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Concise Communication

Effectiveness of commercial portable air cleaners and a do-it-yourself minimum efficiency reporting value (MERV)-13 filter box fan air cleaner in reducing aerosolized bacteriophage MS2

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Abstract

In an unventilated room, 2 commercial portable air cleaners with high efficiency particulate air (HEPA) filters and a do-it-yourself box fan air cleaner with minimum efficiency reporting value (MERV)-13 filters significantly reduced aerosolized bacteriophage MS2. Increasing airflow and addition of ultraviolet-C light plus titanium dioxide–generated photocatalytic oxidation enhanced viral clearance.

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Inadequately ventilated indoor spaces pose a risk for transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1,2] The Centers for Disease Control and Prevention (CDC) has therefore recommended several measures to improve ventilation, including opening windows when feasible and adjusting heating, ventilation, and air conditioning (HVAC) systems to improve airflow and air filtration.[1] In spaces with suboptimal ventilation and in offices where aerosol-generating procedures are performed, portable air cleaners have been recommended as an adjunct to standard ventilation systems.[1–3] Portable air cleaners with high efficiency particulate air (HEPA) filters reduced aerosol particles in school classrooms and a simulated conference room,[3–5] and portable HEPA air cleaners reduced airborne SARS-CoV-2 RNA on COVID-19 units.[6] However, information on the efficacy of different types of portable air cleaners in removing viral particles from air is limited. Therefore, we evaluated the effectiveness of 2 commercial portable air cleaners with HEPA filters and a do-it-yourself box fan air cleaner with minimum efficiency reporting value (MERV)-13 filters in reducing aerosolized bacteriophage MS2 in an unventilated room. The box fan air cleaner was tested because MERV-13 filters are less effective than HEPA filters but are commonly used in do-it-yourself air cleaners.[7] For 1 of the commercial air cleaners, we evaluated the impact of increased airflow and the addition of photocatalytic oxidation using an internal ultraviolet-C (UV-C) light plus titanium dioxide fixture.

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Methods

Comparison of portable air purifiers

The characteristics and purchase costs of the portable air cleaners are shown in Table 1. Supplementary Figure 1 (online) shows pictures of the devices. The commercial test devices included a tabletop device (True HEPA Tabletop Air Purifier, Honeywell) and a room device (Germ Guardian 5-in-1 28" Pet Pure Air Purifier with HEPA, UVC & Digital, Guardian Technologies, Euclid, OH) intended for use in rooms up to 117.6 m^2. The room device was run with and without the operation of an internal UV-C bulb plus titanium dioxide fixture; exposure of titanium dioxide to UV-C results in a photocatalytic oxidation reaction that generates reactive oxygen species.[8,9]

The do-it-yourself air cleaner with MERV-13 filters was constructed according to instructions available online;[7] a box is made with 4 20-inch (~51 cm) (MERV-13 filters (sides of the box), a 20-inch (~51 cm) box fan (top of the box), and a cardboard bottom. Air flows in through the filters and out through the fan.

Testing was conducted in an unventilated 41.7 m^3 room with side ports for aerosol introduction and air sample collection. For each simulation, an Aerogen Solo (Aerogen) nebulizer was used to release 2 mL of droplets containing 10^8 plaque-forming units (PFU) of bacteriophage MS2 over 9 minutes; 70%–80% of particles generated are ≤5 μm in size. The devices were placed in the middle of the room and turned on 5 minutes after bacteriophage release. Air samples were collected 2 m from the aerosol release site using a NIOSH 2-stage bio-aerosol sampler (Tisch Environmental). The air samples were collected over 5-minute periods at baseline (0–5 minutes after aerosol release) and 5–10, 15–20, 30–35, and 60–65 minutes after release. Quantitative cultures for bacteriophage MS2 were processed as previously described.[10] Simulations were repeated in triplicate.

Table 1. Characteristics and Purchase Costs of the Portable Air Cleaners Studied

Device	Device Dimensions in Inches (height × width × depth)	Filter size in Inches[2] (No. of Filters)	Filter Efficiency (Type)	Airflow, m^3/min	Purchase Cost, US$
True HEPA Tabletop Air Purifier (tabletop device)	30.61 × 21.49 × 28.40 cm	124.46 cm (1)	99.97% for 0.3-µm particles (HEPA)[1]	6.62	79.37
Germ Guardian 5-in-1 28” Pet Pure Air Purifier with HEPA, UVC & Digital (Room device)	27.94 × 17.15 × 69.22 cm	232.26 cm (1)	99.97% for 0.3-µm particles (HEPA)[1]	5.51 (low speed setting) and 11.63 (high speed setting)	129.99
Do-it-yourself MERV-13 filter box fan air cleaner	62.23 × 50.80 × 50.80 cm	1016 cm (4)	50% for 0.3–1-µm particles; 85% of 1–3-µm particles (MERV-13)[1]	34.16	99.78

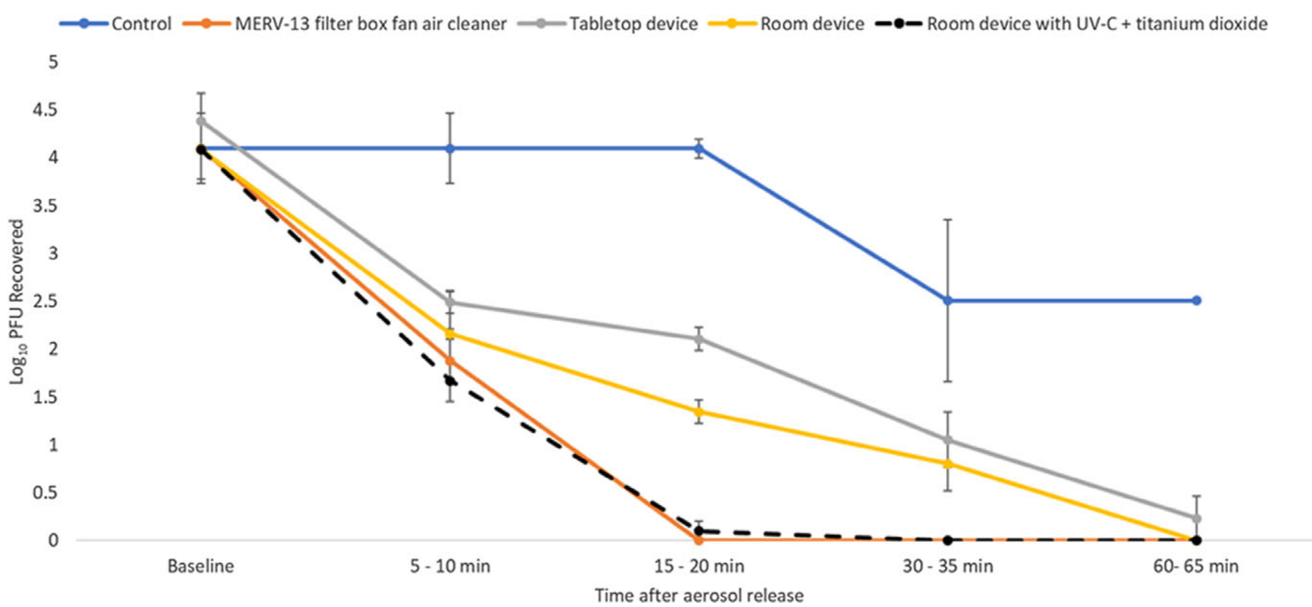

Fig. 1. Efficacy of portable air cleaners in reducing aerosolized bacteriophage MS2 in an unventilated room. The tabletop device was a True HEPA Tabletop Air Purifier. The room device was a GermGuardian 5-in-1 28” Pet Pure Air Purifier with HEPA, UVC and digital. The do-it-yourself minimum efficiency reporting value (MERV)-13 filter box fan air cleaner was constructed as described in the text using 4 20-inch (~51 cm) MERV-13 filters (the sides of the box), a 20-inch (~51 cm) box fan (the top of the box), and a cardboard bottom. Note. PFU, plaque-forming units; UV-C, ultraviolet-C light. Error bars show standard error.

For the room device, additional testing was conducted to compare reductions at the lowest versus highest fan speed. To determine the impact of reactive oxygen species in air without concurrent UV-C, the room device with the UV-C plus titanium dioxide fixture was operated for 15 minutes then turned off followed by the release of bacteriophage MS2. For these assessments, air samples were collected 15 minutes after aerosol release.

Data analysis

For each group, a 2-way analysis of variance model with post-hoc Tukey *P*-value adjustment was used to compare $\log_{10}$PFU recovered from air at each timepoint. Data were analyzed using R version 4.0.3 software (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Figure 1 shows the effectiveness of the portable air cleaners in reducing aerosolized bacteriophage MS2. The concentration of MS2 recovered from air was similar for all groups at baseline ($P > .05$ for each comparison). In comparison to unfiltered control air samples, each of the portable air cleaners significantly reduced recovery of bacteriophage MS2 at 5–10, 15–20, 30–35, and 60–65 minutes ($P < .01$ for each comparison). At 15–20 minutes, the MERV-13 filter box fan air cleaner and the room device operated with the internal UV-C bulb plus titanium dioxide were significantly more effective in reducing bacteriophage MS2 than the commercial tabletop and room air cleaners ($P < .01$). However, there were no significant differences in reductions achieved by the different devices at 30–35 minutes and at 60–65 minutes ($P > .05$ for all comparisons).

The room device was significantly more effective in reducing bacteriophage MS2 when operated at the highest versus lowest fan speed; the $\log_{10}$PFU recovered at 15 minutes after release was 2.3 versus 1.4 ($P < .01$). In comparison to controls, bacteriophage MS2 was reduced by 0.82 $\log_{10}$PFU when released into air conditioned by prior operation of the room device with the UV-C plus titanium dioxide fixture.

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Discussion

In this study, 2 commercial portable air cleaners with HEPA filters and a do-it-yourself MERV-13 filter box fan air cleaner were effective in reducing aerosolized bacteriophage MS2. For the 3 devices, clearance of MS2 by filtration increased with increasing airflow, and clearance was significantly increased at high versus low fan speed for the room device. Although the MERV-13 filter box fan device has reduced filtration efficiency in comparison to the HEPA filtration devices, it has substantially higher airflow and achieved greater reductions in MS2. These findings demonstrate the effectiveness of portable air cleaners in reducing aerosolized viral particles and highlight the importance of ensuring adequate airflow. Our results provide support for use of portable air cleaners to reduce the risk for SARS-CoV-2 transmission in areas with inadequate ventilation.[1,6]

Do-it-yourself box fan air cleaners are easy to assemble using readily available items.[6] The total purchase price of the items used to make the do-it-yourself device studied was <$100. Although MERV-13 filters were used, the device could also be made with filters with greater filtration efficiency.

The finding that the addition of photocatalytic oxidation enhanced viral clearance is consistent with previous reports.[8,9] The mechanism of antiviral activity is presumed to be the generation of reactive oxygen species such as hydroxyl and superoxide radicals.[8] The reduction in bacteriophage MS2 after release into air conditioned by prior operation of the room device with the UV-C plus titanium dioxide fixture is consistent with release of reactive oxygen species into the air. In a previous report, titanium dioxide photocatalyst-mediated damage inactivated SARS-CoV-2 in a time-dependent manner and decreased infectivity by 99.9% after 20 minutes.[9]

Our study has some limitations. Only 3 types of portable air cleaners were studied in an unventilated room. Additional studies are needed to assess other types of air cleaners and in real-world settings. Differences between bacteriophage MS2 (nonenveloped single-strand RNA virus with diameter of 23-28 nm) and SARS-CoV-2 (enveloped RNA virus with diameter 60–140 nm) could impact clearance by filtering or photocatalyst-mediated inactivation. Finally, limited safety information is available for devices that generate reactive oxygen species through photocatalytic oxidation. However, according to the manufacturer, the device tested in the current study meets Underwriters (UL) standard 867 and does not produce ozone at a concentration exceeding 0.05 parts per million.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2022.5

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