

Should We or Should We Not Reuse Filtering Face Piece Masks? A Review

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ABSTRACT

Disposable filtering face piece respirators (FFRs) are usually not approved for routine practice of decontamination and reuse. However, such practice of decontamination and reuse may be needed only as a crisis capacity strategy to ensure continued availability. The current severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) pandemic would help us enlighten about more effective and efficient ways of decontamination and reuse. Based on the limited research available, ultraviolet irradiation, vapors of hydrogen peroxide, and moist heat showed the most promising potential methods to decontaminate FFRs. This article summarizes available research about decontamination of FFRs before reuse.

Keywords: Decontamination, Developing countries, SARS-CoV-2.

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INTRODUCTION

The current pandemic of coronavirus disease-2019 (COVID-19) / severe acute respiratory syndrome-2 (SARS-2) affecting mankind all over the world has caught us unawares. The novelty of the virus and hence no immunity to any one of us, along with the rapidity of disease progress has overwhelmed the health resources even in the most developed countries. The shortage of personal protective equipment (PPE) and filtering face piece respirator (FFR)/masks is common both in developed and in developing countries. The best of the efforts to maintain the supplies are unable to match the ever growing demand of disposable PPE “sand masks worldwide”. At this moment, methods of reuse have to be reviewed to make optimum utilization of resources. The Occupational Safety and Health Outsourcing (OSHO), USA recommends reuse of N95 masks to optimize the imbalance in supply and demand along with other measures.¹

We have made an attempt to review the literature about whether N95 masks can be reused or not? If yes then what are methods to reuse them and how long can they be used?

MATERIALS AND METHODS

Search with keywords—“Filtering face piece respirator (FFR), N95, and Decontamination”—was performed in PubMed, Google scholar, and Embase. Eligible articles were those, which matched the keywords, were published after 2005, and discussed about virus inactivation. Two authors (RS and NS) searched independently for potentially eligible title and abstracts. Finally, full text of the possible articles was retrieved and reassessed for eligibility. Any disputes between the two authors were solved by discussion and consultation with a third author (AA). Total of 44 articles were identified (Flowchart 1). A comparative analysis highlighting the methods, pros, and cons of each article were tabulated in Table 1.

DISCUSSION

In this article, we have summarized the methods available for decontamination of FFR/N95. Before understanding the method of reuse, some basic definition needs to be understood in relation

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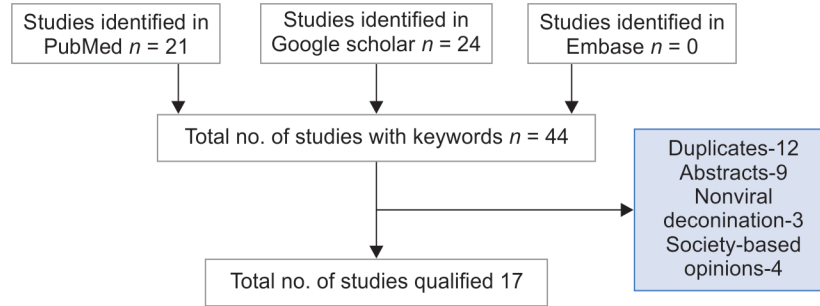
to N95 masks. Reuse refers “to the practice of using the same N95 respirator for multiple encounters with patients but removing it in-between”. Disinfection of the mask will be required between uses.²

Extended use refers “to the practice of wearing the same N95 respirator for repeated encounters with several patients, without removing the respirator between the encounters”.² “Extended use” is preferred over “Reuse”, as less handling is required in the former.³ Only as a part of crisis capacity management N95 masks should be reused; hence, methods to decontaminate them should be assessed. Limited reuse has been recommended and widely used as an option for conserving respirators during previous outbreaks and pandemics by respiratory pathogens.^{4,5} In light of the above-mentioned facts, various methods of decontamination were analyzed, also their efficacy was evaluated along with any physical damage or any change in airflow resistance of masks.

Various methods of decontamination include

- Nonchemical-based measures—Sunlight, ultraviolet (UV) light, microwave.
- Chemical methods—Hydrogen peroxide, ethylene trioxide, bleach.

Flowchart 1: Flow diagram of review of literature



Sunlight

It is the most traditionally available source of decontamination. Except for the mention in an editorial in JAMA, which was adopted, by Society of American and Gastrointestinal and Endoscopic Surgeons (SAGES), it has not been studied.^{6,7} They recommended using four masks and drying each in sunlight for 2–3 days on rotation.⁷ It can be used for homecare but not recommended for healthcare professionals.

Dry Heat

Dry heat is popular due to its convenience and short process time. Older studies have shown reduction in viral load but proper quantification needs to be evaluated.⁸ Viscusi et al. in their study showed dry microwave heat to be effective in inactivation of viral load; however, correlation could not be established for filter aerosol penetration and dry heat.⁹ They further suggested that dry microwave/oven irradiation method requires improvement before it could be recommended for decontamination and subsequent reuse of masks.

Moist Heat

Moist heat to be effective requires a temperature of 60°C and 80% relative humidity (RH). At this temperature and humidity, it causes minimal degradation in the filtration and fit performance of the tested FFRs.^{9,10,11} Heimbuch et al. disinfected FFRs contaminated with H1N1 using moist heat, of 65°C and 85% RH, and achieved a minimal of 99.99% reduction in virus.¹² It can be used both for home and commercial use. Major limitation of the moist heat method is that its disinfection efficacy for various pathogens is under evaluated in the available literature and hence not extensively used.

Bleach (0.6% of Sodium Hypochlorite)

Studies before 2005 emphasized the role of bleaching powder as a method of decontamination. Studies in the 20th century showed bleaching powder as highly active oxidizing agent known to be effective against a broad spectrum of bacteria and viruses.^{13,14} There was a problem of residual bleaching powder and tarnishing of metallic parts. In a recent study by Viscusi et al., they found decontamination with bleach caused slight degradation in filtration performance and caused an odor making it unsuitable for further use.

They concluded that in view of potential health risks, bleaching of FFRs (without process modification) is not recommended for further study. Possible modifications would be to reduce initial bleach concentration, chemical methods for neutralizing residuals, additional rinse steps, and more aggressive air-drying procedures for off gassing.⁹

Vapors of Hydrogen Peroxide

Vapors of hydrogen peroxide (VHP) has been shown to be sporicidal and virucidal at temperatures ranging from 4°C to 80°C, with sterilant concentrations ranging from 0.5 to <10 mg/L.¹⁵ Hydrogen peroxide (HP) vapor is virucidal on hard surfaces, and has been shown not to affect respirator performance.⁹ Initially, the HP gas vapor-generating systems which were used at hospitals proved to be ineffective for FFR's because the foam of filter material absorbed HP vapor causing a drop in vapor concentration making it less efficacious for decontamination and also causing machine to stop.⁹ Later, a Bioquell, Horsham (PA) which normally is used to fumigate hospital rooms was evaluated, it achieved microcondensation on the exposed surfaces as quickly as possible. The efficacy in reducing viruses were up to 99.99% reduction.¹⁶ In this, it was reported that FFR function was excellent, with no impairment of aerosol penetration efficiency or air flow resistance even after 50 cycles of decontamination. Kenney et al. in 2020 during coronavirus pandemic evaluated the same Bioquell HP vapor machine and established its high virucidal activity for N95 respirators which were inoculated with aerosolized virus. Use of this machine can be scaled up to permit simultaneous sterilization of a large number of used but otherwise intact respirators.¹⁷

In another study of Schwarz with OSHO established that hydrogen peroxide vapor (HPV) decontamination of N95 FFRs caused complete viral inactivation (up to a 6-log reduction). They recommended HPV decontamination cycle of 480 minutes duration. Though decontamination was effective even up to 50 cycles, physical degradation was seen after so many cycles. No visible degradation was observed after exposure to 10–20 HPV cycles. However, after 30 HPV cycles, it was observed that elastic material of straps was fragmented when stretched. Hence, contrary to the previous studies, Schwarz et al. recommended HPV decontamination up to 10–20 cycles to prevent physical damage of masks.¹⁸ Hydrogen peroxide vapor is an effective means of decontamination for reuse of FFR up to a maximum of 20 cycles.

Ultraviolet Germicidal Irradiation

Ultraviolet germicidal irradiation (UVGI) is a promising method of dose-dependent decontamination. Most effective virucidal activity is noted with UV light. Filtration performance was unaffected, for doses roughly around 0.5–950 J/cm² and in this range it had minimal effect on fit of masks.^{9,10,19,20} Heimbuch et al. tested filtration and fit of 15 FFRs and found no adverse effects to FFR performance.²¹ Lindsley et al. reported a reduction of the durability of materials of the FFRs for doses ranging from 120 J/cm² to 950 J/cm²; however, an approximate inactivation of 99.9% of bacteriophage MS2, a non-enveloped virus, and H1N1 influenza A were achieved with much lower doses of approximately 1 J/cm².^{2,12,20,22,23} They also reported reduction in strength of masks up to

Table 1: N95 methods of sterilization pros/cons

| <i>S. no.</i> | <i>Study/year</i> | <i>Type of study</i> | <i>Conclusion</i> | <i>Pros.</i> | <i>Cons.</i> |
|---|--|----------------------|---|---|--|
| Sunlight—No original article available | | | | | |
| Microwave oven irradiation | | | | | |
| 1 | Evaluation of five decontamination methods for filtering face piece respirators–2009 ⁹ | Original article | Viruses inactivated on microwave oven in 20 seconds. | Short treatment time | Requires improvisation |
| | | | Filter aerosol penetration and filter airflow resistance were not affected | Home and commercial use | Corrosion of metal bands |
| Moist heat | | | | | |
| 1 | A pandemic influenza preparedness study: use of energetic methods to decontaminate filtering face piece respirators contaminated with H1N1 aerosols and droplets–2009 ⁹ | Original article | 15–30 minutes (60°C, 80% RH), 99.99% reduction in virus | Economical | Time-intensive method Useful for home/small organizations |
| 2 | Evaluation of multiple (3-cycle) decontamination processing for filtering face piece respirators–2010 ¹⁰ | Original article | 30-minutes incubation at 60°C, 80% RH in a Caron model 6010 laboratory incubator (Marietta, OH). 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 minutes with the aid of a fan. | Effective reduction in virus | Physical damage was visible Partial separation of the inner foam nose cushion |
| 3 | Effectiveness of three decontamination treatments against influenza virus applied to filtering face piece respirators–2012 ²⁴ | Original article | A sealable container was filled with 1l of tap water, placed in an oven (Thermo Fisher Scientific Inc., Marietta, OH, USA), and heated to 65–5°C for 3 hours. | Satisfactorily decontaminated the FFRs as measured by a virus culture method. | Apply only to the models tested in this study. No comment on fit. |
| Bleach (0.6% of aqueous sodium hypochlorite) | | | | | |
| 1 | Evaluation of five decontamination methods for filtering face piece respirators–2009 ⁹ | Original article | Oxidizing agent effective against broad spectrum viruses and bacteria | No effect on filter aerosol penetration and its airflow resistance | Residual bleach smell Irritation to skin Tarnish metallic parts Modification of method required |
| 2 | Evaluation of multiple (3-cycle) decontamination processing for filtering face piece respirators–2010 ¹⁰ | Original article | 30-minutes submersion in 0.6% (one part bleach to nine parts of deionized water) solution of sodium hypochlorite | | Models, metallic nosebands FFR s tarnished |

Contd...

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| S. no. | Study/year | Type of study | Conclusion | Pros. | Cons. |
|---|---|------------------|--|--|---|
| | | | Following each exposure, FFRs were hung on a laboratory peg board and dried for a minimum of 16 hours with the aid of a fan before repeating the treatment or performing the laboratory aerosol filtration test. | | Discoloring Bleach odor present |
| Vaporized hydrogen peroxide | | | | | |
| 1 | Evaluation of five decontamination methods for filtering face piece respirators–2009 ⁹ | Original article | Sporicidal/virucidal at temperatures ranging from 4°C to 80°C | Single cycle did not affect aerosol penetration or airflow resistance. Multiple cycles-effect unknown | Headbands made of cotton absorb vapors and reduces efficacy |
| 2 | Final report for the bioquell hydrogen peroxide vapor (HPV) decontamination for reuse of N95 respirators. Prepared by Battelle Columbus, Ohio. Prepared under Contract no. HHS-F223201400098C. Study number 3245. Prepared for the FDA–2016 ¹⁶ | Original article | Bioquell technology of vapor generation–achieve micro-condensation on the exposed surfaces as quickly as possible Significant reduction in virus (99.9999%) | No degradation up to 10–20 cycles, after 30 not recommended | – |
| 3 | Hydrogen peroxide Vapor sterilization of N95 respirators for reuse-2020 ¹⁷ | Original article | Bioquell H ₂ O ₂ generating machine used for sterilization of a large number of FFRs | Ease shortages and provide a good large scale alternative | – |
| 4 | 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 ¹⁸ | Original article | 35% hydrogen peroxide solution and distribution system to disperse Significant reduction in virus up to few cycles (30) Complete inactivation (a 6-log reduction) was demonstrated of SARS COV-2 | Promising method for a potential of high capacity Studied SARS COV-2 virus. | Reuse limiting factor being the elastic straps that started to show degradation |
| Ultraviolet germicidal radiation | | | | | |
| 1 | Evaluation of five decontamination methods for filtering face piece respirators–2009 ⁹ | Original article | Exposures of 1 J/cm ² are capable of decontaminating influenza virus on N95 FFRs | Relatively short irradiation time (30 minutes) | Limited by the available working surface area of a biosafety cabinet |
| 2. | Evaluation of multiple (3-cycle) decontamination processing for filtering face piece respirators–2010 ¹⁰ | Original article | 45-minutes exposure at intensity 1.8 mW/cm ² . | Did not cause any observable physical changes to the FFRs. | Only the exteriors of the FFRs were exposed |

Contd...

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| S. no. | Study/year | Type of study | Conclusion | Pros. | Cons. |
|--------------------------------|--|------------------|---|---|--|
| 3 | A method to determine the available UV-C dose for the decontamination of filtering face piece respirators–2011 ²² | Original article | Assessed the likelihood that UV decontamination will be successful for specific FFR models | Established ultraviolet transmits into and through FFR materials | Did not study about decontamination efficacy |
| 4 | Effect of ultraviolet germicidal irradiation (UVGI) on N95 respirator filtration performance and structural integrity–2015 ²⁰ | Original article | Exposed both sides of material coupons and respirator straps to UVGI doses from 120 J/cm ² –950 J/cm ² . | Effectively disinfect disposable respirators Maximum number cycles will be limited by the respirator model and dose used | At the higher UVGI doses, the strength of the layers of respirator material was substantially reduced (up to >90% in some cases). |
| 5 | N95 filtering face-mask respirator ultraviolet germicidal irradiation (UVGI) process for decontamination and reuse 2020 ¹⁸ | Original article | Single-stranded RNA viruses, such as SARS-CoV-2, are generally inactivated by UVGI exposure of 2–5 mJ/cm ² Used N95 FFRs are subjected to UVGI at a room exposure of 300 mJ/cm ² | Studied with CoV-2 virus Wide margin of safety Effective decontamination | UVGI can cause damage to eyes and skin Prior to decontamination the walls and ceiling were covered with a UV-reflective coating (Biohazard) |
| 6 | Effectiveness of three decontamination treatments against influenza Virus applied to filtering face piece respirators–2012 ²⁴ | Original article | Virus laden respirators were placed inside the cabinet, directly under the ultraviolet lamp with the convex panel facing the treatment, and exposed for a total of 15 months. | A reduction of >4 log of virus load on FFRs, indicating functionally complete removal of detectable virus by culture assay | Apply only to the models tested in this study. No comment on fit. |
| Ethylene trioxide (ETO) | | | | | |
| 1. | Evaluation of five decontamination methods for filtering face piece respirators–2009 ⁹ | Original article | No effect on filter aerosol penetration, filter airflow resistance, or physical appearance | Longer duration of sterilization | – |
| 2 | Evaluation of multiple (3 cycle) decontamination processing for filtering face piece respirator–2010 ¹⁰ | Original Article | One hour at 55°C with EtO gas concentrations ranging from 725 to 833 g/L | Passed filtration performance indices, no physical damage | Potentially harmful |

RH, relatively humidity; FFR, filtration face piece respirator; UV, ultraviolet

90% at higher UVGI exposure.²⁰ However, the higher doses were not defined. Heimbuch et al. tested the performance of 1 J/cm² of UVGI against influenza A (H1N1), avian influenza A virus (H5N1), influenza A (H7N9), MERS-CoV, and SARS-CoV and reported virus inactivation from 99.9% to >99.999%.²¹ Considering the above studies, effective inactivation of virus can be achieved between 0.5 J/cm² and 1 J/cm² without much physical damage.

Proper precautions of shielding are required as UV light is known to be harmful to skin and eyes. Considering the available literature, UVGI is the most effective decontamination methods for viruses in general and it holds good for current pandemic of SARS-CoV-2 if emerging evidences are to be believed.

Ethylene Trioxide

In initial studies, ethylene trioxide (EtO) was found to be harmless on filtration performance for the nine tested FFR models.^{9,10} All tests were conducted for 1 hour at 55°C with EtO gas concentrations ranging from 725 g/L to 833 g/L. However, less data are available for the effect of EtO treatment may have on FFR fit. A serious concern about using EtO for decontamination of large scale is its carcinogenic and teratogenic effects. Chronic inhalation of EtO has been linked to neurological dysfunction and may cause other harmful effects to the wearer and hence it is not widely recommended.²⁵

In this article, the available literature for decontamination of masks was searched and summarized. However, the numbers of

studies are limited and quality of available evidence is poor. The current pandemics would help us come with more studies about methods of reuse of masks and effective decontamination methods. More studies will throw light on reuse of masks specifically in the context of healthcare workers as the previous studies include evidence for home use, commercial, as well as hospital use. Another major limitation could be due to nonuniformity of available mask in different countries and those studied in the article. All the available studies tested the fit and penetration of FFR's after each decontamination process, which may or may not be practical in times of scarcity and due to non-availability of specialized testing labs.

CONCLUSION

Yes, we can reuse FFR masks but it should be remembered that decontamination and subsequent reuse of FFRs should only be practiced as a crisis capacity strategy. Reuse after decontamination may cause improper fit, filtration inefficiency, and decrease breathability of disposable FFRs. Physical damage like degradation of filtering material, straps, and tarnishing of metallic parts is other commonly encountered problems during the process decontamination. However, in times of crisis and to best utilize the resources, UVGI, VHP, and moist heat are the most promising potential methods to decontaminate FFRs. Even though the FFRs are decontaminated, all healthcare workers should take all other standard precautionary measures required to handle these FFRs.

REFERENCES

1. Temporary Enforcement Guidance - Healthcare Respiratory Protection Annual Fit- Testing for N95 Filtering Facepieces During the COVID-19 Outbreak. March 14, 2020. (<https://www.osha.gov/memos/2020-03-14/temporary-enforcement-guidance-healthcare-respiratory-protection-annual-fit>).
2. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH) <https://www.cdc.gov/niosh/topics/hcwcontrols/recommendedguidanceextuse.html> <https://www.cdc.gov/niosh/topics/hcwcontrols/pandemic-planning.htm>.
3. Beckman S, Materna B, Goldmacher S, Zipprich J, D'Alessandro M, Novak D, et al. Evaluation of respiratory protection programs and practices in California hospitals during the 2009-2010 H1N1 influenza pandemic. *Am J Infect Control* 2013;41(11):1024–1031. DOI: 10.1016/j.ajic.2013.05.006.
4. CDC, "Questions and Answers Regarding Respiratory Protection For Preventing 2009 H1N1 Influenza Among Healthcare Personnel" [Online]. Available at https://www.cdc.gov/h1n1flu/guidelines_infection_control_qa.htm, 2010).
5. Rebmann T, Alexander S, Cain T, Citarella B, Cloughessy M, Coll B, "APIC position paper: extending the use and/or reusing respiratory protection in healthcare settings during disasters." [Online] Available at http://www.apic.org/Resource_/TinyMceFileManager/Advocacy-PDFs/APIC_Position_Ext_the_Use_and_or_Reus_Resp_Prot_in_Hlthcare_Settings12091.pdf.
6. Bauchner H, Fontanarosa PB, Livingston EH. Conserving supply of personal protective equipment—A call for ideas. *JAMA* Published online March 20, 2020.
7. N-Reuse, 95 by Society of American Gastroenterology and American Surgeons, <https://www.sages.org/n-95-re-use-instructions/>.
8. Elhafi G, Naylor CJ, Savage CE, Jones RC. Microwave or autoclave treatments destroy the infectivity of infectious bronchitis virus and avian pneumovirus but allow detection by reverse transcriptase-polymerase chain reaction. *Avian Pathol* 2004;33(3):303–306. DOI: 10.1080/0307945042000205874.
9. Viscusi DJ, Bergman MS, Eimer BC, Shaffer RE. Evaluation of five decontamination methods for filtering facepiece respirators. *Ann Occup Hyg* 2009;53(8):815–827. DOI: 10.1093/annhyg/mep070.
10. Bergman MS, Viscusi DJ, Heimbuch BK, Wander JD, Sambol AR, Shaffer RE. Evaluation of multiple (3-cycle) decontamination processing for filtering facepiece respirators. *J Engin Fibers Fabri* 2010;5(4):33–41. DOI: 10.1177/155892501000500405.
11. Bergman M, et al. Impact of three cycles of decontamination treatments on filtering facepiece respirator fit. *J Int Soc Respirat Protect* 2011;28(1):48–59.
12. Heimbuch BK, Wallace WH, Kinney K, Lumley AE, Wu CY, Woo MH, 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):1–9. DOI: 10.1016/j.ajic.2010.07.004.
13. Rutala WA, Weber DJ. Uses of inorganic hypochlorite (bleach) in health-care facilities. *Clin Microbiol Rev* 1997;10(4):597–610. DOI: 10.1128/CMR.10.4.597-610.1997.
14. McDonnell D, Russell D. Antiseptics and disinfectants: activity, action, and resistance. *Clin Microbiol Rev* 1999;12(1):147. DOI: 10.1128/CMR.12.1.147.
15. Joslyn LJ. Gaseous chemical sterilization Block SS, ed. *Disinfection, sterilization and preservation*. 4th ed., Philadelphia, PA: Lea and Febiger, 1991. pp. 344–345.
16. Battelle. Final report for the bioquell hydrogen peroxide vapor (HPV) decontamination for reuse of N95 respirators. 2016.
17. Kenney P, Chan BK, Kortright K, et al. Hydrogen peroxide vapor sterilization of N95 respirators for reuse. *Med Rxiv* 2020.
18. Schwarz A, Stiegel M, Greeson N, Vogel A, Thomann W, Brown M, 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. Durham, NC: Duke University & Health System, Occupational & Environmental Safety Office; n.d.; 2020. Available from: <https://www.safety.duke.edu/sites/www.safety.duke.edu/files/N95%20Decontamination%20Procedure.pdf>.
19. Viscusi DJ, King WP, Shaffer RE. Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models. *J Int Soc Respirat Protect* 2007;24:93–107.
20. Lindsley WG, Martin SB, Thewlis RE, Sarkisian K, Nwoko JO, Mead KR, et al. Effects of ultraviolet germicidal irradiation (UVGI) on N95 respirator filtration performance and structural integrity. *J Occup Environ Hyg* 2015;12(8):509–517. DOI: 10.1080/15459624.2015.1018518.
21. Heimbuch BK, Harnish D, Research to Mitigate a Shortage of Respiratory Protection Devices During Public Health Emergencies. 2019; Available from: <https://www.ara.com/news/ara-research-mitigate-shortage-respiratory-protection-devices-during-public-heal>.
22. Fisher EM, Shaffer RE. A method to determine the available UV-C dose for the decontamination of filtering facepiece respirators. *J Appl Microbiol* 2011;110(1):287–295. DOI: 10.1111/j.1365-2672.2010.04881.x.
23. Mills D, Harnish DA, Lawrence C, Sandoval-Powers M, Heimbuch BK. Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators. *Am J Infect Control* 2018;46(7):49–55. DOI: 10.1016/j.ajic.2018.02.018.
24. Lore MB, Heimbuch BK, Brown TL, Wander JD, Hinrichs. SH. Effectiveness of three decontamination treatments against influenza virus applied to filtering facepiece respirators. *Ann Occup Hyg* 2012;56(1):92–101. DOI: 10.1093/annhyg/mer054.
25. Rutala WA, Weber DJ. Guideline for disinfection and sterilization in healthcare facilities, 2008. Available from: <https://www.cdc.gov/infectioncontrol/guidelines/disinfection>.