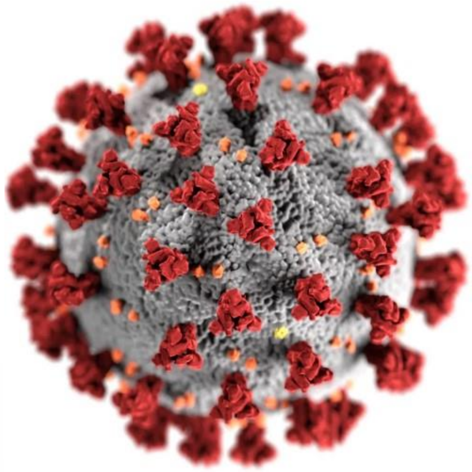
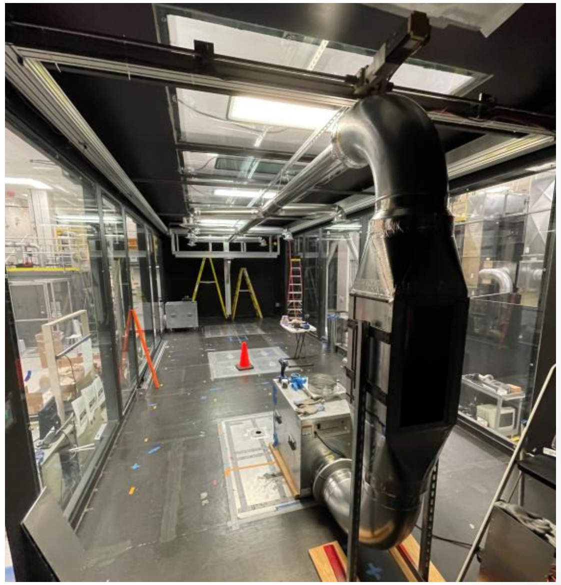
EPA Office of Research and Development

HOMELAND SECURITY RESEARCH

EPA COVID-19 Research: Air Treatment and Transit Technologies





MDOT Tech Talk
March 24, 2022

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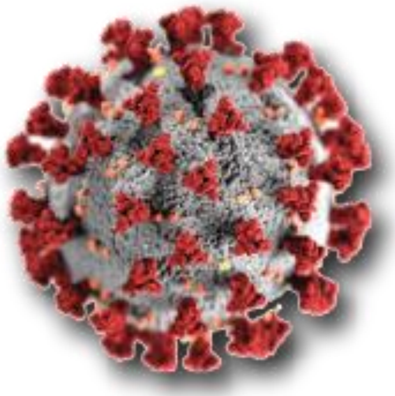
Lukas Oudejans, Ph.D.
ORD's Center for Environmental Solutions and Emergency Response

Overview of EPA Roles

Regulatory

- Pesticide Registration (FIFRA)
- FIFRA Enforcement
- Test Method Development

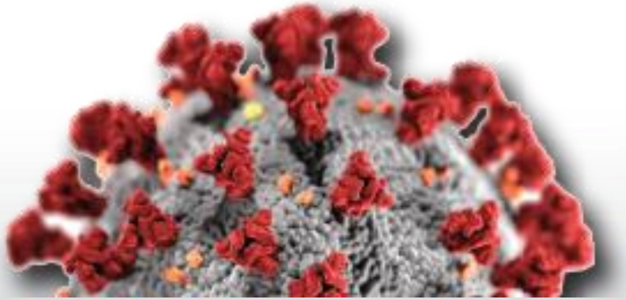


Response

- Cleanup Guidance
- Technical Support
- Preparedness/Mitigation

Research

- Aerosol Treatment
- Surface Cleaning and Disinfection
- Pesticide Application
- Pesticide Devices
- Residual Antimicrobial Coatings



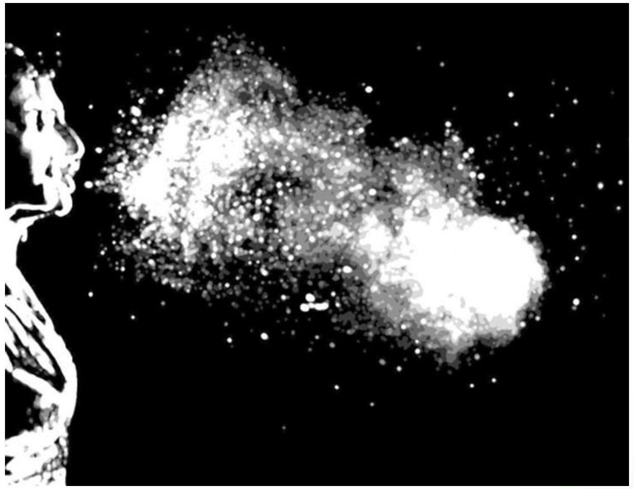
EPA SARS-CoV-2 Research Questions

Research topics were selected because they can result in a critical and rapid impact on the current SARS-CoV-2 response:

- How effective are aerosol treatment technologies and what are appropriate methods to determine effectiveness?
- How effective are alternative disinfection devices, such as UVC?
- Are there ways to disinfect high-touch, public spaces that remain effective for long periods of time?
- *How can real-world surfaces be cleaned and/or disinfected most effectively?*
- *What are effective ways to apply disinfectants?*
- *How can PPE be readily and effectively disinfected and reused?*

Aerosol Treatment Technologies

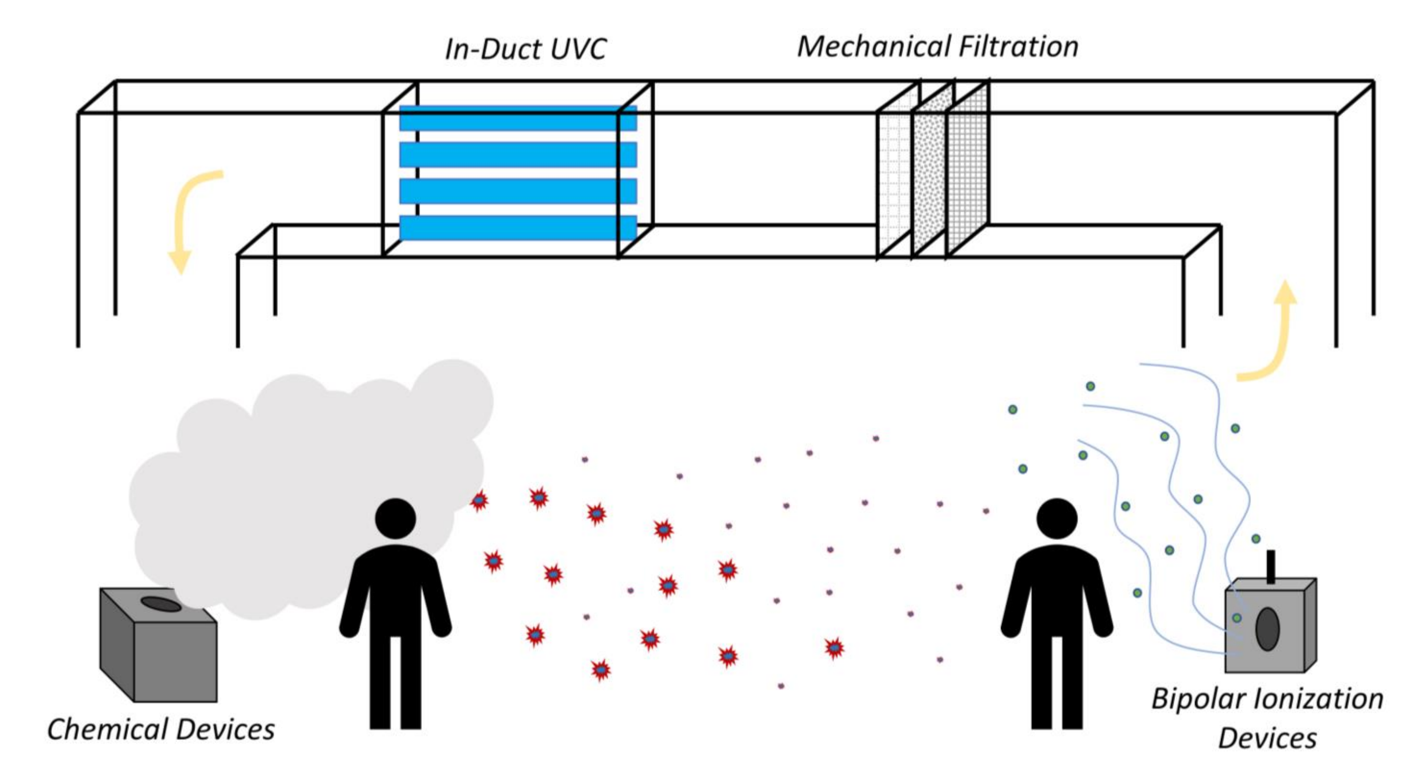
- COVID-19 has heightened awareness about airborne transmission of diseases (and indoor air quality issues)
- Increasing focus on **air treatment technologies**
  - *Many technologies are devices, which are not registered (efficacy not verified by EPA)*
- **Challenges:**
  - Social distancing not always feasible when repopulating indoor spaces (schools, offices, restaurants, public transit, events and gatherings, etc.)
  - Many air cleaning technologies on the market, but they often lack independent testing data



How effective are commercially-available aerosol treatment technologies at reducing concentrations of airborne pathogens?

Aerosol Treatment Technologies

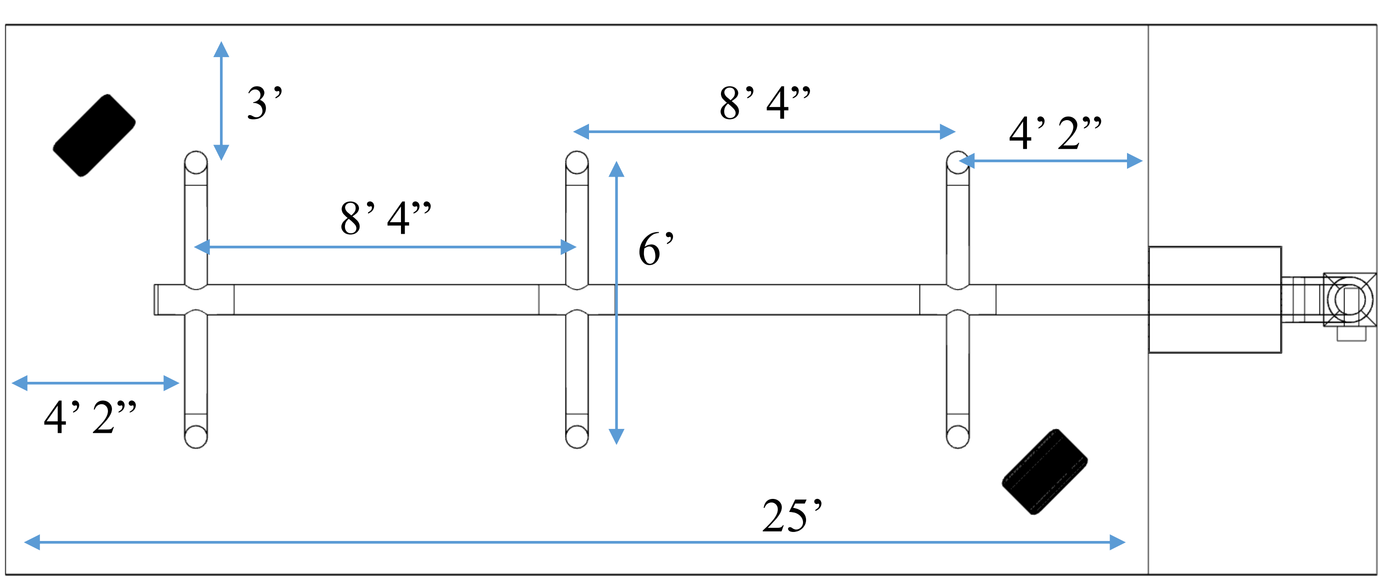
- Ultraviolet-C (UVC) devices: e.g., upper-room germicidal UVC, in-duct UVC
- Chemical products and devices: in-room or in-duct; e.g., low-concentration ozone, low-concentration hydrogen peroxide, low-concentration triethylene glycol, bipolar ionization
- Physical removal: e.g., MERV-13 and specialized filters, portable air cleaners
- Combinations of the above



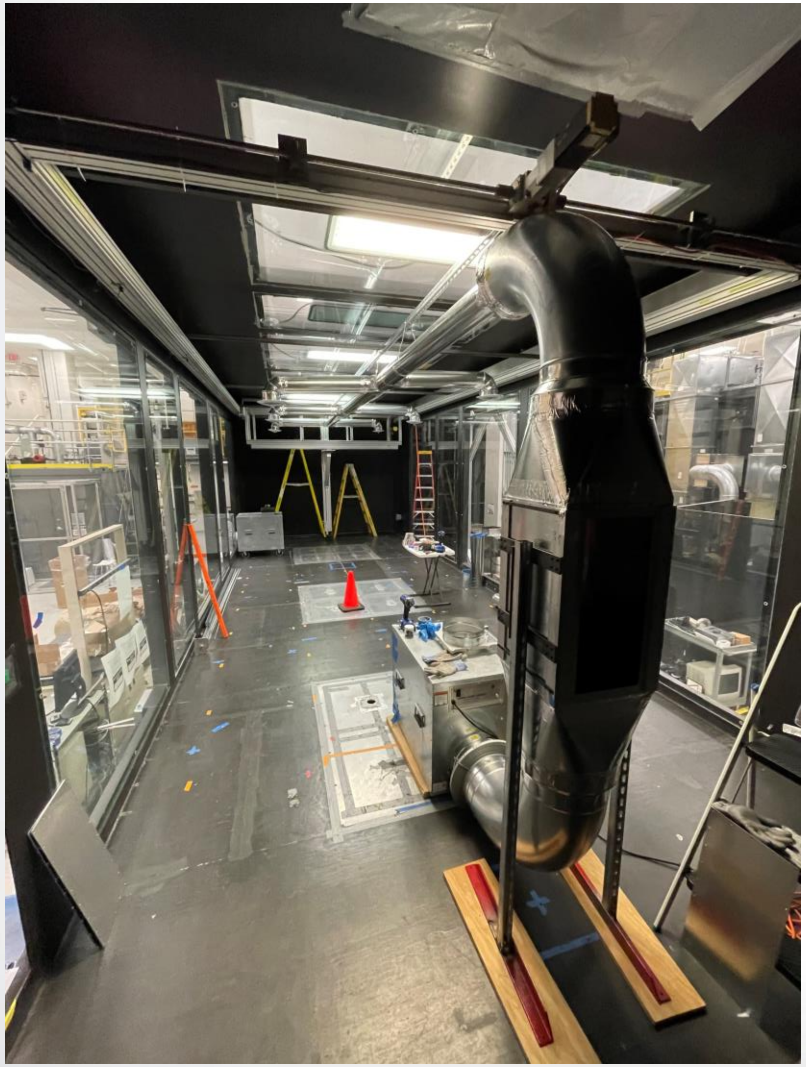
Focus on air treatment technologies and methods that can be continuously operating in occupied spaces (in-room or in-duct)

Aerosol Treatment: Methods

- Evaluate efficacy of technologies against non-pathogenic virus (MS2)
  - Air sampling
  - Surface sampling
- Utilize specialized Aerosol Test Facility in Research Triangle Park, NC
  - Large air treatment test chamber 10 x 12 x 25 ft (3000 ft^3)
  - Controlled temperature / humidity
  - Mock HVAC system designed and installed for testing treatment technologies
- On-site microbiology support
- Particle size & count measurements

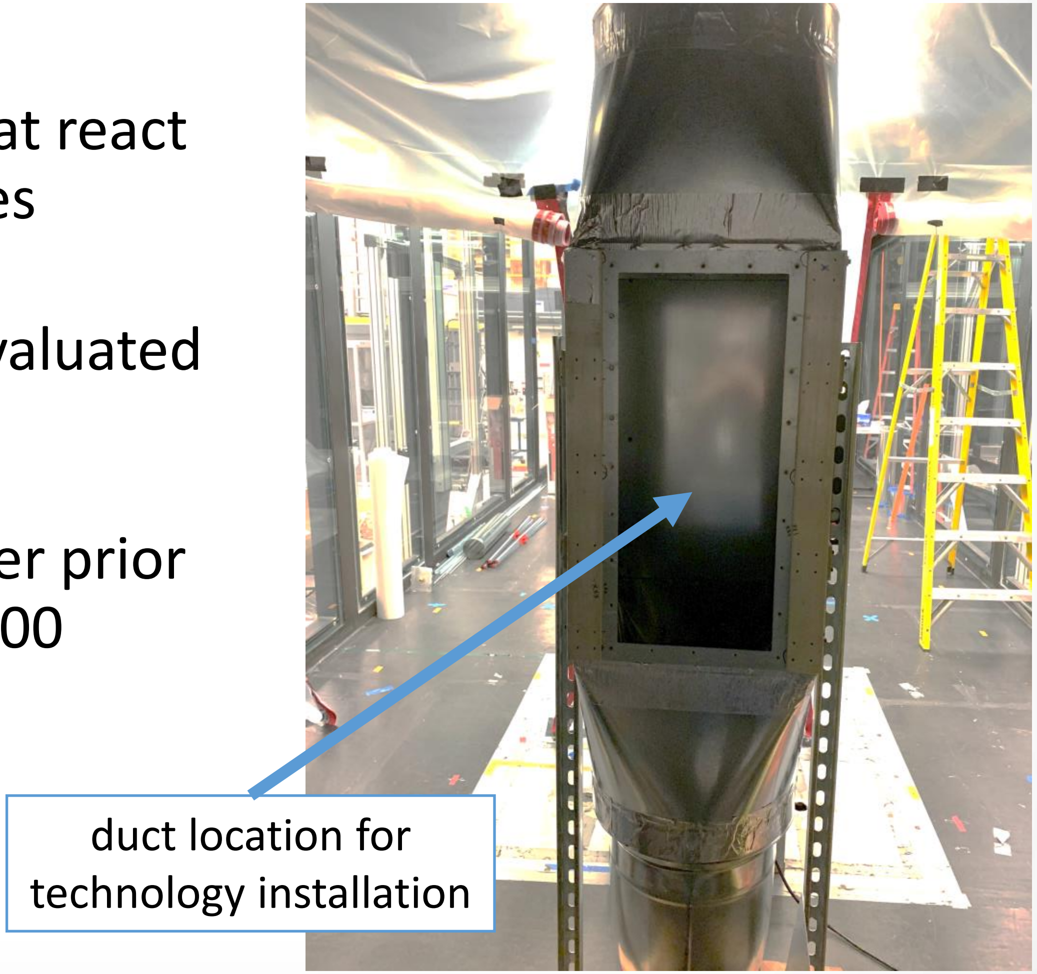


Test Chamber & HVAC System



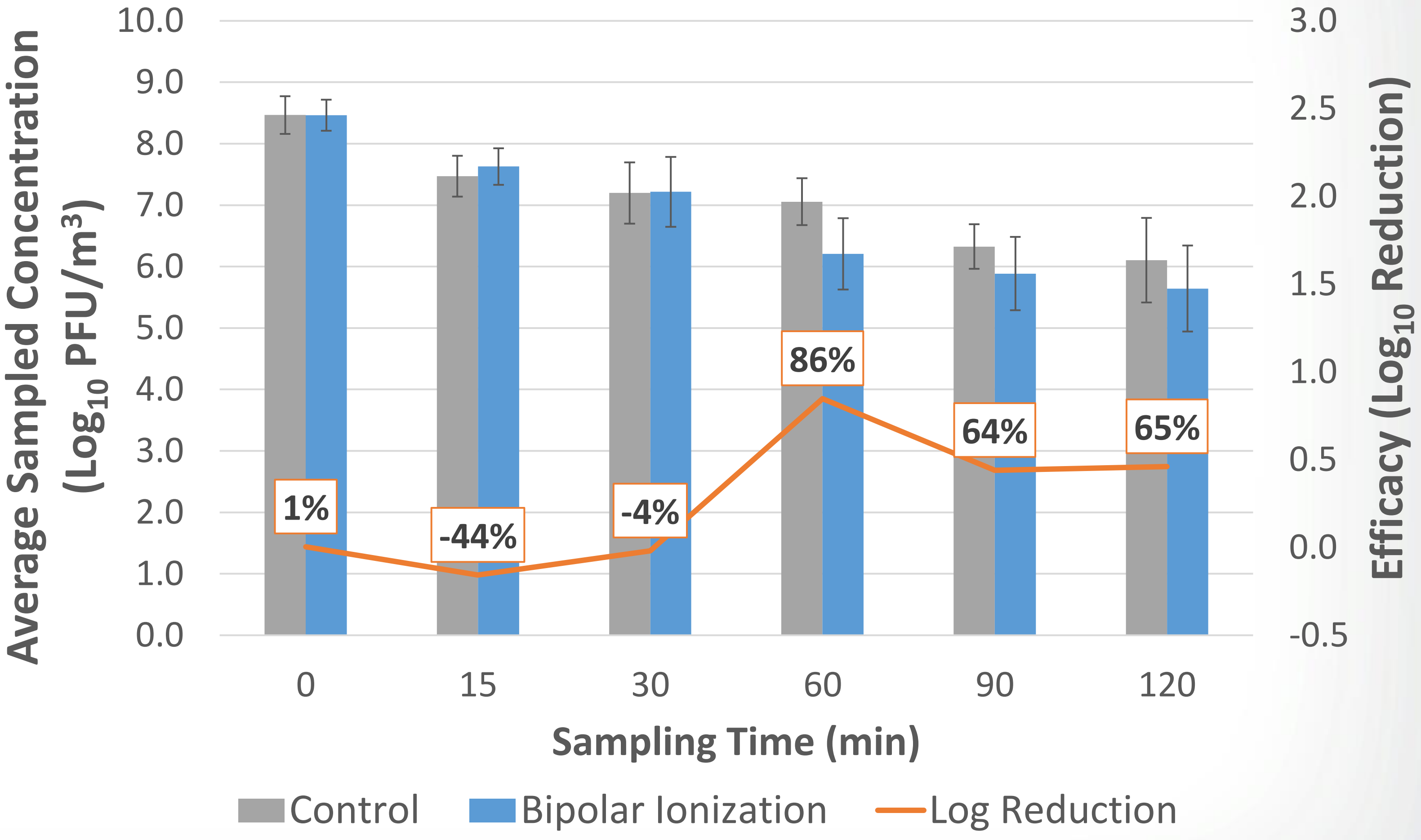
Bipolar Ionization Device

- Bipolar ionization generates charged ions that react with airborne contaminants, including viruses
- Cold plasma bipolar ionization device was evaluated
  - Sized to treat 2000-4000 ft^2 of living space
- 30 to 90-minute ion buildup times in chamber prior to testing, resulting in ion counts of 1000-6000 $ions/cm^3$



Bipolar Ionization Device

- Average percent reduction in recoveries of aerosolized MS2 from initial tests range from <0% to 86% throughout test duration
- No additional virus recovered from surfaces
- No surface inactivation observed



Efficacy:

Log_{10} Reduction = Mean log_{10} recovery (Control) - Mean log_{10} recovery (Test Sample)

Photocatalytic Device

- Metallic catalyst and UVC light convert water vapor from the air into hydrogen peroxide and other reactive oxides and ions

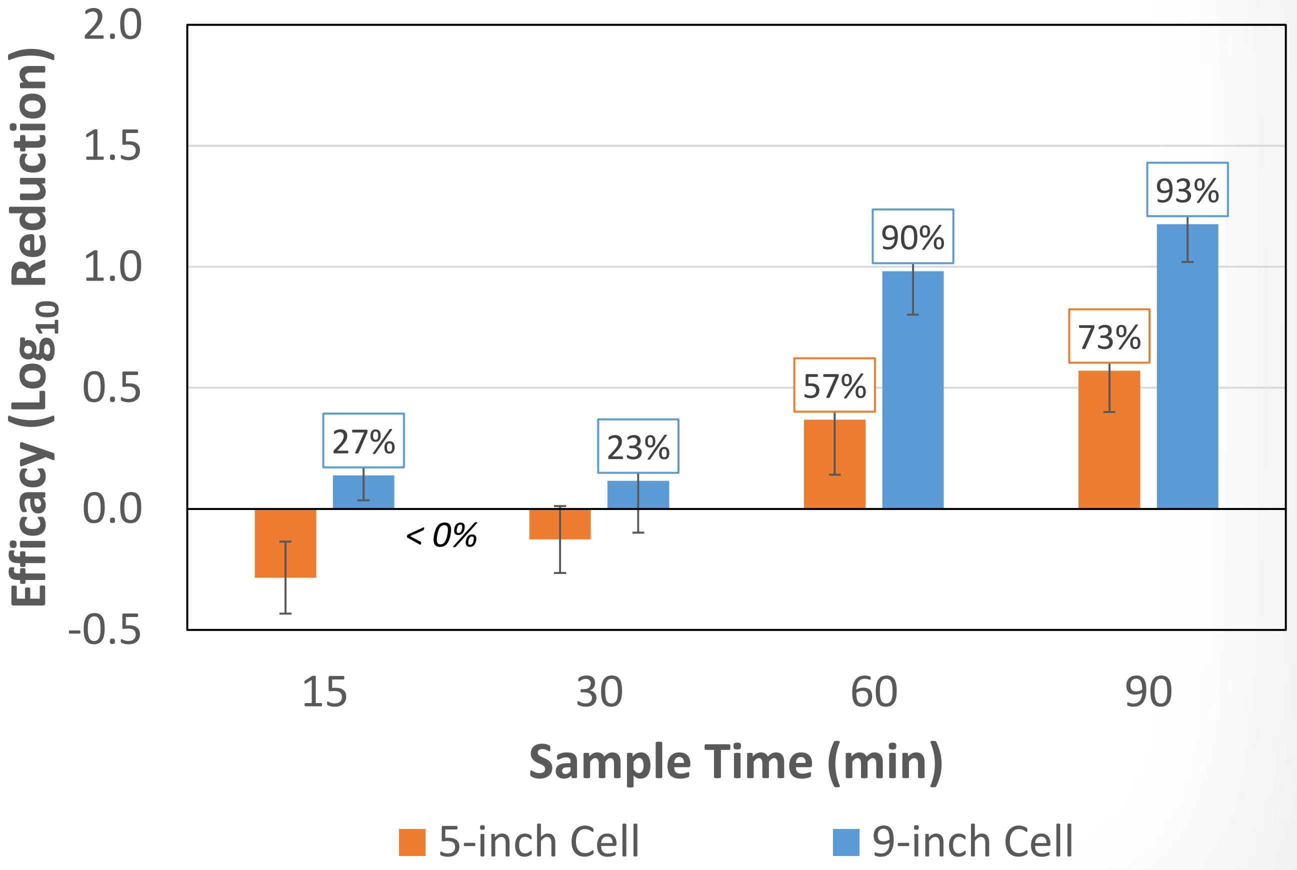
- Two different units with different photocatalytic cell sizes were evaluated

  - 5-inch cell: designed to operate with HVAC blower operating at 250-1200 CFM; powered for 30 minutes prior to MS2 introduction

  - 9-inch cell: designed to operate with HVAC blower operating at 1200-3000 CFM; powered for 5 minutes prior to MS2 introduction

Photocatalytic Device

- Average percent reduction in recoveries during testing ranged from <0% to 73% for the 5-inch cell and from 27% to 93% for the 9-inch cell
- No additional virus recovered from surfaces
- No surface inactivation observed

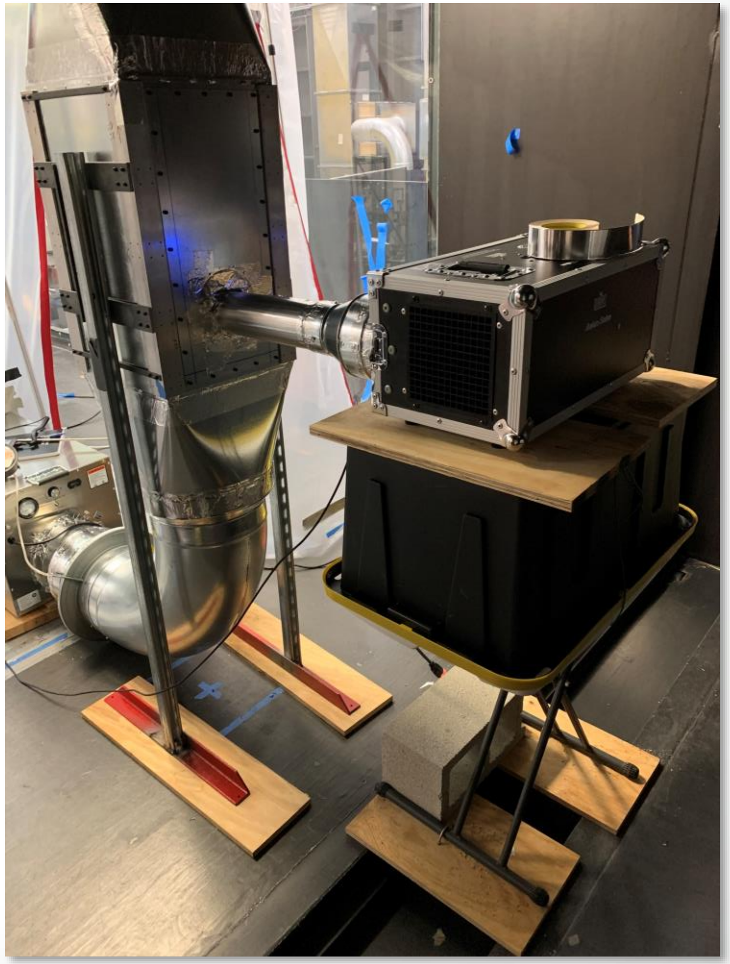


Efficacy:

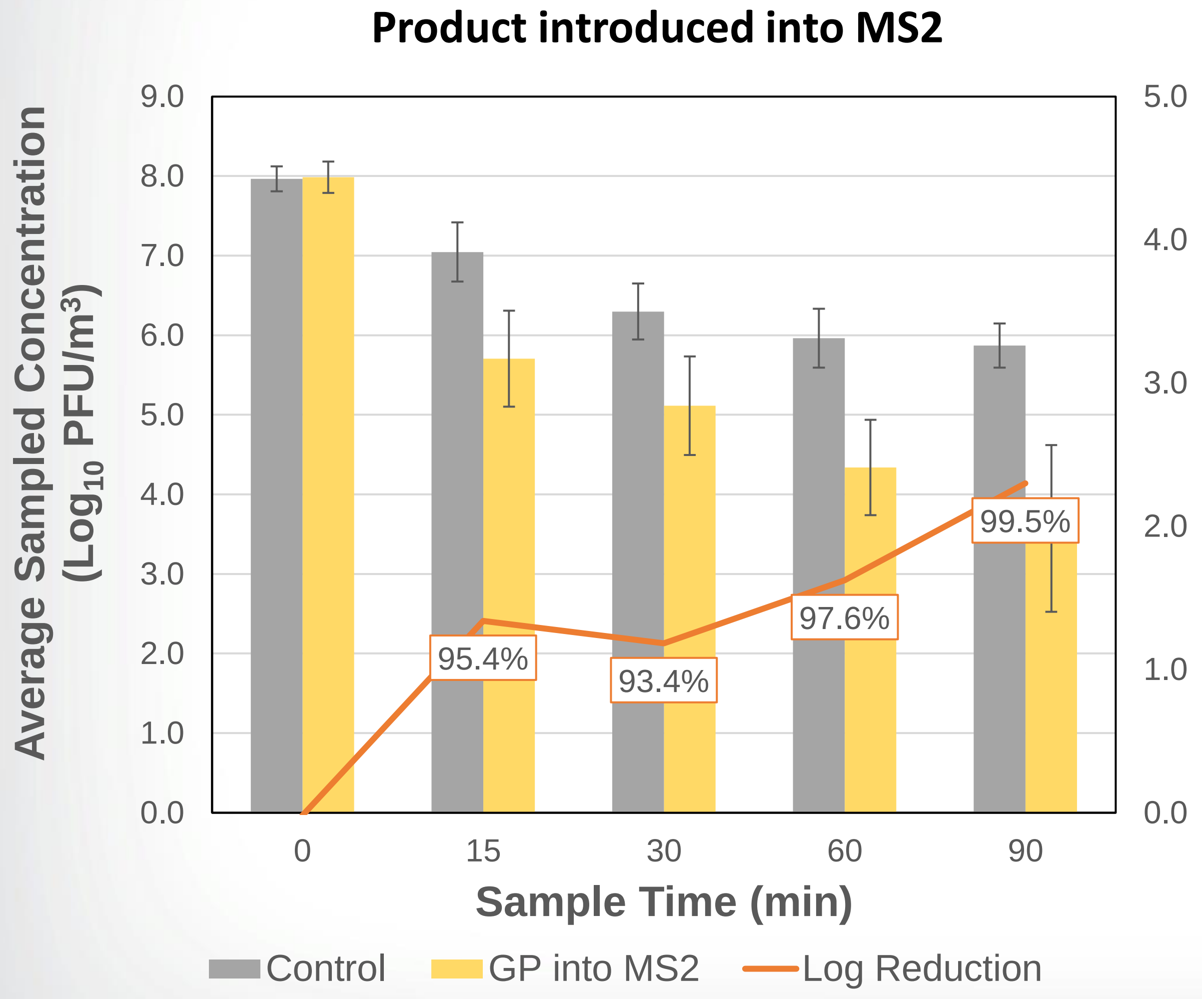
Log_{10} Reduction = Mean log_{10} recovery (Control) - Mean log_{10} recovery (Test Sample)

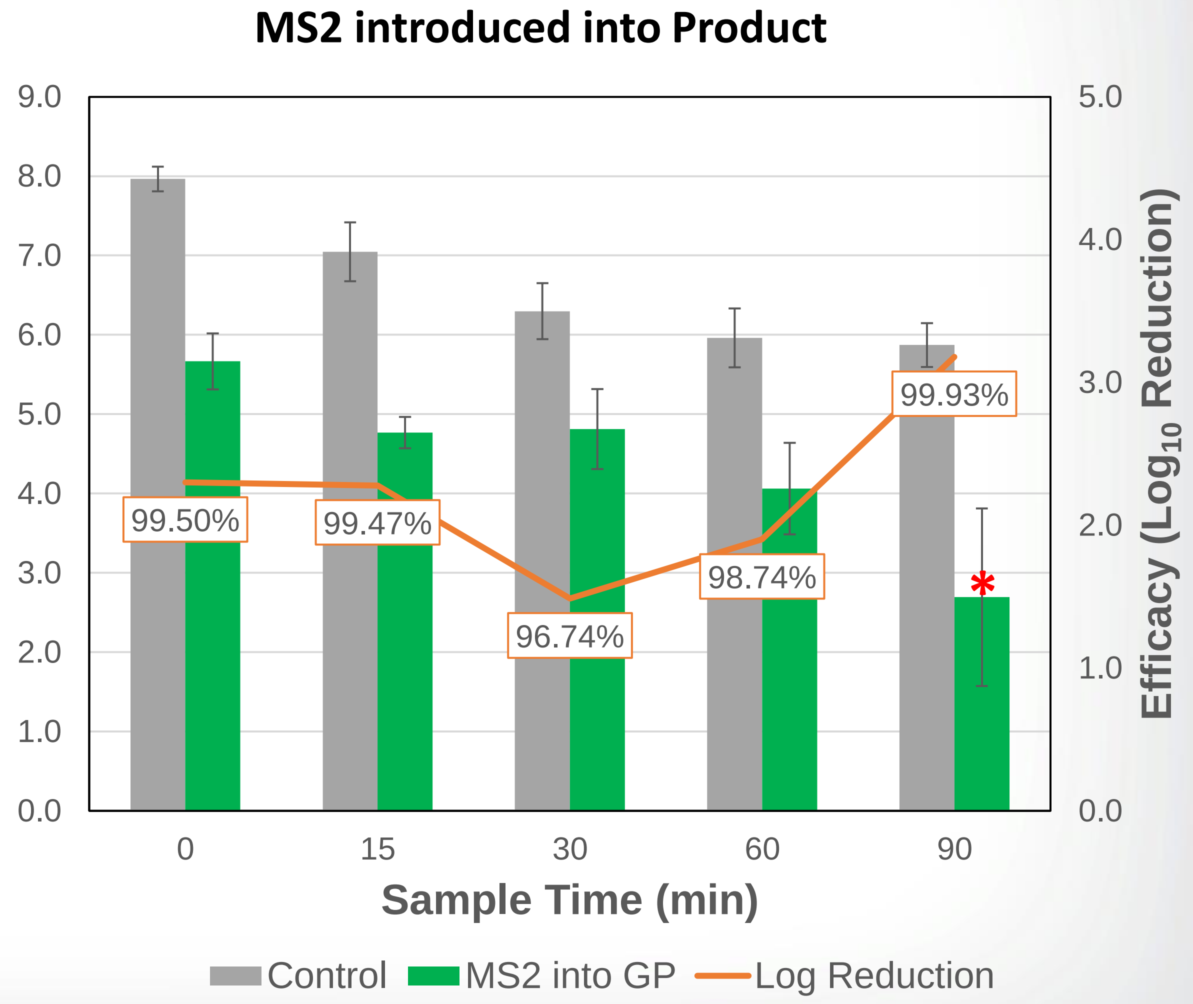
Grignard Pure

- Antimicrobial air treatment product
  - Section 18 Emergency Exemptions for indoor use in GA, MD, NV, PA, TN, TX, VA *(as of 2/9/22)*
- Triethylene glycol (TEG) active ingredient
  - Commonly used in theatrical fog machines
  - Historic publications on air disinfection date to 1940's
  - 1.2 – 1.5 mg/m^3 concentration of TEG during testing (NIOSH Method 5523)
- Two different test sequences evaluated:
  - Introduce product into aerosolized MS2
  - Introduce MS2 into product in chamber already at target concentration



Grignard Pure

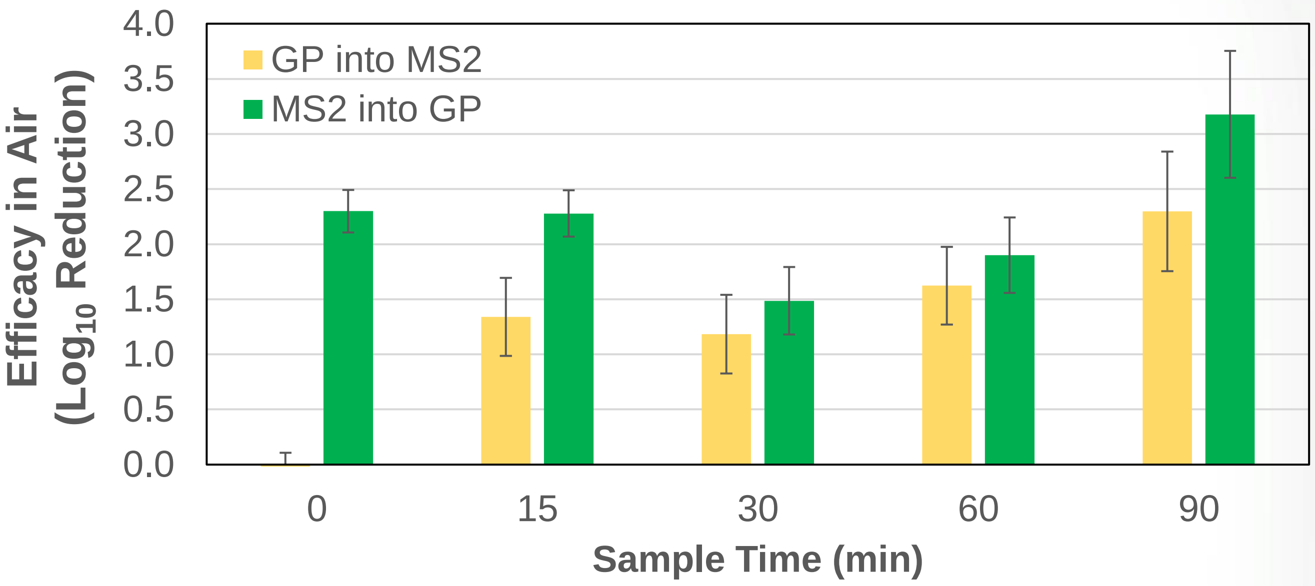


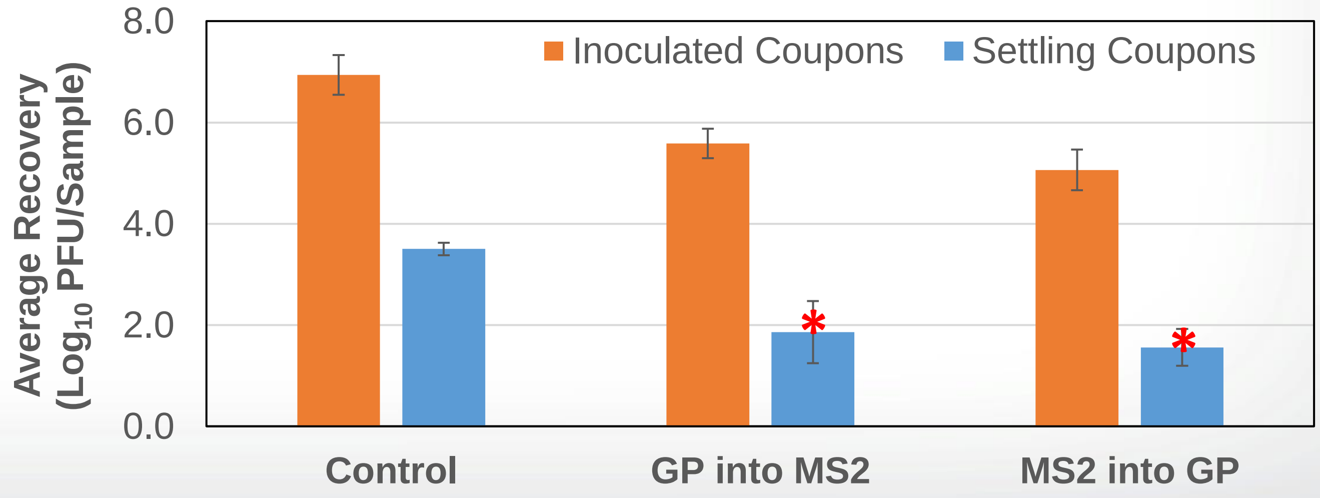


** 2 of 4 replicates at LOD*

Grignard Pure

- Higher calculated efficacy when MS2 aerosolized with product present in test chamber
- Surface inactivation observed on inoculated coupons
  - <u>GP into MS2</u>: average log_{10} reduction 1.6 ± 0.4 PFU/coupon
  - <u>MS2 into GP</u>: average log_{10} reduction 1.9 ± 0.2 PFU/coupon
- Reduced MS2 recoveries on deposition coupons



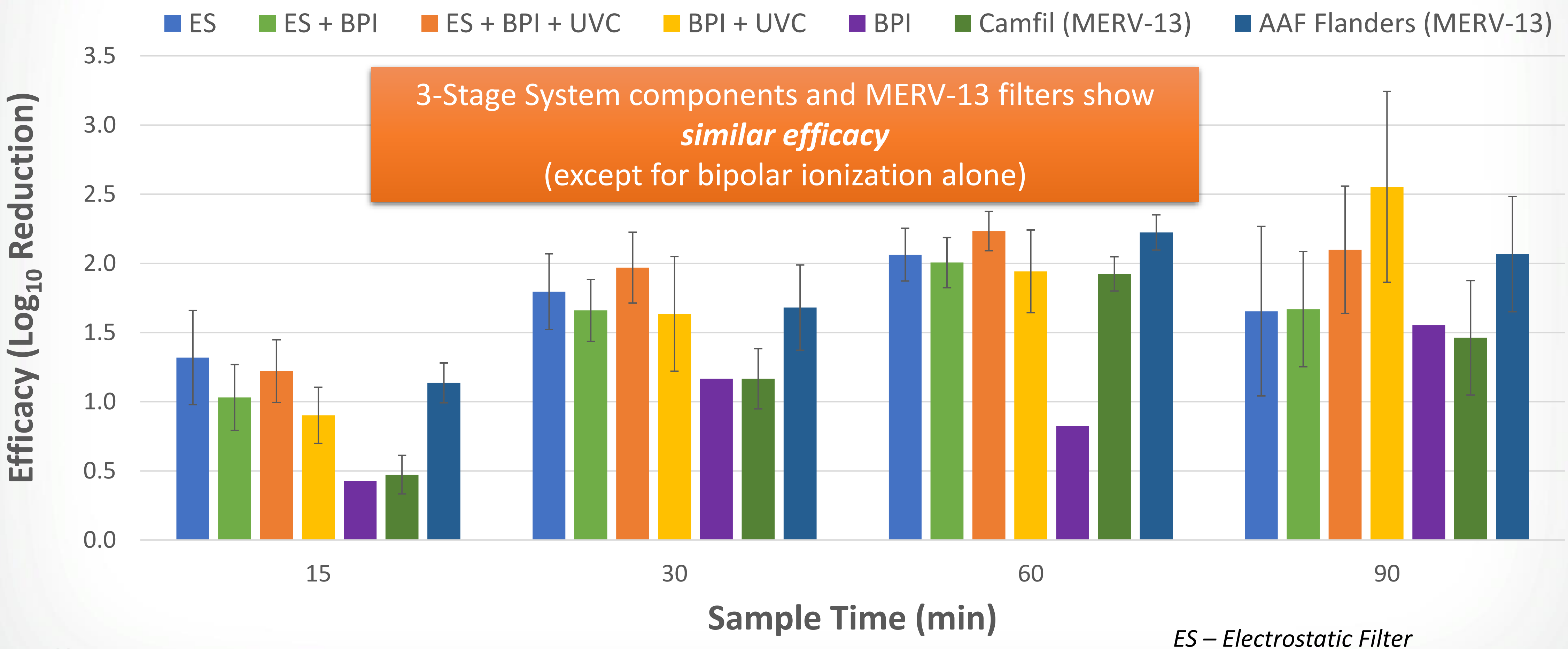


** Some replicates at LOD (1.0 log_{10} PFU/Sample)*

3-Stage System and Filters

- 3-Stage Air Filtration and Purification System
  - Electrostatic filter (active charge applied to physical arrest filter)
  - UVC light bulb (254 nm)
  - Bipolar ionization module
  - Blower (~25 air changes per hour)
- Electret MERV-13 filters
  - Made with charged materials (no electricity applied)
  - Utilize blower of 3-Stage system
  - Two manufacturers

3-Stage System and Filters



Efficacy:

Log_{10} Reduction = Mean log_{10} recovery (Control) - Mean log_{10} recovery (Test Sample)

ES – Electrostatic Filter
BPI – Bipolar Ionization
UVC – Ultraviolet-C Radiation

Aerosol Treatment Summary

Technology Type	Average Percent Reduction* in Recoveries During Testing
Bipolar Ionization Device	< 0% - 86%
Photocatalytic Device	< 0% - 73% for 5-inch cell 27% - 93% for 9-inch cell
Antimicrobial Air Treatment (Grignard Pure)	93% - 99.5% for product introduced into virus 97% - 99.9% for virus introduced into product
3-Stage Air Filtration and Purification System	95% - 99% for electrostatic filter alone 90% - 99% for electrostatic filter + bipolar ionization 94% - 99% for electrostatic filter + bipolar ionization + UVC 88% - 99% for bipolar ionization + UVC 63% - 99% for bipolar ionization alone
MERV-13 (Electret) Filters	66% - 99%

**Percent reduction from test conditions compared to control conditions*

UVC Disinfection: Problem Definition

- Growing interest in UVC for surface disinfection as a result of pandemic
  - ➢ Complement to regular cleaning/disinfection
- Emerging UVC products are being widely marketed
- EPA does not register pesticide (UVC) devices
- Increasing technical support requests for evaluating UVC devices (e.g., from public transit agencies)
  - ➢ Not all UVC is equal – wide range of device types and emitted wavelengths
- Feasibility of UVC in complex environments is relatively unknown

New York Metropolitan Transport Authority invested $1 million on devices from Puro Lighting for their trains and buses

UVC Problem Research Questions

- What UVC doses are achievable in the field?

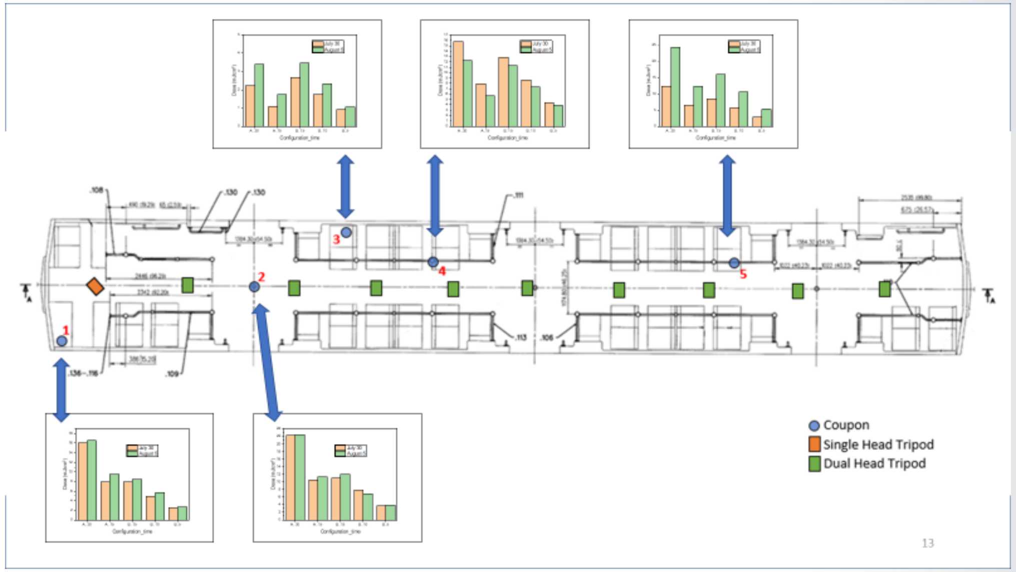
- Is UVC effective in inactivating SARS-CoV-2?

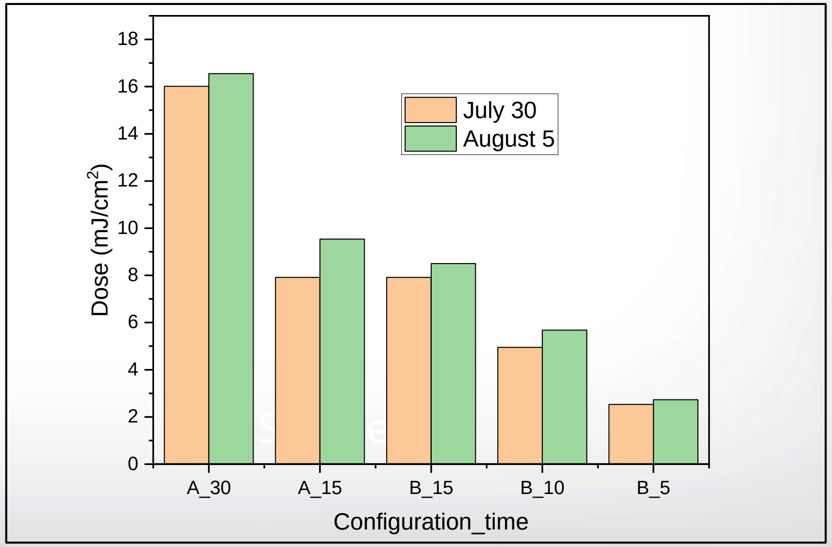
- What parameters impact efficacy?
  - Distance & Time => Dose
  - Material
  - Dry / wet droplets
  - Regular media vs saliva

- Can one overcome these limitations in a real world (outside lab) application?

UVC: LA Metro Field Test

- LA Metro field study (August 2020)
  - Evaluate practicality of Pulsed Xenon UVC units
    - Ease of use, setup time, durability, electrical load, functionality, etc.
  - Evaluate dose in field testing
- EPA supplied MS2-inoculated coupons to incorporate in field test
  - Why MS2? Non-enveloped, hardy virus; non-human pathogen; used in UV testing (e.g., water treatment)
- LA Metro measured UV dose for each coupon location / exposure





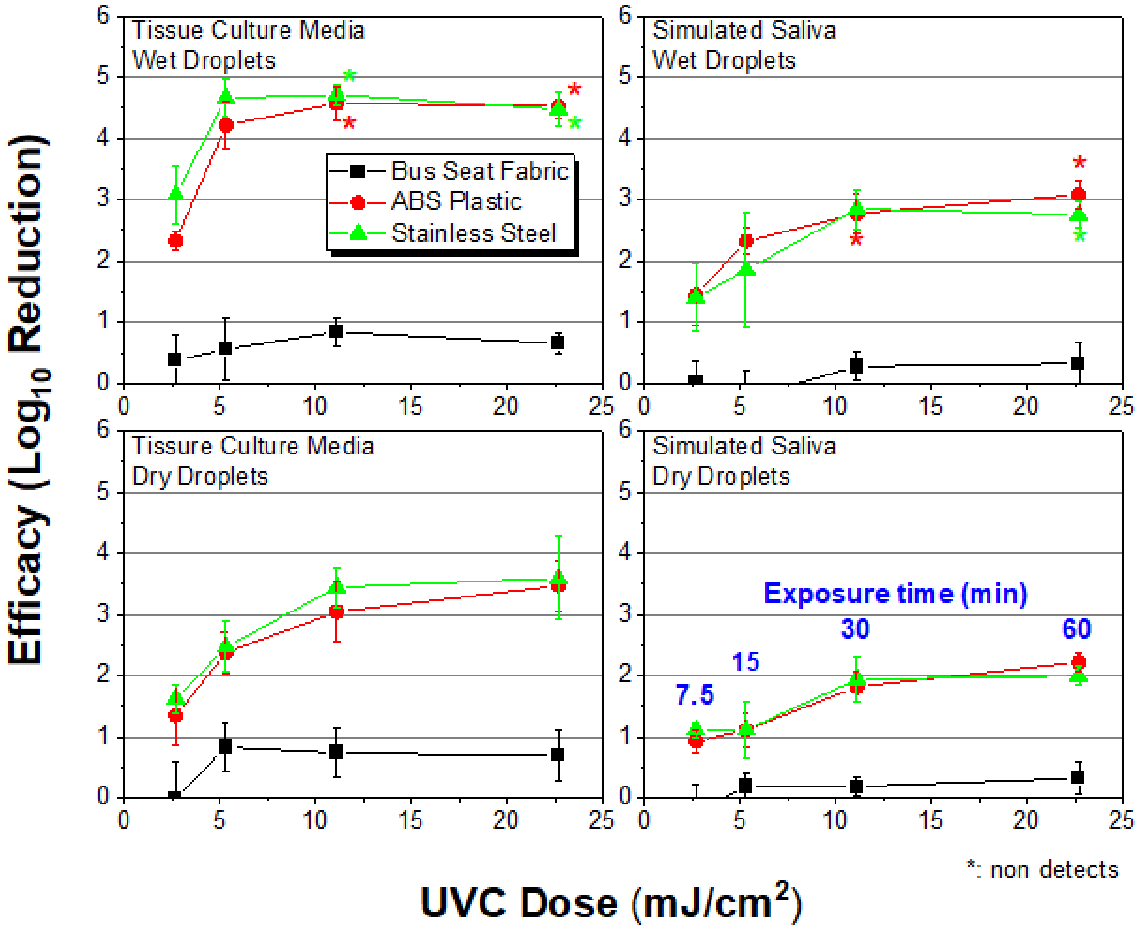
UVC: LA Metro Field Test Results

- Measured range of doses* in LA Metro tests: ≤ 3.5 mJ/cm^2
- Lowest doses at locations outside of direct line of sight or at large distances
- Highest dose for location at ~60” directly in front of light, 30 min exposure time
- High reproducibility in doses between two tests run on different days
- *No significant reduction in MS2 on coupons exposed to UVC in LA Metro test*
    - Laboratory tests needed to understand this lack of virus inactivation

Source: AP

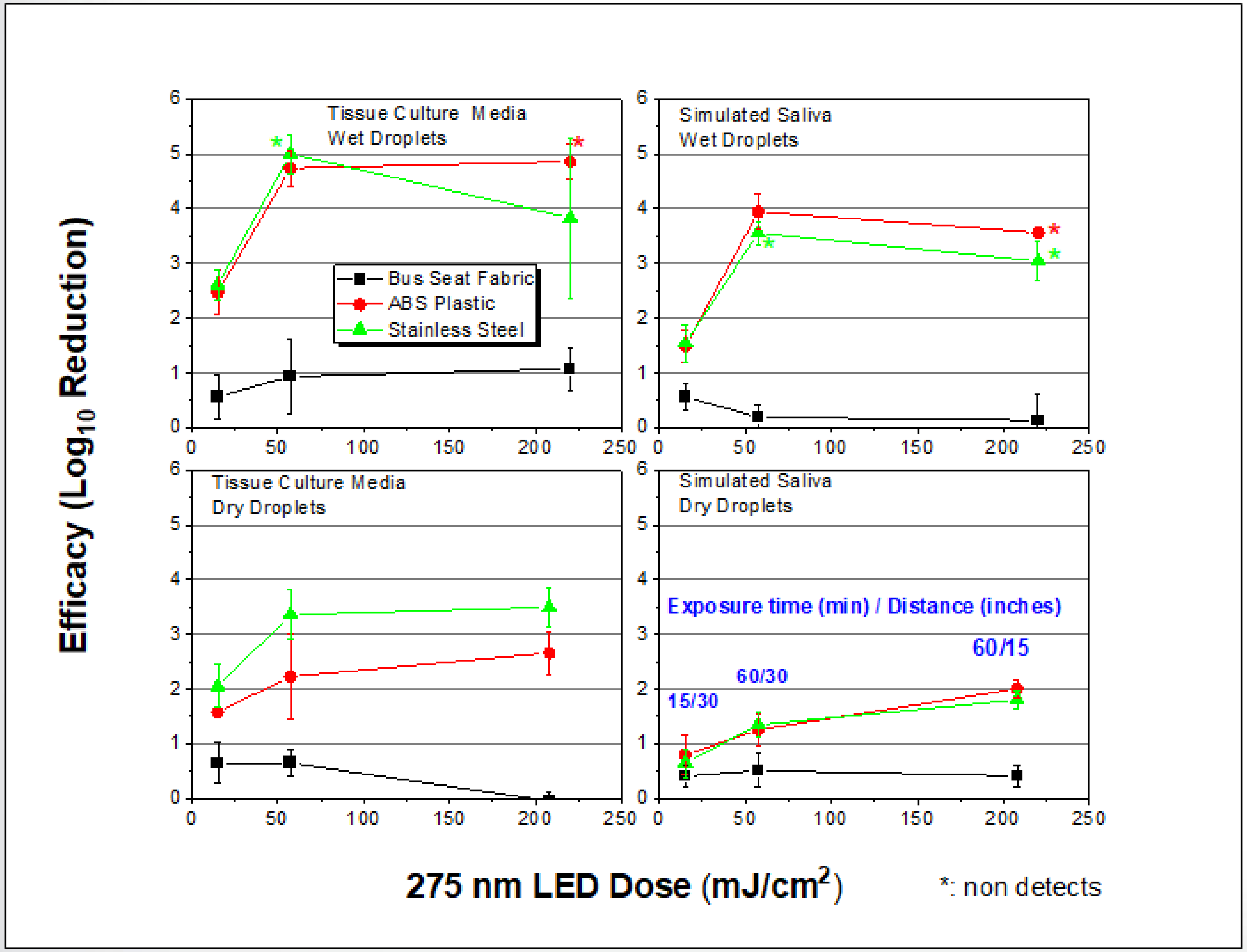
* Dose as measured with ILT SED270C (UV-C only) in metro car

UVC Efficacy Results Pulsed Xenon Light



- High efficacy for smooth materials (ABS plastic and stainless steel)
- Low efficacy for rough, porous surface (bus seat fabric)
  - Virus shielded from UVC light within material fibers
- SARS-CoV-2 in a dried saliva droplet is most difficult to inactivate.
  - Absorption of UVC light in saliva may explain this difference
- LA Metro's highest UVC dose recorded for a surface at 60" distance from a light and a 30 min exposure time was 3.5 mJ/cm^2

UVC Efficacy Results LED (275 nm)



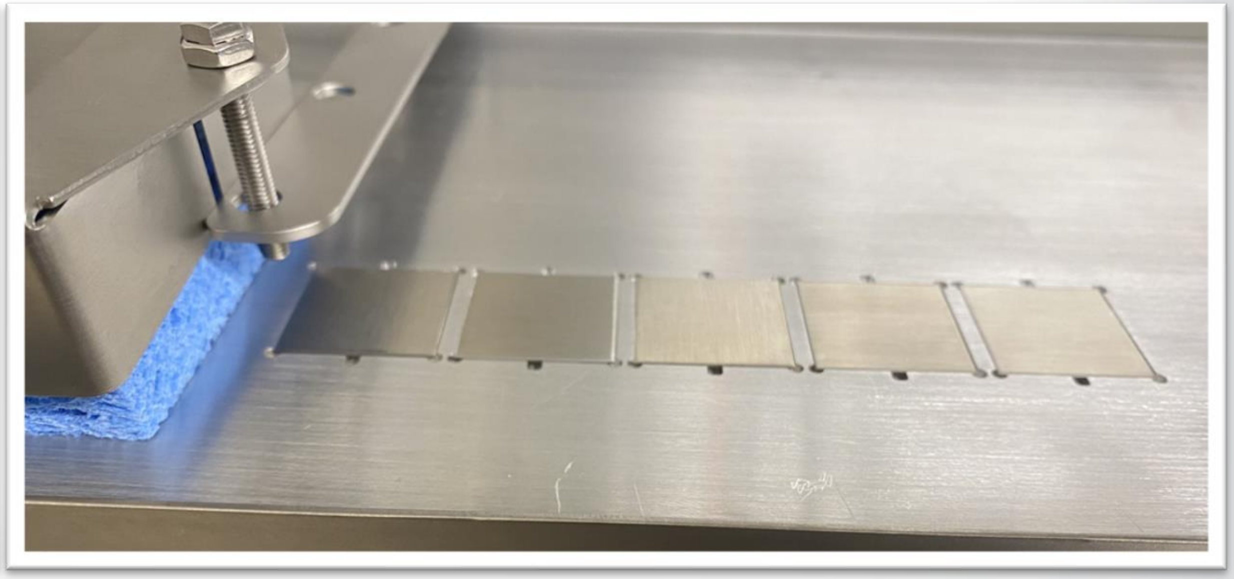
- High log reductions for smooth materials (ABS plastic and stainless steel)
- Low log reductions for rough, porous surface (bus seat fabric)
  - Virus shielded from UVC light within material fibers
- SARS-CoV-2 in a dried saliva is most difficult to inactivate
  - Absorption of UVC light in saliva may explain this difference

UVC Summary

- Estimated UVC doses (for two different light sources) needed to achieve various log reductions of SARS-CoV-2 on surfaces
- UVC dose conditions depend on multiple variables
    - *Lack of established methods makes direct comparisons challenging*
- Required doses for 3 log reduction (99.9%) could only be obtained with these tested UVC light sources at relatively short (30” or shorter) distances for operationally feasible exposure times (<60 min)
    - *Implementation of UVC in complex environments requires design and engineering solutions to increase effective doses.*
    - *UVC light is only effective where there is a direct line of sight between the light source and the contaminated surface*

Antimicrobial Coatings

- Antimicrobial Coatings – Questions:
  - Are they effective at killing viruses?
  - How long do they maintain their activity?
  - How durable are they?

Antimicrobial Coatings

- Approach
  - Collaboration with NYC MTA, LA Metro and other stakeholders to gather input
  - 20+ technology agreements with Vendors
  - Collaboration with EPA regulatory to develop an interim method for registration
  - Laboratory evaluation of products with non-pathogenic viruses to determine efficacy and durability
  - Subset of products evaluated against SARS-CoV-2

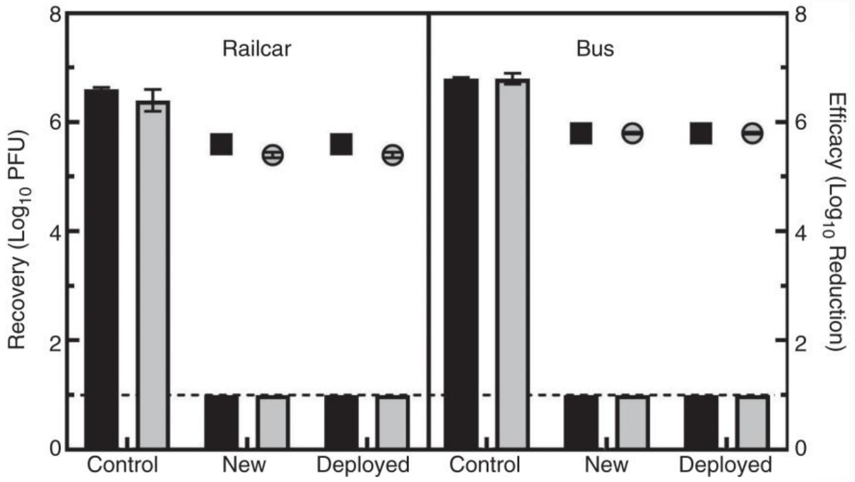
Antimicrobial Coatings: Summary

- Summary
  - Evaluated antiviral efficacy of ~26 antimicrobial coating products
  - Product efficacy against Phi6 ranged from very good to very little
  - Product stability was good, when not abraded
  - Products have low resistance to wetting and abrasion
  - Efficacy against SARS-CoV-2 ranged from 1 to 3 Log Reduction
  - Able to inform transit agencies, on expectation of performance from antimicrobial products and current EPA-registration status

LA Metro Copper Film Study

- Evaluated efficacy of peel-and-stick copper film that had been deployed in LA Metro's buses and railcars for 90 days in high-touch locations

- Both new and deployed copper film were effective against MS2
  - ➢ Suggests good durability



Monge, M., Abdel-Hady, A., Aslett, L.D., Calfee, M.W., Williams, B., Ratliff, K., Ryan, S., Oudejans, L. and Touati, A., 2022. Inactivation of MS2 bacteriophage on copper film deployed in high touch areas of a public transport system. *Letters in Applied Microbiology*, *74*(3), pp.405-410.

What we have learned

- Aerosol treatment
  - Testing air treatment technologies at a large scale is important for understanding efficacy in real-world settings
  - Efficacy can range widely and depends on technology type
- UVC
  - Effective in laboratory studies, depending upon material types
  - Achieving high efficacy in field (real world) applications may be challenging
- Antimicrobial coatings
  - Demonstrate promise from initial effectiveness and stability
  - Challenge with durability as supplemental coating products

Acknowledgements

- EPA Program Offices
  - Office of Chemical Safety and Pollution Prevention
  - Office of Land and Emergency Management
  - Office of Enforcement and Compliance Assurance
  - Office of Air and Radiation
- EPA Regional Offices

- LA Metro
- NYC MTA
- WMATA

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- Battelle (Task Orders 68HERC20F0220, 68HERC20F0231, and 68HERC20F0241)

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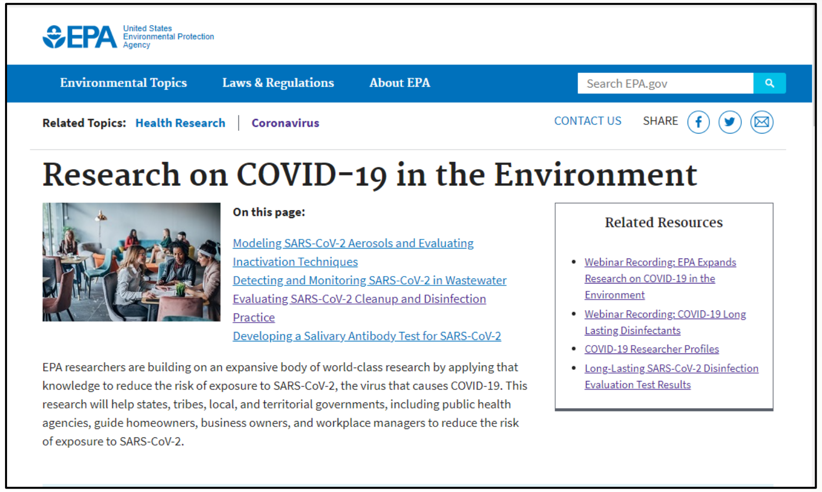

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Research on COVID-19 in the Environment

On this page:

- Modeling SARS-CoV-2 Aerosols and Evaluating Inactivation Techniques
- Detecting and Monitoring SARS-CoV-2 in Wastewater
- Evaluating SARS-CoV-2 Cleanup and Disinfection Practice
- Developing a Salivary Antibody Test for SARS-CoV-2

EPA researchers are building on an expansive body of world-class research by applying that knowledge to reduce the risk of exposure to SARS-CoV-2, the virus that causes COVID-19. This research will help states, tribes, local, and territorial governments, including public health agencies, guide homeowners, business owners, and workplace managers to reduce the risk of exposure to SARS-CoV-2.

Related Resources

- Webinar Recording: EPA Expands Research on COVID-19 in the Environment
- Webinar Recording: COVID-19 Long Lasting Disinfectants
- COVID-19 Researcher Profiles
- Long-Lasting SARS-CoV-2 Disinfection Evaluation Test Results

https://www.epa.gov/covid19-research