Processing Methods to Facilitate the Re-use of Personal Protective Equipment (PPE) – Knowledge Summary

Executive Summary

- Substantial work is being carried out in the UK and worldwide on the most effective methods facilitate the safe re-use of PPE.
- PPE that is designed for re-use can be safely disinfected using a range of methods including thermal treatment, chemical treatment and UV irradiation. The most suitable approach will depend on the particular PPE item. Effective disinfection requires good protocols to be developed and followed. Damaged or heavily soiled PPE items should be discarded.
- Re-use of PPE that is designed for single use should only be considered as a last resort. There is evidence that some items can be safely disinfected, but some methods can damage material integrity and reduce the effectiveness of the items. This is a particular risk for respiratory protective equipment (RPE). Most studies have been carried out using surrogate microorganisms rather than the SARS-CoV-2 virus.
- If PPE needs to be reused, behavioural aspects need to be considered. There is evidence that people are uncomfortable about wearing RPE that has previously been worn by someone else, even when this is designed for re-use and has been safely decontaminated.
- Medical masks are shown to be better than cloth face coverings to protect the wearer from infection, but there is little evidence yet on the most suitable methods of washing cloth face coverings or whether these degrade over time.

The question

This document addresses a request for information about the re-use of personal protective equipment (PPE) and how re-use could be achieved. Activities related to PPE re-use or extended use span occupational sectors and include the public, but primarily affect workers such as healthcare professionals and public facing service providers. The original information request included face coverings, which are not defined as PPE but are now widely used by many members of the public and in certain occupational settings. These are also considered here. At the request of NHS England and NHS Improvement (NHSE&I) – the information has been considered within two main categories:

- PPE designed for re-use and,
- PPE designed for single use only (disposable)

This document provides a summary of the evidence; a more detailed review is provided in the companion repository paper.

Background and context

Some PPE is designed for re-use under specified usage conditions, either in its entirety or in part. For example, the pump housing, air feed tubing and hood of a powered air purifying respirator (PAPR) are designed to be re-used, with appropriate cleaning and/or disinfection between uses for hygiene purposes. Other PPE items that would normally be regarded as re-usable e.g. face shields/visors have largely been treated as disposable during the current Sars-CoV-2 pandemic.

Although they could be cleaned and disinfected, at the height of the pandemic this could not typically be done because re-use was difficult due to pressures such as a) the rate of use in front line care, b) concerns about surface contamination and viral transmission risk to staff, or c) a lack of time and resources to reprocess such items safely and rapidly. It is important to note that even a PPE item designed for re-use may be structurally altered by the chemical or physical process used to disinfect or sterilize it, and this has implications for user protection.

Disposable PPE is designed for limited use, therefore the constituent materials are not necessarily manufactured to endure extended or repeated wear. Any PPE designed for re-use has to be made hygienically safe before re-use and, having undergone that process, the PPE also needs to have retained its original protective properties. This applies to all PPE, including respiratory protective equipment (RPE), gowns and eye protection. For either re-usable PPE or single-use PPE being re-used, hygienic treatment will involve some form of disinfection or sterilization to render it microbiologically safe. However, because disposable items are not necessarily designed to tolerate chemical (i.e., disinfectant) or physical (e.g., irradiation, heat) reprocessing, it is imperative that material integrity is subsequently assessed to ensure that wearer protection continues to be adequate.

The UK Government already provides advice about PPE re-use and sessional (that is, extended) use. This emphasises the need to ensure that health and social care workers are appropriately protected from Covid-19 and states that re-use is only to be considered where single use items of PPE are otherwise unavailable. The advice also states that sessional use or re-use should only be considered as temporary measures *until the global supply chain is adequate to meet the UK's needs*. The US Centers for Disease Control and Prevention provides similar guidelines on this topic. It is within this context, that is, of extreme PPE shortage or a complete absence of PPE availability that the information below should be considered.

Methods used

Specific search term combinations used for publication retrieval were linked to the original research question, as described in the separate technical report. As well as published literature, information was also sought from other authoritative sources such as Government advice pages and industry and scientific contacts working in the field of decontamination technologies. Supplementary literature searches were undertaken using Google, Google Scholar and PubMed where required and scientific contacts were approached to identify relevant unpublished studies.

Evidence based findings

Behavioural aspects of PPE re-use

- For those faced with wearing re-used PPE, acceptance and confidence is important. However, information about the psychological and behavioural aspects of PPE re-use is limited. Where considered, end user 'confidence' in PPE reprocessing is associated with rigorous testing and validation of PPE treatment protocols.
- Some evidence emphasises the importance, for hygiene reasons, of having personalised equipment. For example, re-used respirators need to be individually identified and returned to the same user after reprocessing. This is likely to influence the acceptability of PPE re-use

but would necessitate the implementation of an effective identification and 'return to user' logistical process.

- A 4 year study of filtering facepiece respirator (FFR) included a questionnaire in which health care workers were asked about mask re-use and their preferences related to the process. The authors report that the majority of this group preferred to keep FFRs for their own use, as opposed to sharing.
- Soiling of PPE, e.g., from makeup or sweat deposits on RPE (masks), needs to be considered and visibly soiled items of PPE need to be discarded to ensure wearer confidence.
- The largest labour union for registered nurses in the US has published its concerns about their members having to wear re-used N95 RPE. They conclude that the systems developed by US funded reprocessing facilities cannot be both safe and effective.

PPE designed for re-use

- Studies show that RPE designed for re-use can often be successfully disinfected and, in some cases, sterilized by autoclaving or other means. However, treatments such as chemical fumigation may require additional steps to ensure complete penetration of more complex items, e.g. air-feed tubing used for powered RPE.
- The heat tolerance of re-usable RPE may differ and, if high sterilizing temperatures are used, some component materials such as plastic polymers may be irreversibly damaged. The delicacy of such components may therefore make heat-based sterilization impossible. Low-temperature sterilization methods (e.g., ethylene oxide, gamma irradiation) may also damage respirator components and therefore it is critical to validate such treatment methods, even for RPE designed for re-use.
- To re-use RPE safely, particularly within the frontline healthcare setting, protocols for cleaning and disinfection after use must be developed and followed, preferably with supplier advice. Errors in reprocessing have been reported. Sterilization of RPE prior to re-use provides the maximum level of confidence, but may not be possible for reasons stated and in a central processing department can pose many practical challenges and careful logistical planning.
- The design of some PPE has influenced the potential effectiveness of decontamination methods. For example, bacterial challenges used in hydrogen peroxide fumigation tests for face visors could not all be killed when placed around the thick foam head band. Other work with similar fumigant was more successful, reporting high levels of microbiological kill even in awkward equipment locations and with no damage to visor clarity. This variability means that efficacy must be validated for a particular item and process. Eye protection re-use is an example of a process subject to existing infection prevention and control instructions, which may not always be compatible with re-use procedures.
- Germicidal UV has demonstrated measurable pathogen reductions on re-usable plastic goggles, but is generally less effective than chemical fumigation treatments. Even within the confines of a compact UV cabinet the observed log reduction of a bacterial challenge was variable. Germicidal UV does, however, offer the advantage of no chemical residues and is rapid (typically 15-45 minutes), compared to fumigation (hours).
- Re-usable gowns are widely used in healthcare and there are existing validated methods for their decontamination, e.g. the infectious linen cycle detailed in Department of Health

guidance HTM01-04. Gown manufacturers specify the number of disinfection cycles a garment can tolerate, though tracking this to ensure it is not exceeded may be challenging.

- International advice recognises the potential benefits of extended PPE use, e.g. by not removing eye protection between patients, unless visibly soiled or condensation is present. However, this assumes clinical use is confined to patients infected with the same pathogen, minimising the risk of disease transmission between patients. A recurring message is to discard visibly heavily soiled or damaged items and to avoid re-using them.

PPE designed to be disposable

- The majority of information about disposable PPE relates to RPE. Numerous studies exist, most using bacterial or bacteriophage challenges rather than pathogenic viruses. These surrogates may not be structurally similar to the Sars-CoV-2 virus but are often regarded as more robust and harder to eradicate than the Sars-CoV-2 virus.
- Published and unpublished studies confirm that chemical, germicidal UV and heat based treatments have been assessed for the treatment of FFR type respirators and all can be effective in reducing microbiological load on RPE composite materials.
- Whilst confirming the hygienic efficacy of treatments, several studies also describe significant impact on PPE material integrity, e.g., deleterious effects on the protective fit of the RPE to the point where it fails a fit test after re-processing. Elasticated straps and nose bridge foam are at particular risk of degradation from UV and heat based treatments. For chemical and UV treatments, the maximum number of disinfection cycles tolerated will be determined by the respirator model and the treatment intensity required to eliminate the pathogen. These physical effects on PPE/RPE integrity and performance must be monitored to ensure wearer safety.
- For steam sterilization, RPE treatment may be limited to just a small number of respirator models and for only one round of autoclaving at 121^{o}C before respirator degradation occurs. Associated material changes and a reduction in filtration penetration are the biggest failure modes following autoclaving. Again, these potential failures must be assessed using appropriate testing regimes on representative RPE items.
- Off-gassing of fumigant from porous components of PPE is an area of concern and uncertainty, particularly affecting RPE. Chemical residues may be irritant or toxic and will be influenced by RPE material composition and overall design. Adequate time must be permitted for aeration of treated items prior to re-issue, to avoid worker exposure to potentially harmful chemicals. This effect is being studied in some detail as part of ongoing Government funded research, with technical oversight provided by Public Health England (PHE) and the Health and Safety Executive (HSE).
- Thermal or chemical treatments of protective gowns or coveralls must consider whether their protective qualities, e.g., splash resistance, are maintained after processing. Recent pilot studies in the UK have shown that it is feasible for single use surgical gowns to be laundered for re-use and still provide spray protection. Even the addition of hydrogen peroxide fumigation did not affect material integrity based on in-house spray testing and the process eradicated a heavy inoculum of bacteria, including spores. However, the study was acknowledged as having low statistical power and only tested one garment type.

- As with other PPE, a recurring message is to discard visibly heavily soiled or damaged items and to avoid re-using them.

Face coverings

- A large cluster randomised study has investigated the comparative efficacy of cloth masks and disposable surgical masks in a clinical setting where respiratory infection was common. Participants were either supplied with two medical masks daily for each 8 h shift, or five cloth masks in total for the study duration, which they were asked to wash and rotate over the study period. Cloth masks were washed with soap and water at the end of every day a participant completed their shift. Rates of influenza-like illness were highest in the cloth mask cohort when compared to medical masks. Mask filtration tests undertaken to support the study showed that the penetration of particles through the cloth masks was high (97%) compared with medical masks (44%). By comparison, assessment of N95 type respirators showed less than <0.01% penetration.
- The European Centre for Disease Prevention and Control (ECDC) advises against use of cloth masks in the clinical setting, stating that penetration of viral particles is significantly higher than when wearing surgical masks. The US CDC only recommends the use of cloth facemasks in a clinical setting as a last resort when surgical masks are not available and that these should ideally be used in combination with a face shield. This guidance provides no advice on washing/re-use.
- In terms of advice to the public, John's Hopkins Medicine recommends washing a cloth mask after every period of use. However the UK government do not give specific recommendations on frequency, instead recommending that people should '*wash it in line with manufacturer's instructions at the highest temperature appropriate for the fabric*'
- The US CDC also provides advice to the public about face coverings, including basic information on how to choose, remove and wash the item. CDC states that washing can be done either by hand or in a washing machine. For machine washing it is suggested that 'masks' are put with other regular laundry, using regular laundry detergent and the warmest water setting that can be tolerated by the cloth used to make the mask.