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Disclaimer:

Efficiency of Room Air Cleaners for Removal of Bioaerosols From Ambient Air

The COVID-19 pandemic necessitated the evaluation of commercial air purification units to protect worker safety in indoor spaces. This project evaluated the efficacy of commercial off-the-shelf air purification systems that utilize electrostatic precipitation for the collection and removal of particulates (including bioaerosols) from ambient air.

Awards and Recognition

None

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

SRNL Legal Signature

Signature **Date**

Efficiency of Room Air Cleaners for Removal of Bioaerosols From Ambient Air

Project Team: Wendy Kuhne (Primary), Charles Turick, Candace Langan, Courtney Burckhalter, and Eliel Villa-Aleman

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The COVID-19 pandemic necessitated the evaluation of commercial air purification units to protect worker safety in indoor spaces. This project evaluated the efficacy of commercial off-the-shelf air purification systems that utilize electrostatic precipitation for the collection and removal of particulates (including bioaerosols) from ambient air. An aerosol mist containing Escherichia coli (E. coli) and bacteriophage surrogate virus, MS2, was produced using a nebulizer and delivered to the front intake of the commercial system with the ionizer ON and OFF. Removal efficiency was evaluated by colony/plaque formation assays using a small agar plate (60 X 15 mm) to passively collect E. coli and MS2 exhausting from the electrostatic precipitation cell. The system was determined to remove 98-99% of the microorganism introduced to the system. Testing was performed with all pre- and post-electrostatic cell filters removed so further removal is anticipated.

FY2020 Objectives

- Evaluate the efficacy of the commercial electrostatic precipitation cell to collect and remove *E. coli* from airstream exhausting into the ambient air with fan speeds of low, medium, and high.
- Evaluate the efficacy of the commercial electrostatic precipitation cell to collect and remove the bacteriophage MS2, a surrogate virus, from airstream exhausting into the ambient air with fan speeds of low, medium, and high.

Introduction

The recent emergence of coronavirus (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is characterized by persons displaying symptoms of mild or severe respiratory distress. Primary modes of transmission are through respiratory or aerosol droplets released from an infected person through speaking, coughing, sneezing and normal breathing and can range in size from ≤1 to ≥ 100 µm in size. Large droplets ≥ 100 µm will be dominated by gravitational forces and have a short range in air. They contribute to direct spray transmission and surface contamination contributing to indirect modes of transmission through entrance into mucosal tissue of uninfected person (touching of eyes and mouth). Large droplets can undergo evaporation or desiccation as they sink by gravitation to form droplet nuclei. Smaller droplets and droplet nuclei are ≤ 5-10 µm and commonly referred to as aerosols. Aerosols are responsible for the long-range airborne route of transmission[1].

Electrostatic precipitator (ESP) air purification systems are commercially available to remove aerosols and bioaerosols from indoor air spaces. These systems function by pulling air into the system, ionizing a region where the air containing aerosols and bioaerosols acquire a charge via a corona discharge, and pass into a region of high electric field where they are drawn to oppositely charged collection surfaces thus removing them from the ambient air. It has been recognized for many years that the gaseous corona discharge generates ozone (O_3). The amount of O_3 generated per unit time is a direct function of the amount of electrical power which is dissipated in the ionized sheath[2]. O_3 is a well-recognized disinfectant used to kill microorganisms[3], however its primary application has been limited to contaminated surfaces[4].

To test the capability of the system to purify air by collecting bioaerosols the microorganisms bacteria, *Escherichia coli K-12 (E. coli)* and bacteriophage MS2, a surrogate virus, were selected for testing. *E. coli* was selected as a singular, gram-negative, small (1x2 µm) rod-shaped bacterium that should be easily destroyed upon contact with the ESP. MS2 is 1/5th the size of COVID-19 (23-28 nm diameter) and is a commonly used surrogate virus due to its close morphology to the *Picornaviridae* family, which includes many viruses pathogenic to humans, such as poliovirus. Survival and removal efficiency of the system was determined by colony/plaque formation assays for *E. coli* and MS2 on soft agar plates.

Approach

An aerosol stream containing *E. coli* and MS2 were introduced independently to the commercial air purification system. A board was inserted in the front air intake to direct the primary air flow through the center of the ESP cell. A similar board was placed immediately at the exhaust of the ESP and held a small agar plate (60 X 15 mm) to passively collect exhausting material. An agar plate was placed on the outside of the instrument at the top of the exhaust to collect material re-entering the ambient air (**Figure 1**).

Figure 1. (Top) *E. coli* aerosol delivery to the front of the ESP instrument. Red circle indicates position of the passive agar collection plate on the **top exhaust** plate. (Bottom) Agar plate inside at the exhaust **after the ESP**.

Measurements were made in triplicate at each fan speed (low, medium, and high) and with the ionizer ON and OFF. Two systems were tested: the Oreck XL and the Oreck ProShield. The Oreck XL is the predecessor to the ProShield Model. Both systems are rated for rooms ~80 sq. ft.

Colonies/plaques were allowed to form for 24-h post collection at 37°C and counted using free and open source software OpenCFU.

Results/Discussion

Both commercial systems, with the ionizer ON, applied a charge to *E. coli* passing through the ESP cell. At all fan speeds there was near complete removal of live *E. coli* exhausting into the ambient air (LOG-reduction of 2.0, 98-99% reduction) (**Figure 2**). With the ionizer OFF, live *E. coli* passed through the ESP cell unaffected. Increasing the fan speed from low to medium increased the number of live *E. coli* passing through the ESP by 62%. Increasing the fan speed from medium to high resulted in an additional 12% colony formation of *E. coli* passing through the ESP.

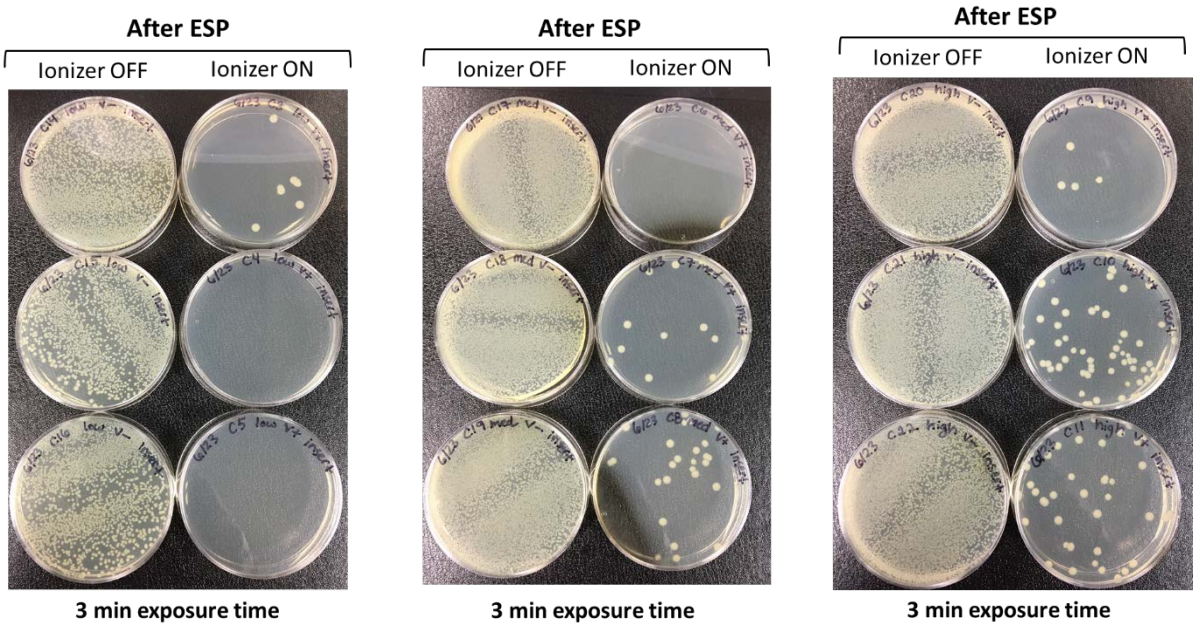

Figure 2. *E. coli* colony formation: (Left) Low fan speed, (Middle) Medium fan speed, (Right) High fan speed.

Aerosol generation of MS2 resulted in the formation of aggregated clusters. With the ionizer ON, the charge applied to the aggregated cluster appeared to break the cluster allowing for some viable MS2 to reach and infect the *E. coli* F+ seeded agar plate immediately after the ESP. Under conditons of the ionizer OFF, the aggregated cluster remained intact and no viable MS2 were able to infect the *E. coli* seeded agar plate. As with the *E. coli*, increasing the fan speed from low, medium, and to high did result in increased numbers of MS2 passing through the ESP cell (**Figure 3**).

While infection of the *E. coli* was observed with the ionizer ON, it is anticipated that the aggregated clusters would, most likely, be collected by the mechanical pre-filter and filter located after the ESP cell during normal operation. All mechnical filters were removed from the instrument during testing to investigate the efficiency of removal by the ESP cell alone.

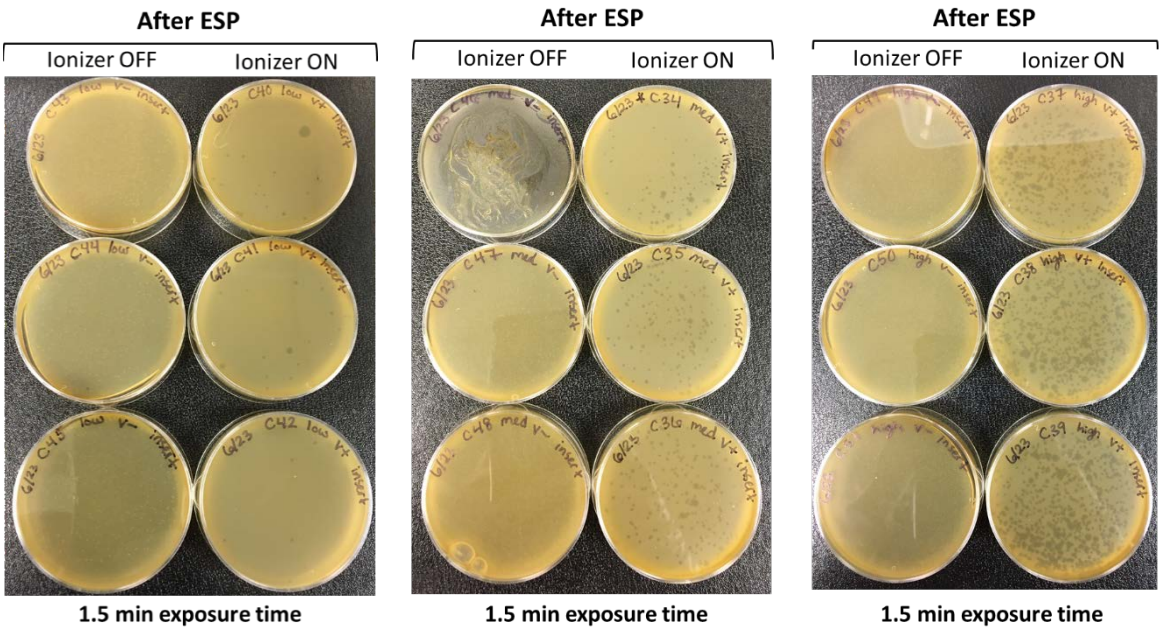

Figure 3. *MS2* plaque formation: (Left) Low fan speed, (Middle) Medium fan speed, (Right) High fan speed. Note: clear zones indicate infected *E. coli*.

FY2020 Accomplishments

- Commercial air purification system utilizing an electrostatic precipitator removed *E. coli* exhausting into ambient air by a LOG-reduction of 2.0 (98-99%).
- Testing with surrogate virus MS2 resulted in the formation of aggregate clusters that, with ionizer OFF, were unable to infect *E. coli* F+. The charge applied to the aggregate cluster with the ionizer ON resulted in some viable MS2 passing through the ESP and infecting *E. coli* F+ seeded on the plate.

Future Directions

None

FY 2020 Peer-reviewed/Non-peer reviewed Publications

None

Presentations

None

References

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Acronyms
None

Intellectual Property
None

Total Number of Post-Doctoral Researchers
One – Dr. Candace Langan (SRNL)

Total Number of Student Researchers
None

External Collaborators (Universities, etc.)
None