



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Journal Pre-proof

Sterilization of disposable face masks by means of standardized dry and steam sterilization processes; an alternative in the fight against mask shortages due to COVID-19

B. van Straten, P. de Man, J. van den Dobbelsesteen, H. Koeleman, A. van der Eijk, T. Horeman

PII: S0195-6701(20)30176-6

DOI: <https://doi.org/10.1016/j.jhin.2020.04.001>

Reference: YJHIN 5966

To appear in: *Journal of Hospital Infection*

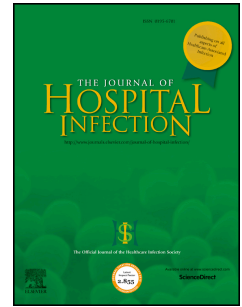
Received Date: 31 March 2020

Accepted Date: 2 April 2020

Please cite this article as: van Straten B, de Man P, van den Dobbelsesteen J, Koeleman H, van der Eijk A, Horeman T, Sterilization of disposable face masks by means of standardized dry and steam sterilization processes; an alternative in the fight against mask shortages due to COVID-19, *Journal of Hospital Infection*, <https://doi.org/10.1016/j.jhin.2020.04.001>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2020 The Healthcare Infection Society. Published by Elsevier Ltd. All rights reserved.



Sterilization of disposable face masks by means of standardized dry and steam sterilization processes; an alternative in the fight against mask shortages due to COVID-19

B. van Straten^{1,3}, P. de Man², J. van den Dobbelsteen¹, H. Koeleman², A. van der Eijk⁴, T. Horeman¹

1. Delft University of Technology, Department of BioMechanical Engineering, Delft, The Netherlands

2. Franciscus Gasthuis & Vlietland, Rotterdam, The Netherlands

3. Van Straten Medical, De Meern, The Netherlands

4. Leiden University Medical Center, Leiden, The Netherlands

Keywords: Covid-19; mouth masks; recycling; medical sustainability; bioinspired recycling

Sir

The Covid-19 pandemic causes imminent shortages of face masks in hospitals globally. In preparation for that scarcity we performed a study to investigate the possibility of reprocessing disposable FFP2 face masks in order to verify their re-usability with a method that could be applied in practice using already available equipment. Therefore single use FFP2 masks (type 1862+3MTM) were sterilized with a 15-minute procedure at 121 °C, using a dry sterilization process as well as with a regular steam process with the masks in sterilization/laminate bags. The effectiveness of these processes are sufficient to inactivate the coronavirus based on knowledge of inactivation of such viruses. [1, 2] A blind comparison of unused sterilized masks was performed with respect to visual inspection, consistency, face fit and breathing resistance. The results of this comparison were that the investigators were unable to distinguish unused new (slightly curved and folded) masks from reprocessed sterilized masks.

We then tested the functionality of the unused and sterilized masks in several ways. First of all permeability properties for bacteria were tested by spraying a bacteria solution of *Staphylococcus epidermidis* (ATCC 12228) on the masks while air was being drawn through the masks. Unused and multiple sterilized masks showed no differences in the amount of passed bacteria (data not shown). In these experiments it was also observed that the reprocessing procedures of the masks did not appear to affect the water-repellent mask properties.

We then assessed pressure/flow and performed particle tests. Before sterilization, the batches were individually packed in laminate bags and sterilized with steam sterilization by means of 121 °C in Getinge autoclaves and in combination with permeable laminate bags, Halyard type CLFP150X300WI-S20. The autoclaves were activated on a 121 °C program and validated accordingly. After sterilization, the samples were tested at Delft University of Technology and at Reinier de Graaf Hospital, and benchmarked with new mouth masks. A custom test set-up was built to measure the pressure drop over the maskers and outflow with regard to the permeability of the masks. A direct comparison between new and sterilized masks did not show substantial differences. Finally, the filtration capacity of the masks was evaluated using a calibrated Lighthouse Solair 3200 particle counter (Lighthouse, San Francisco). It was shown that the mask permeability of small particles did not change after multiple heat sterilization procedures (Table I).

We openly shared our positive experiences with the steam sterilization process with other hospitals in the Netherlands that are also preparing for the outbreak. We were informed that their attempts to steam sterilize mouth masks at 134°C gave poor results as masks started to deform and became sticky while the elastics lost its resilience.

In addition, we tested Gamma radiated masks this process did hamper the filter capacity (Table I). The results of our experiences and experiments indicate that our sterilization process did not influence the functionality of the masks tested. In case of an acute shortage of FFP2 masks, steam sterilization (e.g. in laminate sterilization wrappings) of used masks at 121 °C in laminated bags, is a simple, useful cost-effective and quick procedure that can be used to make used masks available for safe reuse. The sterilization process of available standard autoclaves in hospitals may have to be adjusted in order to use this sterilization method. We also emphasise that we performed these experiments with 3M masks only. However, our method seems to be a potentially useful way to reuse mouth masks; other hospitals facing a shortage of masks may wish to test and validate this approach to reusing masks.

References

1. Henwood AF. Coronavirus disinfection in histopathology. J Histotechnol 2020; Mar 1:1-3. doi: 10.1080/01478885.2020.1734718.
2. Zhang Q, Zhao Q. Inactivating porcine coronavirus before nuclei acid isolation with the temperature higher than 56 °C damages its genome integrity seriously. bioRxiv preprint;2020: <https://doi.org/10.1101/2020.02.20.958785>.

Journal Pre-proof

Table I: Filter efficiency testing of sterilized masks

| | New FFP2 | 1x Heat 121°C (n=2) | 3x Heat 121°C (n=4) | 5xHeat 121°C (n=2) | 10kGy (n=1) | 25kGy (n=2) |
|---------------------|----------|---------------------|---------------------|--------------------|-------------|-------------|
| Filter Efficiency % | | | | | | |
| 0.3 µm | 99.4 | 96,9 | 97.4 | 96.8 | 55.4 | - |
| 0.5 µm | 99.8 | 98,0 | 98.4 | 98.7 | 79.1 | 57.5 |
| 5.0 µm | 99.8 | 95.2 | 95.5 | 94.3 | 98.1 | 98.7 |
| | | | | | | |