FOGGING

A POWERFUL DISINFECTING LAYER FOR BIOHYGIENE ?

AMERICAN BIODEFENSE INSTITUTE

WORLD HEALTH ORGANIZATION, EPA & CDC COMPLIANCE

BIOHYGIENE AND THE POST PANDEMIC 'NEW' NORMAL

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The American BioDefense Institute is a Washington, D.C. based Think Tank, dedicated to nonpartisan analysis of U.S. and international biodefense capabilities and strategies, created in response to the COVID 19 pandemic. ABI challenges the conventional boundaries of scientific disciplines by combining expertise in medicine, biology, chemistry, communication, and public policy to provide multidirectional strategies to meet future biosecurity challenges.

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Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes coronavirus disease 2019 (COVID-19), most likely spreads through invisible respiratory droplets created when an infected person coughs or sneezes. Those droplets can be inhaled by nearby people or land on surfaces that others might touch, spreading the infection when they touch their eyes, nose, or mouth (Science, 2020).

There is a lot that is not fully known about the new SARS-CoV-2 virus, like how long does it remain active in the air or on surfaces. According to a recent study, the virus remains in the air for up to 3 hours and approximately 2-3 days on stainless steel and plastic surfaces (Van Doremalen et al, 2020). Another study found that a related SARS-CoV-1 virus that causes SARS can persist up to 9 days on non-porous surfaces such as plastic or stainless steel (Kampf et al, 2020).

Several reports found that the SARS-CoV-2 virus has been detected in feces, indicating that the virus can spread by people who don't properly wash their hands after using the bathroom (Wang et al, 2020). However, the CDC says there is no indication that it spreads through drinking water, swimming pools, or hot tubs (CDC, 2020a). The virus has been found to spread less effectively outdoors due to a variety of factors.

Previous research on the relationship between respiratory-borne infectious diseases and temperature have indicated that the ability of SARS and influenza viruses to spread decreased with increasing temperature (Jaakkola et al, 2014; Chan et al, 2011). The underlying hypothesis includes higher vitamin D levels, resulting in better immune responses (Aranow, 2011); increased UV radiation; and school holidays in the summer. Reports of correlation between respiratory diseases and the levels of UV radiation have also been considered, and previous studies have reported that high levels of UV exposure can reduce the spread of SARS-CoV virus (Duan et al, 2003).

However, according to the current results, the cumulative incidence rate and R0 of COVID-19 holds no significant association with ambient temperature, suggesting that ambient temperature has no significant impact on the transmission of SARS-CoV-2 (Yao et al, 2020). This is similar to the Middle East respiratory syndrome (MERS) epidemic, where the MERS coronavirus continued to spread even at temperatures of around 45°C (Alshukairi et al, 2018).

Measures to minimize airborne transmission of COVID-19 indoors include sufficient and effective ventilation, possibly enhanced by particle filtration and air disinfection, avoiding air recirculation, and avoiding overcrowding (Morawska et al, 2020).

Fogging is a deep cleaning method that has been used in hospitals for dealing with MRSA. Fogging uses an antiviral disinfectant solution to clean and sanitize large areas of a building quickly and effectively by spraying a fine mist from a spray gun, which is then left to evaporate, usually for less than an hour. It can kill off viruses and other biological agents in the air and on surfaces. The task requires full protection from the sprayed chemicals. The product used is safe on electronics and other equipment as the mist is exceptionally fine to penetrate all areas to kill off the virus effectively.

Fogging should be conducted only using products whose product label specifically includes disinfection directions for fogging, fumigation, or wide-area spraying. It means that the product's safety and efficacy have been evaluated by the EPA, specifically for fogging. Otherwise, the product might not be effective in disinfecting surfaces by fogging (EPA.gov, 2020a). The EPA has been expediting applications to add directions for use with electrostatic sprayers to products intended to kill SARS-CoV-2 (EPA.gov, 2020b).

Wet or chemical fogging employs a fine mist of disinfectant solution which remains on surfaces for several hours until it evaporates. Dry fogging, on the other hand, uses smoke to treat the area, leaving no chemical trace behind. The main advantages of fogging are the ability to cover large areas quickly and effectively; the ability to reach areas difficult to clean using other techniques. It eliminates pathogens in the air and on all surfaces, including furniture, walls, and ceilings.

The downsides are that it requires a thorough cleaning in advance as dirt and other materials might cover parts of a surface, protecting it from the effects of the biocide spread by fogging; the chemicals used are often more expensive than other disinfectants, and the required amount depends on the size of the space that is being disinfected. However, fogging is cost-effective because it allows the rapid disinfection of large areas with minimal disruption.

Ultraviolet (UV) radiation can be used for non-contact disinfection, where UV-C light is used to kill or inactivate pathogens by damaging their DNA or destroying nucleic acids. UV disinfection is commonly used to treat water – its advantages are lack of chemical agent, ease of use, and low economic cost. The lack of chemical agent means that UV disinfection can be used as often as needed, without any fear of long-term consequences for the operator or the client.

However, UV disinfection requires a direct impact of UV radiation for some time – if the light shines indirectly, or is obscured by dirt or something else, the disinfecting effect is lost. Also, prolonged exposure to UV light can be harmful to humans – skin exposure can produce sunburn and skin cancer. In addition, eye exposure can damage the cornea or, in rare cases, the retina, leading to temporary or permanent vision impairment or even blindness. The risk is compounded by the fact that UV light is invisible to the human eye. Therefore, the operation of UV disinfection equipment requires caution.

World Health Organization and CDC Guidance

WHO

The World Health Organization (WHO) issued an interim guidance document on May 15th, 2020 (WHO, 2020)

"Cleaning should progress from the least soiled (cleanest) to the most soiled (dirtiest) areas, and from higher to lower levels so that debris may fall on the floor and is cleaned last in a systematic manner to avoid missing any areas. Use fresh cloth at the start of each cleaning session (e.g., daily cleaning in a general inpatient ward). Discard cloth that is no longer saturated with solution. For areas considered to be at high risk of COVID-19 virus contamination, use a new cloth to clean each patient's bed. The soiled cloth should be reprocessed properly after each use, and an SOP should be available for the frequency of changing cloth.

Cleaning equipment (e.g., buckets) should be well maintained. Equipment used in isolation areas for patients with COVID-19 should be color-coded and separated from other equipment. Detergent or disinfectant solutions become contaminated during cleaning and progressively less effective if the organic load is too high. The continued use of the same solution may transfer microorganisms to each subsequent surface. Thus, detergent or disinfectant solutions must be discarded after each use in areas with suspected/confirmed patients with COVID-19. It is recommended that a new solution be prepared daily or for each cleaning shift. Buckets should be washed with detergent, rinsed, dried, and stored inverted to drain fully when not in use."

"For indoor spaces, routine application of disinfectants to environmental surfaces by spraying or fogging (also known as fumigation or misting) is not recommended for COVID-19. One study has shown that spraying as a primary disinfection strategy is ineffective in removing contaminants outside of direct spray zones. Moreover, spraying disinfectants can result in risks to the eyes, respiratory or skin irritation, and the resulting health issues. Spraying or fogging of certain chemicals, such as formaldehyde, chlorine-based agents or quaternary ammonium compounds, is not recommended due to adverse health effects on workers in facilities where these methods have been utilized."

"The spraying or fumigation of outdoor spaces (such as streets or marketplaces) is also not recommended for killing the COVID-19 virus or other pathogens because disinfectant is inactivated by dirt and debris. Furthermore, it is not feasible to manually clean and remove all organic matter from such spaces.

Spraying porous surfaces, such as sidewalks and unpaved walkways, would be even less effective. Even in the absence of organic matter, chemical spraying is unlikely to adequately cover all surfaces for the duration of the required contact time needed to inactivate pathogens. Furthermore, streets and sidewalks are not considered to be reservoirs of infection for COVID-19. Besides, spraying disinfectants, even outdoors, can be harmful to human health.

Spraying individuals with disinfectants (such as in a tunnel, cabinet, or chamber) are not recommended under any circumstances. This could be physically and psychologically harmful and would not reduce an infected person's ability to spread the virus through droplets or contact. Moreover, spraying individuals with chlorine and other toxic chemicals could result in eye and skin irritation, bronchospasm due to inhalation, and gastrointestinal effects such as nausea and vomiting."

CDC

CDC and HICPAC have recommendations in the 2008 'Guidelines for Disinfection and Sterilization in Healthcare Facilities' which state that the CDC does not support disinfectant fogging (Rutala and Weber, 2008).

These recommendations refer to the fogging or spraying of chemicals (e.g., phenol-based agents, formaldehyde, or quaternary ammonium compounds) to decontaminate environmental surfaces or disinfect the air in patient's rooms. The recommendation against fogging was based on 1970s studies that reported a lack of microbicidal efficacy (e.g., use of quaternary ammonium compounds in mist applications) and adverse effects on healthcare workers and others in facilities where these methods were utilized. In addition, some of these chemicals are not EPA-registered for use in fogging-type applications.

These recommendations do not apply to the newer technologies involving fogging for room decontamination (e.g., vaporized hydrogen peroxide, ozone mists) that have become available since the 2008 recommendations were made. The newer technologies were assessed by CDC and HICPAC in the 2011 'Guideline for the Prevention and Control of Norovirus Gastroenteritis Outbreaks in Healthcare Settings (MacCannell et al, 2011), which makes the following recommendation:

"More 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). Although the 2008 recommendations still apply, the CDC does not yet make a recommendation regarding these newer technologies. This issue will be revisited as additional evidence becomes available."

The following are general guidelines for disinfecting and cleaning non-emergency transport vehicles (CDC, 2020b):

"At a minimum, clean and disinfect commonly touched surfaces in the vehicle at the beginning and end of each shift and between transporting passengers who are visibly sick. Ensure that cleaning and disinfection procedures are followed consistently and correctly, including the provision of adequate ventilation when chemicals are in use. Doors and windows should remain open when cleaning the vehicle. When cleaning and disinfecting, individuals should wear disposable gloves compatible with the products being used as well as any other PPE required according to the product manufacturer's instructions. The use of a disposable gown is also recommended, if available.

- For hard non-porous surfaces insider the vehicle such as hard seats, armrests, door handles, seat belt buckles, light and air controls, doors and windows, grab handles, clean with detergent or soap and water if the surfaces are visibly dirty, before the disinfectant application. For disinfection of hard, non-porous surfaces, appropriate disinfectants include:
    - EPA's Registered Antimicrobial Products for Use Against Novel Coronavirus SARS-CoV-2, the virus that causes COVID-19. Follow the manufacturer's instructions for concentration, application method, and contact time for all cleaning and disinfection products.
    - Diluted household bleach solutions prepared according to the manufacturer's label for disinfection, if appropriate for the surface. Follow the manufacturer's instructions for application and proper ventilation. Check to ensure the product is not past its expiration date. Never mix household bleach with ammonia or any other cleanser.
    - Cleaning solutions with at least 70% alcohol.

- For soft or porous surfaces such as fabric seats, remove any visible contamination, if present, and clean with appropriate cleaners indicated for use on these surfaces. After cleaning, use products that are EPA-approved against the virus that causes COVID-19, and that is suitable for porous surfaces.

- For frequently touched electronic surfaces such as tablets or touch screens used in a vehicle, remove visible dirt then disinfect following the manufacturer's instructions. If no manufacturer guidance is available, consider the use of alcohol-based wipes or sprays containing at least 70% alcohol to disinfect."

EPA Approved Products Against SARS-CoV-2 (COVID-19)

There is a total of 479 approved disinfection products with the full list available at https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2-covid-19

List of active ingredients of approved disinfectants:

1,2-Hexanediol
Chlorine dioxide
Chlorine dioxide; Quaternary ammonium
Citric acid
Citric acid; Thymol
Dodecylbenzenesulfonic acid; L-Lactic acid
Ethanol (Ethyl alcohol)
Ethanol (Ethyl alcohol); Phenolic
Ethanol (Ethyl alcohol); Quaternary ammonium
Glycolic acid
Hydrochloric acid
Hydrogen chloride
Hydrogen peroxide
Hydrogen peroxide; Ammonium carbonate; Ammonium bicarbonate
Hydrogen peroxide; Octanoic acid; Peroxyacetic acid (Peracetic acid)
Hydrogen peroxide; Peroxyacetic acid (Peracetic acid)
Hydrogen peroxide; Peroxyacetic acid (Peracetic acid); Octanoic acid
Hydrogen peroxide; Peroxyoctanoic acid; Octanoic acid
Hydrogen peroxide; Peroxyoctanoic acid; Peroxyacetic acid (Peracetic acid)
Hydrogen peroxide; Silver
Hypochlorous acid
Isopropanol (Isopropyl alcohol)
Isopropanol (Isopropyl alcohol); Phenolic
Isopropanol (Isopropyl alcohol); Quaternary ammonium
L-Lactic acid
Octanoic acid
Peroxyacetic acid (Peracetic acid)
Peroxyacetic acid (Peracetic acid); Hydrogen peroxide
Phenolic
Phenolic; Ethanol (Ethyl alcohol)
Potassium peroxymonosulfate; Sodium chloride
Quaternary ammonium
Quaternary ammonium; Citric acid
Quaternary ammonium; Ethanol (Ethyl alcohol)

Quaternary ammonium; Ethanol (Ethyl alcohol); Isopropanol (Isopropyl alcohol)
Quaternary ammonium; Ethanol (Ethyl alcohol); Phenolic
Quaternary ammonium; Glutaraldehyde
Quaternary ammonium; Hydrogen peroxide
Quaternary ammonium; Isopropanol (Isopropyl alcohol)
Quaternary ammonium; Sodium carbonate peroxyhydrate
Silver
Silver ion; Citric acid
Sodium carbonate peroxyhydrate; Tetraacetyl ethylenediamine
Sodium chloride
Sodium chlorite
Sodium chlorite; Citric acid
Sodium chlorite; Sodium dichloroisocyanurate dihydrate
Sodium dichloroisocyanurate
Sodium hypochlorite
Sodium hypochlorite; Sodium carbonate
Tetraacetyl ethylenediamine
Thymol
Triethylene glycol; Quaternary ammonium

Application of Fogging

Food Production

Fogging has been successfully employed for disinfection and decontamination of large spaces in the animal production industry. A recent study of the effects of the disinfectant fogging procedure on dust, aerobic bacteria, ammonia concentration, and fungal spores in a farrowing-weaning room found that the fogging disinfection procedure improved air quality in the piggery, thereby enhancing workers and animals' health (Costa et al, 2014).

A study looked at the use of fogging for the disinfection of food processing factories and equipment using numerical models of the dispersion of airborne particles to simulate the fogging process (Burfoot et al, 1999). The results showed that fogs should be most effective when the median diameter of the fog droplets lies between 10 and 20 mm. The droplets in this range disperse well and settle within about 45 min. It gives good coverage, and the fog clears from the air quickly enough not to pose a significant disruption to factory operations.

A research looking at the effectiveness of different disinfection regimens on removing Salmonella Enteritidis infected poultry concluded that disinfection regimens using formaldehyde, either as a spray or as a fogging agent, were most effective in the field (Davies et al, 1995).

A study evaluated the disinfectant efficacy of three strategies for high-volume directed mist application of accelerated hydrogen peroxide and peroxymonosulfate disinfectants; 4.25% accelerated hydrogen peroxide (Accel®; AHP) at a 1:16 dilution; single and double applications of 2% peroxymonosulfate solution (Virkon-S®; VIR -1 and VIR -2) for decontamination of a large animal hospital environment (Saklou et al, 2016).

All three disinfectants applied as a directed mist were effective at reducing CFUs in a veterinary hospital environment. Effective disinfection using this method of application is dependent on adequate cleaning prior to application, and the use of adequate volumes of disinfectant.

Hospitals

Bacterial culture tests were performed on the floor, walls and other areas of an operating theater to evaluate the results of disinfection. In addition, the number of colony-forming units was used as an index of effectiveness (Nakata et al, 2001). Benzalkonium chloride, sodium hypochlorite, alkyldiaminoethylglycine, glutaral, and acidic electrolytic water were used for operating theaters. The average disinfection effect was 90% or better for all disinfectants, except acidic electrolytic water. The automatic fogging unit allows safe and effective disinfection and may be suitable for disinfecting ward rooms and operating theaters.

A recent study of the efficacy of three disinfectant formulations and hydrogen peroxide/silver fogging system on surfaces experimentally inoculated with methicillin-resistant Staphylococcus pseudintermedius found that the mean percentage reduction in colony-forming units was 52.14% after fogging, compared to 97.81-99.98% after manual disinfection (Soohoo et al, 2020). It indicates that a disinfectant will not necessarily be as effective when applied using a fogging apparatus. Due to the different variables involved in fogging applications, it may be important to validate a fogging system in real-world settings.

A study of the effectiveness of hypochlorous acid against meticillin-resistant Staphylococcus aureus (MRSA) and Acinetobacter baumannii showed 99.99% - 99.9998% reduction after the first fogging and -99.99998% reduction after the second fogging (Clark et al, 2006). A comparison of the use of liquid and fog-based application of hypochlorous acid against human norovirus showed that liquid application had effectiveness higher than 99.9%. Meanwhile, fog application had an effectiveness of at least 99.9% (Park et al, 2007). This study shows that while the liquid application is more effective than fog application, the difference appears to be negligible.

A review of the studies of “no-touch” automated room disinfection systems in hospitals included hydrogen peroxide (H2O2) vapor systems, aerosolized hydrogen peroxide (aHP), and ultraviolet radiation (Otter et al, 2013). These systems have essential differences in their active agent, efficacy, delivery mechanism, process time, and ease of use.

Typically, there is a trade-off between effectiveness and time among NTD systems. There is substantial evidence that NTD systems are an effective adjunct to conventional methods of terminal disinfection, and that peroxide vapor systems reduce transmission in endemic and epidemic settings.

However, the cost-effectiveness of interventions using NTD systems requires further evaluation. More head-to-head comparisons of NTD systems, ideally including comparisons with conventional cleaning and disinfection is required. Furthermore, assessing both microbiological and clinical outcomes is also required. The choice of NTD system should be influenced by its intended application, practicalities of implementation, the evidence base for effectiveness, and cost constraints.

Transportation

The recent coronavirus pandemic has spurred the development and deployment of several new technologies for screening and preventing the spread of the COVID-19 virus (Matthew, 2020). Livestock is sprayed with disinfectants before transportation. Aerial fogging has been useful in controlling the aerial transmission of respiratory diseases in livestock. However, there are no studies yet documenting the effectiveness of such methods to disinfect humans, with safety concerns and effectiveness being the main issue. Furthermore, not all disinfectants are effective against the coronavirus.

American Industrial Hygiene Association (AIHA) warns that fogging can create health hazards if not performed with proper protective measures (AIHA, 2020). Special care should be taken in the selection of PPE for use with UV or fogging equipment (APTA, 2020). When cleaning and disinfecting with pesticides, individuals typically are required to wear disposable gloves that are compatible with the products being used including any other PPE required according to the product manufacturer’s instructions. Typically, masks, N95 respirators, face shields, and coveralls or gowns will be required PPE for the cleaning and disinfecting process.

Fogging is also used as one of the components of smart solutions for reducing the COVID-19 risk using smart city technology (Jaiswal et al, 2020). This study presents how smart city technology can be used to maintain social distancing, employ smart healthcare and other technology, including sanitizing tunnels, to reduce the risk of infection.

Ultraviolet Disinfection

UV technology has already been used for water disinfection due to significant advances in technology achieved in the past several years, such as the development of UV light-emitting diodes (Song et al, 2016; Jarvis et al, 2019).

Comparison of the surface disinfection capabilities automated devices using ultraviolet light versus hydrogen peroxide fogging machine showed that there was a 3-4 log reduction of the organism with the automated fogging machine for all tests (Chan-Myers et al, 2012). For the UV device, it was evident that the orientation of the carriers (direct line of sight or indirect) affected the disinfection efficacy, and log reduction ranged from 1-4 logs. The study shows that the automated fogging machine was more consistent and efficient than the UV device, where efficacy was dependent on the orientation of the contaminated surfaces, with indirect exposure of UV showing minimal efficacy.

A study of comparative inactivation of adenovirus serotypes by UV light disinfection showed that the effectiveness varies for different adenoviruses. Furthermore, the effectiveness of a particular virus serotype depends on the UV light dose, with log dependence of UV dose and disinfection effectiveness (Nwachuku et al, 2005). This means that if a dose of X achieves 90% effectiveness, a dose of 2X is required for 99% effectiveness, a dose of 3X for 99.9%, and a dose of 4X for 99.99% effectiveness.

UV technology has also been tested for the disinfection of agricultural products, like surface fungal disinfection of fresh fruits (Lagunas-Solar et al, 2006). Plant (fungal) pathogens were rapidly (<10s), efficiently (>5 log), and reproducibly killed on fruit surfaces. For maximum disinfection efficiency, uniform exposure to the UV source must be ensured because only partial disinfection was obtained when UV shielding (shadowing) effect was present, preventing the highly directional, coherent UV beam from reaching its target.

The UV techniques may provide effective, commercial-scale, reliable, and residue-free alternatives to chemical (contact) pesticides. Besides, UV technology could be a source for pasteurization of liquids, or disinfection of solid foods as an alternative technology, instead of thermal treatment or application of antimicrobial compounds (Guerrero-Beltran et al, 2004).

The World Health Organization states, ‘Ultra-violet (UV) lamps should not be used to disinfect hands or other areas of your skin.’ UV radiation may cause skin irritation and damage your eyes. Cleaning your hands with alcohol-based sanitizer or washing your hands with soap and water are the most effective ways to remove the virus.

Conclusions

Fogging and UV disinfection have been used for a long time. Fogging provides the capacity to disinfect large areas quickly and effectively with minimal disruption using either a mist or smoke of biocide to disinfect the air and all surfaces the biocide comes in contact with, including furniture, walls, and ceilings. It has already been successfully employed in food production and has been tested extensively in a hospital environment.

However, the results of these tests have shown that fogging can be unreliable if not performed with the chemical agent tested and approved for this purpose. Besides, the application requires protective measures to prevent inhalation of the biocide. Therefore, caution is required when conducting fogging.

UV disinfection is a method that allows disinfection without the use of a chemical agent, employing UV-C light to destroy or inactivate pathogens on surfaces, in the air, or water. Studies have shown that it can be unreliable because its effectiveness can be significantly reduced by improper operation. Furthermore, it should not be used on humans, as UV radiation can cause harm and requires caution. Its primary advantage is that there are no residual effects of disinfection, which are typical of other methods that employ chemical agents. Long-term regular use of chemical disinfectants is correlated with an increased incidence of asthma and other conditions, which is not an issue with UV disinfection. It can be used as often as needed without any potential long-term consequences.

The COVID-19 pandemic has significantly increased the importance of disinfection methods in people's lives and our economy. To safely re-open our society and, at the same time, avoid a surge in new infections associated with it, disinfection methods represent a vital epidemic countermeasure.

The two methods described in this document are at opposing ends of the spectrum: (1)fogging is best suited for large-area disinfection, like buildings and large transport vehicles, (2) UV disinfection is best suited for personal use to avoid potentially harmful effects of long-term usage of chemical disinfectants in our homes and workspaces.

Although both methods have been widely used before the pandemic under different circumstances, their full potential has not yet been utilized to combat the pandemic. Going forward, they can provide us with vital tools to re-open the economy and move forward beyond the pandemic safely.

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