270 (46767) • Respirator fit AND face seal leakage were measured with 10 participants using PORTACOUNT® Plus Model 8020A Respirator Fit Tester with an N95 Companion™ Model 8095 accessory | Bergman et al, 2011<sup>25</sup> Study utilized an abbreviated fit test protocol, only three FFR models and a small group (n = 10) of respirator test subjects per FFR model. Subjects wore their FFRs for a shorter total test time of ~5 min (which includes the 3 min acclimatization period) using the modified protocol compared to the standard OSHA-accepted protocol (~12 min) • MHI decontamination cycle was shorter than previous study. Slight separation of the inner foam nose cushion was not exacerbated with multiple MHI treatments compared to a single treatment. Respirator fit was maintained throughout three MHI decontamination cycles alternating with four donning/doffing cycles. Face seal leakage value was maintained at below 1% |
| Moist heat incubation | Caron Model 6010 laboratory incubator (Marietta, Ohio) = 60°C, 30 min, 80% relative humidity. | FFR (6 models, 3M, Moldex, Kimberley Clark) - Phase 1: fit test to identify fit factor Phase 2: Physically examined for degradation and smell Multidonning fit test procedure – metal nose bridge was return to the original position – multidonning fit factor (MDFF) 10 subjects x 6 FFR models x 4 treatments Subjective questionnaires Standard visual analog scale | Viscusi et al, 2011\(^{26}\) - Each FFR model is constructed uniquely, which may affect the impact that decontamination has on that model. - Any physical damage or strong odour - The MDFF were lower than the control depending on the mode | No significant changes in fit, odour detection, comfort, or donning difficulty with each of the six models. | TCID50 = 50% tissue culture infectious dose |
References

2. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338532/


Acknowledgements

This document was developed in consultation with WHO Health Emergencies Program (WHE) Ad-hoc Experts Advisory Panel for Infection Prevention and Control (IPC) Preparedness, Readiness and Response to COVID-19 and other international experts including (alphabetical order):

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WHO continues to monitor the situation closely for any changes that may affect this interim guidance. Should any factors change, WHO will issue a further update. Otherwise, this interim guidance document will expire 2 years after the date of publication.

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