Choosing Safe & Effective Disinfection in the Post-COVID-19 World

An Exploration of Available Methods

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Abstract

This white paper explains in practical, fact-based terms the important differences in SARS-CoV-2 disinfection methods. In addition, it provides useful information to owners and operators to help better inform them about the different choices they have and help to select the right option for their needs.

Commercial and institutional facility owners and operators should carefully select appropriate cleaning and disinfection methods to ensure hard, impervious surfaces within interior spaces are safely and effectively disinfected. Only disinfectants on EPA's List N are authorized for use against SARS-CoV-2. There are important differences in both relative toxicity of different disinfectants and the relative risk in how they are applied to treat hard, impervious surfaces. These differences, in turn, raise critical considerations of safety, efficacy, and practicality. The use of conventional wipes and sprays for disinfection are proven, safe and reliable. Fogging applications which disperse the disinfectant in the air over a wide area pose greater relative risks, which is reflected in their complex and time-consuming use protocols, such as respirators, sealing of room spaces and HVAC systems, and longer wait times for re-occupancy to ensure safety, efficacy and compliance with FIFRA. The airborne nature of disinfectants applied by fogging and their greater associated health risks pose special challenges which increase risks and costs and clearly are not a substitute for manual cleaning techniques. Both EPA and CDC discourage the use of fogging applications to treat interior spaces for SARS-CoV-2 due to questions about their effectiveness.

Introduction

Our collective shock at the arrival of the COVID-19 pandemic in January 2020 has now been replaced with a focused determination to safely and reliably reopen public spaces. This whitepaper is intended to help guide commercial and institutional facility owners and operators on the selection and use of appropriate cleaning and disinfection methods to safely and effectively disinfect hard, impervious surfaces within interior spaces. We examine the key role played by the pesticide registration process and the labeling of disinfectant product, including a discussion of why fumigation methods that rely on vaporization or aerosolization of the disinfectant—commonly referred to as "fogging," "misting", and "fumigating"—pose special challenges and potential risks associated with the difficulties and limitations of the application method. Important differences in choices of disinfection products and methods of applying disinfectants and related considerations of safety, efficacy, and practicality should be carefully weighed before choosing disinfectant means and methods.

Important Facts About SARS-CoV-2

We summarize here some relevant facts about SARS-CoV-2 (the virus that causes COVID-19 disease), which helps inform these important decisions. First, we know from the Centers for Disease Control (CDC) that the SARS-CoV-2 (the virus that causes COVID-19 disease) is highly contagious and transmissible. The virus is transmitted primarily through respiratory droplets projected when a person coughs, sneezes, or talks in close contact (within 6 feet) with another person, but also possibly when an infected person contaminates impervious surfaces, like countertops, tabletops, door handles, and other high-touch hard surfaces with respiratory droplets which another person touches and then touches their own mouth,

nose, eyes, face [1] Second, we know that asymptomatic people—those with no disease symptoms—can carry the virus and contaminate surfaces unknowingly. Third, we know SARS-CoV-2 can survive on impervious surfaces for at least a few hours to up to seven days[2] but like most so-called "enveloped viruses" it also easily can be deactivated or killed with standard disinfection techniques.[3] Fourth, we know that cleaning of visibly dirty surfaces followed by the application of a disinfectant deemed effective at killing the virus is a best practice measure for prevention of COVID-19 (and other viral respiratory illnesses) in commercial and institutional facilities, households and community settings. Fifth, the CDC recommends reducing the risk of exposure to COVID-19 by regularized cleaning and disinfection and using an EPA-registered disinfectant.[4] Sixth, CDC recommends against use of alternative disinfection methods, such as ultrasonic waves, high intensity UV radiation, and LED blue light because their efficacy against the SARS-CoV-2 virus is not known.[5] In view of this knowledge about SARS-CoV-2, institutional, commercial, and industrial facility owners and operators are on notice of the role of contaminated impervious surfaces in the transmission of SARS-CoV-2. Clients and customers demand safe, reliable and effective disinfection solutions to prevent disease transmission.

Important Considerations When Selecting a COVID-19 Disinfectant

Careful selection of disinfectants and methods of use is essential to avoid unintended harm that might result from choosing an improper disinfectant or misusing one that is otherwise proper. We want to be confident about the adequacy of the disinfection and the safety of the process. Failure to implement and follow proper disinfection protocols increases risk of infections and exposes facility owners and operators to legal liability in tort. Also, personnel using disinfectants must strictly follow EPA disinfectant label instructions which are designed to ensure both the safety of the user, other people, and the environment, and the effectiveness or "efficacy" of the disinfectant to achieve the desired elimination of the pathogen. Failure to strictly follow disinfectant use instructions on product labels regulated by the U.S. Environmental Protection Agency may expose those persons applying the disinfectant to possible violations of federal law carrying both civil and criminal penalties.

The Roles of Government Agencies

Several federal agencies have responsibility for guiding COVID-19 disinfection, namely the Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), and Occupational Safety & Health Administration (OSHA). State and local health departments also have an important role.

The CDC provides advice on infectious disease prevention through, among other means, the use of disinfectants to kill pathogens such as SARS-CoV-2, based upon its expertise in public health and medicine. It does not have regulatory or enforcement authority over means and methods for disinfection. The EPA is the primary regulatory and enforcement authority for the use of disinfectants to kill pathogens that

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[1] CDC, *How COVID-19 Spreads* (last reviewed April 13, 2020); CDC, *Cleaning and Disinfection for Households Interim Recommendations for U.S. Households with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19)*, May 7, 2020).

[2] Department of Homeland Security, Science and Technology Master Question List for COVID-19 Weekly Report (March 25, 2020)

[3] CDC, *Guidance for Cleaning and Disinfecting Public Spaces, Workplaces, Businesses, Schools, and Homes* (April 28, 2020).

[4] CDC, *Reopening Guidance for Cleaning and Disinfecting Public Spaces, Workplaces, Businesses, Schools, and Homes*

[5] CDC, *Coronavirus Disease 2019, Cleaning and Disinfecting Your Facility Everyday Steps, Steps When Someone is Sick, and Considerations for Employers* (Last reviewed April 4, 2020)

threaten public health, such as SARS-CoV-2. EPA acts pursuant to its authority to test and label disinfectants to ensure safety and efficacy under the Federal Insecticide Fungicide & Rodenticide Act (FIFRA). FIFRA forbids any person to use any registered "pesticide" in a manner inconsistent with its labeling. A "pesticide" is any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any "pest," which includes viruses, bacteria, or other micro-organisms. EPA strictly regulates disinfectants (also known as "antimicrobials" or "antimicrobial pesticides") used to kill or deactivate micro-organisms which threaten public health, such as the SARS-CoV-2 virus. Only those disinfectants EPA has authorized for use on the SARS-CoV-2 virus can be used to disinfect facilities to prevent transmission of SARS-CoV-2. In other words, the use of a disinfectant not authorized for use on the SARS-CoV-2 virus, or the use of an authorized disinfectant in a manner inconsistent with its label instructions is a violation of FIFRA.

The EPA has responsibility to ensure the safety and effectiveness of disinfectants used to kill pathogens like SARS-CoV-2. EPA has published a list of authorized SARS-CoV-2 disinfectants, known as "List N" (https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2). It currently contains 410 products and is frequently updated. EPA's List N identifies those surface disinfectant products that will kill the SARS-CoV-2 virus based upon demonstrated efficacy against harder-to-kill viruses or other types of human coronavirus similar to SARS-CoV-2. A disinfectant used to kill SARS-CoV-2 must achieve strict performance levels under the specific usage instructions.[6] All surface disinfectants on List N can be used to kill viruses on hard impervious surfaces such as counters, desks, doorknobs, and equipment provided the label instructions are strictly followed.

OSHA is the primary regulatory and enforcement authority over workplace safety, which includes measures for protecting workers from exposure to and infection with SARS-CoV-2, including housekeeping practices involving routine cleaning and disinfecting of surfaces with EPA-approved disinfectants (see OSHA, Guidance on Preparing Workplaces for COVID-19). OSHA's "general duty clause" mandates that each employer shall furnish to each of its employees a place of employment free from recognized hazards that are causing or are likely to cause death or serious physical harm.

State and local public health and environmental agencies also have a major front-line role in controlling infectious diseases through their traditional police power exercised by the various state and local departments of public health. They generally have the authority to investigate and mitigate contagious and infectious diseases, define and abate nuisances dangerous to the public health, including directing building owners to clean and disinfect. States also have been delegated authority to enforce use of disinfectants and other pesticides under FIFRA.

Choice of Disinfectant Active Ingredients & Application Methods Has Important Implications for Safety & Efficacy

There are multiple active ingredients used in disinfectants listed on List N, including quaternary ammonium, alcohol, chlorine and chlorine compounds, peracetic acid, lactic acid, citric acid, peroxyacetic acid, isopropanol, ethanol, phenolic, sodium chloride, sodium chlorite, sodium hypochlorite, soctanoic acid, hypochlorous acid, thymol, and hydrogen peroxide.[7] All disinfectants have risks, since they are designed and intended to kill living organisms. But risk is a relative term and some disinfectants certainly may pose greater, long-term risks to custodial workers and building occupants than others. For example,

[6] EPA, *Product Performance Test Guidelines OCSPP 810.2200: Disinfectants for Use on Environmental Surfaces Guidance for Efficacy Testing* (Feb. 2018).
[7] See EPA, *List N: Disinfectants for Use Against SARS-CoV-2*.

some List N active ingredients are respiratory irritants and sensitizers found to cause or contribute to asthma (e.g., chlorine bleach/sodium hypochlorite, peroxyacetic acid, and quaternary ammonium compounds) and skin sensitization (e.g., chlorine bleach and thymol).[8]

EPA has established four "Toxicity Categories" for acute hazards of pesticide products.[9] Category I is the highest toxicity category and Category IV the lowest based upon data collected for five types of acute exposures, Oral LD_{50}, Dermal LD_{50}, Inhalation LC_{50}, Eye Irritation, and Skin Irritation. Between 2009 and 2017, EPA's *Design for the Environment Pesticide Pilot Project* (DfE) identified a list of disinfectant active ingredients determined to be on the "green" end of the pesticide spectrum. Disinfectants making the cut qualified for a special product logo on their pesticide labels indicating they: (1) are in the least-hazardous classes (i.e. III and IV) of EPA's acute toxicity category hierarchy; (2) are unlikely to have carcinogenic or endocrine disruptor properties; (3) are unlikely to cause developmental, reproductive, mutagenic, or neurotoxicity issues; (4) contain mixtures that have been reviewed and accepted by EPA, including inert ingredients; (5) have no unresolved or unreasonable adverse effects reported; (6) have no unresolved compliance or enforcement actions associated with it.[10] Comparing the disinfectant active ingredients previously qualifying for EPA's DfE pilot program and those on EPA's SARS-CoV-2 List N yields a fairly small list: citric acid, hydrogen peroxide, L-lactic acid, ethanol, isopropanol, and peroxyacetic acid. A recent analysis of data on relative toxicity of various disinfectants used in child care settings finds that "peroxide products are preferable when other factors are equal, because they have less respiratory toxicity than bleach or quaternary ammonias . . . [and] do not present the same concerns for reproductive toxicity that the quats do."[11]

The method by which a disinfectant is applied in accordance with its EPA-approved label also is a significant factor in the relative safety and efficacy of the disinfectant. While all disinfectants registered with and approved by EPA for use on SARS-CoV-2 and other viruses are deemed safe and effective if used in accordance with the label instructions, some products have greater potential risk than others. EPA has expedited all requests for inclusion of products on List N in order to assure that users have sufficient access to products shown to be effective against the coronavirus. EPA has been concerned about assuring an adequate supply of products that can meet a particular user's needs and circumstances. While we

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[8] See generally, San Francisco Department of the Environment, Green Purchasing Institute (2014), *Safer Products and Practices for Disinfecting and Sanitizing Surfaces*; Holm, S et al., *Do we know how best to disinfect child care sites in the United States? A review of available disinfectant efficacy data and health risks of the major disinfectant classes.* Am J Infect Control 2019;47:82-91; Pechter, E. *Occupational health risks associated with use of environmental surface disinfectants in health care*. Am J Infect Control 2016:1755-63; Quinn MM, Henneberger PK, National Institute for Occupational Safety and Health (NIOSH), National Occupational Research Agenda (NORA) Cleaning and Disinfecting Healthcare Working Group, Braun B, Delclos GL, et al. *Cleaning and disinfecting environmental surfaces in health care: toward an integrated framework for infection and occupational illness prevention*. Am J Infect Control 2015;43:424-34; Arif AA, Delclos GL. *Association between cleaning-related chemicals and work-related asthma and asthma symptoms among health care professionals*. Occup Environ Med 2012;69:35-40.; Rosenman KD. *Cleaning products-related asthma*. Clin Pulm Med 2006;13: 221-8; Delclos GL, Gimeno D, Arif AA, Benavides FG, Zock JP. *Occupational exposures and asthma in health-care workers: comparison of self-reports with a workplace specific job exposure matrix*. Am J Epidemiol 2009;169:581-7; Saito R, Virji MA, Henneberger PK, Humann MJ, LeBouf RF, Stanton ML, et al. *Characterization of cleaning and disinfecting tasks and product use among hospital occupations*. Am J Ind Med 2015;58:101-11; New Jersey Department of Health (2013), *Health Alert Bulletin, Fogging Ambulances with Toxic Disinfectants May Cause Illness*.

[9] 40 C.F.R. 156.62.

[10] EPA, *Design for the Environment (DfE) Logo for Antimicrobial Pesticide Products.*

[11] Holm, S et al*., Do we know how best to disinfect child care sites in the United States? A review of available disinfectant efficacy data and health risks of the major disinfectant classes*. Am J Infect Control 2019;47:82-91

mention certain products here, it is important to pay careful attention to the labeling for any and all products on the List.

Disinfectant products for use on hard impervious surfaces contaminated with the SARS-CoV-2 virus also come in different forms, including water soluble powders and liquids, spray products, towelettes, and fogging/gas/vapor.[12] The efficacy of a disinfectant depends upon a number of factors that must be controlled the most important being contact time (also known as "dwell time" or "kill time"). Contact time requires the surface of materials being cleaned to be wet with disinfectant for the EPA registered identified time. EPA's efficacy testing guideline requires all disinfectants to meet the performance standard associated with the method and microbe at ≤10 minutes of contact.[13] EPA evaluates the success of the viral disinfectants—known as "virucides"—by measuring whether the virus remaining after treatment under the use conditions demonstrates effectiveness in killing the virus.[14]

Disinfectants may be applied through manual application methods, such as wipes, towelettes, cloths, sponges and sprayers (both conventional and electrostatic), or through fumigation methods that rely on vaporization or aerosolization of the disinfectant. Fumigation methods disperse the disinfectant through the air within a secured space. The air becomes saturated with the disinfectant which then falls onto surfaces within the secured area. Such methods function by saturating the air with a prescribed concentration of vaporized or aerosolized disinfectant over a defined period of time to ensure efficacy.[15] Airborne methods for applying a disinfectant are inherently less controlled and commonly may be referred to as "fogging," "misting", and "fumigating."[16] Disinfectants applied through these airborne methods are not tested in the same way as manual methods (e.g. liquids, spray products, towelettes) but are subject to case-by-case testing methodologies that must be developed in consultation with EPA.[17]

Much information and misinformation is circulating about the use of fogging, fumigation, or similar methods for disinfecting and sanitizing buildings to prevent transmission of SARS-CoV-2.

Wipes & Sprays (Conventional and Electrostatic) Generally Are Easy, Safe & Effective

The majority of the products on EPA's List N appear to be applied through manual ready-to-use means, such as liquids, wipes and sprays. With these methods the disinfectant applicator directs and controls where to apply the disinfectant, visually confirms the surface has been adequately pre-cleaned to remove organic contaminants, and visually confirms both the amount of disinfectant applied and the contact time. There is no need to seal the space to prevent unintended exposures to airborne disinfectant because the disinfectant is in liquid form (applied through wipes or spray) during its application. With an electrostatic sprayer droplets of liquid disinfectant are positively charged to make the droplets electrically stronger than the surface being treated. Similar to magnets, the charged droplets are drawn to each other and

[12] EPA, *Product Performance Test Guidelines OCSPP 810.2200: Disinfectants for Use on Environmental Surfaces Guidance for Efficacy Testing* (Feb. 2018).
[13] Ibid.
[14] Ibid.
[15] EPA, *Summary of the Effectiveness of Volumetric Decontamination Methods as a Function of Operational Conditions*
[16] See EPA, *Can I apply a product using a method that is not specified in the directions for use on Coronavirus (COVID-19)?* (April 17, 2020); EPA, *Can I use fumigation or wide-area spraying to help control COVID-19?* (April 17, 2020).
[17] EPA, *Product Performance Test Guidelines OCSPP 810.2200: Disinfectants for Use on Environmental Surfaces Guidance for Efficacy Testing* (Feb. 2018).

attach when one surface is more positively charged than the other. An electrostatically-charged spray solution surrounds the object and is believed to result in greater efficiency and more uniform distribution of the disinfectant, particularly over uneven surfaces compared to conventional spray systems.[18]

Examples of EPA List N wipes and sprays deemed effective in killing SARS-CoV-2 is Diversey, Inc. Oxivir Tb hydrogen peroxide (HP) wipes (EPA Reg. 70527-80-60), Kaivac Kaibosh quaternary ammonium spray (EPA approved through equivalent Maquat (EPA Reg. 10324-93), and CloroxPro™ Clorox Total 360® quaternary ammonium electrostatic spray (EPA Reg. 67619-38) .

Foggers & Misters Pose Greater Complexity and Application Challenges

As discussed above, only disinfectants on EPA's List N may be used to disinfect spaces to prevent transmission of SARS-CoV-2. EPA's List N contains a limited number of disinfectants that can be applied through fogging/misting for use against SARS-CoV-2. Precisely which products may be used in a fog/mist application requires a detailed review of each product label to determine which ones have use instructions that align fogging/misting with the viral disinfection claims. For example, one product on EPA's List N, TOMI Environmental Solutions, Inc., Binary Ionization Technology (BIT) Solution (EPA Reg. No. 90150-2) (healthcare, institutional, residential use) (7.8% HP aerosol), claims that aerosolized hydrogen peroxide (HP) applied through special equipment which generates HP aerosol kills viruses and is therefore authorized for use on SARS-CoV-2. Other products on List N have labels authorizing application of the disinfectant by means of fogging, but only under limited conditions that do not apply to most building applications. For example, Mason Chemical Co's Maquat 64-PD quaternary ammonium (EPA Reg. 10324-93) (healthcare, institutional, residential) (identical to Kaivac Kaibosh quaternary ammonium spray) claims that quaternary ammonium at 2 oz. per gallon of water (700 ppm active) and 5% soil on hard, non-porous surfaces kills the virus in 10 minutes. The label also contains directions for use in fogging applications but these appear to be limited only to surfaces "cleaned and disinfected in accordance with label instructions prior to fogging. . . fogging in food premises [including] dairies. . . food processing plants . . . poultry houses . . . ." Accordingly, it is important to carefully review List N product labels before making a determination that a disinfectant on the list can be used in a fogging application for specific property use (e.g., institutional, commercial).

Health Challenges Associated with Disinfectant Application

For those viral disinfectants labeled to permit application by fogging, expect to find complex instructions that pose challenges for safely managing the active ingredients which are airborne. Airborne disinfectant products pose safety concerns because the disinfectant carries greater potential risks to people and the environment compared to disinfectant wipes or sprays. Elevated risks associated with inadvertent exposures from fumigation methods for applying disinfectants are well-documented.[19] For example, the New Jersey Department of Health strongly recommends against fogging of ambulances with quaternary ammonium after finding that emergency responders were sickened by residual exposure.[20] "Fogging uses a fine mist to kill microrganisms and generates micro-particles (and possibly nano-particles) of

[18] EPA, *Application of Electrostatic and Backpack Sprayer Systems for Decontamination of Building Materials Contaminated with Malathion* (Nov. 2015).

[19] See New Jersey Department of Health (2013), *Health Alert Bulletin, Fogging Ambulances with Toxic Disinfectants May Cause Illness*; see also, CDC (2018), *Illnesses and Injuries Related to Total Release Foggers --- Eight States, 2001—2006*, Weekly Morbidity and Mortality Weekly Report.

[20] New Jersey Department of Health (2013), Health Alert Bulletin, Fogging Ambulances with Toxic Disinfectants May Cause Illness;

disinfectant. . . which can be absorbed into the body much quicker and in greater quantities than larger particles . . . the long-term consequences of converting disinfectant from liquid to dry mist (i.e. fogging) are unknown."[21]

At least one List N product, the TOMI Environmental Solution 7.8% HP aerosol product, is applied through special aerosolization equipment which generates aerosols that micro-condense and passively fall onto surfaces where they kill SARCS-CoV-2 and other microorganisms. The product uses HP, which generally is considered one of the "safer" disinfectants, because it quickly breaks down and leaves behind no residual chemical on treated surfaces.[22] However, even HP poses elevated risks when applied as a fogger since it is a corrosive gas that can cause irreversible eye damage, skin burns and may be fatal if inhaled.[23] HP has an OSHA Permissible Exposure Limit (PEL) of 1.0 ppm (1.4 mg/m) for workers. HP in vapor or aerosol form poses an inhalation risk to sensitive people, including children and asthmatics. Workers applying HP in vapor or aerosol form must be trained and properly fitted with a respirator, pursuant to an OSHA respirator program meeting the requirements of 29 C.F.R. 1910.134, and wear personal protective equipment (PPE), such as safety goggles and protective clothing.

The extent of the PPE and other requirements required for safe application of disinfectants varies depending on the hazardous nature of the active ingredient and the process used to apply it. Spray and wipe methods generally are less hazardous for the operator than fogging/fumigation and this is reflected in lesser requirements for PPE and other safety protocols.

Instructions for use of fogging disinfectants generally require detailed planning and protocols, sometimes referred to as a Fumigation Management Plans (FMPs), to ensure the safety of the applicator and other people, including bystanders located outside the containment zone.[24] Under the terms of labeling of these types of products, prior to treatment, the treatment area must be fully evacuated and sealed.[25] Rooms and HVAC systems must be completely sealed to prevent leakage of the disinfectant outside the containment area. Monitoring must be conducted to ensure building occupants, workers, bystanders and residents are not exposed. Dräger tubes to measure ambient levels are generally recommended to assure airborne concentrations outside the treatment area remain below the applicable PEL, which for HP is 1 ppm.[26] If the level is exceeded, the treatment process should immediately be aborted to ensure safety. Use instructions generally recommend having a notification plan to alert local emergency authorities if there is an incident. Depending on conditions and volume, treated spaces may require 5-6 hours following treatment to return to a safe levels.[27] However, certain absorbent materials, like paper or cardboard, may absorb disinfectant and pose a longer-term risk of off-gassing.

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[21] New Jersey Department of Health (2013*), Health Alert Bulletin, Fogging Ambulances with Toxic Disinfectants May Cause Illness*.

[22] See, San Francisco Department of the Environment, Green Purchasing Institute (2014), *Safer Products and Practices for Disinfecting and Sanitizing Surfaces*.

[23] Agency for Toxic Substances and Disease Registry (2015), *Medical Management Guidelines for Hydrogen Peroxide (H2O2)*.

[24] See, e.g., TOMI™ Environmental Solutions, Inc., *Environmental Binary Ionization Technology® (BIT") Solution is for use exclusively with the SteraMist™ Environment System*.

[25] Ibid.

[26] Ibid.

[27] Freyssenet, C, Karlen, S. (2019), *Plasma-Activated Aerosolized Hydrogen Peroxide (aHP) in Surface Inactivation Procedures*, Journal of ABSA International.

Before considering the use of products registered for fogging type application, careful consideration should be given to the institution's ability to manage the specific terms of use required for such products.

Efficacy Challenges Associated with Application

Fogging systems also come with detailed and complex use directions in order to ensure efficacy. These systems work by spraying a vapor or aerosol mist into the air which falls onto exposed, open surfaces and objects. Disinfectant may not reach unexposed voids, cracks, crevices, drawers, closets, cabinets, undersides, or surfaces covered with papers or other objects where the virus may be present. If the necessary deep cleaning methods to remove dirt and organic matter followed by wiping with a disinfectant are properly conducted, the use of additional wide-area vaporized or aerosolized methods is likely redundant and therefore unnecessary.[28]

Fogging systems to apply disinfectant are subject to the same contact time as conventional application methods such as wipes. For example, HP systems require adequate ambient air concentrations and exposure time to be effective. They generally have contact time of 15 minutes, which is longer than more traditional disinfectants and may be difficult to achieve. As is the case with hand-wiping methods, HP systems must be preceded by extensive preparation efforts involving manual cleaning and removal of organic debris and dust, which if not removed may shield the virus from contact with the HP and hamper its efficacy. Application space generally must be completely sealed and dehumidified to a 10-70% relative humidity range; the time needed to dehumidify the space increases with the volume of the enclosure.[29] Ambient temperature also must be maintained at recommended levels throughout the fumigation process. If there are temperature gradients within the target area, micro-condensation may form earlier and in a greater quantity on cooler surfaces compared to warmer areas within the same room, leading to uneven vapor distribution throughout the target enclosure and potential reduced efficacy.[30] Ambient HP must be maintained at a set concentration over a minimum period of time to achieve the contact time to be effective. The HP concentration must be monitored with electrochemical sensors capable of measuring the ambient level of HP in the parts per billion and low parts per million levels to ensure an adequate concentration level is maintained throughout the entirety of the sterilization phase of the process. These HP chemical indicators must be placed throughout the enclosure being treated to verify adequate distribution of HP throughout the treatment process.

Foggers Not Recommended by EPA and the CDC for SARS-CoV-2

Likely for these reasons, neither the CDC nor EPA recommend the use of fogging/misting to disinfect buildings. In fact, both agencies have expressed concerns about the appropriateness of using fogging methods to disinfect hard impervious surfaces within buildings. [31] In its most recent guidance on

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[28] EPA, *Letter to Registrants of Antimicrobial Fogging/Misting Products* (April 1, 2013).

[29] See, e.g., TOMI™ Environmental Solutions, Inc., *Environmental Binary Ionization Technology® (BIT") Solution is for use exclusively with the SteraMist™ Environment System*.

[30] EPA, *Letter to Registrants of Antimicrobial Fogging/Misting Products* (April 1, 2013).

[31] See CDC, *Guideline for the Prevention and Control of Norovirus Gastroenteritis Outbreaks in Healthcare Settings* (last updated February 15, 2017) ("[m]ore research is required to clarify the effectiveness and reliability of fogging, UV irradiation, and ozone mists to reduce norovirus environmental contamination. (No recommendation/unresolved issue)."); EPA, *Letter to Registrants of Antimicrobial Fogging/Misting Products* (April 1, 2013) ("Application by fogging/misting results in much smaller particle sizes, different surface coverage characteristics, and *potentially reduced efficacy when compared to sanitization or disinfection product applications by spraying, sponging, wiping or mopping*. . . .The absence of pre-cleaning in the presence of soil contamination,

foggers/misters, EPA stated "EPA does not recommend use of fumigation or wide-area spraying to control COVID-19. The Centers for Disease Control and Prevention (CDC) recommends that you clean contaminated surfaces with liquid products, such as those provided on List N, to prevent the spread of disease…"[32] EPA's Science Advisory Board also recently concluded there is need for more research on whether "methods of application of List N products via fogging and/or electrostatic spraying provide the necessary contact time on surfaces to be efficacious against SARS-CoV-2?"[33]

Conclusion

Commercial and institutional facility owners and operators should carefully select appropriate disinfectants and methods of application to ensure hard, impervious surfaces within interior spaces are safely and effectively disinfected. Only disinfectants on EPA's List N may be used to treat building spaces for SARS-CoV-2. Important differences in the types of disinfectants and the methods of applying them and associated considerations of safety, efficacy, and practicality should be carefully weighed before choosing disinfectant means and methods. The use of conventional wipes and sprays for disinfection are proven, safe and reliable. Fogging applications require careful analysis due to the complexity of use instructions and limitations on appropriate uses that must be strictly followed to ensure safety, efficacy and compliance with FIFRA. The airborne nature of disinfectants applied by fogging and associated health risks pose special challenges that increase risks and costs and clearly are not a substitute for manual cleaning techniques.

potential reaction with or absorption of the active ingredient for different surfaces, and humidity/temperature fluctuations *can also impact distribution and efficacy of the product*. . . .A surface treated by fogging/misting does *not receive the same amount of active ingredient per unit area* as the standard methods of application and, as a result, the level of efficacy actually achieved may not be the same level claimed on the label.")

[32] EPA, *Can I use fumigation or wide-area spraying to help control COVID-19?* (Last updated April 17, 2020).

[33] EPA, *Science Advisory Board Review: Identifying Research Needs to Address the Environmental and Human Health Impacts of COVID-19* (April 21, 2020).