What are the effective methods of decontaminating N95 mask for reuse?

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KEY FINDINGS

Based on one study, hydrogen peroxide vapor and ultraviolet radiation were shown to be effective in decontaminating SARS-CoV-2 on N95 fabric while maintaining respiratory integrity.

- Considering the current pandemic, there is a potential for shortage of N95 facepiece filtering respirator (FFR) for healthcare workers.
- No studies in humans were found comparing effectiveness of N95 post-decontamination.
- Based on one mechanistic study, hydrogen peroxide vapor and ultraviolet radiation were shown to be effective in decontaminating SARS-CoV-2 on N95 fabric while maintaining respiratory integrity. Dry heat and ethanol were also able to reduce the viral load of SARS-CoV-2 but with significant reduction in respirator fit and function.
- Mechanistic studies done on influenza virus (A/H5N1, H1N1) have shown that ultraviolet germicidal irradiation, microwave generated steam, or warm moist heat was able to reduce the viral load by as much as 4 log and at the same time maintain respirator performance by keeping the percent penetration below 5% and the pressure drop within standards.
- While UV germicidal irradiation was able to maintain integrity of FFRs up to 3 cycles, microwave generated steam may melt the metallic components of certain N95 masks.
- Bleach, ethanol and isopropanol all affected the integrity of the mask by increasing the mean penetration of the mask beyond the 5% limit.
- The Centers for Disease Control (CDC) does not recommend decontamination then reuse of FFRs as standard care but decontamination with UVGI, HPV or moist heat may be considered as an option in FFR shortages.

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RESULTS

No studies in humans were found comparing effectiveness of N95 after decontamination.

Hydrogen peroxide vapor (HPV) demonstrated SARS-CoV-2 inactivation after 10 minutes for N95 fabric and stainless steel with more than 4-log reduction. Filtration performance was similar with controls after 2 cycles and was still within acceptable standards after 3 cycles of decontamination. Respirator performance of previous studies on HPV were also within standards up to 20 cycles with no significant changes in form, filtration or fit. Successful decontamination of *G. stearothermophilus* [19], MRSA [6] and aerosolized bacteriophages [20] was also reported.

Decontamination with ultraviolet light (UV) at a wavelength of 260-285 nm revealed rapid inactivation of SARS-CoV-2 on steel after 10 minutes but slower inactivation on N95 fabric with a 4-log reduction after 60 minutes. Respirator fit and function were similar with controls up to 2 cycles and within OSHA standards up to 3 cycles. The UV dose used in the study was 0.33 J/cm^2 at 10 minutes, 0.99 J/cm^2 at 30 minutes and1.98 J/cm^2 at 60 minutes [5]. While there are no set recommendations on the minimum UV dose required for decontamination, a study has reported a significant reduction in viral loads of MS2 coliphage with a minimum dose of 1 J/cm^2 [11] and other decontamination studies using a set UV dose between 1 J/cm^2 and 1.8 J/cm^2 demonstrated a reduction of >4 log in both H1NI and H5N1 influenza virus when virus was aerosolized or in droplets. However, performance may go down to a reduction of log 1.25 if mask is soiled with mucus or sebum. [4-10]. Structural integrity, filtration and fit of N95 masks in previous studies were also not significantly altered up to 3 cycles. The efficiency of UVGI, however, may be affected by shadowing and material of respirator facepiece and straps.

SARS-CoV-2 inactivation was also demonstrated after decontamination in a 70^{o}C oven for 60 minutes and 70% ethanol for 10 minutes. However, significant reduction in respiratory integrity was observed for subsequent decontamination cycles. Other studies have also shown chemicals such as bleach, ethanol and isopropanol increase the mean penetration of the mask above the 5% limit.

Warm moist heat and microwave generated steam had good decontamination performance on bacteriophages and influenza virus. Both reduced viral load of influenza by >4 log with mean penetration and resistance still within acceptable standards. Although respirator filtration and fit were preserved for most of the N95 models tested, partial separation of the inner foam nose cushion from the respirator was noted on one model of N95 respirator tested. Also, N95 metal parts may melt when subjected to microwave generated steam. Steam sterilization was effective against B. subtilis spores but a decrease in filtration performance was detected.

The Centers for Disease Control (CDC) does not recommend decontamination then reuse of FFRs as standard care but decontamination with UVGI, HPV or moist heat may be considered as an option in FFR shortages. However, proper precautionary measures need to be taken such as cleaning hands with soap and water before and after touching the FFR, using a pair of non-sterile gloves when donning the respirator and performing a seal check, inspecting the respirator for any defects or degradation of parts, and performing a user seal check.

CONCLUSION

Hydrogen peroxide vapor and ultraviolet radiation were shown in one study to be effective in decontaminating SARS-CoV-2 on N95 fabric while maintaining respiratory integrity. On the other hand, dry heat and ethanol were also able to reduce the viral load of SARS-CoV-2 but with significant reduction in respirator fit and function. Warm moist heat may also be considered for N95 decontamination though its effect on SARS-CoV-2 has not been tested.

None of the studies on N95 decontamination have extensively evaluated and met all the important criteria for decontamination methods which are as follows: the method must be effective against the target organism, not damage the respirator's filtration, not affect the respirator's fit and be safe for the person wearing the respirator. If any of the above measures are done, it should be tailored to the capacity of the hospital and its viability while taking the necessary precautions.

Declaration of Conflict of Interest

No relevant conflict of interest

REFERENCES

1. NPPTL. *NIOSH-Approved N95 Particulate Filtering Facepiece Respirators*. 2020 [cited 2020 March 30]; Available from: https://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/n95list1.html.
2. WHO, *Rational use of personal protective equipment (PPE) for coronavirus disease (COVID-19): Interim Guidance*. 2020, WHO: Geneva.
3. NIOSH. *Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare*. 2020 March 27,2020 [cited 2020 March 30]; Available from: https://www.cdc.gov/niosh/topics/hcwcontrols/recommendedguidanceextuse.html.
4. Mills, D., et al., *Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators.* Am J Infect Control, 2018. **46**(7): p. e49-e55.
5. Fischer, R., et al., *Preprint. Assessment of N95 respirator decontamination and re-use for SARS-CoV-2.* medRxiv, 2020.
6. Cadnum, J.L., et al., *Effectiveness of Ultraviolet-C Light and a High-Level Disinfection Cabinet for Decontamination of N95 Respirators.* Pathog Immun, 2020. **5**(1): p. 52-67.
7. Lindsley, W.G., et al., *Effects of Ultraviolet Germicidal Irradiation (UVGI) on N95 Respirator Filtration Performance and Structural Integrity.* J Occup Environ Hyg, 2015. **12**(8): p. 509-17.
8. Hamzavi, I.H., et al., *Ultraviolet germicidal irradiation: possible method for respirator disinfection to facilitate reuse during COVID-19 pandemic.* J Am Acad Dermatol, 2020.
9. Lowe, J.L., et al., *N95 Filtering Facepiece Respirator Ultraviolet Germicidal Irradiation (UVGI) Process for Decontamination and Reuse*, N. Medicine, Editor. 2020.
10. Card, K.J., et al., *UV Sterilization of Personal Protective Equipment with Idle Laboratory Biosafety Cabinets During the COVID-19 Pandemic.* medRxiv, 2020.
11. Li, D.F., et al., *It's Not the Heat, It's the Humidity: Effectiveness of a Rice Cooker-Steamer for Decontamination of Cloth and Surgical Face Masks and N95 Respirators.* Am J Infect Control, 2020.
12. Fisher, E.M. and R.E. Shaffer, *A method to determine the available UV-C dose for the decontamination of filtering facepiece respirators.* J Appl Microbiol, 2011. **110**(1): p. 287-95.
13. Heimbuch, B.K., et al., *A pandemic influenza preparedness study: use of energetic methods to decontaminate filtering facepiece respirators contaminated with H1N1 aerosols and droplets.* Am J Infect Control, 2011. **39**(1): p. e1-9.

14. Lore, M.B., et al., *Effectiveness of three decontamination treatments against influenza virus applied to filtering facepiece respirators.* Ann Occup Hyg, 2012. **56**(1): p. 92-101.
15. Ma, Q.X., et al., *Decontamination of face masks with steam for mask reuse in fighting the pandemic COVID-19: experimental supports.* J Med Virol, 2020.
16. Viscusi, D.J., et al., *Impact of three biological decontamination methods on filtering facepiece respirator fit, odor, comfort, and donning ease.* J Occup Environ Hyg, 2011. **8**(7): p. 426-36.
17. CDC. *Steam Sterilization: Guideline for Disinfection and Sterilization in Healthcare Facilities* 2008 April 19, 2020.]; Available from: cdc.gov/infectioncontrol/guidelines/disinfection/sterilization/steam.html.
18. Lin, T.H., et al., *Relative survival of Bacillus subtilis spores loaded on filtering facepiece respirators after five decontamination methods.* Indoor Air, 2018.
19. Lin, T.H., et al., *Filter quality of electret masks in filtering 14.6-594 nm aerosol particles: Effects of five decontamination methods.* PLoS One, 2017. **12**(10): p. e0186217.
20. Carrillo, I., et al., *Immediate Use Steam Sterilization (IUSS) Sterilizes N95 Masks Without Mask Damage.* Infect Control Hosp Epidemiol, 2020: p. 1-5.
21. Viscusi, D.J., et al., *Evaluation of five decontamination methods for filtering facepiece respirators.* Ann Occup Hyg, 2009. **53**(8): p. 815-27.
22. Bergman, M., et al., *Evaluation of Multiple (3-Cycle) Decontamination Processing for Filtering Facepiece Respirators.* Journal of Engineered Fibers and Fabrics, 2010. **5**(4): p. 11.
23. Batelle, *Final Report for Bioquell HPV Decontamination for Reuse of N95 Respirators*, F.C. Officers, Editor. 2016: Columbus. Ohio
24. Kenney, P., et al., *Hydrogen Peroxide Vapor sterilization of N95 respirators for reuse. .* medRxiv, 2020.
25. Heimbuch, B.K., et al., *Cleaning of filtering facepiece respirators contaminated with mucin and Staphylococcus aureus.* Am J Infect Control, 2014. **42**(3): p. 265-70.
26. Schwartz, A., Stiegel, M., Greeson, N., et al., *Decontamination and Reuse of N95 Respirators with Hydrogen Peroxide Vapor to Address Worldwide Personal Protective Equipment Shortages During the SARS-CoV-2 (COVID-19) Pandemic*. 2020. Available at https://www.safety.duke.edu/sites/default/files/N-95_VHP-Decon-Re-Use.pdf

Appendix 1. Characteristics of included studies

Study	Infectious Agent	Method of Decontamination	Outcomes	Number of N95 models tested
Fischer 2020[5]	SARS-CoV-2	1. Hydrogen Peroxide Vapor 2. UV 3. Dry heat 4. Ethanol	Decontamination Respirator fit and filtration	1 (N95 fabric)
Lore 2012[14]	Influenza Virus (A/H5N1)	1. Ulltraviolet Germicidal Irradiation (UVGI) 2. Microwave-generated steam (MGS) 3. Warm Moist Heat (WMH)	Decontamination measured by viral culture Decontamination measured by qRT-PCR Post-decontamination Filter Performance	2
Heimbuch 2012[13]	Influenza Virus (H1N1)	1. Ulltraviolet Germicidal Irradiation 2. Microwave-generated steam 3. Moist Heat	Decontamination measured by viral culture	6
Heimbuch 2014 [25]	Staphylococcus aureus	1. Hypochlorite 2. Benzalkonium chloride 3. Nonantimicrobial wipes	Decontamination measured by culture	3
Batelle 2016 [23]	G. *stearothermophilus*	1. Hydrogen Peroxide Vapor	Decontamination Filter performance Respirator fit (manikin head form)	1
Kenney 2020 [24]	bacteriophages: T1, T7, and Pseudomonas phage phi-6	1. Hydrogen Peroxide Vapor	Decontamination	3
Mills 2018[4]	Influenza Virus (H1N1)	1. Ulltraviolet Germicidal Irradiation (UVGI)	Decontamination measured by viral culture	15
Lin 2018[18]	B. subtilis spores	1. Ethanol 2. Bleach 3. UVGI 4. Autoclave 5. Traditional electric rice cooker	Relative survival	4

Viscusi 2009[21]	None	1. UVGI 2. Ethylene Oxide 3. Hydrogen Peroxide Vapor 4. Microwave oven irradiation 5. Bleach	Observational physical changes Filter aerosol penetration	6
Bergman 2010 [22]	None	1. UVGI 2. Ethylene Oxide 3. Hydrogen peroxide glass plasma (HPGP) 4. Hydrogen peroxide vapor (HPV) 5. Microwave oven generated steam 6. Bleach 7. Liquid hydrogen peroxide 8. Moist heat incubation/pasteurization	Observational physical changes Odor Filtration performance: filter aerosol penetration and filter airflow resistance	6
Lindsley 2015 [7]	None	1. UVGI	Filter penetration Flow resistance	4
Lin 2017[19]	None	1. Dry heat (rice cooker) 2. Moist heat (autoclave) 3. Ethanol 4. Isopropanol 5. Bleach	Filtration performance: Filter aerosol penetration, most penetrating particle size	1
Viscusi 2011[16]	None	1. UVGI	Respirator Fit Odor Comfort Donning Ease	6
Schwartz 2020 [26]	G. *stearothermophilus*	1. Hydrogen Peroxide Vapor	Decontamination Filter performance Respirator fit	1
Fisher 2020[12]	MS coliphage	1. UVGI	Decontamination	6
Cadnum 2020[6]	MRSA Bacteriophage (MS2 and Phi6)	1. Hydrogen peroxide 2. Dry Heat 3. UVGI	Decontamination	3
Li 2020[11]	MRSA MS2 bacteriophage	1. Warm moist heat (steam) 2. Dry heat	Decontamination	1
Ma 2020[15]	Avian infectious bronchitis virus H120	1. Warm moist heat (steam)	Decontamination Filtration efficiency	6