Modern Problems Require Modern Solutions: Exploring Strategies for Recycling N-95s in the Age of COVID-19

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Abstract

The COVID-19 pandemic has forced healthcare systems throughout the world to adapt to N-95 shortages, and several strategies aimed at preserving limited equipment exist. N-95 mask recycling helps not only the overburdened health system, but also reduces healthcare's carbon footprint.

Vaporous hydrogen peroxide, ultraviolet germicidal radiation, and moist heat are all explored as potential solutions to N-95 recycling. All three methods prove to be effective in decontaminating N-95 masks, with certain modalities exhibiting degradation of mask components after several cycles.

Hospitals need to develop their own strategies for N-95 mask decontamination, procedures, and personnel training pertaining to N-95 mask recycling and reuse.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), commonly known as COVID-19, has ravaged nations and healthcare systems throughout the world since late 2019. Hospitals across the United States continue to experience shortages in both reusable medical devices as well as limited use personal protective equipment (PPE) such as face masks, face shields, gloves, and gowns.

As strained and overburdened medical systems continue to grapple with the immense shortage of PPEs in light of this transnational crisis, novel strategies to protect our nation's front-line workers and our most vulnerable populations must be explored. These potential solutions serve as a two-pronged solution, not only to help alleviate the current global pandemic, but also humanity's massive carbon footprint contributing to the impending crisis of climate change we have to face in the future.

This article will outline current strategies from the CDC for recycling limited use N-95 respirators.

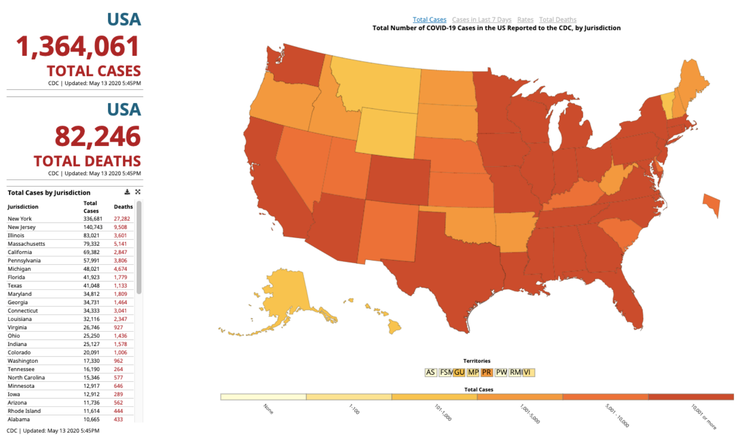

Figure 1. United States COVID-19 cases and deaths

Current Strategies

Vaporous hydrogen peroxide (VHP)

Investigations into VHP decontamination of N-95 masks of *Geobacillus stearothermophilus* spores demonstrate limited effects to filtration and fit with a 6-log reduction of organisms, equating to 99.9999% efficiency in killing bacterial spores.[1] Filtration performance was also found to be preserved for up to 50 cycles of VHP treatment, with strap degradation noticeable after 20 cycles.[2]

Ultraviolet germicidal irradiation (UVGI)

UVGI was also explored as a promising method, but the disinfection efficacy has been determined to be dose-dependent. Additionally, not all UV lamps provide the same intensity, thus treatment times would vary accordingly. Lastly, UVGI is unlikely to kill all the viruses and bacteria on N-95 masks due to shadow effects from the multiple layers of the mask's construction.

Acceptable filtration performance was recorded for eleven N-95 mask models exposed to various UV doses ranging from roughly 0.5–950 J/cm2 and UVGI was shown to have minimal effect on fit.[3] Heimbuch et al. tested the performance of 1 J/cm2 of UVGI against two strains of Influenza A (H1N1, H7N9), Avian influenza A virus, MERS-CoV, and SARS-CoV and reported inactivation of the viruses from 99.9% to greater than 99.999%.[4]

Moist heat

Moist heat at 60°C and 80% relative humidity (RH) caused minimal degradation in the filtration and fit performance of the tested N-95 masks[5] Heimbuch et al. disinfected N-95 masks contaminated with H1N1 influenza using moist heat, of 65°C and 85% RH, and achieved a minimum of 99.99% reduction in virus.[6]

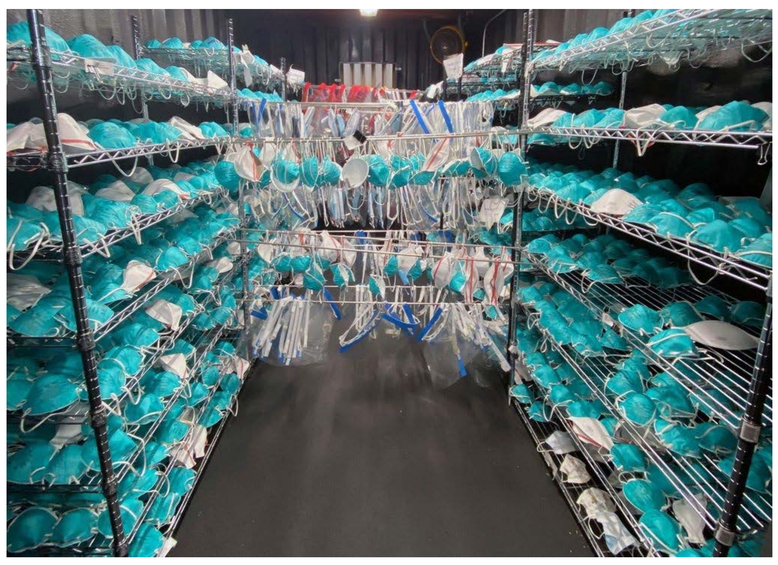

Image 1.N-95 respirators staged for decontamination

Results

Thus far, vaporous hydrogen peroxide, ultraviolet germicidal irradiation, and moist heat are currently the most promising decontamination methods for N-95 masks.

These existing strategies do not significantly break down filtration or compromise the safety of the N-95. These methods can only be used for limited times, however, until certain components of the N-95 mask are degraded.

The following table reveals the findings.

Method	Treatment level	Microbe tested	Antimicrobial efficacy
Vaporous hydrogen peroxide (VHP)	Battelle report: Bioquell Clarus C HPV generator: The HPV cycle included a 10 min conditioning phase, 20 min gassing phase at 2 g/min, 150 min dwell phase at 0.5 g/min, and 300 min of aeration.	*Geobacillus stearothermophilus spores*	>99.999%
	Bergman et. al.: Room Bio-Decontamination Service (RBDS™, BIOQUELL UK Ltd, Andover, UK), which utilizes four portable modules: the Clarus® R HPV generator (utilizing 30% H2O2), the Clarus R20 aeration unit, an instrumentation module and a control computer. Room concentration = 8 g/m3, 15 min dwell, 125-min total cycle time.	T1, T7, and phi-6 bacteriophages	
	Kenney personal communication: Bioquell BQ-50 generator: The HPV cycle included a 10 min conditioning phase, 30–40 min gassing phase at 16 g/min, 25 min dwell phase, and a 150 min aeration phase.		
Ultraviolet germicidal irradiation (UVGI)	0.5–1.8 J/cm2	Influenza A (H1N1) Avian influenza A virus (H5N1), low pathogenic Influenza A (H7N9), A/Anhui/1/2013 Influenza A (H7N9), A/Shanghai/1/2013 MERS-CoV SARS-CoV H1N1 Influenza A/PR/8/34 MS2 bacteriophage	99.9% for all tested viruses
Moist heat incubation	15–30 min (60°C, 80% RH)	H1N1 influenza A/PR/8/34	99.99%

Table 1. Effectiveness of N-95 decontamination

While these modalities have effectively demonstrated safe decontamination of N-95 masks for repeat use, questions remain regarding the various hospital infrastructure, recycling procedures, staff training, and in-house guidelines to safely and efficiently perform decontamination uniquely inherent to each institution.

Detailed strategies must be outlined, and exact guidelines must be developed for each hospital in accordance to available equipment and personnel capabilities.

As we await a more robust national standard for decontamination of N-95 masks, hospitals must chart their own paths towards conservation, recycling, and reuse of a scarce resource.

Conclusions

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As we await a more robust national standard for decontamination of N-95 masks, hospitals must chart their own paths towards conservation, recycling, and reuse of a scarce resource.

References

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