Evaluation of electrostatic sprayers and foggers for the application of disinfectants in the era of SARS-CoV-2

EPA ORD Covid-19 Research Webinar

July 15, 2021

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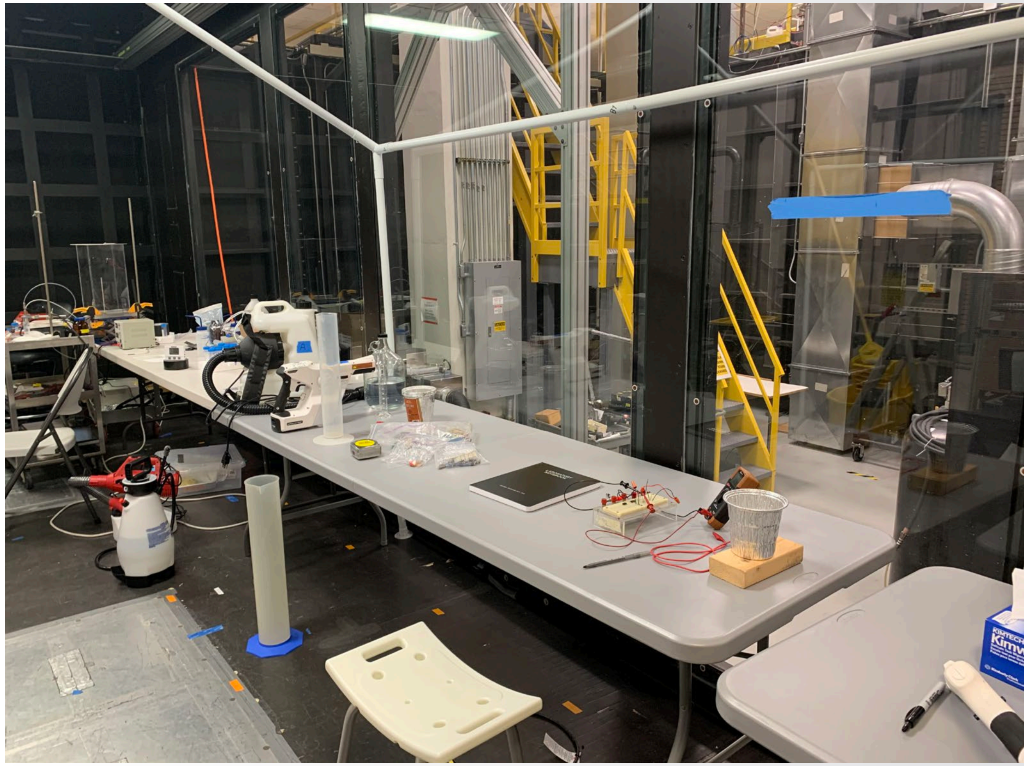
Acknowledgements

- JTI lab support contractor
  - Stella McDonald, Jonathan Sawyer, Timothy Chamberlain, Dahman Touati, Adam Hook, Jerome Gilberry
- EPA project team

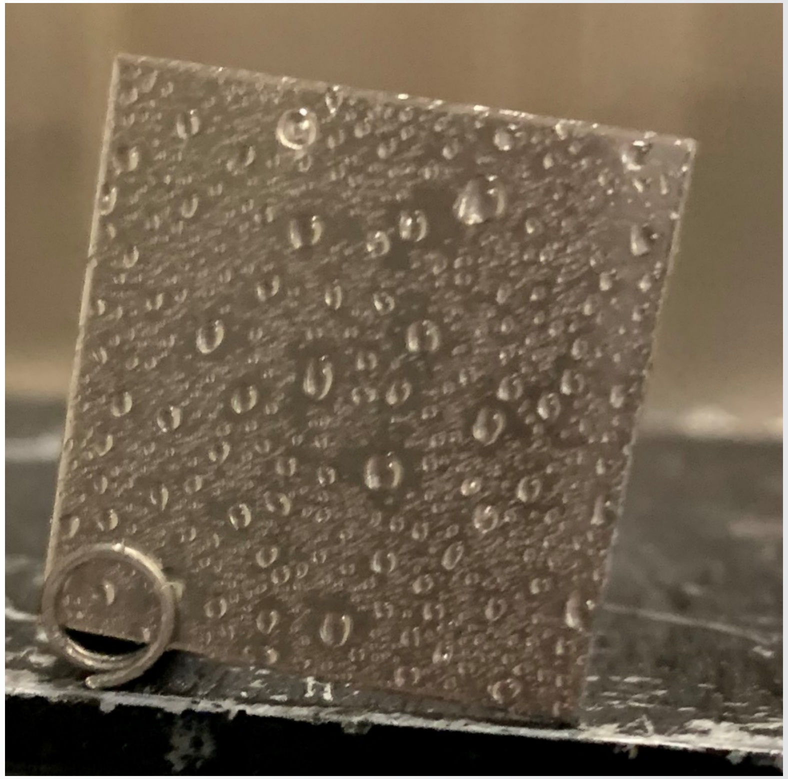
Outline of presentation

- Background
- Droplet size distribution of sprayers and foggers
- Loss of disinfectant active ingredient when spraying
- Spray droplet charge
- Deposition and related tests
  - Recommended amount of disinfectant to apply to surfaces
  - Wetness tests
  - Black light tests
  - Wetness sensor tests
- Disinfection efficacy tests



Background

- COVID-19 primarily caused by airborne transmission of the SARS-CoV-2 virus, but cleaning and disinfection of surfaces is recommended by the U.S. Centers for Disease Control and Prevention
- Use of electrostatic sprayers (ESS) and foggers to rapidly apply disinfectants over large areas or complex surfaces increased substantially with the COVID-19 outbreak
- ESS impart an electrostatic charge to the disinfectant spray droplets with the goal of improving deposition of the droplets onto surfaces

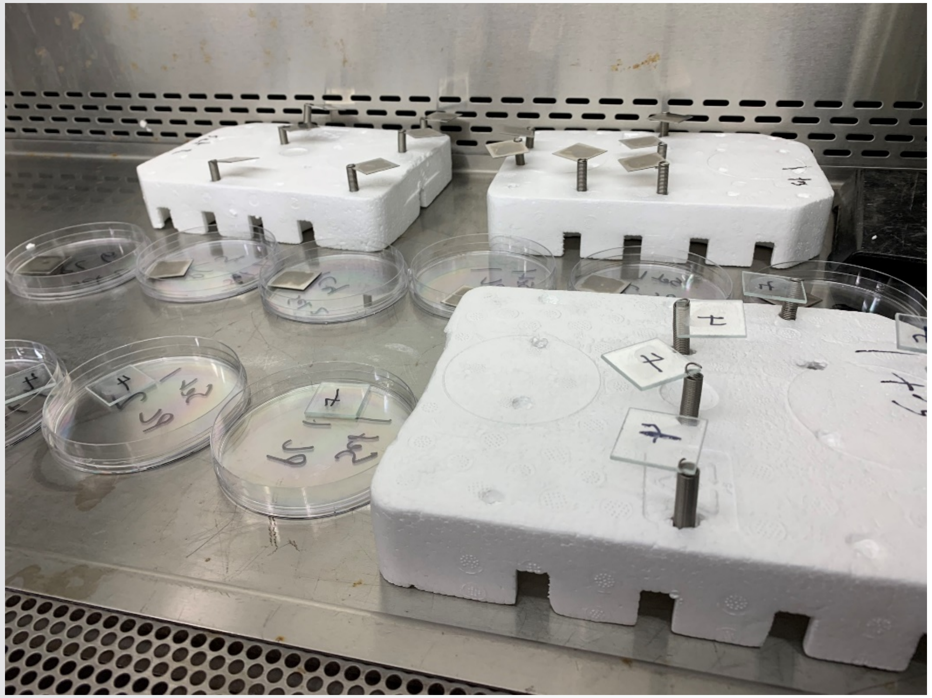


Research objective

- Evaluate some of the underlying operating parameters for several ESS and foggers to elucidate any issues related to their application of disinfectants to surfaces

ESS parameters evaluated

Some parameters may impact disinfectant ability to inactivate virus on surfaces



- The electrostatic charge imparted to the spray
  - May affect ability to deposit onto surfaces, including surfaces not in the direct path of the spray
- The amount of disinfectant to apply to a surface
  - Must remain wet for required contact time of disinfectant
- Loss of disinfectant’s active ingredient to the air
  - Any loss of active ingredient to air will diminish concentration of the active ingredient on the surface, thus potentially reducing disinfection efficacy

ESS only as effective as the disinfectant being sprayed

Spraying of disinfectants may create exposure concerns

- Active ingredient of the disinfectant may be inhaled as vapor/gas or via droplets
- Droplet size distribution of the spray was measured
  - Smaller droplets more readily inhaled
  - EPA Office of Pesticide Programs guidance indicates volume median diameter should be ≥ 40 microns

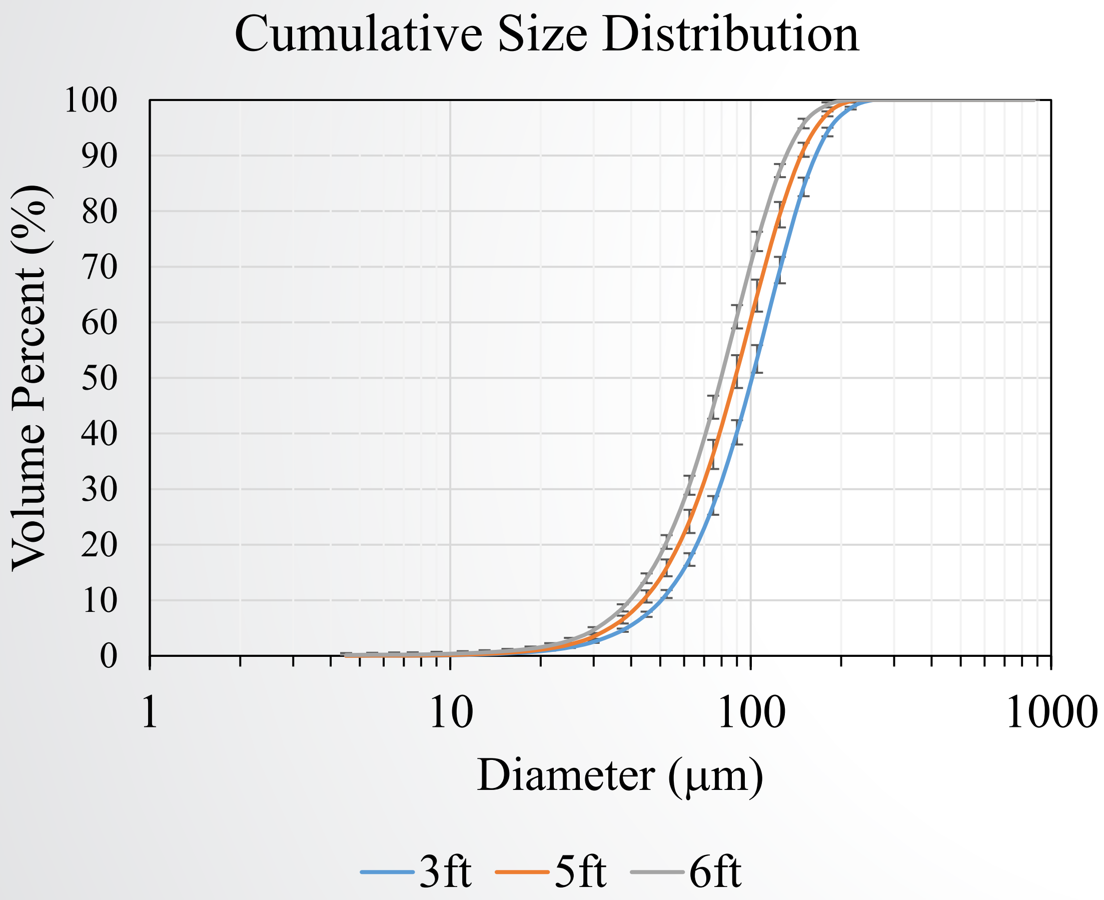
Sprayers and foggers tested

Model	Type of device	Source of electrical power	Notes
PX200ES handheld (HH)	ESS	Battery	This model has the ability to turn on and off the electrostatics. The Li ion battery for this device was later recalled.
PX300ES backpack	ESS	Battery	This sprayer came with a 40-micron (red) and 80-micron (green) nozzle. The Li ion battery for this device was later recalled.
SC-ET	ESS	Cord plug-in	Purchased in ~ 2015 and used in several US EPA studies over the years, prior to this study. All the other devices evaluated were newly purchased for this study.
EM360 HH	ESS	Battery	
R40	ESS	Battery	Lithium ion battery failed and was later replaced
Total 360	ESS	Cord plug-in	
Professional Sprayer 2-gallon R20S16	garden sprayer	None; hand pumped	
Flex ULV cold fogger U120	fogger	Cord plug-in	
KB-15002E 12L	fogger	Cord plug-in	This device was not tested for spray charge due to it becoming non-functioning during the droplet size distribution tests.

Droplet size distribution test methods

- Tests conducted in EPA's Aerosol Test Facility in Research Triangle Park, NC
- Laser diffraction instrument used to measure droplet size distribution, similar to ASTM method
- Measured 5 times at each of several spray distances
- Measured with tap water, deionized water, and a few disinfectants

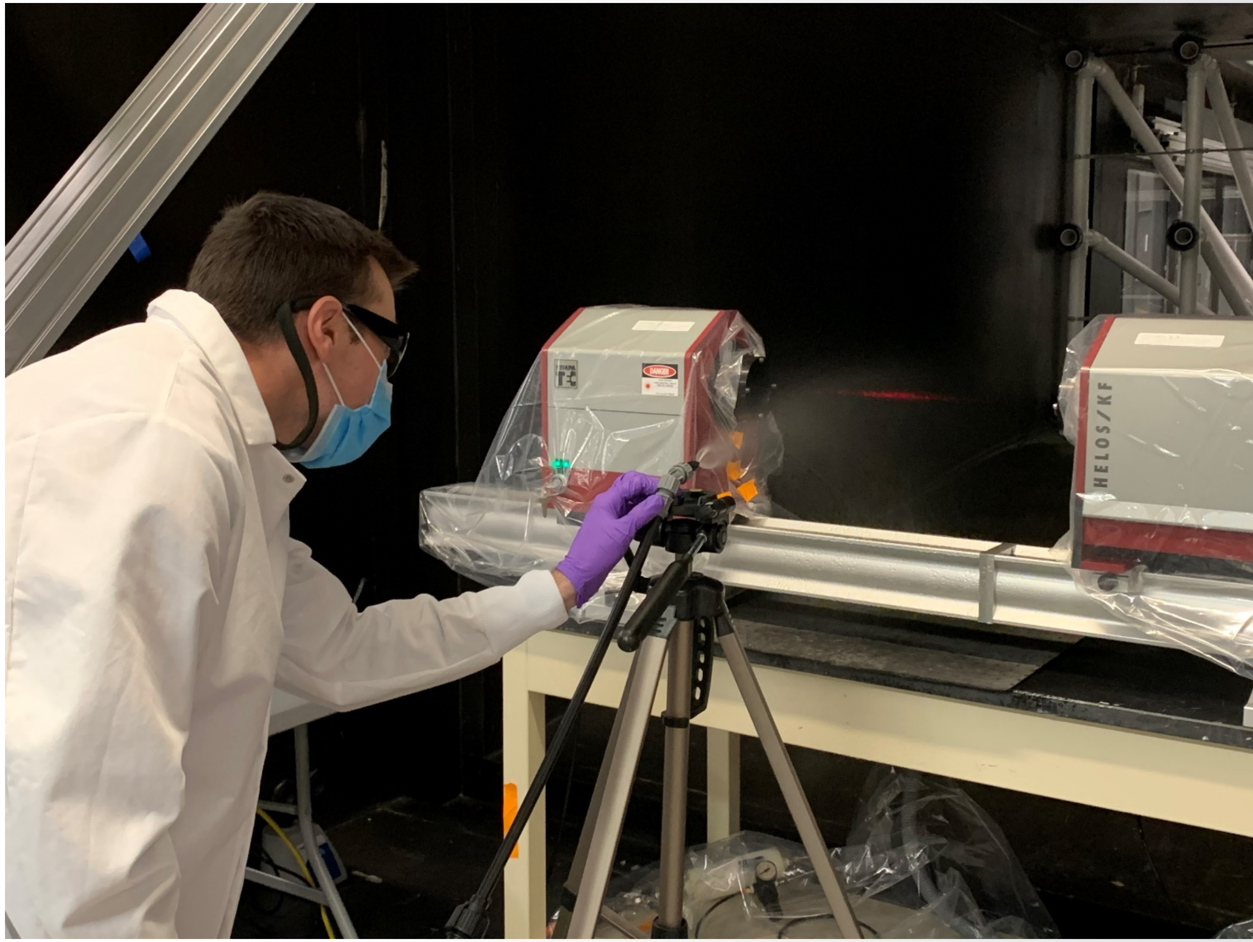
Droplet size distribution – example results



	Measured Flow rate (oz/min)	Volume median diameter range (microns)
PX200ES HH (on)	3.7	37-84
PX200ES HH (off)	3.8	40-90
PX300ES backpack; red (40 micron) nozzle	3.9	40-65
PX300ES backpack; green (80 micron) nozzle	4.5	36-58
SC-ET	3.7	28-31
EM360 HH	1.9	83-105
R40	6.1	44-75
Total 360	4.1	46-53
Garden sprayer	17	50-180
Flex ULV cold fogger	4.4	43-46
KB-1500 12L	11.2	42-43

Droplet size distribution findings

- Most of the devices tested had volume median diameter ≥ 40 microns
- Volume median diameter typically decreased with spray distance
- Water source or use of disinfectant did not significantly impact droplet size distribution
- Device with adjustable nozzles size showed no difference in volume median diameter
- Most sprayers report droplet size, but not clear how they're determined



Loss of active ingredient test methods

- Tests conducted with a hydrogen peroxide- and dichlor-based disinfectant
- Used a handheld ESS
- Active ingredient measured in air using electrochemical sensors
- Disinfectants collected at 3 locations in the spray process, then measured active ingredient using titration techniques
  - Reservoir
  - Nozzle
  - 3 feet away

Loss of active ingredient results

Results for spraying hydrogen-peroxide based disinfectant

Quantity or sample location	Hydrogen peroxide concentration (%) of disinfectant
As shown on label	8
Undiluted 11/8/20	6
Undiluted 12/22/20	5.7
1:32 dilution (label for SARS-CoV-2) – collected from reservoir	0.19
Diluted per label – collected at nozzle	0.19
Diluted per label – collected 3 feet away	0.20

Maximum vapor concentration of hydrogen peroxide was 0.35 parts per million (Permissible Exposure Limit = 1 ppm)

Loss of active ingredient results

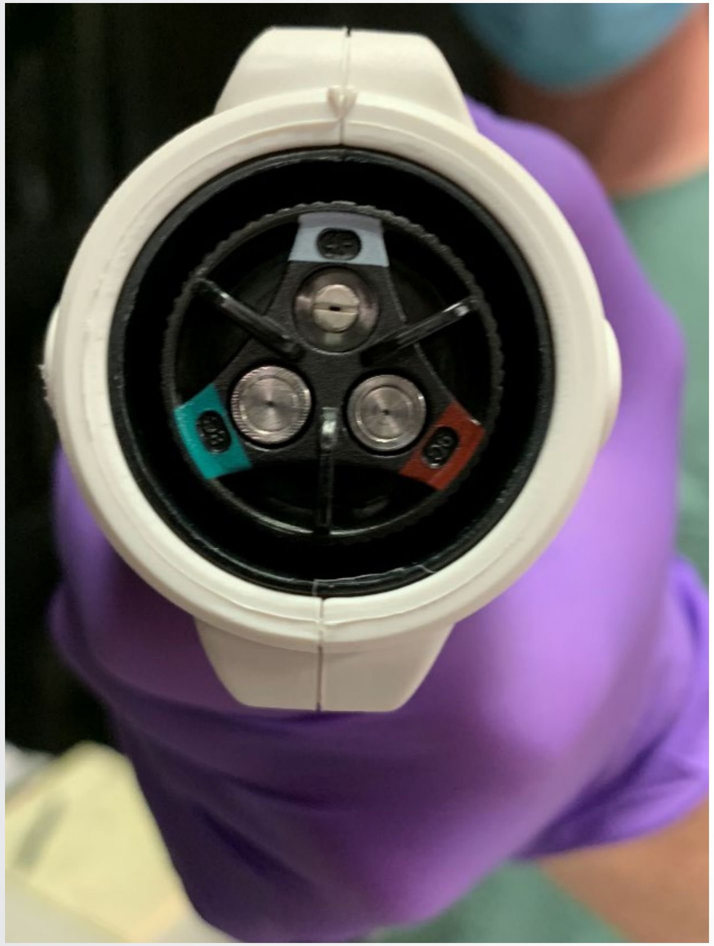
Results for spraying dichlor-based disinfectant

Quantity or sample location	Disinfectant free available chlorine Parts per million
Label (4 tablets per quart)	4306
As prepared stock solution	4347
Sampled from reservoir	4607-5028
Sampled from nozzle	4427-4667
Collected 3 feet away	1703*-4908

Maximum vapor concentration was 0.19 parts per million chlorine gas (Permissible Exposure Limit = 0.5 ppm)

* Believed to be erroneous result

Droplet charge measurement methods



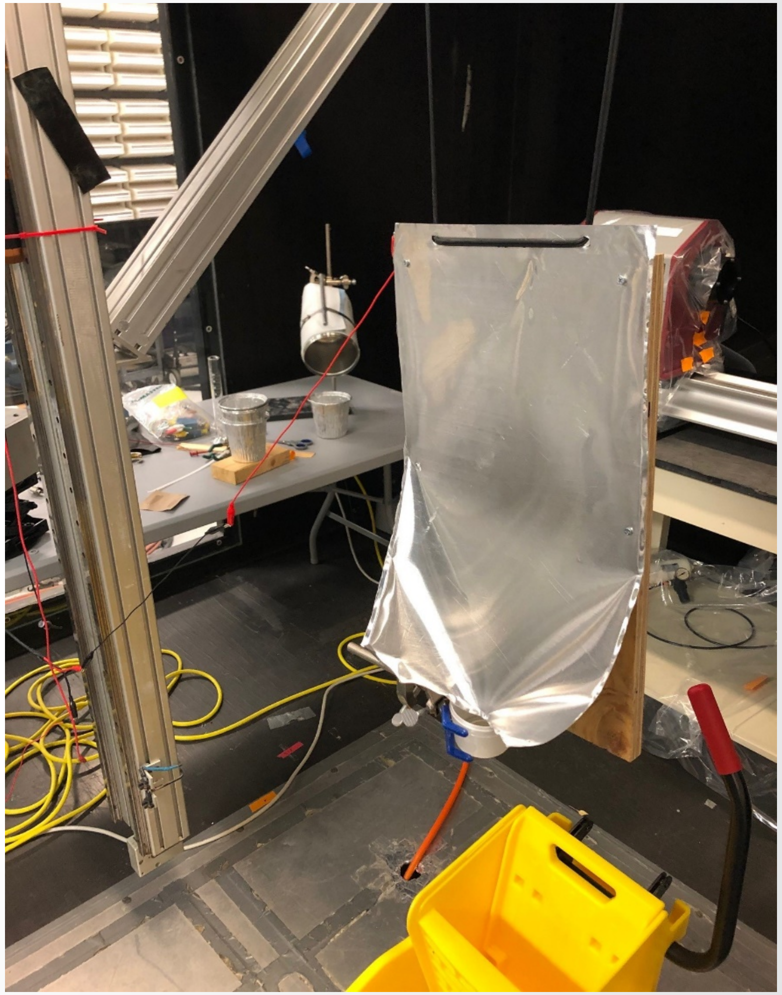
- No standard method to measure overall charge of the spray
- We used method as described in literature
- Picoammeter used to measure current when sprayed on to an aluminum plate
- Results reported in charge/mass (milli-Coulombs/kg)
- Tests conducted with tap water and deionized water for all sprayers tested
- One sprayer tested with 3 different disinfectants

Spray charge results

Sprayer	Average Charge to Mass Ratio, mC/kg DI water	Average Charge to Mass Ratio, mC/kg Tap water
PX200 ES on	0.109 ± 0.00	0.134 ± 0.03
PX200 ES off	0.005 ± 0.00	0.004 ± 0.00
PX300 red	0.049 ± 0.00	0.053 ± 0.00
PX300 green	0.045 ± 0.00	0.049 ± 0.00
Total 360	-6.05 ± 0.09	-5.74 ± 0.20
EM360	0.28 ± 0.00	0.29 ± 0.01
SC-ET	-3.56 ± 0.22	-3.28 ± 0.06
R40	0.00	0.00
Garden sprayer	0.00	0.00
Airofog	0.00	0.00
	Average Charge to Mass Ratio, mC/kg disinfectant	
Total 360 HP	-1.79 ± 0.06	
Total 360 Quat	-1.08 ± 0.06	
Total 360 dichlor	-1.53 ± 0.00	

Droplet charge results summary

- Unclear what charge/mass is necessary to elicit benefits of electrostatic deposition of disinfectants on surfaces for virus disinfection
  - One reference suggests at least 0.1 mC/kg is needed for some applications other than disinfection (Gaunt, Hughes; 2003)
  - Four out of the six ESS tested for charge/mass produced sprays above that level
- Plug-in ESS, which have pneumatically assisted spray, showed highest charge and also negative charge
- No significant difference in charge when spraying deionized water vs tap water, but significant difference when spraying disinfectants



How much disinfectant to apply to a unit area?

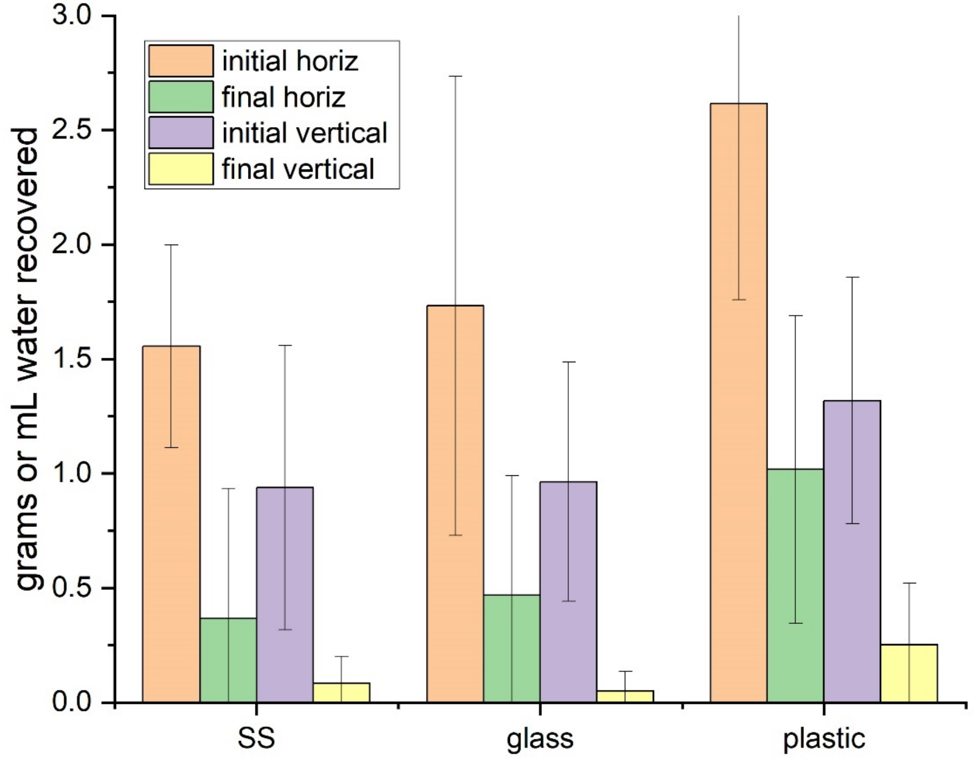
- Need to apply enough disinfectant so that surface remains wet for required contact time
- If surfaces are dry before contact time, then reapply to maintain wetness
- Some sprayer suppliers provided a recommended amount
  - For the devices tested and where info was available, ranged from 2-53 fluid ounces/1000 ft^2
  - One vendor recommended conducting a "wetness" test
  - One vendor recommended spraying disinfectant until droplets start to coalesce

Wetness test methods

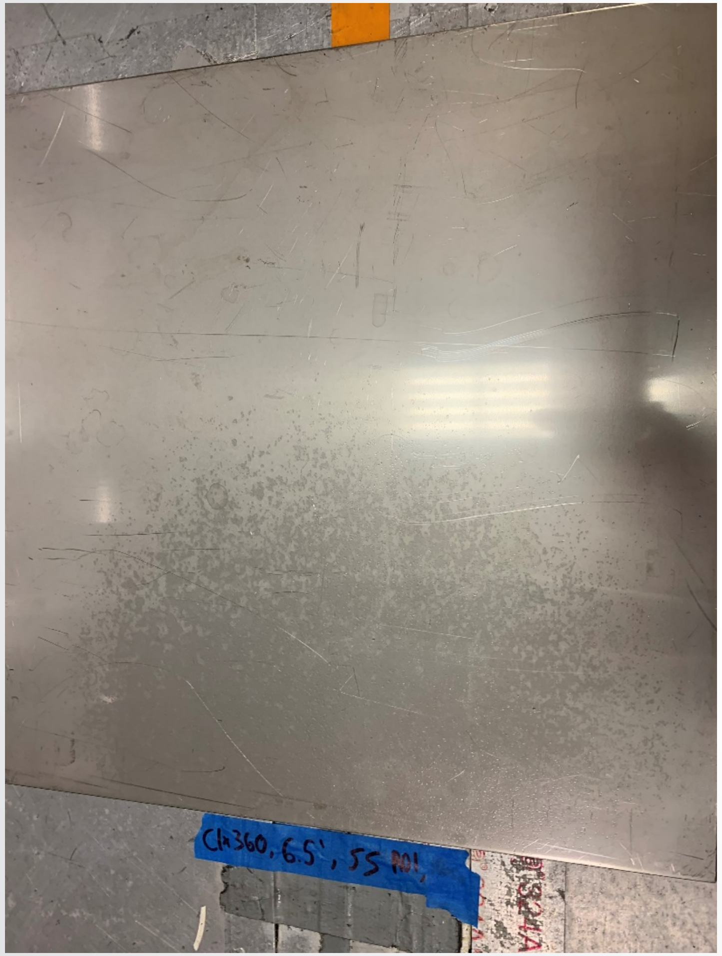
- Conducted to determine if a surface would remain wet at 10 minutes
- Used five different sprayers, using water
- 14 X 14-inch coupons in vertical & horizontal position
- Sprayed coupons until droplets started to coalesce
- Coupons made from stainless steel, glass, and plastic
- Wipes used to recover water immediately after spraying, and after 10 minutes
  - Weighed to determine mass
- Temperature at 21 °C, 35% RH, air flow 1 m/s

Wetness tests results

- Coupons in horizontal position generally had higher initial deposition
- Amount of water initially deposited was in range recommended by ESS vendors
- Percent water loss somewhat higher for vertical coupons
- Plastic had the least amount of water loss



Wetness tests results continued

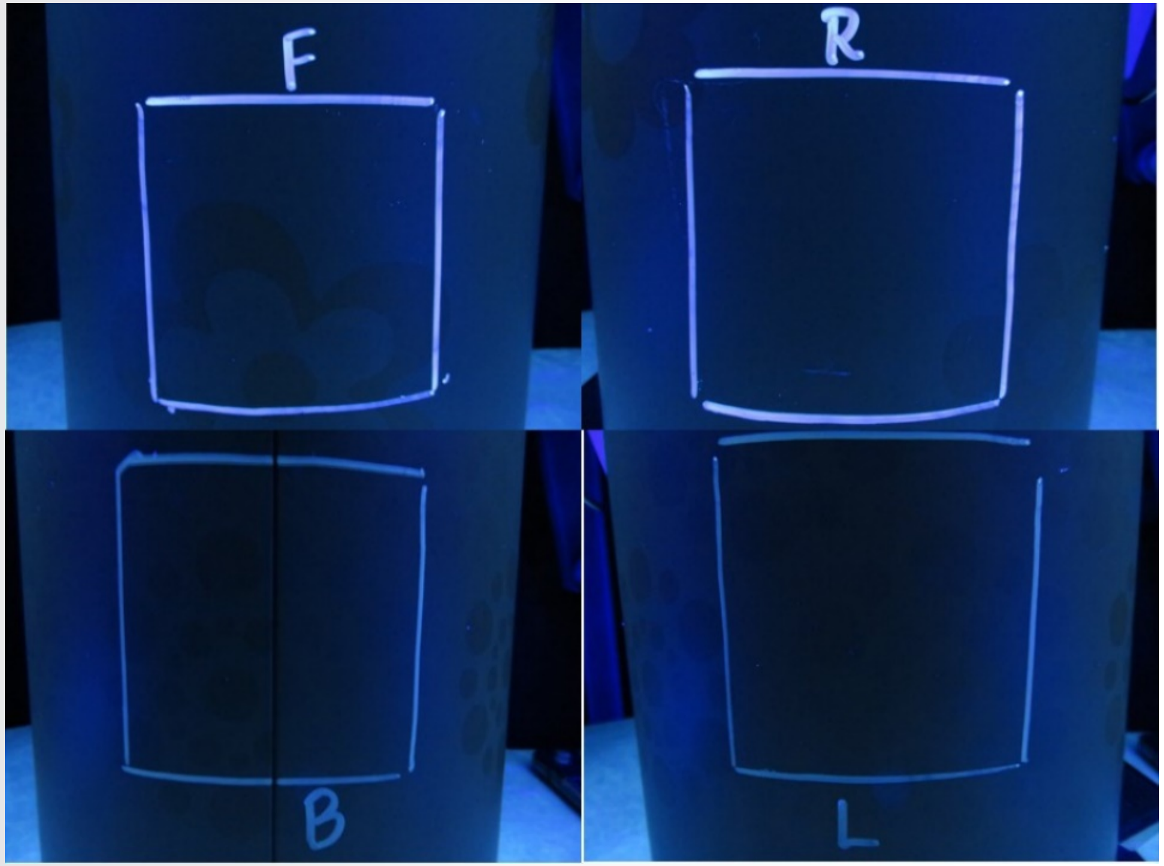


- About 13 % of coupons were completely dry after 10 minutes – based on weight
- Drying on the surface was uneven
  - Dry areas may not be effectively disinfected
  - gravimetric method reports coupon as still wet
- Many factors affect drying time
  - Initial deposition
  - Temperature, relative humidity, air flow
  - Material type and orientation
  - Active ingredient vapor pressure
  - Droplet size

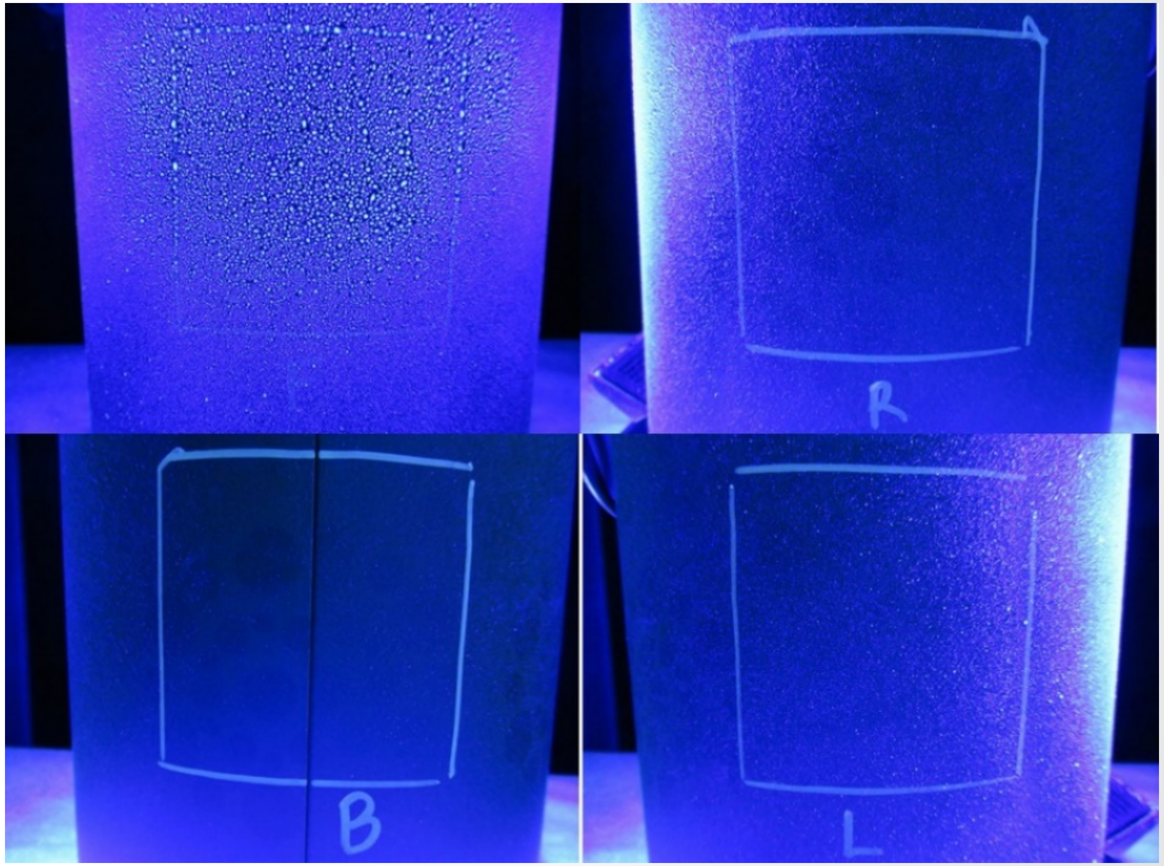
Black light test methods

- Tests conducted to visually assess wrap-around effect
  - Spray 8-inch diameter black trash can with aqueous fluorescent dye
  - illuminate with black light, take photograph
- Photodocument front, left, right, back of can
  - whole can
  - 3 by 3-inch square
- Sprayed ~ 7-8 mL onto trash can or other objects, 1-4 second spray
  - step ladder, clip-on lamp, chair

Black light test results



Example positive controls



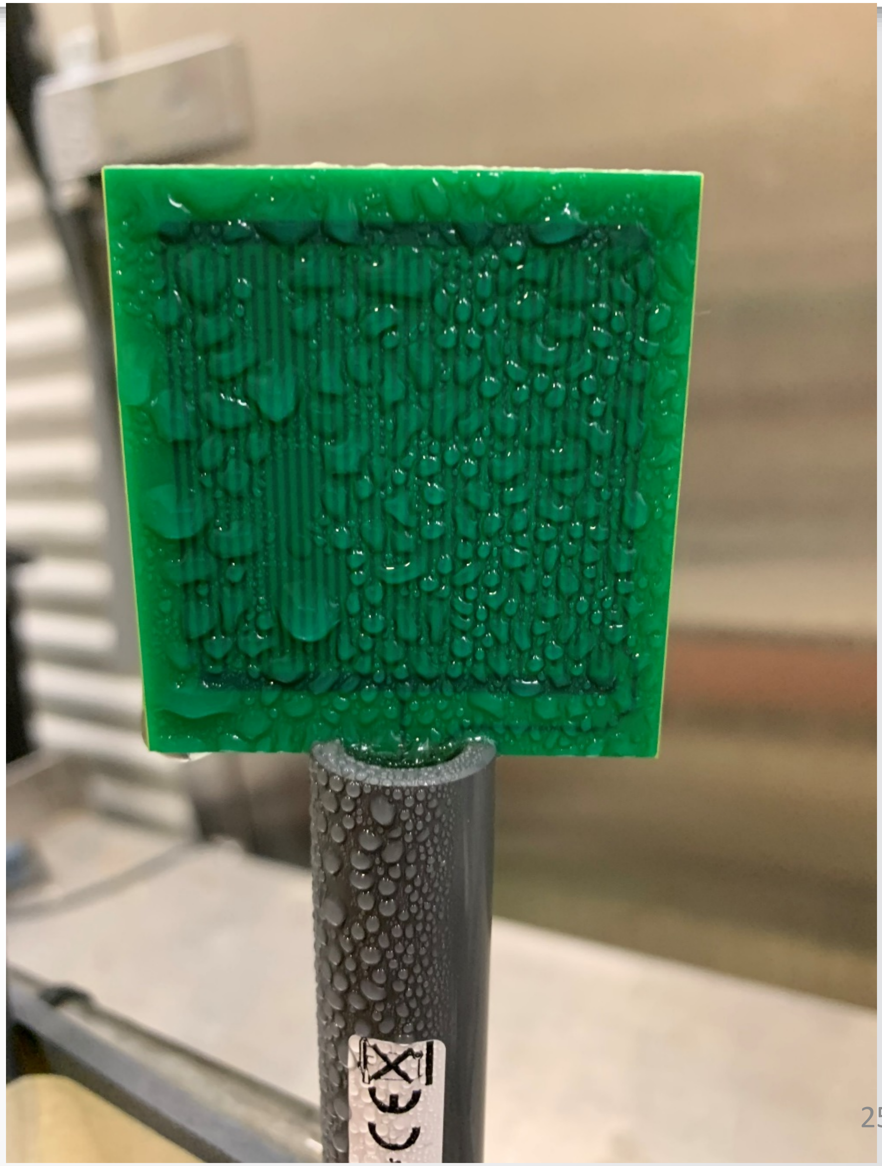
Example results for sprayed trash can

Black light test results continued

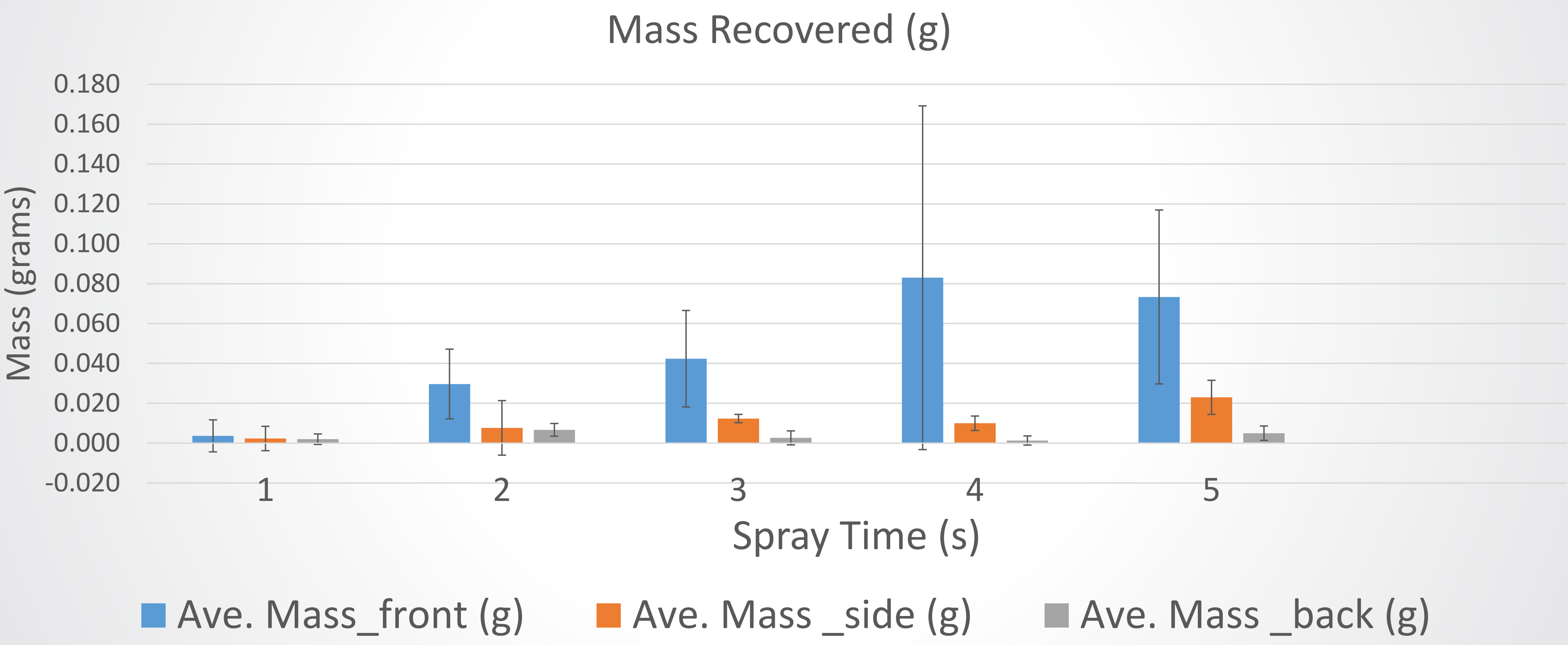
- Deposition results very similar for all ESS and foggers tested
- Wrap around effect not as pronounced as expected
- Small objects like lamp shade showed more of an effect

Wetness sensor test methods

- Leaf wetness sensors used to quantify deposition (as opposed to qualitative visual results)
- Sensor provides percent wet reading; we correlated to mass deposited
- Sensor placed directly facing ESS, turned to side (90 degrees), and turned completely around (180 degrees)
- Test conducted with ESS



Wetness sensor test results



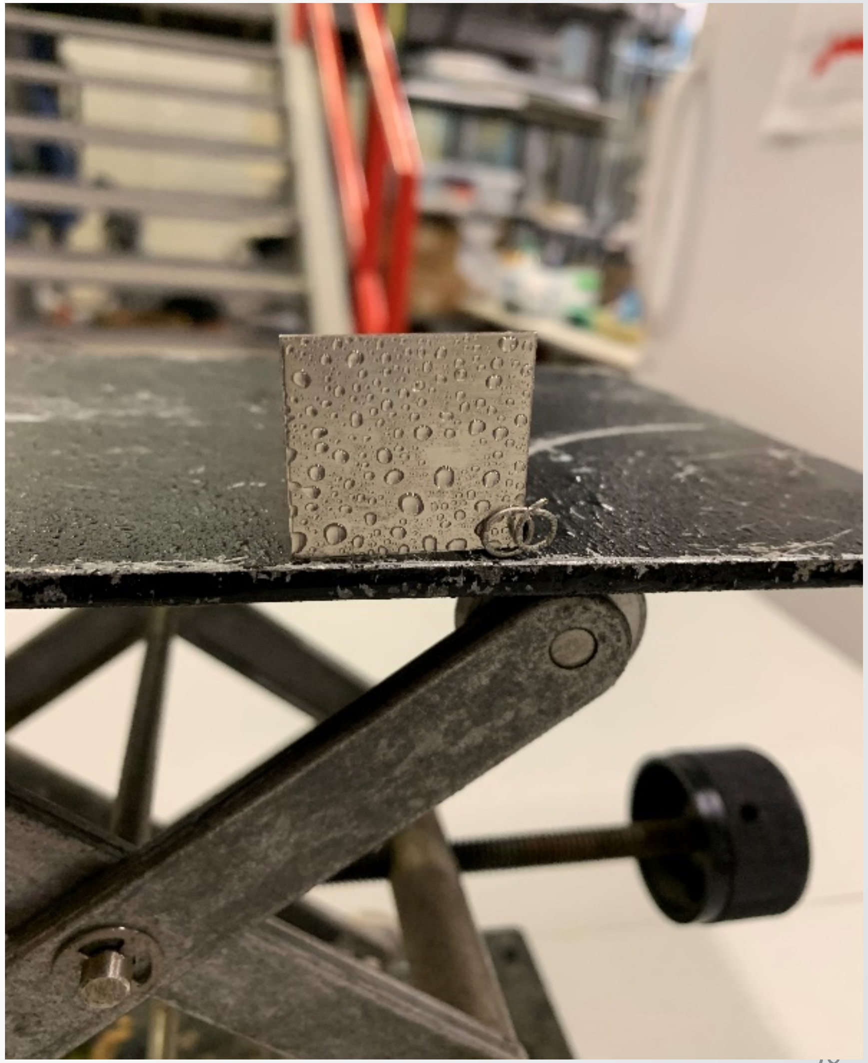
R^2 = 0.94 correlation between mass recovered and sensor reading

Disinfection efficacy test methods

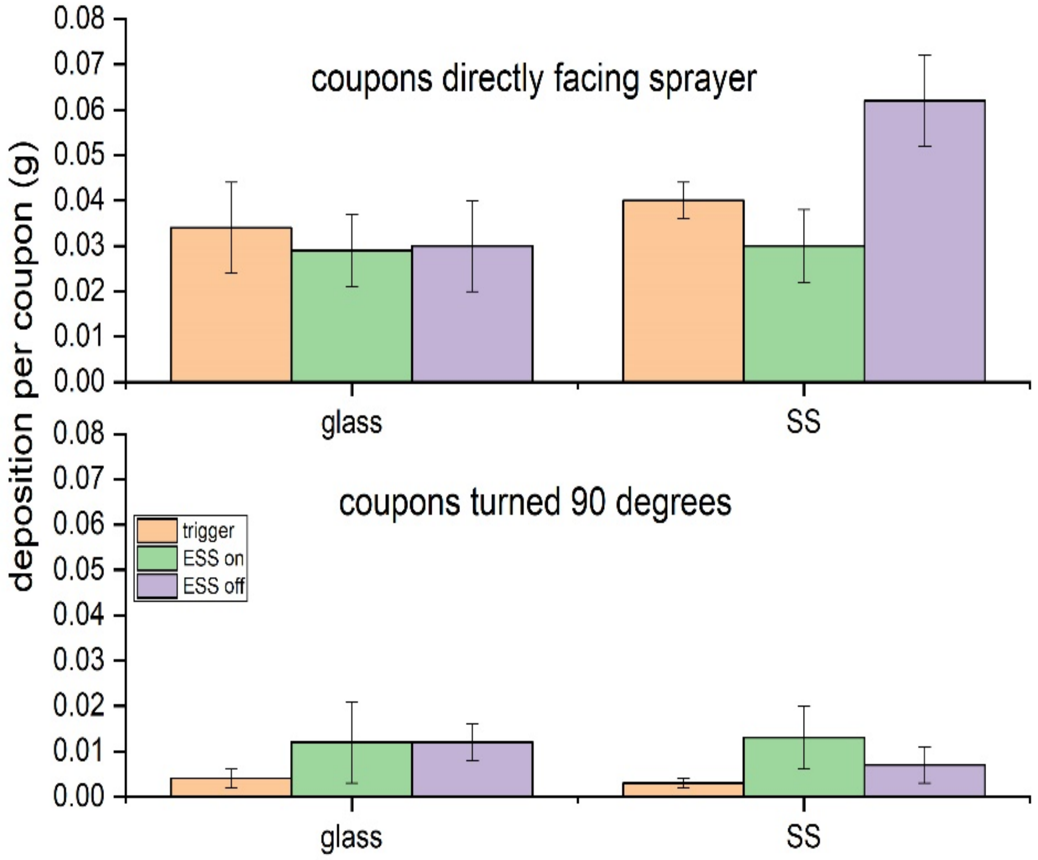
- Compared a trigger pull sprayer with an ESS
  - ESS tested with and without charging of spray
- Conducted deposition tests beforehand to ensure the mass of water deposited on coupons when facing forward was similar for the ESS and trigger sprayer
  - 2 trigger pulls at 1 ft or 2 sec spray from ESS handheld resulted in about 0.03-0.04 gram/coupon

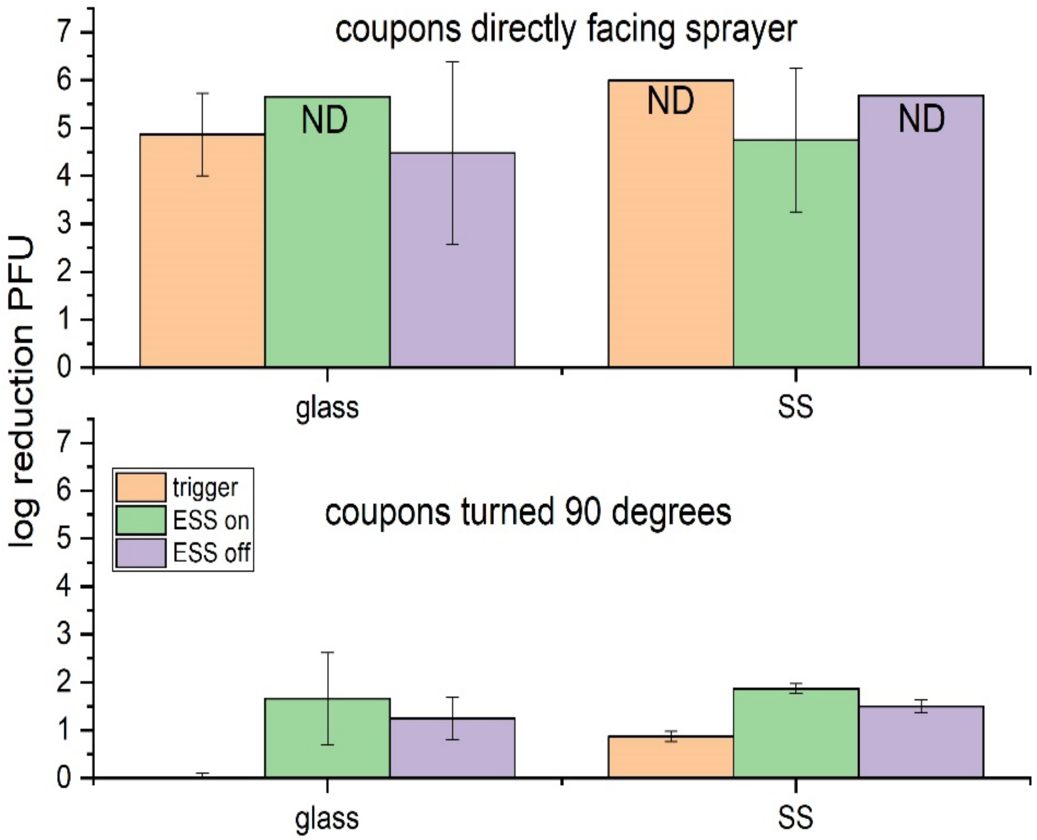
Disinfection efficacy test methods

- Coupons faced directly forward and turned 90 degrees
  - Glass and steel
- Used CDC dilute bleach recipe (1 part bleach in 50 parts water), 1 minute contact time (was about 2000 ppm Free Available Chlorine)
- Used Phi6 phage as potential surrogate for SARS-CoV-2
- 3 replicate coupons for each condition



Disinfection efficacy test results





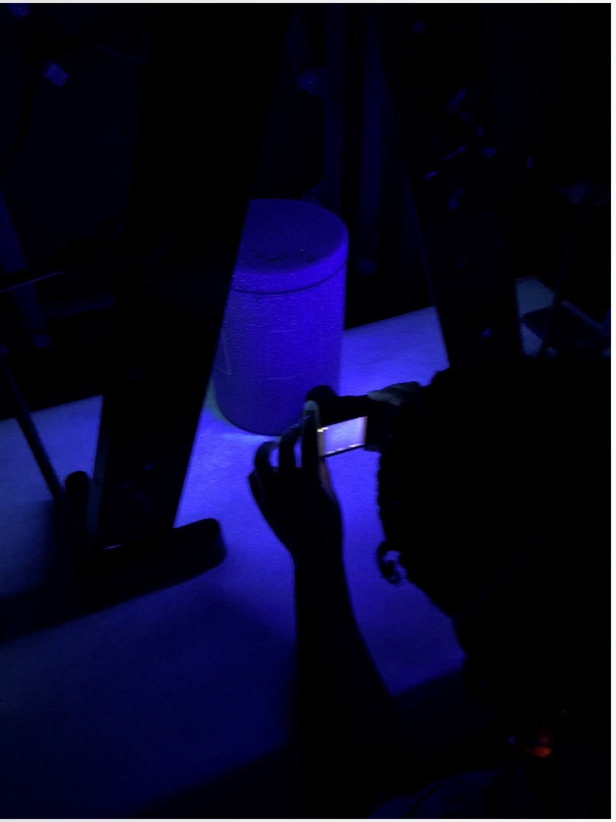
Disinfection efficacy test results

- The Log Reduction of virus correlated well with spray deposition on the coupons (R^2 =0.90)
  - Efficacy was much better w coupons directly facing sprayer, consistent with more spray deposited on coupons when facing that way
- For the coupons facing the sprayers, the efficacy and deposition results were not significantly different among the 3 sprayers, except maybe in one case (which may have been an outlier)
- For the coupons turned 90°, the electrostatic sprayer performed better than the trigger sprayer, by about 1-2 LR plaque forming units – *regardless of whether the ESS was on or off.* Again, this was consistent with having more spray deposited
  - Minor, insignificant difference in efficacy for the ESS when the electrostatics were on or off
  - Reason for the higher deposition and thus higher efficacy compared to the trigger sprayer may be due to some other phenomenon, such as droplet size

Overall takeaways from ESS study

- Purpose of the study was to evaluate several different sprayers (ESS) and foggers for parameters related to their use for the application of disinfectants
- Multiple factors may affect deposition of spray on to a surface and thus may affect whether a surface can remain wet for the required contact time
- Disinfection efficacy was highly correlated to amount of disinfectant deposited on surface
- Most of the devices evaluated had a Volume Median Diameter ≥ 40 microns

Takeaways (continued)



- 4 out of 6 of the devices tested for charge produced sprays ≥ 0.1 mC/kg
- 2 out of 6 ESS produced sprays carrying a negative charge, while the other four carried a positive charge
- There was minimal apparent wrap-around effect of the spray deposition onto an 8-inch diameter cylindrical object, even for the ESS with the highest charge/mass
- The loss of Active Ingredient to the air due to spraying the dichlor- and hydrogen peroxide-based disinfectants was minimal (below occupational health levels of concern)

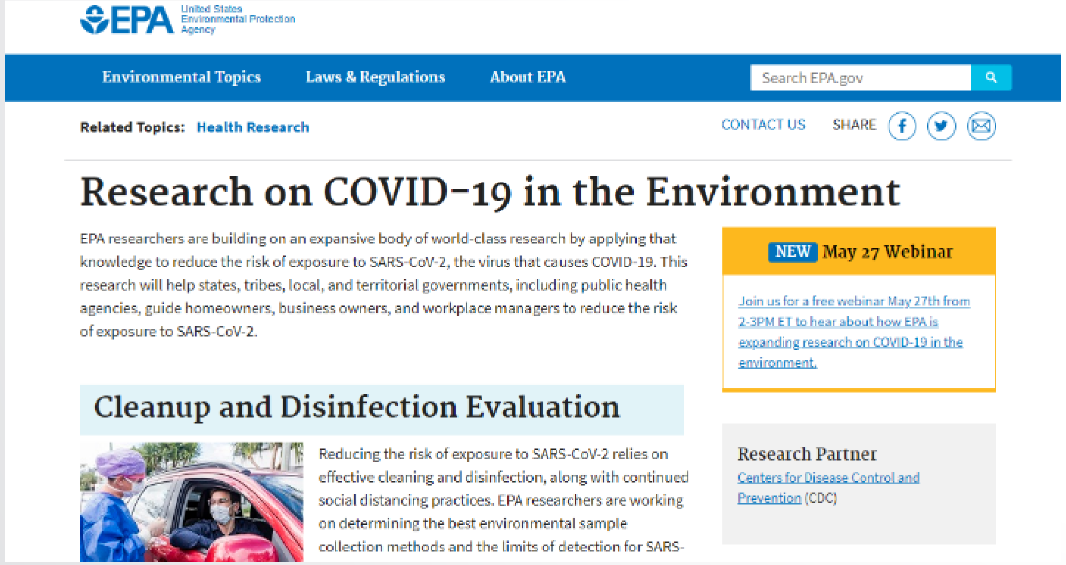
Suggested further research

- Gaps in the science related to the electrostatic charge of the spray and any association with the following:
  - Deposition and wrap around effect
  - Disinfection efficacy
  - Spray distance, flow rate
  - Disinfectant chemistry
  - Spray and deposition uniformity
  - Spray charge measurement method

EPA COVID-19 Research Website

- More information is available at US EPA's CoV-2 Research website:

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



SCAN ME

STATE OF MAINE
DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
BOARD OF PESTICIDES CONTROL
28 STATE HOUSE STATION
AUGUSTA, MAINE 04333

JANET T. MILLS
GOVERNOR

AMANDA E. BEAL
COMMISSIONER

To: Board Members
From: Staff prepared by Pamela J. Bryer, Ph.D. | Pesticides Toxicologist
Re: Changes in disinfection procedures and COVID-19 protocols
Date: August 27, 2021

When the COVID-19 pandemic began little was known about how to best manage this novel virus. In an abundance of caution, surface disinfection was encouraged in an attempt to create safe work and living spaces. Below are updates to the information regarding disinfection and sanitization of common spaces that was part of the initial COVID-19 response.

Transmission of the viral pathogen

SARS-CoV-2 primarily spreads person to person via air transmission When the pandemic began, it was believed that transmission from touchable surfaces in a hand-to-mouth format was going to be significant, as it is in many communicable diseases. Currently, it is known that, aside from vaccination, masks, handwashing, and social distancing seem to be some of the best actions individuals can take to avoid infection. Increasing fresh air exchange indoors and employing the use of air filters to trap viral particles and reduce spread can also aid in reducing the risk of infection.

Current CDC guidance for cleaning and disinfecting

In most situations, cleaning surfaces with typical cleaning agents is sufficient to avoid transmission of SARS-CoV-2 from most surfaces. In public spaces this cleaning is suggested as a daily activity and disinfection is only required when someone becomes sick or tests positive with COVID-19. The current action items listed in the CDC guidance for schools on How to Protect Yourself and Others is as follows: Get vaccinated, Wear a mask, Stay 6 feet away from others, Avoid crowds and poorly ventilated spaces, Wash your hands often, Cover coughs and sneezes, Clean and disinfect, and Monitor your health daily.

MEGAN PATTERNSON, DIRECTOR
90 BLOSSOM LANE, DEERING BUILDING

PHONE: (207) 287-2731
WWW.THINKFIRSTSPRAYLAST.ORG

Snippet taken from CDC's guidance on 'How to Protect Yourself and Others' page for schools.

Clean and disinfect

- Clean high touch surfaces daily. This includes tables, doorknobs, light switches, countertops, handles, desks, phones, keyboards, toilets, faucets, and sinks.
- **If someone is sick or has tested positive for COVID-19, disinfect frequently touched surfaces.** Use a household disinfectant product from EPA's List N: Disinfectants for Coronavirus (COVID-19) according to manufacturer's labeled directions.
  - **If surfaces are dirty, clean them** using detergent or soap and water prior to disinfection.

https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

New data on powered application equipment for disinfecting

Recent work by EPA indicates that in many cases, electrostatic sprayers, the powered application equipment that became very popular early in the pandemic, do not provide any greater efficacy over traditional sprayers. Many schools in Maine purchased electrostatic sprayer systems based on claims that the disinfectant would cover – curved surfaces and disinfect hard to reach places. Preliminary data indicates that currently used sprayer models with currently registered products do not "wrap around" objects during application.. The electrostatic charge these devices are indicated to deliver does not seem to provide any difference in spray pattern. Different models produced droplets with differing charges (positive/negative charges). When devices were used in repeat tests with the electrostatic feature on versus off there was no significant difference in deposition. The EPA has research available on this topic at their Webinar: COVID-19 Electrostatic Sprayers and Foggers for Disinfectant Application at: WEBINAR FOR EVALUATION OF ELECTROSTATIC SPRAYRS AND FOGGERS FOR THE APPLICATION OF DISINFECTANTS IN THE ERA OF SARS-COV-2.PDF (PDF, NA pp, 2759.417 KB, about PDF) and Evaluating Electrostatic Sprayers for Disinfectant Application page at: https://www.epa.gov/covid19-research/evaluating-electrostatic-sprayers-disinfectant-application

Snippet from the guidance on CDC's webpage for Workplaces & Businesses

- In most cases, fogging, fumigation, and wide-area or electrostatic spraying are not recommended as primary methods of surface disinfection and have several safety risks to consider, unless specified as a method of application on the product label.

https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html#other-facilities

Key to getting good disinfection performance

The key components of effective surface disinfection remain the same as before COVID-19: using the proper application rate and allowing the product to sit and stay wet for the appropriate amount of contact time (as listed on the label). For more information about Maine registered disinfectants and using disinfectants to control COVID-19, visit the Maine BPC webpage.

Consequences of greatly increased disinfection activities

Hospitals and poison control centers across the nation experienced increased demands for services for exposures to disinfectant products in 2020, as highlighted by Northern New England Poison Center's website (https://www.nnepc.org/national-news/poison-safety-during-a-pandemic-guidance-for-school-nurses-teachers-and-daycare-providers). Essential workers suddenly became tasked with regularly applying disinfectants, and in some cases, without the appropriate personnel protection equipment. Electrostatic spraying, in particular, exposed many people to breathing in aerosols and vapors of disinfection products. The recent EPA presentation mentioned above highlighted concerns of exposures from use of disinfectants and powered application devices. Below is an excerpt from an EPA Incident Report (6(a)(2) report we received that highlights the nature of the confusion, exposure, and workplace dynamics that have led to disinfectant exposures.

Portion of a recent 6(a)(2) incident report

Voluntary Industry Reporting Form for 6(a)(2) Adverse Effects Incident Information

Provide all known, required information. If required data field information is unknown, designate as such in appropriate area Page 3 of 5

Dear Renee,

Last August My employer, The University of [redacted], had directed myself and other bus drivers to use fogging machines to disperse Oxivir Tb in enclosed buses.
The only PPE we were provided was vinyl gloves.

I had a bad reaction to the fogging immediately and expressed my health concerns repeatedly to both of my supervisors and was assured the procedure was safe.
I used the foggers for several months (fogged 47 buses) in order to comply with my employer [redacted].

In December of 2020, I spoke to three [redacted] technicians who emailed me data stating that the use of fogging machines is prohibited due to possible breathing and other health hazards.
I forwarded this information to my supervisors and the machines were removed the next day.

I have been seeing doctors (including a skin specialist) since November.
In order to help me gain my health back, I request the following:

1-a complete list of ingredients contained in the Oxivir Tb .

2-all the possible side effects(immediate and latent) of using this product improperly (ie: a fogging machine).

3-The potential hazards created due to the lack of PPE (ie: N-95 cartridge respirator, eye protection, skin/body protection).

Thank you,

130th Legislature
State of Maine
Senate District 19

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Senator Richard A. Bennett
3 State House Station
Augusta, ME 04333-0003
Office (207) 287-1505
Cell (207) 592-3200
Richard.Bennett@legislature.maine.gov

Environment and Natural Resources Committee
Government Oversight Committee

July 19, 2021

John Pietroski
Manager of Pesticide Programs
Maine Department of Agriculture, Conservation and Forestry
28 State House Station
Augusta, ME 04333-0028

Dear Mr. Pietroski,

As you know, with the end of the State of Emergency, so too ended the temporary exemption for employees at schools, universities, hospitals, and municipalities from obtaining a pesticide license to apply general use sanitizers with powered application equipment.

Those who utilized the exemption will now need to obtain a Commercial Applicator license, which will take both time, and money to earn. I have heard from folks in my district who have been operating without the license for over a year now, and doing so safely and effectively. Therefore, I ask that the Maine Board of Pesticides Control enter into rulemaking to change the requirements for those who have been operating safely during the pandemic.

I ask that your office look into this matter and get back to me regarding what can be done. Thank you.

Sincerely yours,

Richard A. Bennett
Senator

Cc: Commissioner Amanda Beal