

ISSUES IN MEDICINE

Personal protective equipment (PPE) in a pandemic: Approaches to PPE preservation for South African healthcare facilities

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Personal protective equipment (PPE) is key to protecting healthcare workers from COVID-19 infection, but the pandemic has disrupted supply chains globally and necessitated rapid review of the scientific evidence for PPE re-use. In South Africa, where the COVID-19 epidemic is still developing, healthcare facilities have a short window of opportunity to improve PPE supply chains, train staff on prudent PPE use, and devise plans to track and manage the inevitable increases in PPE demand. This article discusses the available PPE preservation strategies and addresses the issue of decontamination and re-use of N95 respirators as a last-resort strategy for critical shortages during the pandemic.

S Afr Med J. Published online 30 April 2020. <https://doi.org/10.7196/SAMJ.2020.v110i6.14831>

Healthcare workers (HCWs) are at high risk of COVID-19 infection, with 22 073 cases in HCWs from 52 countries reported to the World Health Organization (WHO) by early April 2020.^[1,2] Continuous availability of personal protective equipment (PPE), correct PPE application/removal and appropriate decontamination of re-usable PPE are key to protecting HCWs from infectious pathogens, including COVID-19.

The current pandemic has challenged PPE supply chains globally and necessitated rapid review of the scientific evidence for PPE use and re-use. Both the WHO and the US Centers for Disease Control and Prevention have updated their guidance on PPE preservation strategies in the face of critical shortages.^[3-6] As South African (SA) healthcare facilities develop contingency plans for expected PPE shortages, the following tiered PPE preservation strategies should be considered:

- Restricted use: use PPE as recommended in the national infection prevention guidelines,^[7] minimise access of visitors to healthcare facilities, cohort staff to COVID high- v. low-risk areas, and limit the number of staff performing aerosol-generating procedures, e.g. one staff member performs COVID-19 testing.
- Extended use: use PPE for longer periods of time than normally recommended and/or while caring for several different patients without removal, e.g. visors and surgical masks.
- Procurement of alternative or emergency replacement PPE, e.g. 3D printed face shields, and plastic rain ponchos or refuse bags to replace aprons.
- Use of PPE after the manufacturer-designated shelf-life, e.g. use of masks after the expiry date.
- Procurement of re-usable PPE, e.g. goggles or re-usable plastic visors instead of disposable visors.
- Re-use of PPE: this involves the decontamination of PPE items that would normally be disposed of after use (single-use items), e.g. N95 respirators. Re-use should only be considered as a last resort when PPE supplies are about to run out and there are no alternatives

available. Re-use of PPE in COVID-19 critical care settings should be avoided owing to increased risk of HCW infection.

In SA, where the COVID-19 epidemic is still developing, healthcare facilities have a short window of opportunity to improve PPE supply chains, train staff on prudent PPE use, and devise plans to track and manage the inevitable increases in PPE demand. Restricted use of PPE should be implemented in all facilities. This effort would be aided by the use of non-medical (cloth) masks for visitors and administrative staff,^[8,9] and preserving medical masks for frontline workers.

For public sector SA HCWs exposed to tuberculosis, extended use of N95 respirators is already practised, with continuous use over 1 day or intermittent use over 1 week, if respirator integrity and the seal is maintained. This extended-use policy applies to COVID-19, with the same caveats of respirator integrity, an intact seal, appropriate storage (labelled paper bag or envelope), and thorough hand hygiene when donning and removing the respirator. Respirators should not be shared between HCWs.^[3,6] Surgical mask use can be extended to a single shift, particularly for HCWs with minimal close patient contact. Most face shields, visors and goggles are suitable for re-use following careful decontamination (soap and water cleaning, followed by disinfection with 70% alcohol). Re-usable face shields are preferable to goggles and disposable shields as they reduce droplet contamination of the mask/respirator. For COVID-19 intensive care wards, extended use of gowns for the duration of the shift is permissible. Aprons should preferably be changed between patient care activities, especially when contaminated with respiratory secretions or body fluids; aprons are not suitable for re-use. Gloves cannot be re-used and should be changed between each patient contact, followed by thorough hand hygiene.^[3]

There is a limited evidence base to guide methods for decontamination of N95 respirators, although new data are rapidly emerging and commercial systems are being developed.^[10-12] Decontamination of N95 respirators should only be considered

as a last resort to ensure a supply of N95 respirators for HCWs performing aerosol-generating procedures on patients with suspected/confirmed COVID-19. Problems with respirator re-use following decontamination include an inadequate seal (following wear or damage to the elastic straps), damage to the integrity of filter fibres, and lack of local testing to verify virus and particle filtration efficiency after respirator processing.^[5,6] In most low-resource settings, N95 respirator decontamination is unlikely to be feasible or affordable, and it is at best a stop-gap approach until a supply of new respirators is assured. Should SA healthcare facilities embark on N95 respirator decontamination programmes, the costs, feasibility, reproducibility and safety of the available methods should be carefully considered (Table 1).

An urgent and critical review of healthcare facility PPE supply and preservation strategies should be undertaken at every SA healthcare facility, incorporating national and international recommendations.^[3-4,7] Restricted use, extended use, procurement of re-usable PPE and development of alternative PPE items should remain the focus of local PPE preservation activities. However,

decontamination to enable re-use of N95 respirators could be a last resort strategy for critical shortages during the pandemic. Current obstacles to implementing N95 respirator decontamination in SA and other low-resource settings are the substantial financial costs and lack of available technology for rapid implementation. Given the heightened risk of COVID-19 infection in HCWs and potential PPE shortages, SA healthcare facilities should actively implement PPE preservation approaches and consider options for N95 respirator decontamination should a supply crisis occur.

Declaration. None.

Acknowledgements. None.

Author contributions. CIR and AD conceptualised the manuscript, CIR reviewed the current evidence base, both authors drafted and revised the manuscript.

Funding. AD is supported by a National Institutes of Health Fogarty Emerging Global Leader Award (K43TW010682).

Conflicts of interest. None.

Table 1. Methods for reprocessing of N95 respirators during critical shortages

Disinfection method	Equipment requirements, processing time and volume*	Advantages and disadvantages
Hydrogen peroxide vapour	<ul style="list-style-type: none"> Hydrogen peroxide vapour generator, e.g. Sterrad or Bioquell Clarus^[3] A sealed chamber 8-hour processing time, including conditioning, gassing, dwell and aeration phases^[10] 	<ul style="list-style-type: none"> Respirator performance maintained for 10 re-uses.^[3,10,11] Large-volume processing is possible.^[12] Allows for even penetration of vapour over entire respirator, as opposed to UVGI, where there may be a shadow effect on some respirator surfaces.^[5] Currently the most cost-effective form of gas sterilisation,^[13] with low toxicity.^[10,14] Carcinogenic, but safe for use following an aeration period; can cause eye damage if in contact.^[15] Not compatible with material containing celluloses. Respirator straps may absorb hydrogen peroxide, causing low vapour concentration and aborted cycle.^[14]
UVGI	<ul style="list-style-type: none"> A UV-C lamp emitting a minimum effective dose of 1.8 J/cm² A reflective chamber or box^[3,5] 15-minute exposure time for each side of the respirator^[3,14,16] 	<ul style="list-style-type: none"> UVGI application does not affect filtration performance,^[3,5,16] but may cause elastic strap degradation. Avoid dose >950 J/cm.^[2] Respirator fit must be assessed following UVGI; 90 - 100% correct fit after three cycles, depending on respirator type. A shadow effect (UV light not reaching within folds of respirators) can occur, with incomplete decontamination.^[5,17] Precautions taken to avoid UVGI exposure to eyes and skin.^[5]
Microwave-generated steam	<ul style="list-style-type: none"> Microwave (>1 100 watts) Microwave steam bags (for sterilisation of formula bottles) Run at a minimum of 1 100 watts for 90 seconds in a bag filled with 60 mL tap water^[5,11] 	<ul style="list-style-type: none"> Microwaves are widely available, but the method is limited to processing a single respirator at a time. Has potential to rapidly decontaminate a respirator in the clinical area as needed. Metal strip in respirators can cause sparks in the microwave. Microwaves differ in power output; the effect of higher power on respirator integrity is unknown.^[3,5,17]
Methods not currently endorsed owing to limited evidence	<ul style="list-style-type: none"> Moist heat incubation: currently not recommended owing to limited evidence of efficacy of killing various pathogens.^[5,17] Incubation temperature of 65°C at 85% relative humidity for 30 minutes.^[3,5] Mask rotation: each HCW has a set number of respirators that they rotate use of. Respirators are dried for >72 hours, whereafter virus is no longer viable and the respirator can be re-used.^[17] Ozone: requires an ozone generator and a sealed box or chamber.^[18] Very limited scientific literature. Toxic in high concentrations. Need for aeration time.^[18-21] Other methods not recommended either owing to lack of evidence of efficacy or damage to the respirator include: liquid hydrogen peroxide/hydrogen peroxide plasma; dry heat; 70% isopropyl alcohol; autoclave; soap; dry microwave irradiation; gamma irradiation; bleach.^[3,5,11,14-18] Ethylene oxide is not recommended as it may harm the wearer, among other reasons.^[3,5,13,15,22] 	

UVGI = ultraviolet germicidal irradiation; HCW = healthcare worker.

*For most methods, the volume of N95 respirators that can be processed in a single cycle is determined by the chamber size.

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Accepted 27 April 2020.