SOLUTIONS TO EFFECTIVELY COMBAT COVID-19 IN RESTAURANTS

This white paper provides a review of possible approaches and technologies that may help reduce transmission risk of the coronavirus disease (COVID-19) in the restaurant industry. The information included in this white paper was prepared by industry experts at the global engineering design and consulting firm, EXP. The combined and collective expertise of our multidisciplinary engineers, our hospitality experts, our health care experts, and other supporting expertise provides insight into delivering effective solutions to the restaurant industry. The purpose of this white paper is to provide information about potential conventional and innovative methodologies to minimize the transmission of COVID-19. It is not intended to be a scientific brief; therefore, all references are provided at the end, along with a list of EXP experts who provided information and oversight to the paper.

As restaurant enthusiasts, multidisciplinary professionals and concerned members of our communities, we are committed to helping others develop a better understanding of the steps that can be taken to better protect our employees, our clients and their guests. The recommended preventative treatments outlined herein are ones we consider to be the most effective, at this time, to reduce and/or stop the spread of COVID-19 in restaurants.

EXECUTIVE SUMMARY

The Center for Disease Control and Prevention (CDC) has identified controlling risk as a critical factor in infection control (Centers for Disease Control [CDC], 2020). It includes a multilevel systems approach, with consideration to complex variations in transmission, people, the environment they interact in, efficiency and purposeful redundancy. Regarding COVID-19, there are four known possible paths of transmission:

(1) Directly via large droplets (e.g., emitted when sneezing or coughing or talking)
(2) Indirectly via surface contact when those large droplets fall out of the air and land on surfaces (e.g.., hand-hand, hand-surface, etc.)
(3) Transmission through small droplets that remain suspending in the air for hours (i.e., aerosolized virus)
(4) Fecal-oral transmission route (e.g.., water closet flushing)

To effectively reduce the risk of transmission, several measures for each path must be put in place. An effective plan should include purposeful redundancy based on the level of risk of that path. Fortunately, some measures will reduce the risk associated with all of the possible paths. For example, if a significant number of infected individuals are not permitted to enter a property, the risks for all paths are reduced. These strategies would include staff surveys, staff temperature checks, and even guest temperature checks.

EXP'S RECOMMENDATIONS AND STRATEGIES TO SIGNIFICANTLY REDUCE THE RISK OF TRANSMISSION OF COVID-19 IN RESTAURANTS

In addition to the CDC recommendations and overall measures like staff and guest temperature checks, additional engineering approaches to reduce the risk of transmission of COVID-19 in restaurants can be employed.

Primary direct path (large droplets):

- Separation (e.g., glass partitions between dining booths)
- Social distancing
- Protection of nose and mouth (e.g., staff face mask)

Indirect path (surfaces):

PRIORITY
- Personal hygiene and frequent handwashing
- Electrostatic spray applied disinfectant to all surfaces
- Frequent sanitation of high touch surfaces
- Employee to wear gloves at touchpoint activities
- Contactless payment systems
- Contactless doors and public facilities
- Separate "cash" payment station

Additional engineered system approaches to reduce risk
- Ionization in all HVAC systems
- Localized FaR-UV (Ultraviolet Light) on high-contact surfaces

Probable path (small droplets)

PRIORITY
- MERV 13+ air filtration
- High ventilation rates and airflow patterns that direct fresh air to and draw contaminants out of the breathing zone
- Negative pressurization from high-risk areas to low-risk areas
- Ultraviolet light (UVC) in all HVAC systems to capture and inactivate pathogens that are entrained

Additional engineered system approaches to reduce risk
- Localized supplemental High-Efficiency Particulate Air (HEPA) air cleaning systems in High occupancy areas (e.g., waiting areas)
- Upper Air UVC

Possible path (fecal-oral):

PRIORITY

- High ventilation rates and airflow patterns that draw contaminants to the water closets
- Negative pressurization from high-risk areas to low-risk areas
- Electrostatic Spray Applied Disinfectant
- Frequent sanitation of high touch surfaces
- Trap Primers and/or Trap Guards on all Floor Drains
- UVC in all HVAC systems to capture and inactivate pathogens that are entrained

Additional engineered system approaches to reduce risk

- Low exhaust at each WC
- Ionization
- Upper Air UVC units or WC stall FaR-UV with occupancy sensors and stall door interlock

In addition to the measures above, CDC guidelines should be followed to support the reduction of transmission. The above is not a complete or prioritized list. Each measure we take is a link to a chain that if effectively done can support the reduced transmission of COVID-19. Our team of experts believe these types of increased and robust efforts will help us create safer environments for all.

BACKGROUND

In January 2020, The World Health Organization (WHO) issued information on the large coronavirus outbreak in China. The virus responsible for the coronavirus disease (COVID-19) is Severe Acute Respiratory Syndrome Coronavirus 2 (*SARS-CoV-2)*. The Initial assumption by the World Health Organization and Centers for Disease Control and Prevention were that this new virus had transmission characteristics of similar type and magnitude to the virus SARS-CoV-1, which caused the global SARS outbreak in 2003 (The World Health Organization (WHO) 2020)). That outbreak subsided after nine months resulting in about 8,000 infected cases in 26 countries. Those cases occurred mostly in healthcare settings. By the end of January 2020, scientists determined COVID-19 had considerably higher human-to-human transmission rates. On February 16, WHO declared the COVID-19 outbreak a Public Health Emergency of International Concern (PHEIC). On March 12, 2020, WHO proclaimed COVID-19 a pandemic. At that time, there were more than 118,000 cases in 114 countries and 4,291 deaths. As of the middle of May 2020, nearly five million COVID-19 cases have been reported throughout 213 countries, with more than 320,000 deaths.

In the United States, the White House and prominent public health agencies have urged individuals and communities across the country to stay at home to prevent the spread of COVID-19. Many states have issued lockdown orders for their residents, with some easing into phased re-opening plans in May 2020.

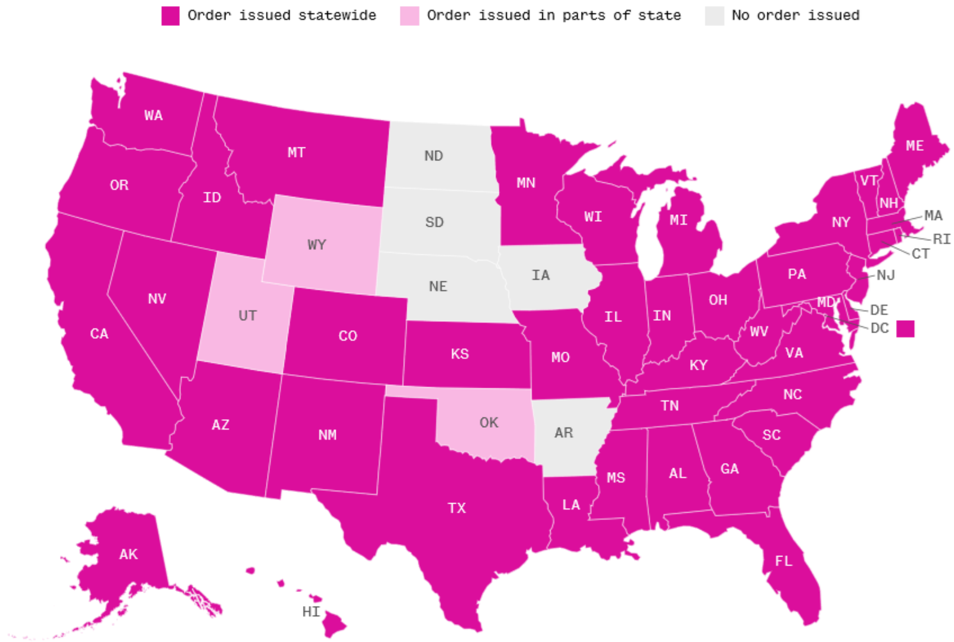

Figure 1. States that issued stay-at-home orders

With these orders requiring residents to stay indoors, except for essential workers or by following outlines issues by local and/or national guidelines, many businesses have been impacted and a significant financial crisis has ensued. As businesses look to reopen and maintain safe operations, many are asking what the future will bring. We are advising our clients to consider another important question:

What engineering interventions may be applied to minimize the spread of the disease?

TRANSMISSION PATHS

The size of a coronavirus particle is 80-160 nanometers, which is carried in droplets from affected individuals. SARS-CoV-2 reportedly remains active up to 3 hours in indoor air and 2-3 days on room surfaces at common indoor conditions. It is understood there are four main routes of transmission, including (1) directly via large droplets (i.e., droplets/particles emitted when sneezing or coughing or talking) and (2) surface contact (i.e., hand-hand, hand-surface, etc.,) when those large droplets fall out of the air and land on surfaces, (3) transmission through small droplets or aerosolized virus that can remain suspended in the air for hours and (4) the fecal-oral transmission route (i.e., water closet flushing).

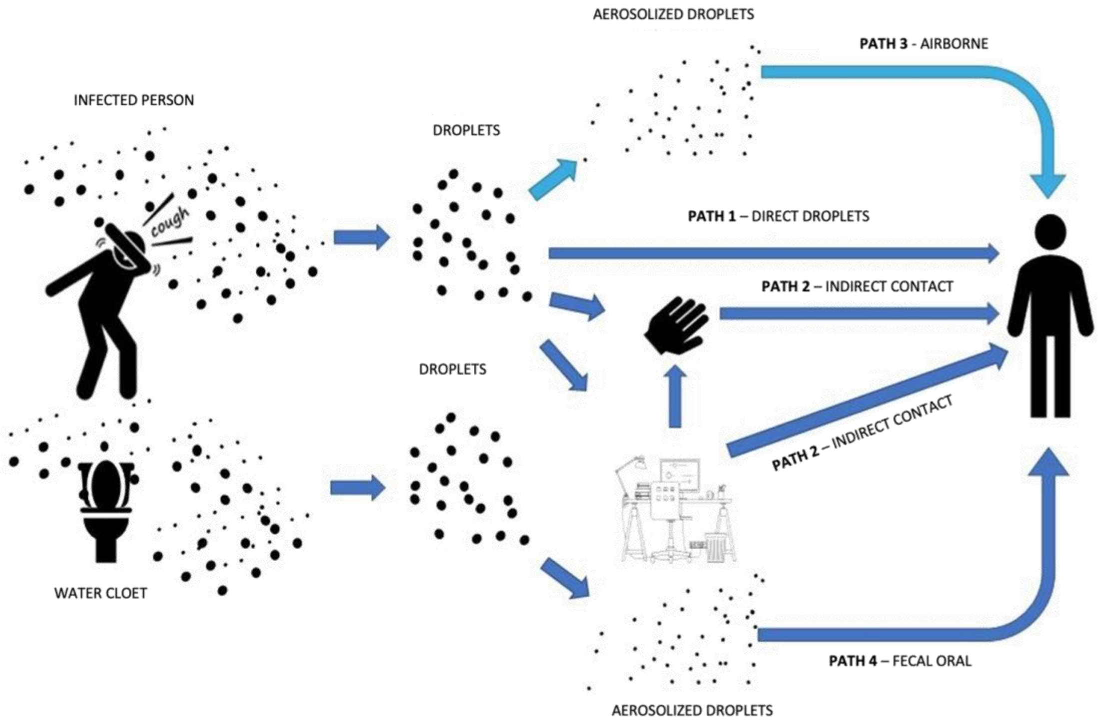

Figure 2. Possible SARS-CoV-2 transmission routes

1. **LARGE DROPLET DIRECT DISSEMINATION -** Close contact transmission is known to occur through large droplets (> 10 microns), which are released to an area six (6) feet from the infected person. Droplets are forcibly expelled when coughing and sneezing, though sneezing typically forms more particles. If people are standing within 6 feet of an infected person, they can contract COVID-19 directly by breathing in these droplets. General dilution ventilation and pressure differentials do not significantly influence this short-range transmission. Social distancing has been highly recommended due to the increased likelihood of contracting coronavirus from an infected individual in closer proximities.

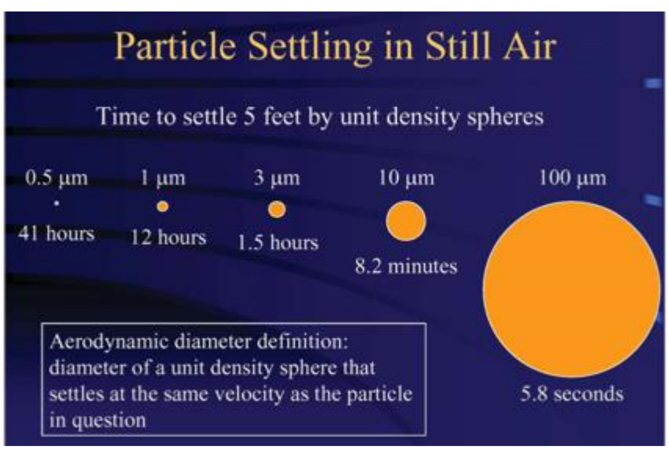

Figure 3. Comparative settling times by particle diameter for particles settling in still air

2. **INDIRECT SURFACE CONTACT DESSEMINATION -** Transmission of the virus also occurs via large droplets (> 10 microns) that fall on nearby surfaces and objects. People can then become infected by touching those contaminated surfaces or objects and afterward touching their eyes, nose or mouth.

3. **AEROSOLIZED AIRBORNE DISSEMINATION -** The CDC and other global health agencies have identified COVID-19 as primarily transmitted by person-to-person contact and by contact with virus-laden droplets expelled through coughing and sneezing (i.e., Paths 1 and 2 noted above). In addition, airborne transmission is possible through small expelled particles (< 5 microns), which may stay airborne for hours and can be transported long distances in airflows within a space. Small particles can also form from larger droplets that evaporate and desiccate (i.e., become aerosolized particles). It is known airborne transmission caused infections of SARS-CoV-1 in the 2003 outbreak. Airborne transmission has not been heavily documented for SARS-CoV- 2. However, it has been isolated from swabs taken from exhaust vents in rooms occupied by infected patients. This discovery implies that keeping six feet distance from infected persons might not be enough and additional measures including increasing the ventilation and filtration of the HVAC system is useful.

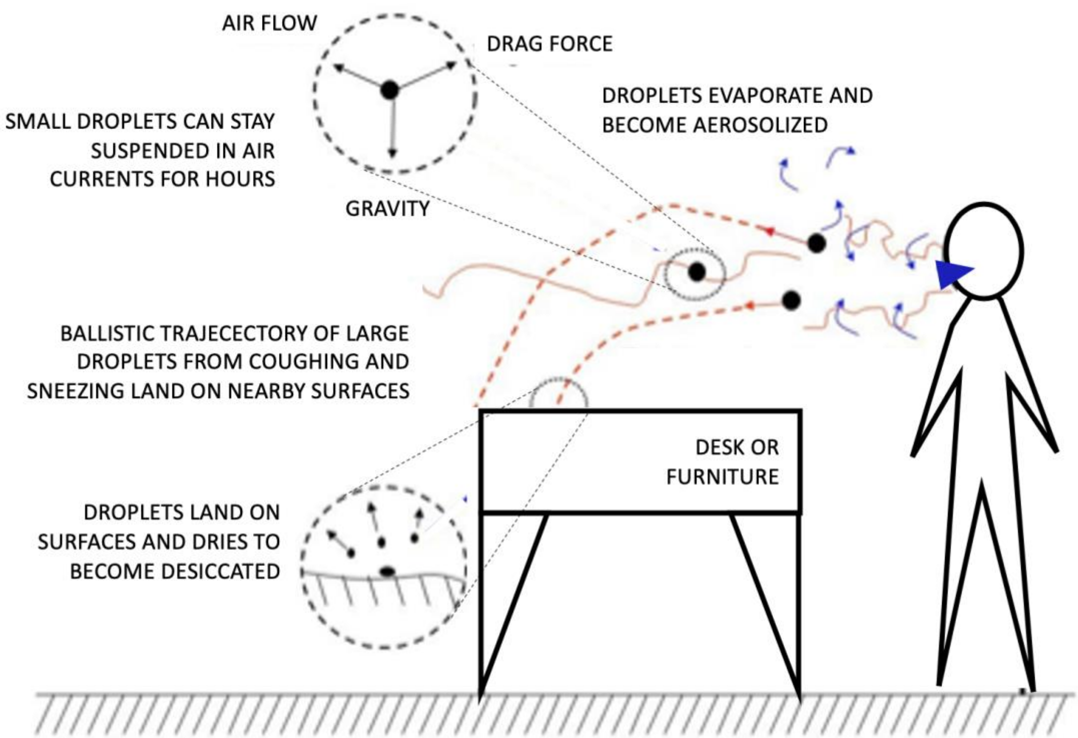

Figure 4. Transmission of droplets and small airborne particles produced by an infected patient.

While ventilation systems cannot interrupt the rapid settling of large droplets, they can influence the transmission of droplet nuclei in infectious aerosols. Directional airflow can create clean-to-dirty flow patterns and move infectious aerosols to be captured or exhausted.

4. **FECAL ORAL DISSEMINATION -** The fecal-oral transmission route for SARS-CoV-2 infections is implicitly recognized by the World Health Organization (WHO). This aligns with an observation during the SARS 2003 outbreak. Open connections with sewage systems were found to be the likely transmission route in the Amoy Garden apartment building in Hong Kong during that outbreak. SARS-CoV-2 has also been detected in stool samples (reported in *"Gastrointestinal Manifestations of SARS-CoV-2 Infection and Virus Load in Fecal Samples from the Hong Kong Cohort and "Systematic Review and Meta-analysis"* in Gastroenterology Journal).

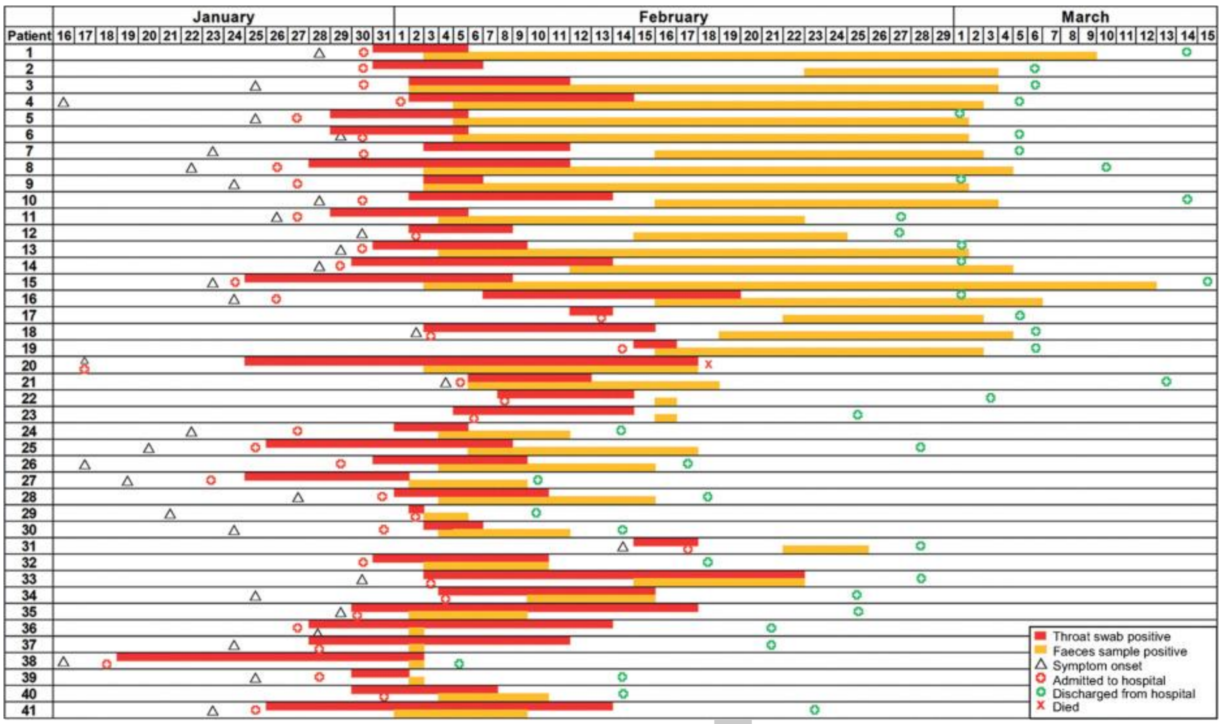

Figure 5. Timeline of results from throat swabs and fecal samples through the course of disease for 41 patients with COVID-19

When flushed with open lids, toilets create plumes containing droplets and droplet residue, referred to as a fecal cloud. These droplets can contain SARS-CoV-2 of an infected individual. The assumed conclusion is that fecal-oral transmission routes cannot be excluded as transmission routes and actions should be taken to protect our employees and guests.

PREVENTION

SKIN TEMPERATURE SCREENING

As businesses begin to open, it is becoming increasingly necessary for them to protect staff and guests. Initial COVID-19 symptoms vary, but the Centers for Disease Control and Prevention (CDC) says most people with a coronavirus infection will experience:

- Fever (83-99 percent).
- Cough (59-82 percent).
- Fatigue (44-70 percent).
- Anorexia (40-84 percent).
- Shortness of breath (31-40 percent).
- Sputum production (28-33 percent).
- Muscle aches (11-35 percent).

If these symptoms can be identified and potentially infected individuals can be kept out of facilities risks of transmission inside will be reduced. A method to screen for potentially sick individuals is by conducting an Elevated Skin Temperature screening (EST) at common checkpoints. In some countries, handheld infrared thermometers are used. However, this creates a point of contact between the tester and tested, which can result in the transmission of the virus if an infection is present. The contactless temperature reading option is a preferred method, which is where thermal imaging cameras can provide a safe solution.

Thermal imaging cameras were used as a screening method during the 2003 SARS outbreak in China, to some success. The camera would measure temperatures at the tear duct, which is close to the body's core temperature. If the measurement there is higher than an acceptable threshold, the screened individual is not admitted past the checkpoint. The entire process takes a few seconds.

A possible drawback to a thermal camera designed for commercial and industrial use is potential fluctuations of the subtle temperature fluctuations can indicate a false fever.

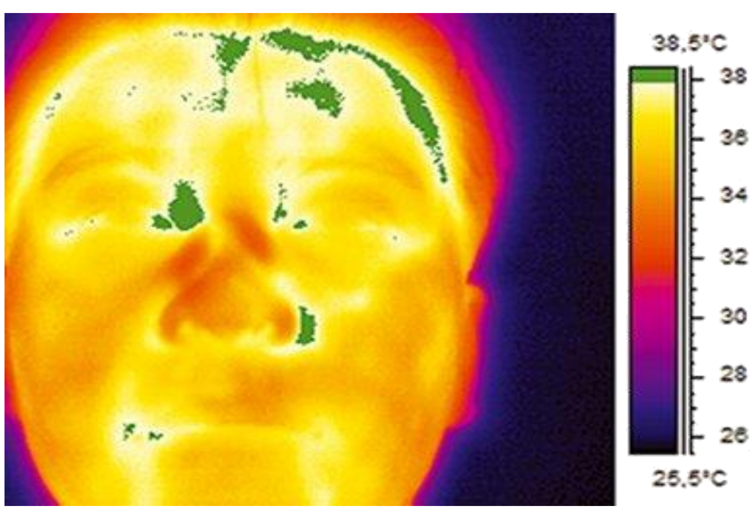

Figure 6. Example of someone exhibiting a fever via EST screening

FLIR, the leader in thermal camera technology in the US, has developed a line of cameras with a "screening mode" that calibrates a sampled average temperature and then measures individual screenings against that average, with an alarm set to alert when a screened individual falls out of an acceptable range.

FLIR indicated, "The Sampled Average Temperature should be updated through the screening operation period. By doing this, Screening mode helps account for many potential variations during screening throughout the day, including fluctuations in average person temperatures due to natural environmental changes, like ambient temperature changes. Screening mode reduces the need for absolute accuracy throughout the day and even self-calibrates to remove potential errors in absolute accuracy from camera to camera" (FLIR, 2020).

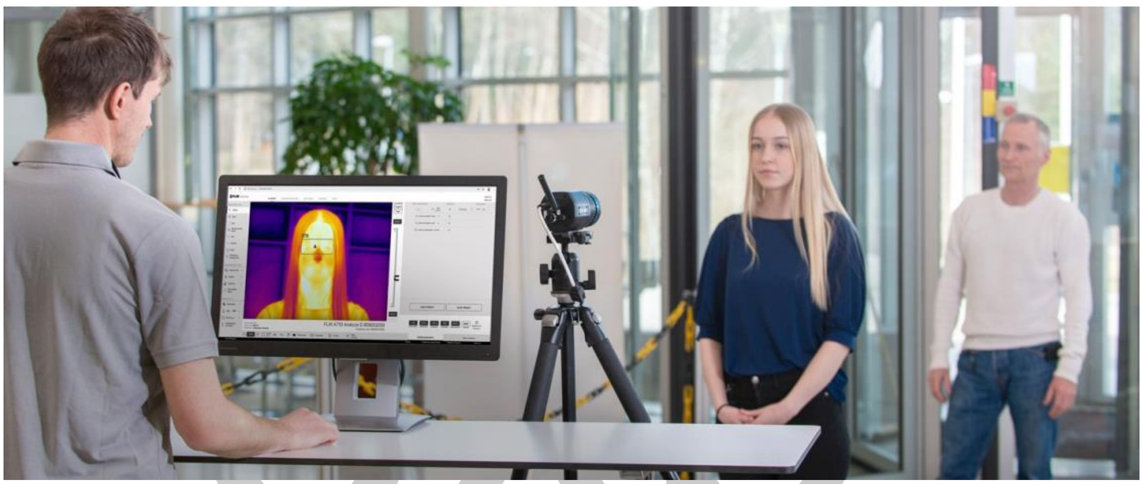

Figure 7. Example checkpoint utilizing EST screening protocols.

If the more sophisticated FLIR approach is outside your budget, simple thermal skin temperature devices can be used by staff to read temperatures of arriving guests. While the use of EST screening does not eliminate the possibility of admitting an infectious individual past a checkpoint, when combined with other measures of disease transmission mitigation, it is a first step in reducing transmission risk to guests and staff.

HUMIDITY

Indoor humidity appears to play a role in the transmission of viruses and resulting infections. The relative humidity of the air in a space affects both the ability of our lungs to fight the virus as well as how long the virus survives in droplets in the air. Researches of viral diseases have found very high humidity levels support viral spread as the virus can survive for longer periods of time on the surfaces, they may settle down on. Studies in mice found that an environment of 50% relative humidity contributed to good viral clearance and efficient immune response. Low humidity levels raise the following concerns:

- It has been found that low humidity makes it easier for airborne viral particles to travel.
- The hair-like organelles outside of cells that line the body's airways, called cilia, do not function as well in dry conditions.

- Studies have shown that "Dry air exposure of mice impairs epithelial cell repair in the lung after influenza virus infection" (Miyu, Hugentobler and Iwasaki, 2020).
- Wuhan, China researchers confirmed that respiratory infection was enhanced during unusually cold and low humidity conditions.

Studies also show that the viability of viruses in suspended aerosols and droplets is RH dependent (REHVA, 2020). These results suggest that environmental conditions have the potential to influence the transmission of certain pathogens by affecting their viability while they are transmitting between hosts. While bacteria survived better at humid conditions than dry conditions, viruses survived best at both low and extremely high RHs while experiencing greater decay at intermediate RHs. The difference in viability patterns suggests that different mechanisms may dominate the humidity-dependent decay of bacteria and viruses.

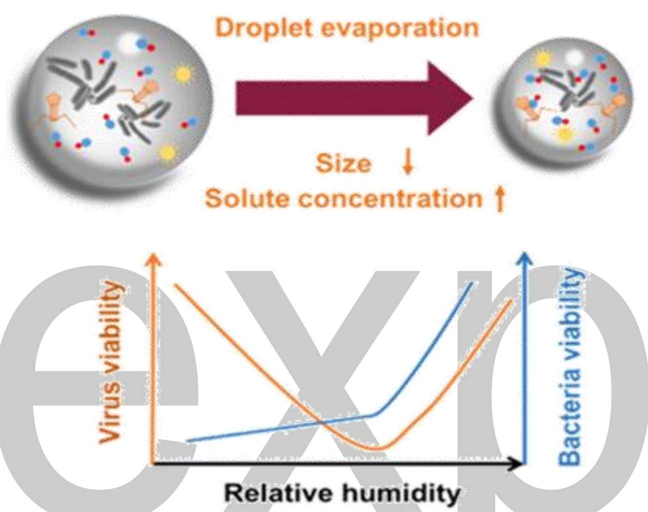

Figure 8. Humidity Dependent Decay of Viruses, but Not Bacteria, in Aerosols and Droplets

Consistent with the above findings, it is suggested that humidity levels in the space should be maintained at levels consistent with current design levels (50 to 60% RH). To provide preventative and responsive measures, it may be determined for space temperatures to shift to be warmer or colder to help maintain the space relative humidity within these goal boundaries. A strategy to allow higher or lower space temperatures could allow other beneficial changes to the HVAC system. For example, higher quality filtration and the associated increase in static pressures would force a lower airflow in an existing system. The change in space design temperatures would allow these lower airflows.

RISK REDUCTION

Infection control is about controlling risk. It includes a multileveled systems approach, with consideration given to complex variations in transmission, people, the environment they are in, and purposeful redundancy. SARS-CoV-2 has four known paths of transmission. We must prepare a plan to take adequate steps to reduce the risk of transmission with purposeful approaches and appropriate systems. The following sections review the known technologies that may help us reduce the associated risk with each path.

PATH ONE (LARGE DROPLET) TRANSMISSION

Air handling systems, general dilution ventilation and pressure differentials do not influence this short-range transmission of large droplets. Health organizations recommend social distancing as the only solution to reduce risk. Planners, architects and interior designers should be consulted to identify the best method to organize spaces and people. Emerging approaches that we all have seen at our local neighborhood grocery store may include partitions and/or glass barriers. In addition, it is now assumed cloth face mask may help reduce the size and number of droplets coming from infected individuals. Because of this, our employees wearing face masks will become a part of our new normal.

Figure 9. Creative social distancing solutions will be developed

PATH TWO (SURFACE CONTACT) TRANSMISSION

As virus latent droplets land on surfaces, those surfaces become the origin of transmission of this indirect path. Individuals touching these surfaces complete the path. PATH 2 transmission risks are significantly reduced by frequent washing with soap and water. If soap and water are not available, alcohol-based hand rubs can suffice. In addition, cleaning surfaces and/or somehow killing the virus that lay in wait on those surfaces, is part of this battle.

CHEMICAL SOLUTIONS

Routine cleaning of commonly touched surfaces with approved disinfectants is recommended. The Environmental Protection Agency (EPA) reviews the safety and efficacy of cleaners, disinfectants and sanitizing agents. EPA’s List N provides information about disinfectants that meet EPA’s criteria for Use Against SARS-CoV-2 (EPA, 2020).

ELECTROSTATICALLY APPLIED COATINGS - There are reports of success with a product that is adhered to surfaces electrostatically. Such an application method provides longer-lasting “kill” effects. It is reported some of the Quaternary Sanitizers can be applied in this manner. Many “quats” are on industry and university-published lists of agents effective against SARS-CoV-2. Proctor and Gamble and Gasco offer broad-spectrum quaternary sanitizers that are reported by the manufacturers to stay effective for prolonged periods. Our teams are currently exploring and becoming more familiar with the manufacturers’ recommendations for the products.

Consumers are more familiar with quaternary ammonium compounds as one of the ingredients in Clorox wipes. Bulk concentrate quaternary sanitizer is diluted to recommended strengths and used for sanitizing food services and glassware after rinse cycles as well.

PESTICIDAL DEVICES

Pesticides are commonly thought of as chemicals. These are regulated by the EPA among other agencies. The EPA also has a role in regulating devices used to control pests. Per the EPA, a pesticide device is an instrument or contrivance that is used to destroy, repel, trap or mitigate (lessen the severity of) any pest such as insects, weeds, rodents, certain other animals, birds, mold/mildew, bacteria and viruses (EPA, 2020). The EPA indicates it does not routinely review the safety or efficacy of the “pesticidal devices” that don’t use chemical pesticides, and therefore cannot confirm whether, or under what circumstances, such products might be effective against the spread of COVID-19. For these devices, the EPA refers readers to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA is a federal law that sets up pesticide regulation to protect applicators, consumers, and the environment. It is administered and regulated by the EPA and state environmental agencies. Pesticidal devices, while not required to be registered with EPA, are subject to certain regulatory requirements under FIFRA, including labeling and reporting requirements. As expected, the rapid progression of this pandemic’s events has outpaced regulatory agencies’ ability to react to new offerings on the market. Unless we are familiar with underlying technologies and pesticidal devices, we will not recommend their use if they have not been approved by federal agencies.

In the following section, we investigate the opportunities available to us that may affect the virus that has settled out on surfaces in the buildings we work, live and play (i.e., PATH 2). The options include:

- Heat
- Hydrogen Peroxide: Portable and Full Facility Systems
- UV
- Ionization
- Ozone

HEAT

There is evidence that high temperatures will inactivate the SARS-CoV-2 virus. Preliminary reporting from a study done in France tested samples for inactivation of SARS-CoV-2 for use by laboratory personnel in lab settings. The study found that a temperature of 198°F for 15 minutes completely inactivated the virus. Testing at 140°F for 30 minutes and 133°F for 60 minutes did not completely inactivate the virus but did result in a clear drop of infectivity. It is noted in the study, "*Considering that low SARS-CoV-2 viremia is observed in COVID-19 patients even at the acute stage of the disease, the 133°F and 140°F protocols appear sufficient for inactivating SARS-CoV-2*" (Pastorino, Touret, et al. 2020). While this study was performed to make sample safe for studying in lab environments, the data could be carried over to treating spaces that may have been occupied by infected individuals.

It is not practical to heat a typical space such as a guest room to 198°F but is possible to heat it up to 140°F. In fact, a typical treatment for bed bugs in guest rooms is inserting temporary heaters in the room to heat them up near this temperature for up to 4 hours. One option is to use the same portable heater on an as-needed basis to assist in protecting employees while cleaning a space. However, another option is to enhance the heating capacity of the HVAC system so that it can heat the room to 140°F for a longer time period. For example, in a hotel, the HVAC system could be programmed to heat the room automatically once the guest has checked out.

The benefits and concerns to be considered with this approach are listed below.

BENEFITS

- Inactivate the virus with no residual effects
- Also kills bed bugs

CONCERNS

- Possible furniture delamination
- Significant energy use
- Shortens fire sprinkler head life

HYDROGEN PEROXIDE

PORTABLE H202 DECONTAMINATION SYSTEM - Hydrogen peroxide decontamination systems have been used to disinfect and sterilize hospital patient rooms, clean rooms, biopharmaceutical manufacturing areas, ambulances, police cruisers, medevac helicopters, etc. for over two decades. During this time, these systems have become more prevalent, resulting in an increased number of manufacturers making units of different sizes, capacities and features, thus reducing cost. The systems can be very mobile, moved with a hand cart and places inside ambulances, cruisers and helicopters. Additionally, independent service companies have emerged on the market that performs these services without the need for owners to have to purchase and/or train their own staff, if not desired. From a turnover perspective, hotel rooms have a similar dynamic as hospital patient rooms, with the need for cleaning between guests.

Figure 10. Curis Hydrogen Peroxide Decontamination Device

Hydrogen peroxide is a manufactured chemical, although small amounts of it occur naturally in the air. It is a colorless liquid at room temperature with a bitter taste. Hydrogen peroxide is not considered a carcinogen but can still be harmful to humans. During the decontamination process, all people must be outside the room. Additionally, room supply and exhaust grilles should be closed during treatment to maintain effectiveness.

Hydrogen peroxide is unstable, decomposing readily to oxygen and water with the release of heat. Although nonflammable, it is a powerful oxidizing agent that can cause spontaneous combustion when it encounters organic material. Hydrogen peroxide is an oxidizing agent that produces hydroxyl radicals that kill microorganisms by disrupting DNA, membrane lipids and other critical cell structures.

This decontaminating technology is designed to project either dry mist, noncondensing or condensing vapor onto rooms surfaces over a specified time period. The two methods below have competing pros and cons. The vaporized solution uses a higher concentration of hydrogen peroxide while the aerosolized solution uses less but requires additives (Boyce J. M., 2016).

- Vaporized hydrogen peroxide: 30% H_2O_2. Shown to be effective against a variety of pathogens, including *Mycobacterium tuberculosis, Mycoplasma, Acinetobacter*, *C. difficile*, *Bacillus anthracis*, viruses and prions.

- Aerosolized hydrogen peroxide: 3-7% H_2O_2 with or without the addition of silver ions. Particle size ranges from 2 to 12 micrometers. Generally, a 4log10 reduction of bacteria spores. No randomized controlled studies to test the efficacy.

The disinfecting and sterilizing process involves three phases. First is the disinfectant/sterilant dispersal phase, followed by the dwell time phase. The third phase called aeration is needed to reduce hydrogen peroxide concentration levels below regulated levels. As stated above, no one should be in the room when the disinfecting process is occurring. Some equipment manufacturers have solutions with built-in carbon filters that when the aeration process begins, can speed the process along by drawing air through an onboard carbon filter. Manufactured equipment solutions have become more sophisticated with some having on-board controls that look for inputs such as room size, pathogen involved, and it will determine the duration of all three phases and let the operator know when complete.

The time to complete all three phases depends on the manufacturer, with additional consideration for equipment cost. Patient room decontamination times have been reported from four hours down to 45 minutes. High demand hospitals desire quick turnaround of their patient rooms.

An alternative to hydrogen peroxide decontamination systems is the manual wipe down method using hydrogen peroxide wipes. Proponents of the automated systems claim the manual approach has practical challenges, some listed below;

- Not all surfaces targeted
- Human error with targeted surfaces
- Not targeting all surfaces leaves reservoir of pathogens in the space
- Training and oversight may prove daunting and difficult to sustain
- A clean surface does not necessarily equate to a pathogen-free surface.

Hydrogen peroxide decontamination systems have been an accepted technology in hospitals for years, and studies proven reduced patient-to-patient contamination over detergent wipe down and hydrogen peroxide wipe down. A variety of equipment solutions and service providers exist in the market making this a viable solution when there is a clear demarcation of when space is no longer in use and is to be prepared for the next user. As discussed above, this is ideal for patient rooms and vehicles, and therefore hotel guestrooms as well. Continuously occupied spaces such as casinos, or large occupancy spaces such as theaters and restaurants appear to be less suited for this technology.

Regarding the portable HP systems, we see the following benefits and concerns:

BENEFITS

- Existing market of vendors with trained staff.
- Complete and uniform surface coverage
- Can be moved from room to room
- Immediate confirmation via test strips that surfaces have been covered

CONCERNS

- Requires trained staff if not subcontracted out
- Spaces must be aerated afterward to remove the risk to personnel
- Portable systems may not be scalable for large areas.
- Unknown effect on fabrics (unintentional discoloration)

CONTINUOUS H2O2 DECONTAMINATION SYSTEM - Clean Air and Surface Pathogen Reduction (CASPR) is a device that can be inserted into HVAC systems for the continuous disinfection of the target spaces. Titanium Dioxide Photocatalytic Oxidation or TiO2 PCO is a titanium dioxide photocatalytic air purifier that uses ultraviolet light and a TiO2 catalyst to convert molecules of pollution into more harmless substances. Manufacturers have indicated standard TiO2 PCO approach does not affect viruses; however, the ultraviolet light used in the process does. However, the CASPR device creates an oxidation reaction through photocatalysis with Titanium Dioxide (TiO2) and an additional proprietary “undisclosed” coating. It is reported during the CASPR reaction, water molecules from the humidity in the air and oxygen form Hydroxyl Radicals (OH-), Oxygen Ions (O2) and Hydrogen Peroxide (H2O2).

Figure 11. CASPR device inserted in ductwork.

CASPR indicates their special coating creates safe concertation of hydrogen peroxide to disperse throughout the rooms on the system which reduces dangerous pathogens on all surfaces. It is noted, 1 ppm is the 8-hour TWA limit set by OSHA for hydrogen peroxide concentrations, but the concentration of hydrogen peroxide produced from CASPR is below the limit at 0.01-0.03 ppm. Testing with these low levels provided by this product has shown microbial burden reductions ranging from 91% to over 99.998% depending on the agent. CASPR notes, the Influenza A (H1N1) virus was reduced over 99.93% during a controlled experiment (Garcia, 2019).

While it is known hydrogen peroxide in the right concentrations kills SARS-CoV-1, CASPR has not been tested for SARS-CoV-2, so its effectiveness for our goals has not been yet proven. If it is proven effective, the main attraction of the CASPR technology would be that it is no-touch and works continuously. There would be no staff training required; the modules are just placed in the ductwork depending on the area they are disinfecting. It can be installed in new or existing HVAC systems. This could provide thorough disinfection of the entire space to help mitigate the spread of diseases and infections.

BENEFITS

- Continuous disinfecting
- Disinfects all surfaces, including some that may be missed during traditional cleaning
- No training required

CONCERNS

- Not much is known about the PCO technology with CASPR's new "secret" coating
- Not yet proven to kill SARS-CoV-1 or SARS-CoV-2

ULTRAVIOLET LIGHT / FAR UV SURFACE TREATMENT

Conventional germicidal Ultraviolet Light (**UVC)** has a lost history of being an effective solution to killing viruses. These lights have been used in laboratories and hospital operating rooms to sanitize surfaces. Biological safety cabinets that are used in the lab setting to test viruses and find cures are enclosed hoods that utilize UVC to kill viruses and other pathogens when not in use. The disadvantage of this type of light is that it is a safety hazard in occupied spaces since it causes skin cancer and eye damage (Kobe University, 2020). This light has a wavelength of approximately 240-300 nanometers. UV light in this wavelength penetrates the outer layer of the skin and eyes and does damage which may lead to cancer or other health issues (Wallace 2018). Recent research has yielded a newer UV technology, Far-UVC Light, which in studies has proven not to penetrate our skin or get through the outer layer of the eyes.

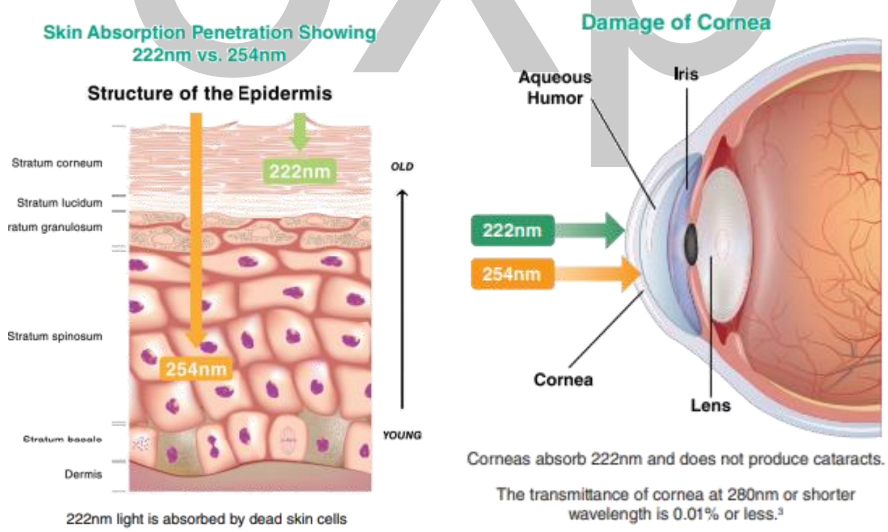

Figure 12. Difference in UV Wavelengths

FAR-UV LIGHT – Far-UVC light is safe for people but lethal for viruses (Columbia University Center for Radiological Research, 2020). Far-UVC can penetrate and kill viruses floating in the air and on surfaces. It is effective in killing H1N1 influenza viruses as well as other strains of influenza. The effectiveness of Far-UVC's on SARS-CoV-2 is promising but currently unproven. If research can confirm that far-UVC light can effectively kill coronaviruses, lights could be deployed anywhere people congregate, including casinos, hotels, restaurants, bars, hospitals, airports, train stations and airplanes.

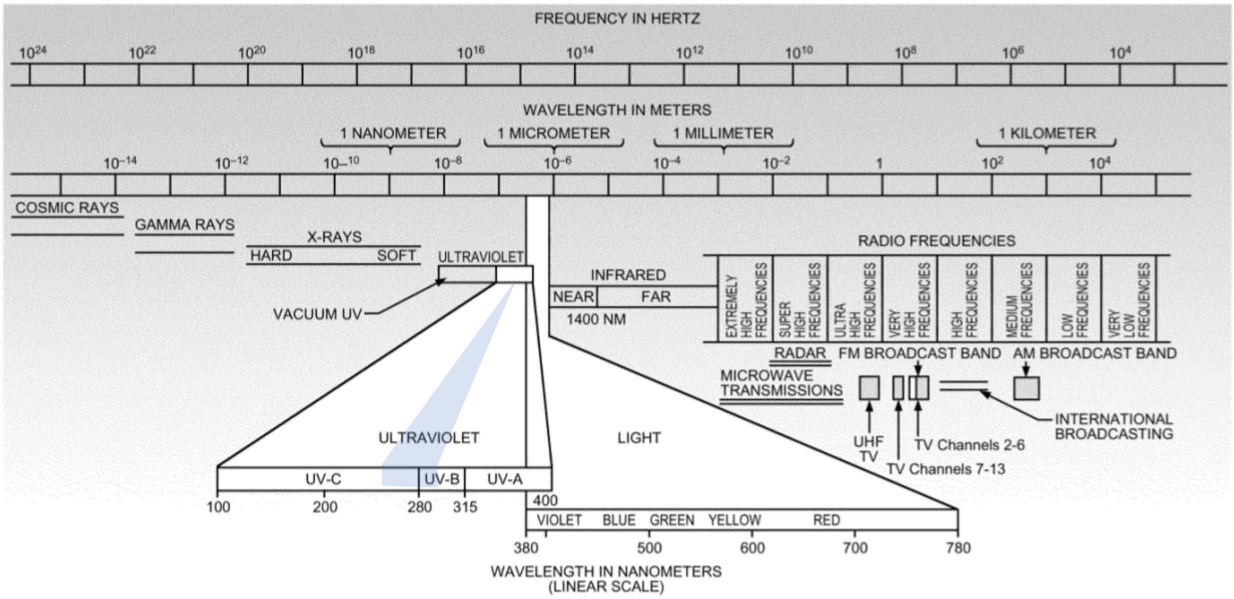

Figure 13. Electromagnetic Spectrum

Many companies have developed electromagnetic spectrum lamps and are incorporating them into conventional light fixtures. As this technology is further developed into existing and new products, there are many applications that will make buildings a safer place. Whether integrating into hand washers, in ceiling light fixtures or public restrooms, UV may become a promising tactic in a building's fight against airborne viruses and bacteria (Cantor, 2020).

Figure 14. Far-UVC Applications

UVC LIGHT WAND DEVICES - UV based solution for PATH 3 airborne particles are discussed in additional detail later. For surface disinfection, newer handheld devices are becoming widely available. Housekeeping staff in hotels can use these devices for high touch areas in guest rooms, and restaurant staff can utilize them to sanitize tables and menus between customers.

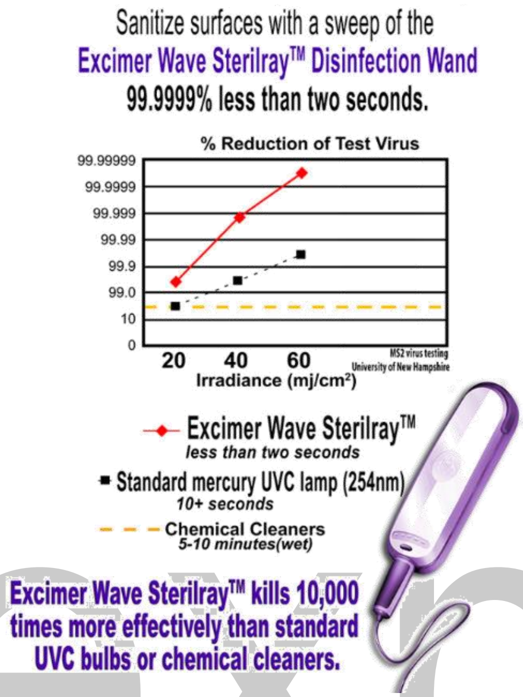

Figure 15. Far-UVC Handheld Wand

The benefits and concerns with this UV surface treatment are as shown below.

BENEFITS

- Inexpensive
- Effective when used correctly
- Quick, space is occupiable immediately

CONCERNS

- Dangerous for humans
- UV requires line of sight, necessitating rotation of surfaces
- Shadows lesson effectiveness
- No confirmation of disinfection
- Potential human error

BI-POLAR IONIZATION

Ions are present naturally in the air. They are found in the highest concentrations where the ocean meets the shore and high elevation in the mountains. The bi-polar ionization (BPI) process artificially creates the ions found in these desirable locations and supplies them into the building, enhancing the indoor air quality.

- Waterfalls/Elevation – 5,000 ions/cc
- City – 200 ions/cc
- Inside Buildings - <100 ions/cc

Bi-polar ionization (BPI) first arrived in the US in the 1970s as a tool to control pathogens in food manufacturing. Since that time its use has expanded into HVAC systems for many different building types. BPI has been touted as a system that could be used to reduce outside air rates in buildings without compromising indoor air quality (IAQ), thus still saving energy.

At EXP, we use bi-polar ionization in all our casino HVAC designs where smoking is allowed within facilities to keep contaminants from compromising non-smoking spaces. In addition, we have used this technology in hotel rooms to improve IAQ within those guestrooms. Today we are exploring the idea of using BPI technology to control/kill viruses in the air and on surfaces. Although every BPI manufacturer may claim that their technology is special, we believe that there are only two main types of BPI: tube type and needlepoint.

Tube type bi-polar ionization is created when an alternating voltage source (AC) is applied to a special tube with two electrodes. When voltage is applied to the tubes' electrodes an invisible ionization field is produced around the tube resulting in "mountain air" freshness. These ions occur naturally, especially on mountain tops and waterfalls, where the production of both positive and negative ions purify the air. The HVAC system distributes the energized ions into all spaces served by the duct system in an in-duct installation or into the application space if a standalone system is used.

Figure 16. Tube type Bi-Polar Ionization Examples

Needle point bi-polar ionization (NPBI) does not use a dielectric tube, but rather electrodes or needles made from carbon fiber, titanium, silver, gold, stainless, or other corrosion-resistant, conductive materials (Waddell 2019). These needles are charged with power that is specifically controlled to stay under 12.07 eV (electron Volts). NPBI generates both positive and negative ions similar to a tube type system. The ions have a life span of approximately 60 seconds. This lifespan gives the ions time to travel with the airflow in ductwork to get to the occupied space(s). Below are some examples of NPBI devices.

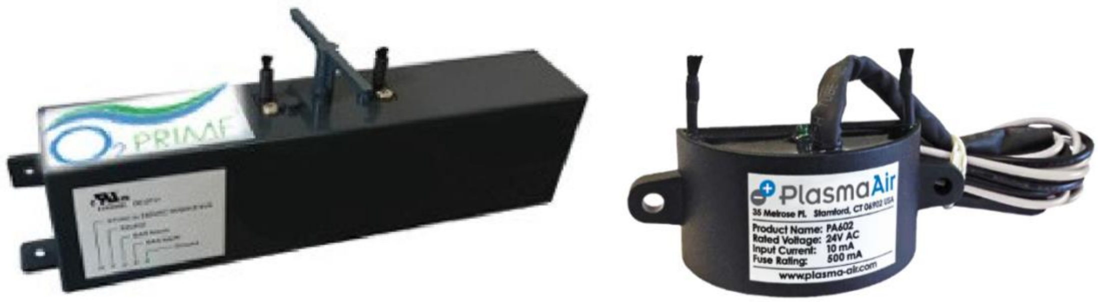

Figure 17. Needle Point Bi-Polar Ionization Examples

In both types of BPI, the ions produced cause some particles to become positively charged and others to become negatively charged. Since opposite charges attract, these particles become magnets and start sticking to one another, called agglomeration. As the particles become bigger, they gain surface area and mass. This particle growth enables them to either fall out of the air to the ground or is pushed back to filters in the HVAC systems where they become trapped. Multiple sources state that using a MERV 8 filter along with bi-polar ionization is the equivalent of using a stand-alone MERV 13 filter. This filtration improvement equates to fan energy savings and filter replacement cost savings.

The ions produced also break down pollutants or gases and turn them into ordinary compounds or molecules already prevalent in the atmosphere like oxygen, nitrogen, and carbon dioxide. Some common gases or VOCs that are impacted by BPI include formaldehyde, ammonia (think body odor), and cigarette smoke. This is a case where the technology is considered to attack SARS-CoV-2 provides notable additional benefits to the indoor environment.

Our current interest in this technology is because ions are attracted to pathogens. When the ions combine on the surface of a pathogen, they rob the pathogen of the hydrogen bonds necessary for them to survive (Haiken, 2020). During the final step of deactivation, the ions eliminate hydrogen from the pathogen, making the airborne virus inactive or non-viable. Substantial testing to confirm the kill rates of various pathogens has been performed. Below is a chart that shows the results of testing that has been completed by various 3rd party, independent testing firms.

Table 1. Table indicating kill rates for previous viruses with bi-polar ionization

PATHOGEN	TIME IN CHAMBER	KILL RATE	TEST AGENCY	NOTES
TB	60 minutes or less	69.09%	EMSL	The kill rates are indicative of those in the entire space
C. difficile	30 minutes or less	86.87%	EMSL	
Norovirus	30 minutes or less	93.50%	ATS Labs	
MRSA	30 minutes or less	96.24%	EMSL	90% of MRSA reduction will occur every 24 minutes
Mold Spores	48 hours or less	99.50%	GCA	
E. coli	15 minutes or less	99.68%	EMSL	
Legionella	30 minutes or less	99.71%	EMSL	
VRE	15 minutes or less	43.78%	EMSL	Bacterium that can live on catheters and surfaces can cause infections
VOCs	Less than 2 hours	99.9%	Field tested	

Device manufacturers do not have access to the COVID-19 virus for testing purposes but have successfully tested against other viruses. Dr. John Oxford, a virologist and professor at the Institute of Cell and Molecular Sciences at The Royal London Hospital, states that BPI has proven to be effective against several viruses: H1N1 influenza, H5N1 avian influenza (bird flu), and corona. The mechanism by which BPI inactivates airborne viruses is that the bipolar ions surround the hemagglutinin (surface proteins that form on organisms and trigger infections) and change into highly reactive hydroxyl radicals. The ions destroy the virus surface structure, in the case of coronavirus the spikes, on a molecular level. As a result, the virus cannot cause infection, even if it enters the body.

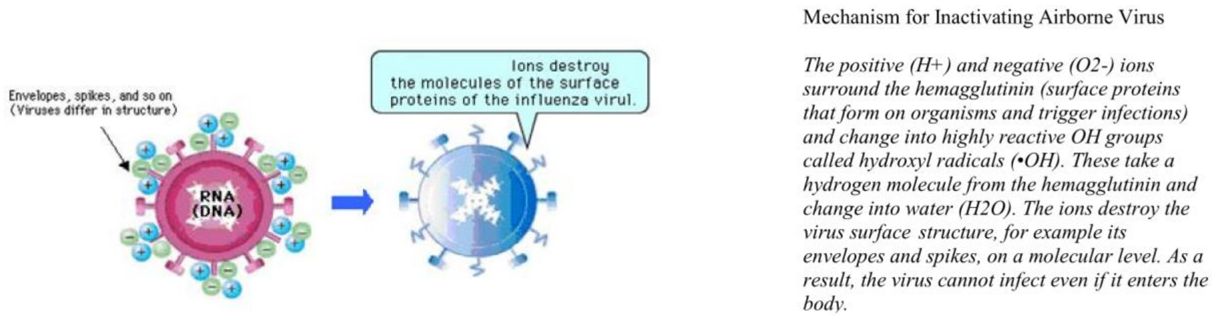

Figure 18. Positive and Negative Ions Destroying Surface Proteins of a Virus

BPI effectiveness is based on the number of ions in the space. BPI manufacturer Plasma Air states that the target air purifying ion density is 1,000 ions/cc in the space. Extrapolating that for a sample air handling yields the following design criteria:

2,400 CFM = 40 ft^3/sec
40 ft^3/sec = 1,132,674 cm^3/sec.
@ 1000 ions/cc yields <u>1.13 billion ions/sec</u>

The controversy that surrounds BPI technology is discussions around the possible product ozone. In elevated quantities, ozone can be harmful to human organ tissue (i.e., lungs). Both the tube type and needlepoint manufacturers argue that their technologies comply with all governmental guidelines (summary shown below).

Table 2. Acceptable Indoor Ozone Levels per Different Regulatory Groups

TABLE B-1 Comparison of Regulations and Guidelines Pertinent to Indoor Environments[a]

(The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

	Enforceable and/or Regulatory Levels			Non-Enforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. B-4)	OSHA (Ref. B-5)	MAK (Ref. B-2)	Canadian (Ref. B-8)	WHO/Europe (Ref. B-11)	NIOSH (Ref. B-13)	ACGIH (Ref. B-1)
Carbon dioxide		5000 ppm	5000 ppm 10,000 ppm [1 h]	3500 ppm [L]		5000 ppm 30,000 ppm [15 min]	5000 ppm 30,000 ppm [15 min]
Carbon monoxide[c]	9 ppm [g] 35 ppm [1 h] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 h] 25 ppm [1 h]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 h] 10 ppm [8 h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm[i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081 ppm) [30 min][p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 $\mu g/m^3$ [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 $\mu g/m^3$ [1 yr]	0.050 mg/m^3	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 h]	0.1 ppm[1 h] 0.02 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 h][g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 h]	0.064 ppm (120 $\mu g/m^3$) [8 h]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm[m] 0.2 ppm[n]
Particles[e] <2.5 μm MMAD[d]	15 $\mu g/m^3$[1 yr][o] 35 $\mu g/m^3$ [24 h][o]	5 mg/m^3	1.5 mg/m^3 for <4 μm	0.1 mg/m^3 [1 h] 0.040 mg/m^3 [L]			3 mg/m^3 [C]
Particles[e] <10 μm MMAD[d]	150 $\mu g/m^3$ [24 h][o]		4 mg/m^3				10 mg/m^3 [C]
Radon				800 Bq/m^3 [1 yr]			
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 h][g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total Particles[e]		15 mg/m^3					

The benefits and concerns with this approach are as follows:

BENEFITS

- Total Indoor Air Quality Improvement
- Minimal first cost and maintenance cost
- Easy to retrofit into an existing system
- Known to kill past airborne viruses similar to SARS-CoV-2

CONCERNS

- Concerns with ozone as a by-product

OZONE

Ozone is a naturally occurring gas created from oxygen atoms. While ozone creation is a possible negative side effect of BPI, as discussed above, ozone treatment is also a stand-alone technology generating interest during this COVID pandemic. Ozone therapy is effective at breaking a virus down, therefore, you can eliminate the virus in the lungs before causing substantial harm to the patient.

While EXP does not utilize ozone in our systems because of health concerns, it is an effective solution for targeted environments. Ozone can be an effective solution to clean cigarette smoke out of smoking casinos. A manufacturer, Casino Air, has a system to deliver ozone through the HVAC systems and keep the concentration down below the regulated levels. In addition, many hoteliers have ozone generators in their toolbox to fight odors in their hotel rooms.

Figure 19. Typical Ozone generator found in hotel operations.

The promising part is Ozone gas has been proven to effectively destroy the SARS-CoV-.1 Ozone destroys enveloped viruses by diffusing through the protein coat into the nucleic acid core, resulting in damage to the viral RNA. At higher concentrations, ozone destroys the capsid or exterior protein shell by oxidation. Coronaviruses are an enveloped virus. Since the structure of the new 2019-nCoV coronavirus is almost identical to that of the SARS coronavirus, we can assume that ozone will likely work just as well on the new coronavirus. The level of ozone concentration required to be effective and achieve over 95% morbidity rates of viruses and other disease-causing agents varies depending on the time the agents are exposed to the ozone. Ozone concentrations of approximately 100 ppm are very effective to kill infectious agents and may require exposure times for as little as 10 to 15 minutes. Lower ozone concentrations as low as 20 ppm were also found effective, although, more time would be required (such as 30 to 70 minutes) for the ozone to be effective.
Unfortunately, studies have shown even at these high concentrations, ozone may have no effect on biological contaminants embedded in porous material such as duct lining or ceiling tiles. However, SARS-CoV-1 naturally breaks down in porous surfaces more quickly than on hard surfaces. SARS-CoV-2 has been found to react similarly.

For ozone to be effective against the virus, it must be used at concentrations that exceed public health standards. Ozone is very dangerous to humans. It can destroy cells lining the mouth, nasal pathways and lungs. It can cause cell mutations and cancer. And for those with other underlying disease, even brief exposure to it can be dangerous. The National Ambient Air Quality Standard allows for ozone concentrations of up to 75 parts per billion over an eight-hour period. A new study found that 6.6 hours of exposure to mean ozone concentrations as low as 70 parts per billion have a significant negative effect on lung function. Hence an HVAC based ozone system would be of little use. As with portable hydrogen peroxide disinfection devices, portable ozone systems such as those employed by hotels would be more effective and may be an option is used by qualified personnel in temporarily unoccupied and subsequently ventilated spaces.

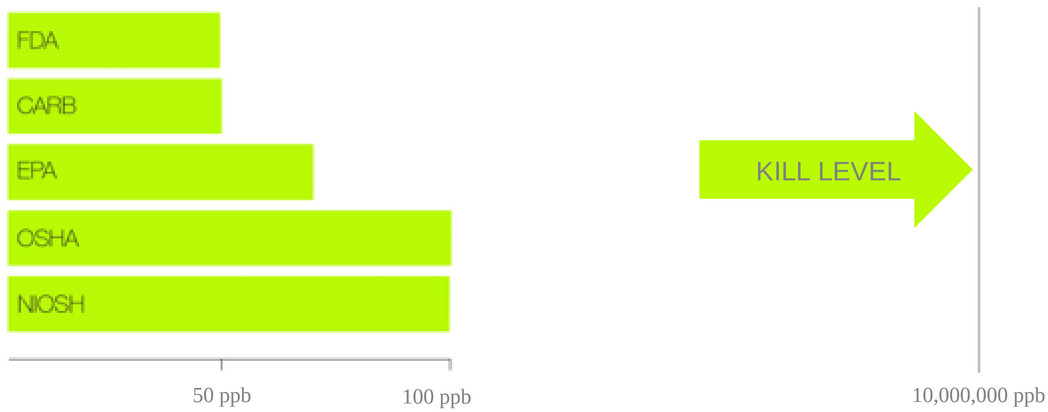

Figure 20. Indoor Ozone standards by Government Agency

Often the vendors of ozone generators make statements and distribute material that leads the public to believe that these devices are always safe and effective in controlling indoor air pollution. Health professionals have consistently refuted these claims. While few vendors suggest that these devices have been approved by the federal government for use in occupied spaces, our research has established that no federal agency has approved these devices for use in occupied spaces.

The benefits and concerns with this approach are as shown below.

BENEFITS

- Kills everything at high enough levels

CONCERNS

- Dangerous for humans at very low levels
- Can break down inorganic materials like plastics if exposed too long.

TOUCHLESS OPTIONS

All of the Path 2 options above focus on making surfaces safer to touch. Understanding that we can achieve huge reductions in risk by eliminating the need or frequency in which staff and guests touch common surfaces makes touchless options a high value solution.

DOORS - The general public and everyday businesses recognize that doors and door hardware are surfaces that are likely laden with germs of all types. Individuals can be found pushing doors open with their bodies or attempting to use their elbows to pull on handles, and doors that are typically closed are sometimes propped open with doorstops to allow customers and staff touch-free access. It follows that engineered solutions should be implemented during design as well as retrofit into buildings wherever possible. Many larger public restrooms are already designed with vestibules and no doors to facilitate freer movement in and out of the spaces. Where spaces have doors, sight lines can be evaluated to see if doors can be removed or held open (with overhead hold-opens rather than doorstops.) Actuators on hinged and revolving doors should be included where possible. At a minimum, hands-free manual opening of doors can be retrofit most anywhere.

Figure 21. Install door pulls wherever possible

RESTROOMS - Flush valves, lavatory faucet handles, towel dispensers, and ironically even soap dispensers are possible contamination points we all encounter daily. Automatic flush valves should be a given in public spaces in the current environment. Automatic lavatory faucets can provide the safety measure of avoiding surface contact and also be set up to deliver the 20 seconds of hand washing time recommended to kill the virus. Several manufacturers offer automatic soap dispensers combined with faucets, or even automatic faucets with built in hand dryers.

Figure 22. Hands free faucets will become more relevant

PATH THREE (AEROSOLIZED AIRBORN) TRANSMISSION

The CDC notes SARS-CoV-2 is primarily transmitted by person-to-person contact and by contact with virus-laden droplets expelled through coughing and sneezing (i.e., PATH 1 and 2 noted above). However, it is known airborne transmission caused infections of SARS-CoV-1 in the 2003 outbreak. It is likely COVID-19 is also transmitted via this transmission path. The good news is ventilation systems can influence the transmission of droplet nuclei in infectious aerosols.

American Society of Heating, Refrigeration and Air-Conditioning Engineers or ASHRAE's Epidemic Task Force has issued guidance on managing the spread of SARS-CoV-2 regarding the operation and maintenance of HVAC systems in buildings. ASHRAE officially opposes any advice not to run commercial HVAC systems (AHRAE, 2020). ASHRAE asserts that keeping air conditioners on during this time can help control the spread of the virus. It is recommended systems are re-programmed to operate 24/7 if they are not already doing so.

ASHRAE also recommends the employment of HVAC filters and other strategies that help to reduce virus transmission while removing other air contaminants. However, some strategies to reduce aerosol airborne dissemination of viruses at the air handling system may not be possible without impacting existing HVAC system capacities. Modifications to existing HVAC systems may not be possible if there is a goal to keep space design temperatures and relative humidity the same as the pre-pandemic goals. Possible modifications to HVAC systems that will help reduce PATH 3 transmission risk include the following:

INCREASED VENTILATION

ASHRAE recommends the continued operation of all HVAC systems. Outside air for ventilation should be increased to as much as the HVAC system can accommodate and still maintain acceptable indoor conditions during occupied hours. Special flushing control sequence should be implemented to operate the HVAC system with a maximum outside airflow of two hours before and after occupied times.

MERV 13 or 14 FILTERS

Higher efficiency filtration removes more suspended particles from the recirculated air within a building. As shown below, a MERV 11 filter will capture 50% of the particles of 0.5 microns in size. On the other hand, a MERV 14 filter will capture 85% of those same size particles. Most existing air handling systems can move appropriate air flows with either MERV 13 or 14 filer replacements.

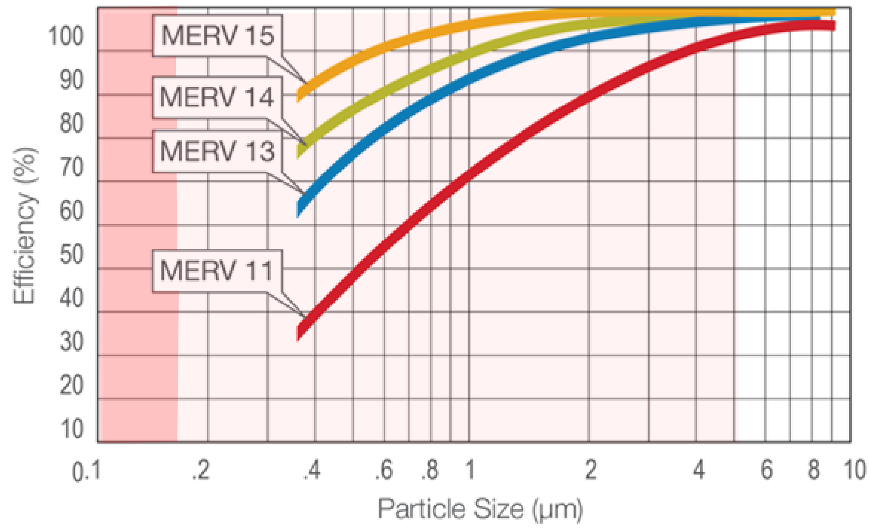

Figure 23. Minimum efficiency curve for several filter ratings

PRESSURIZATION AND AIR FLOW

ASHRAE recommends systems maintain equal pressures on all the floors in multi-floor buildings while maintaining a slightly positive pressure as compared to outside. Within spaces, pressurization can be provided to maintain airflow from low-risk areas to high-risk areas (like restrooms). In addition, it is recommended return air registers be located away from entry points to create a lower risk area when individuals enter a space. Return air should be provided in every space even if those spaces are open to each other. This will minimize the risk of virus freely flowing from one infected space into another uninfected space.

HEPA

High-efficiency particulate air (HEPA) is an efficient standard of air filter. HEPA filters are used in applications that require strict contamination control.

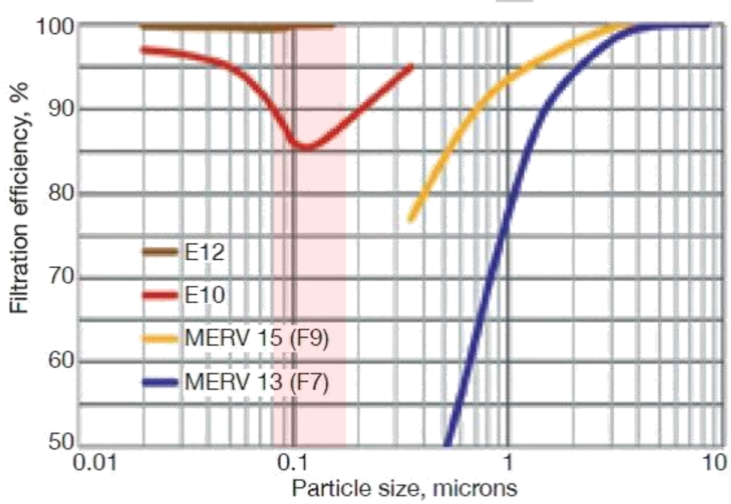

Figure 24. Effectiveness of HEPA E10 and E12 air filters compared to MERV 13 and MERV 15 filters.

The virus that causes COVID-19 is approximately 0.125 micron (125 nanometers) in diameter. It falls within the particle-size range that HEPA filters capture with extraordinary efficiency: 0.01 micron (10 nanometers) and above. HEPA filters are a good solution to removing the aerosolized virus. However, they do require significantly higher fan energies in HVAC systems to be able to push the recirculated air through the filter. For this reason, they are likely not a cost-effective option in existing HVAC systems without replacing and/or upsizing the fan motor.

PORTABLE HEPA UNITS – As noted above, the position taken both by the CDC and by other global health agencies is that the coronavirus is primarily transmitted by person-to-person contact and by contact with virus-laden droplets expelled through coughing and sneezing. For this reason, we do not believe the HVAC system based HEPA filtration should be considered the first line of defense against reducing the spread of COVID-19. If the airborne dissemination path (i.e., PATH 3 noted above) becomes a concern, HEPA could be part of the answer. Unfortunately, most existing HVAC systems do not have the capability to simply add HEPA filters to their central system. A more effective method would be to install this portable HEPA room purifiers. These type systems would be of value in high occupancy areas like waiting rooms.

ULTRAVIOLET LIGHT

Conventional germicidal Ultraviolet Light (UVC) has been proven effective in killing viruses. As noted earlier, the issue with this type of light is that it is a safety hazard for humans if installed in occupied spaces. This light has a wavelength of approximately 240-300 nanometers. UV light in this wavelength penetrates the outer layer of the skin and eyes and does damage which may lead to cancer or other health issues.

When installed inside air handling systems, humans are protected from the light while the viruses in the airstream are effectively irradiated. These conventional germicidal UVC lights have been utilized in air handling systems for a long time and can easily be implemented as a protection device against viruses if the UV energy is distributed uniformly at the appropriate UV dose.

Figure 25. UVC Air Handling Unit and Ductwork Application

There is still a potential safety aspect to using these lamps if access doors to the equipment are not interlocked with the UV light operation, however manufacturers of listed systems have the required safeties built into their equipment.

UPPER AIR UVC – Various upper-air UVC devices are designed to generate a controlled UVC field above the heads of occupants and to minimize UVC in the lower, occupied area of the room. The primary objective of upper-air UVC is to interrupt the transmission of airborne infectious pathogens with the indoor environment. For occupied spaces with lower ceilings, various louvered upper-air UVC devices (wall-mount, pendant, and corner-mount) are available for use in combinations and are mounted with at least 2.1 m from the floor to the bottom of the fixture. The fixture should be mounted so that its UV energy is distributed parallel to the plane of the ceiling. Device construction and placement prevent excessive ultraviolet energy from striking occupants below.

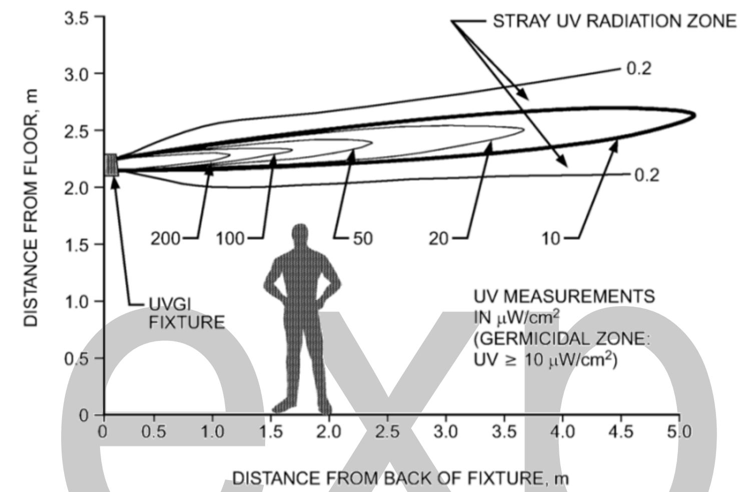

Figure 26. Typical Elevation View showing UVGI energy placed above heads of room occupants

In areas where there is not a viable opportunity for duct mounted UVC (i.e. spaces with minimal or no ventilation), upper-air UVC is a very promising approach. Even if space is ventilated and has duct mounted UVC, upper-air UVC could provide a “one-two-punch” where floating viruses that remain uncaptured by the HVAC system are inactivated before they can fall into the occupied zone. Ventilation patterns (natural and mechanical) should promote good air mixing in a space equipped with UVC so that infectious microorganisms are drawn through the UVC “kill zone.”

In both duct-mounted and unoccupied in-room UVC, the amount of radiation applied can be much higher compared to what can be used for upper-zone UVC, resulting in higher aerosol exposure and quicker inactivation. Duct-mounted UVC can be contrasted to HEPA filtration in the central ventilation system, in that it inactivates the potentially infectious organisms while filtration removes them, and filtration imposes additional load on the fan that UV does not.

FAR UV – Far-UV, is emerging an option that can provide airborne mitigation in a vertical direction downwards rather than projected horizontally across the upper-air level.

Figure 27. Possible terminal application of far UV

TiO2 PCO OR TITANIUM DIOXIDE PHOTOCATALYTIC OXIDATION

In a titanium dioxide photocatalytic air purifier, ultraviolet light shines onto a titanium catalyst, which converts molecules of pollution into more harmless substances. The big advantage that photocatalytic air purifiers have over other air-cleaning technologies is they completely transform the harmful chemicals and effectively destroy them. While the standard PCO approach does not affect viruses; the ultraviolet light used in the process does (see above).

COSATRON

Particles in a room vary in size, concentration and settling time. What happens to these particles depends greatly on their size. Two primary forces at work affect particle movement. One is air movement created by the HVAC system and the second is the naturally occurring electrical fields that exist in all rooms. Large droplets settle out fast while smaller droplets do not. A very large percentage of indoor air particles are three microns or smaller in size. The very small particles are not affected by air currents. Particles of this size are influenced to a much larger degree by the naturally occurring electrical fields in and around the space they are in.

CosaTron creates an atmosphere where the natural process of coagulation is increased using a “non-homogenous in-duct electrical field” in the air handling system (CosaTron, 2019). The non-homogenous electrical field used in this system is comprised of two grids mounted a small distance apart from one another. One grid is a high voltage (HV) field and the other is a high frequency (HF) field. The rate of particle collisions is increased by this field which results in a rapid decrease in small particles (submicron) and a rapid increase in particle size. Generically, this process is called “excitation technology.” As particles increase in size, they can then be picked up by the HVAC system and moved through ducts and trapped by the filters to be removed.

CosaTron does not affect the virus, however, it will create an environment where the smaller particles in a room collide and become larger causing them to “fall out” of the air as they grow in size or be caught in air currents to allow them to travel back to the air handling system where other technologies can work.

<u>PATH FOUR (FECAL ORAL) TRANSMISSION</u>

To protect against transmission risk from the sewer system, floor drains must have trap primers or barrier type trap seal protective devices (i.e., to prevent trap seal evaporation and the backwards flow of sewer gases). If trap primers or trap guards are not installed, the World Health Organization (WHO) suggests preventing dried-out floor drains by regularly adding water (every 3 weeks depending on climate) so that the water seal works properly.

As noted earlier, the primary source of this transmission path is from what is referred to as the fecal cloud which is created when we flush water closets. WHO also proposes as precautionary measure to flush toilets with closed lids. Unfortunately, commercial facilities in the USA do not have lids on water closets. It follows, it is suggested high ventilation rates and airflow patterns that draw contaminants to the WC exhaust is important. The bathroom areas must be held at a negative pressurization to other low risk areas. If exhaust can be modified to exhaust air at the water closet bowl, it would be of value.

In addition, EXP proposes adding UV systems in the restroom environment is positive upgrade. Upper Air UVC is a good option. However, an EXP developed FaR-UV concept may be able to stop the fecal cloud at its source. As shown in the sketch below, FaR-UV fixtures installed in each stall would be interlocked with the stall door and occupancy sensor to increase bulb life. Indicators would show when a stall has been treated.

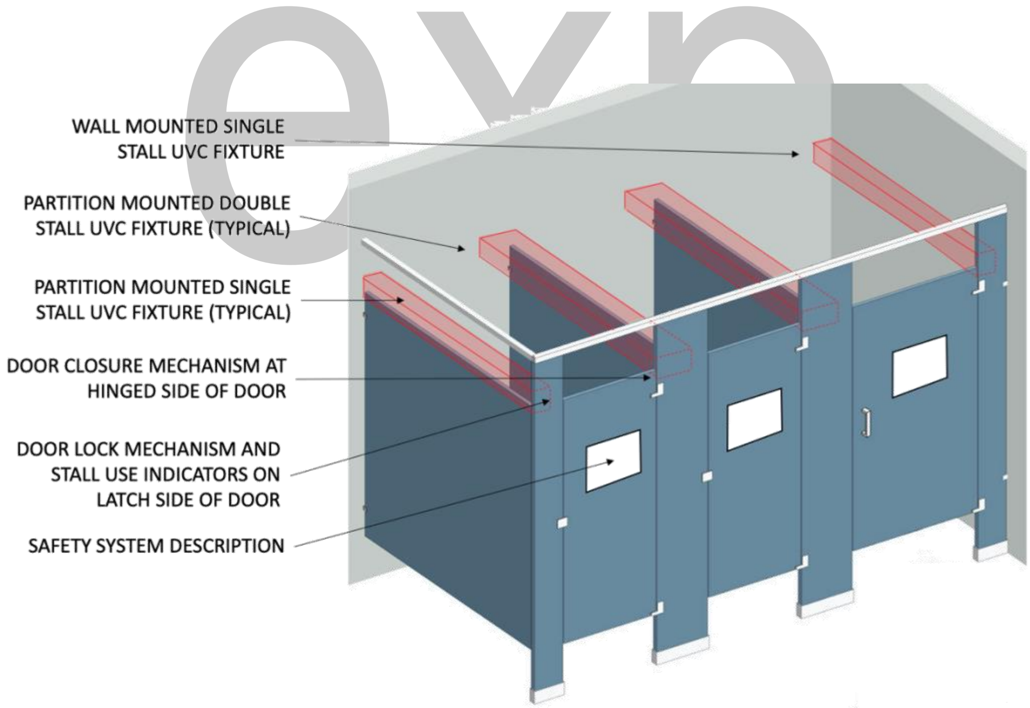

Figure 28. Restroom WC stall FaR-UV concept

CONCLUSION – APPLICATIONS FOR RESTAURANTS

Infection control is about controlling risk. It includes a multi-level systems approach, with consideration to complex variations in transmission, people, the environment they interact with and purposeful redundancy. SARS-CoV-2 has four known paths of transmission. We must take adequate steps to reduce the risk of transmission through purposeful and meaningful measures for each path. Some measures we take will positively affect each path. For example, if measures are taken to not allow infected individuals to enter the property the risks for all paths are reduced. These may include:

- Staff Survey and Temperature Check
- Guest Temperature Check

Our team of experts has identified a plan to strategically reduce the risk of transmission in restaurant environments. This plan is detailed below:

PATH ONE (LARGE DROPLETS):

PRIORITY

- Separation (e.g., glass partitions between dining booths)
- Social distancing
- Protection of nose and mouth (e.g., staff face mask)

PATH TWO (SURFACES):

PRIORITY

- Protection of nose and mouth (e.g., staff face mask)
- Personal hygiene and frequent handwashing
- Electrostatic Spray Applied Disinfectant to all surfaces
- Frequent sanitation of high touch surfaces
- Employee to wear gloves at touchpoint activities
- Contactless payment systems
- Contactless public facilities
- Separate “cash” payment station

ADDITIONAL SYSTEM MEASURES

- Ionization in the HVAC System
- Localized Far-UVC on high contact surfaces
- Portable UVC wand surface treatment

PATH THREE (SMALL DROPLETS):

PRIORITY

- MERV 13+ air filtration
- High ventilation rates and airflow patterns that direct fresh air to and draw contaminants out of the breathing zone
- Negative pressurization from high-risk areas to low-risk areas
- UVC to capture and inactivate pathogens that are entrained into the HVAC system

ADDITIONAL SYSTEM MEASURES

- Localized supplemental HEPA air cleaning systems in high occupancy areas (e.g., waiting areas)
- Ionization in the HVAC system
- Upper Air UVC

PATH FOUR (FECAL ORAL):

PRIORITY

- High ventilation rates and airflow patterns that draw contaminants to the WC
- Negative pressurization from high-risk areas to low-risk areas
- Electrostatic Spray Applied Disinfectant
- Frequent sanitation of high touch surfaces
- Trap Primers and/or Trap Guards on all floor drains

ADDITIONAL SYSTEM MEASURES

- Exhaust at each WC (just above WC rim)
- Upper Air UVC units
- WC Stall FaR-UV with occupancy sensors and stall door interlock
- Ionization in the HVAC system

In addition to the proactive measure above, CDC guidelines should be followed. Each measure we take is a link to a chain reaction – effectively done can support the reduced transmission of COVID-19. Our team of experts believe these increased and robust efforts can support safe environments for employees and guests.

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