# The Role of Active Air Disinfection in Mitigating the Effects of Aerosol Generating Dental Procedures

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# Abstract


Infection control has always been at the heart of patient safety. Never has it been more critical than with the arrival of the COVID 19 pandemic, which has broadened the understanding of risks of transmission and risks to personnel include healthcare providers and front-line workers, impacting healthcare settings, systems, and services.

This white paper introduces CASPR Medik, now available in a portable unit called CASPR Compact with Medik inside (CASPR Compact), a proven technology for reducing pathogens and the risk of transmission of infection. Recent scientific evidence shows that aerosols are responsible for the transmission of SARS-CoV-2, the virus that causes COVID_19. Aerosols are generated from speaking, singing, coughing, sneezing and regular breathing, or through Aerosol-Generating Procedures. (AGPs). The latter includes Aerosol Generating Medical Procedures (AGMPs) and Aerosol Generating Dental Procedures (AGDPs). While the infectious dose required for transmission of SARS-CoV-2 is not yet known, prolonged, close contact is a major risk factor, with aerosols suspended in the air a known risk.

Dental workers have significant occupational risks. The Department of Labor has established 966 categories of workers ranked for risk of transmission of COVID-19. Dental hygienists were ranked the highest, followed closely by dental assistants, general dentists and oral surgeons. (www.onet/dol.org)

In dental settings, risks come primarily from respiratory and waterborne pathogens. Research indicates that aerosols and Aerosol Generating Procedures (AGPs) can spread infections. This includes tuberculosis, measles, Methicillin Resistant Staphylococcus aureus (MRSA), Middle East Respiratory Syndrome (MERS), and legionella. Bloodborne pathogens may be present in aerosols, as well.

In response to the COVID-19 pandemic, dental professionals have adopted enhanced infection control practices to mitigate the transmission risk of SARS-CoV-2. The most common of these include expanded use of Personal Protective Equipment (PPE), adequate airflow considerations, and post-AGP disinfection procedures.

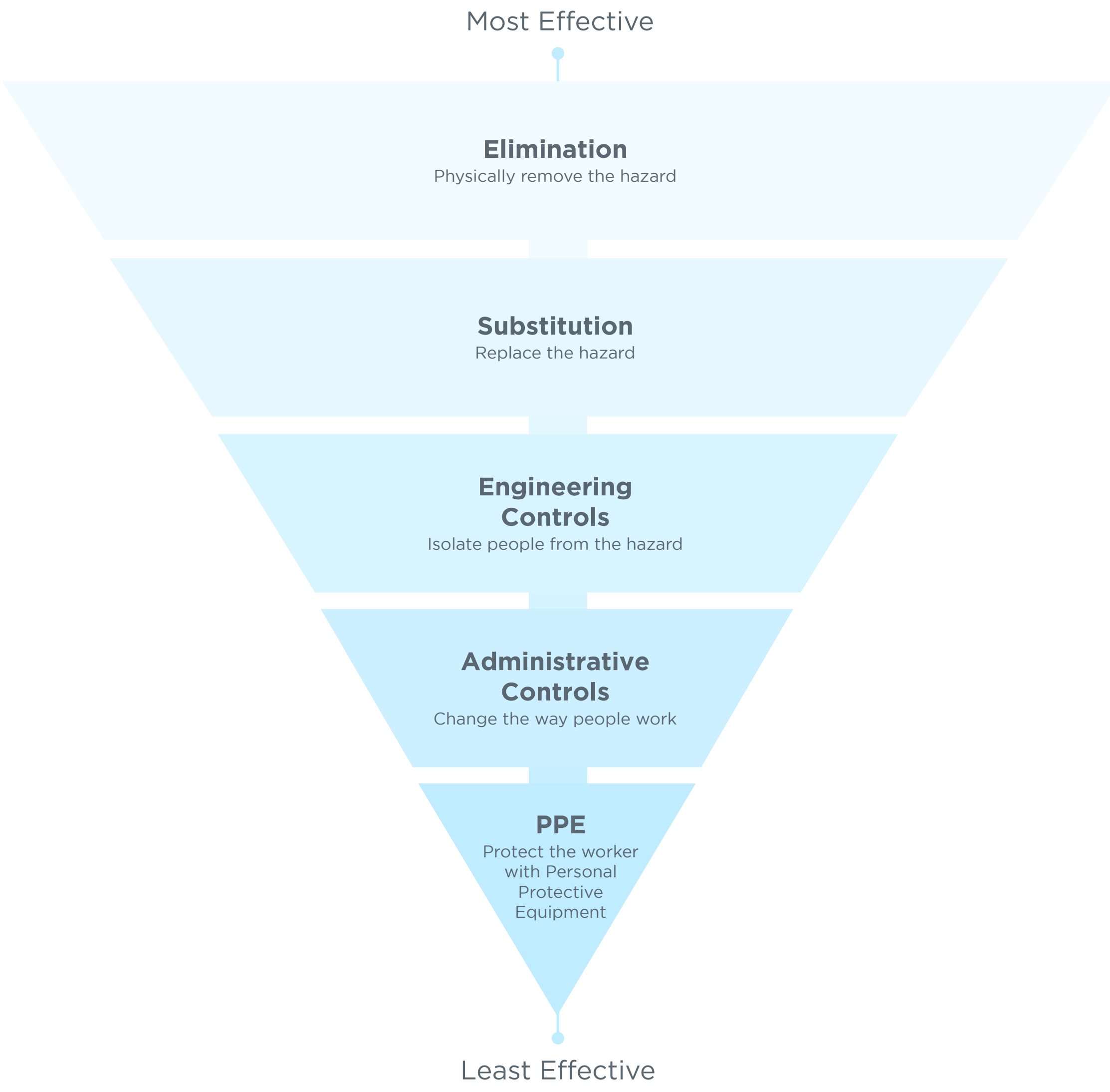
In addition to these important protocols, hydrogen peroxide (HP), $H_2O_2$ at a low dose is known to be highly effective at deactivating a wide variety of pathogenic organisms. CASPR Compact leverages the sterilizing and disinfecting qualities of HP with a unique engineering technology that synthesizes low concentration levels of HP in a gaseous (not vapor) form and distributes it at a safe level, destroying pathogens from aerosols in the air and on surfaces. Used in conjunction with enhanced infection control procedures, CASPR Compact can reduce the risk from pathogens released during AGDPs and lower the risk of healthcare associated infections (HAIs).

The National Institute for Occupational Safety and Health (NIOSH) hierarchy of controls showcases engineering controls as providing a higher level of protection than PPE alone.

The Occupational Safety and Health Administration (OSHA) strongly recommends the implementation of a Respiratory Protection Program wherever AGPs are being generated in the health care setting.

CASPR Compact provides a layer of engineering control, and should be considered for risk mitigation in dental offices and other outpatient care settings.

# Hierarchy of Controls



## Introduction

The dental industry has been significantly impacted by COVID-19, requiring substantial modifications to enhance infection control, change workflow and reduce unnecessary contact.

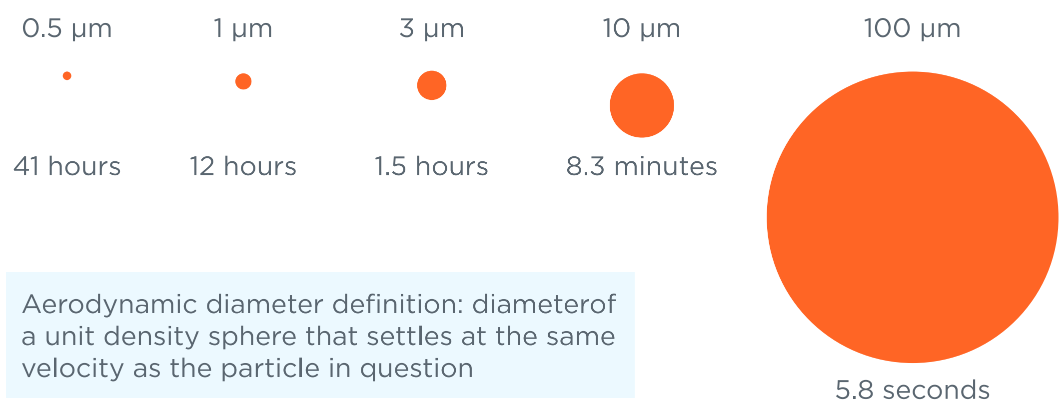
With the onset of COVID-19 in Spring 2020, stay-at-home orders were implemented across the United States to contain the spread of the disease. In the first two months, following interim recommendations by the Centers for Disease Control and Prevention (CDC) (1) and the American Dental Association, (2) most health facilities were closed, and treatment was limited to emergency patients or urgent care. Healthcare and dental facilities reopened with enhanced infection control procedures to prevent the spread of SARS-CoV-2, the virus that causes COVID-19, primarily through prolonged close contact with infected persons.

SARS-CoV-2 virus is transmitted via droplets through the nose, mouth, and eyes. Droplets emitted when speaking, singing, coughing, breathing, and sneezing are known to travel distances anywhere from 6 to 27 feet. Although the precise dose that causes infection is still unknown, aerosols pose a significant risk. (3)

Aerosol generating procedures, (AGPs) like bronchoscopy and intubation, ultrasonic scalers, high speed handpieces, or air-water syringes, increase risks for transmission to healthcare practitioners. Neither aerosol generating dental procedures (AGDPs) nor aerosol generating medical procedures (AGMPs) have been studied enough to quantify those risks. Dental researchers at the University of Alabama have however ranked risks from a range of procedures. (4,5)

## Particles Settling in the Still Air (6)

**Time to settle 5 feet by unit density spheres**




Aerodynamic diameter definition: diameterof a unit density sphere that settles at the same velocity as the particle in question

In general, the most minute particles generated during AGPs carry the greatest risk for respiratory transmission as they are likely to settle in the smallest part of the respiratory tract, the alveoli, where removal is difficult. Larger droplets either settle on surfaces or remain suspended, are breathed in and enter the upper respiratory tract, causing milder infection. Large droplets often containing both air and water may settle on surfaces, while smaller droplets can desiccate, remain suspended in air for a longer period, get dispersed by air flow, and then inhaled into the respiratory tract. (7)

The CDC recommends waiting an appropriate time, based on room air calculations, before disinfecting an environment after conducting AGDPs, thus allowing larger droplets to settle. (1) Sufficient time must also be left between scheduled patients. They state:

> “*Limit the use of demand-controlled ventilation (triggered by temperature setpoint and/or by occupancy controls) during occupied hours and when feasible, up to 2 hours post occupancy to assure that the ventilation rate does not automatically change. Run bathroom exhaust fans continuously during business hours.(1)*”

For most small outpatient health facilities or dental practices, these recommended protocols for treating multiple patients simultaneously present a challenge.

In addition to enhanced personal protective equipment (PPE), a Respiratory Protection Program for AGPs is required by OHSA, 29 CFR 1910.134. This includes recommendations for either Air Infection Isolation Rooms (AIIR) or negative pressure rooms, the costs of which are prohibitive for most dental practices.

**The CASPR Compact is a practical, cost-effective engineering solution that provides an additional layer of respiratory protection.**

# 1.0 Healthcare-Associated Infections (HAIs)

Quantifying risks of HAI's for patients and healthcare personnel is not precise. After AGPs, pathogens can remain in the air and on surfaces for long periods of time. While larger particles settle on the floor, smaller particles may remain suspended in air, or dessicate and then rehumidify to become airborne.

Healthcare-associated infections (HAIs), also known as nosocomial infections, are contracted by patients while receiving treatment for other conditions or diseases. HAIs occur in a variety of healthcare settings including hospitals, rehabilitation centers, ambulatory surgical centers, end-stage renal disease facilities and long-term care facilities.

HAIs are often contracted from devices such as catheter tubing and dialysis apparatus, as well as lack of stringent hygiene protocols. They are caused by a wide range of bacteria, fungi, viruses, and less common pathogens, too numerous to detail here. Included among these are Methicillin Resistant Staphylococcus aureus (MRSA), pseudomonas infections, bloodborne pathogens, and respiratory illnesses, such as Middle East Respiratory Syndrome (MERS), Severe Acute Respiratory Syndrome-1 (SARS), influenza, Nipah virus, Crimean-Congo hemorrhagic fever and Ebola virus. (7)

HAIs are better known in the medical community than in the dental community. While licensing of facilities, outbreak reporting and investigations are utilized in tracking and preventing HAIs, these policies and procedures are not currently in place for dentistry. However, both medical and dental facilities do require training on infection control, which varies by state regulatory board requirements.

## 1.1 The Societal Impact of HAIs /Nosocomial Infections

HAIs are a significant cause of illness and death, with serious consequences that impact emotional, financial, and medical outcomes. HAIs account for more than $1.7 Billion in increased healthcare costs, and approximately 99,000 deaths annually. At any given time, 1 in 25 inpatients has an infection related to hospital care. Since the mid-2000s, the US Department of Health and Human Services has issued several calls for an end to HAIs through comprehensive safety protocols and reporting requirements.  No data on HAIs are available for dentistry.

### Lack of tracking

Despite these calls, HAI data from outpatient care settings are poorly documented, due to an absence of in-house epidemiologists or infection preventionists. Routine HAI surveillance for many outpatient health centers and dental offices does not currently exist in the US. Nosocomial transmission of viruses via AGMPs are not tracked. (7) Even less information is available about dental environments and while no dental healthcare workers are known to be infected, these settings are not tracked. Lack of tracking and data leaves them vulnerable.

As enhanced infection control procedures are developed and utilized in dental offices, there is a growing recognition that managing aerosols may be the right approach. While the current focus is on SARS-CoV-2, infection control and hygiene protocols are also key to controlling other potentially lethal airborne and waterborne pathogens, such as tuberculosis, Influenza A and MRSA.

# 1.2 Need to Mitigate HAI Risks, Including COVID-19

Certain medical or dental procedures are likely to generate higher concentrations of infectious respiratory aerosols than coughing or sneezing. AGPs put healthcare personnel and others at an increased risk for pathogen exposure, transmission, and infection.

Direct respiratory transmission of the SARS-CoV-2 from patients to healthcare professionals (HCPs) occurs through droplet contamination from spatter in the nose eyes or mouth. This usually happens with prolonged, close patient contact. Indirect transmission can occur by inhaling residual airborne contamination and/or by fomites although the latter are viewed as less efficient in transmitting respiratory pathogens.

As mentioned above, pathways for transmission in healthcare settings outside of dentistry are well-documented; however, dentistry has no well-established HAI tracking programs or testing of air samples or surface environments. This lack of oversight must be remedied because of the frequency of AGPs.

Certain areas of the dental office (e.g. sterilization areas with steam autoclaves or areas where contaminated PPE is removed or discarded) have increased risk of contamination due to excess humidity with venting of the autoclaves. A recently published commentary calls for HAI surveillance of providers and patients in outpatient dental clinics. (8) While testing of dental providers for COVID-19 may occur in some locales, it is not available everywhere, and establishment of a surveillance system for monitoring safety within dental offices, remains aspirational.

Although fomites are believed to be less of a risk for SARS-CoV-2 transmission than more direct droplet transmission, surfaces should be cleaned to reduce bioburden, and then disinfected. Fortunately, the lipid envelope around the SARS-CoV-2 virus is easy to kill by handwashing with soap and water for 20 seconds and disinfection.

> “ Disinfection with HP can easily inactivate SARS-CoV-2.

Disinfection with HP can easily inactivate SARS-CoV-2. This diagram (9) ranks resistance to disinfection, with prions as most resistant and lipid viruses, such as HIV (Human Immunodeficiency Virus) or Hepatitis B relatively easy to kill. In its guidelines for disinfection and sterilization, the CDC notes that Hydrogen Peroxide (HP), even at low levels, has effective germicidal activity and bactericidal, viricidal, sporicidal and fungicidal properties. HP, with a highly efficacious profile in disinfection, is at the top range of disinfectants. While it has yet to be studied for its capacity to kill SARS-CoV-2, HP's ability to kill microorganisms, including spores that are more resistant than coronaviruses, suggests it will be equally effective. It should be noted that the EPA (Environmental Protection Agency) has developed a SAR-CoV-2 claim for disinfectants.

## Decreasing Order of Resistance of Microorganisms to Disinfection and Sterilization and the Level of Disinfection or Sterilization

**Resistant**

- Prions (Creutzfeldt-Jakob Disease)
- Bacterial sopres (*Bacillus atrophaeus*)
- Coccidia (Cryptosporidium)
- Mycobacteria (*M. tuberculosis, M. terrae*)
- Nonlipid or small viruses (polio, coxsackie)
- Fungi (*Aspergillus, Candida*)
- Vegetative bacteria (*S. aureus, P. aerugionsa*)
- Lipid or medium-sized viruses (HIV, herpes, hepatitis B)

**Susceptible**

**Level**

Prion reprocessing

Sterilization

Disinfection

***High***

***Intermediate***

***Low***

# 1.3 HP's Proven Capacity to Kill Viruses and Pathogens

CDC guidelines for disinfection and sterilization in healthcare facilities (2008) reported the antiviral activity of HP against Rhinovirus. The time required for inactivating three serotypes of rhinovirus using a 3% HP solution was 6–8 minutes; this time increased with decreasing concentrations (18-20 minutes at 1.5%, 50–60 minutes at 0.75%). Rhinovirus is a common non-enveloped virus, much more difficult to kill than SARS-CoV-2. (10)

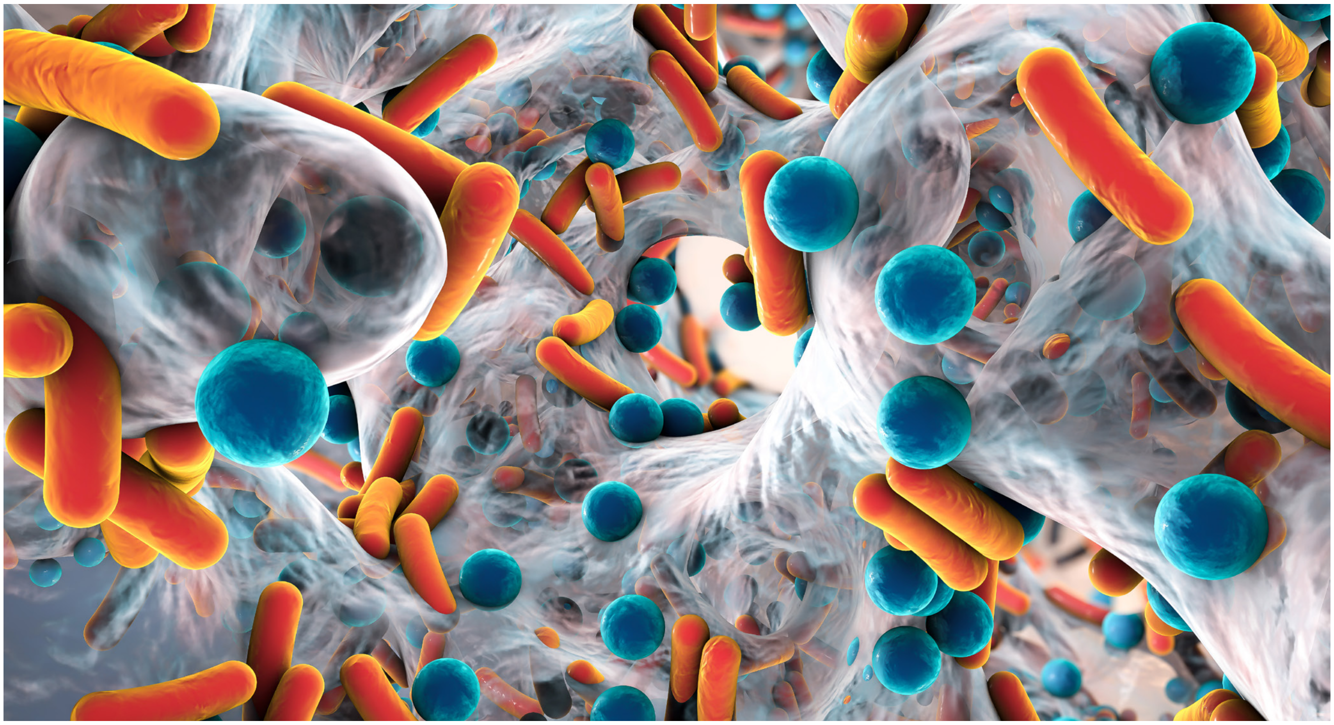
HP decontaminating technology is designed to project either dry mist or noncondensing or condensing vapor onto surfaces in patient or treatment rooms over a specified time period. H2O2 vapor systems use a concentration of 30%-35% H2O2, while the aerosolized systems combine 5%-7% H2O2 with <50 ppm Ag cations.

Mobile decontaminating systems using HP have been well studied. Trials using pathogens inoculated onto test disks and subjected to HP vapor were inactivated within 90 minutes, while spore biologic indicators were reduced by >6 log10.

Inactivation of several important viruses has also been proven using the system. Advanced decontaminating technology using HP significantly reduces MRSA, vancomycin-resistant Enterococcus bacteria (VRE), and multidrug-resistant gram-negative bacteria on contaminated surfaces in hospital rooms, with reported reductions of 86%-100% in pathogens in ten published studies. (11-22)

Multiple clinical trials have been conducted to assess the effect of HP room decontamination on HAIs. In one trial conducted over 30 months on six high-risk units in a large acute care hospital, use of HP decontamination in rooms after patient discharge with a known Multi-drug Resistant Organism (MDRO) was demonstrated to reduce the risk of a subsequently admitted patient acquiring the same organism by 64%, with VRE accounting for a major portion of the decrease. The risk of acquiring *C. difficile*, MRSA, and multidrug-resistant gram-negative bacteria, although reduced, was not significant.

As an additional example of disinfection efficacy, a 7.5% HP is a high-level disinfectant when used for 30 minutes at 20 degrees Centigrade. At concentrations of 6 to 25%, HP shows promise as a sterilant, inactivating 10 to the 5th multidrug resistant *M. Tuberculosis* after 10 minutes of exposure. At lower concentrations below 2%, it is an excellent high-level disinfectant. (11-22).



# 1.4 Particular Risks to Dental Personnel

Occupational risk of dental personnel is high. The Department of Labor has established 966 categories of workers ranked for risk of transmission of COVID-19. Dental hygienists were ranked the highest, followed closely by dental assistants, general dentists and oral surgeons. (www.onet/dol.org)

Moreover, research on airborne pathogens in dentistry is either dated or non-existent. Without any surveillance of dental outpatient clinics, the actual risks to dental team members cannot be determined. While the University of Alabama has attempted to categorize procedures by risk, no actual supporting research with air or environmental sampling was used. (4,7) Risks were simply categorized as low, moderate, or high, based on potential for fluid exposure.

A recent article states that the risk of HIV seroconversion after exposure to blood is 0,2% to 0.3%, and 0.1% or less for mucous membrane exposures. (24) Assuming all healthcare workers are vaccinated against hepatitis B so have no risk, the risk of seroconversion for hepatitis C after exposure is about 1.8%. (23)

Acquisitions of respiratory infections and other HAIs by healthcare workers cannot distinguish community transmission from transmission in dental offices, as there is no active surveillance system in place. (25) In addition to outbreaks of legionella and TB in dental settings, as well as hepatitis C and HIV/AIDS, idiopathic pulmonary fibrosis was identified in a cluster of nine dentists and one dental assistant in Virginia in 2018. The exact cause could not be determined and remains a mystery. Most recently, a New Jersey oral surgeon was implicated in the death of one patient and significant cardiac complications in fourteen patients. (26,27)

# 1.5 The Role of Small Droplets in Respiratory Infections

As mentioned above, the lower respiratory tract is particularly sensitive to small particles. Judson and Munster's 2019 paper provides a useful measure for categorizing droplets by size and highlights their role in transmitting respiratory infections:

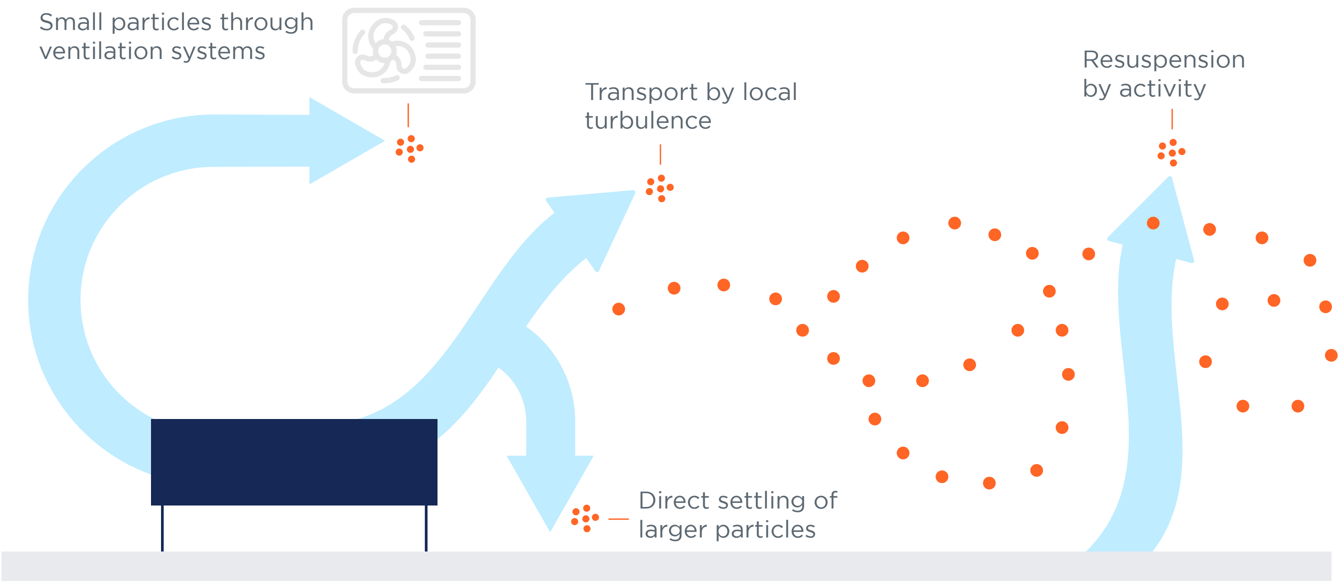
> *Aerosols are particles suspended in air and are categorized as small droplets (which some exclusively call aerosols) and large droplets. Small droplets have the potential to desiccate and form droplet nuclei that travel long distances, while large droplets do not evaporate before settling on surfaces. Classifying aerosols by their initial size is relevant in relation to their dispersal patterns, but it is also important to classify aerosols according to where they deposit in the respiratory tract because pathogenesis can be influenced by whether a virus deposits in the upper respiratory tract (URT) or lower respiratory tract (LRT).*
>
> *Dispersal and deposition depend on a variety of factors, and there is no exact cutoff for small and large droplets. Some authors use ≤5 Qm in diameter as a cutoff for small droplets, while another cutoff between aerosol types is 20 Qm, since aerosols ≤20 Qm in diameter can desiccate to form droplet nuclei, and aerosols ≥20 Qm do not deposit in the LRT. It is unknown whether certain AGMPs generate either small or large droplets, or both. Therefore, depending on what aerosols are formed, AGMPs could potentially amplify a normal route of transmission for respiratory viruses or open up a new route of transmission for other viruses. (7)*

NIOSH categorizes aerosols into 4 different sources when AGMPs are performed:

1. Aerosol Source Characteristics from the patient
2. Resuspension of aerosols
3. Large droplets of aerosols that land on surfaces (a loss of airborne particles)
4. All of the above are impacted by air transport (such as HVAC system, air flow, temperature, humidity)

## Pathways for Particles After Aerosol Generating Procedures (6)

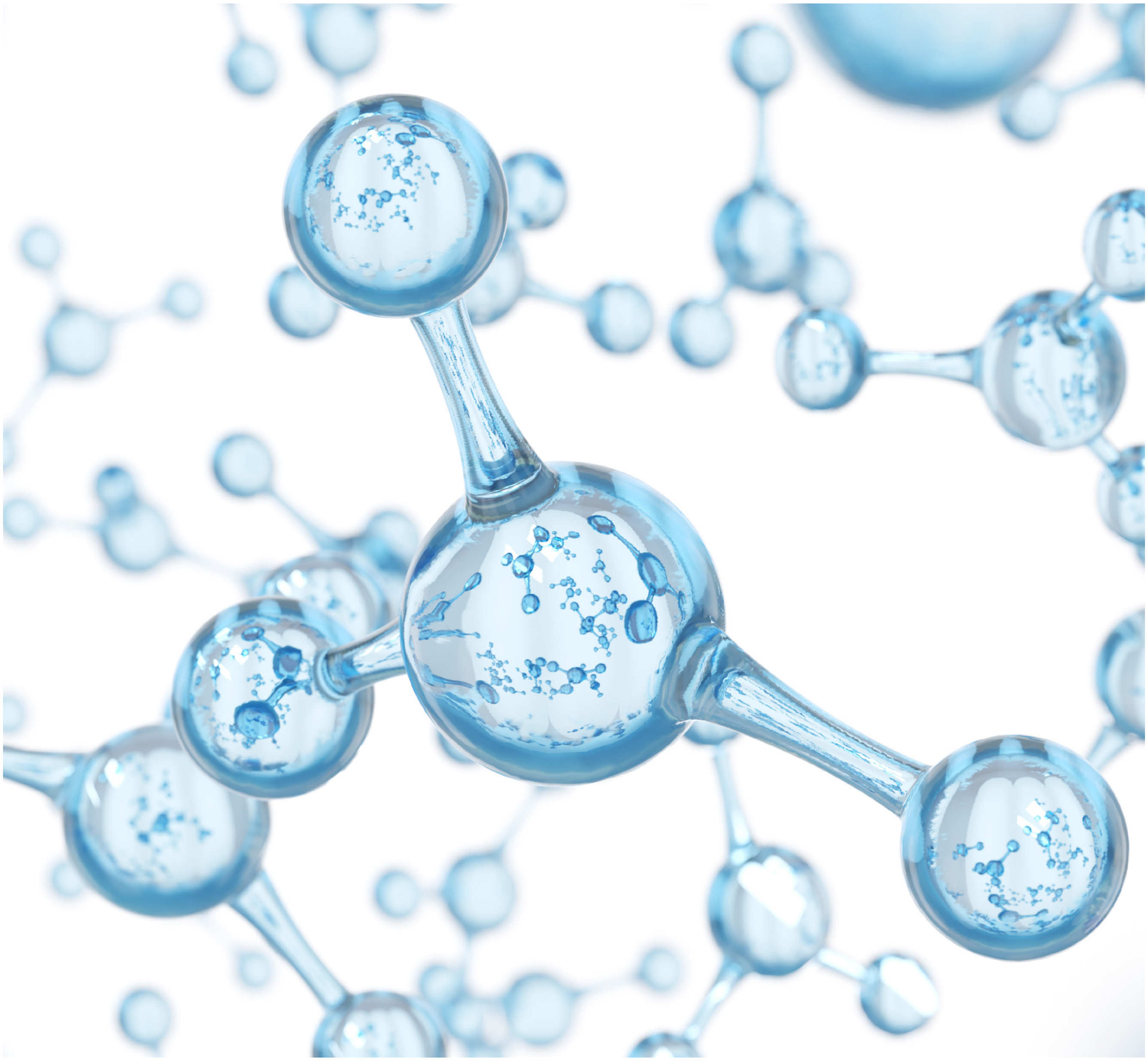
This demonstrates that smaller particles are drawn through the ventilation return systems, and that larger particles settle on the floor or are resuspended in air. These resuspended particles can be transported to other areas by local turbulence. Desiccated particles on the floor or surfaces can be rehumidified and resuspended in air.



# 1.6 Need for Protection from Aerosols

Dentistry now uses enhanced infection control with face shields, N95 masks and additional cleaning and disinfection to clean spatter. However, protection from residual aerosol mists after AGDPs is not being addressed until now. Access to proper PPE for all healthcare personnel during AGPs remains a challenge. Inventory for PPE remains low in dentistry.

More than 100,000 US healthcare workers are estimated to have had COVID-19. The majority are believed to have been infected by patients due to inadequate use or contamination of PPE. About 10% of all healthcare workers in affected areas had symptoms or tested positive for COVID-19, but no dental workers have been reported as of this writing.



# 2.0 Respiratory Protection for Dental Personnel

## Respiratory Protection Programs which include PPE and protection from aerosols are necessary for dental personnel.

Comprehensive Respiratory Protection Programs are becoming standard protocol for enhanced infection control in the COVID-19 era. PPE protection for HCPs is clearly outlined in OSHA guidance, 22 CFR 1910.134, as it is for both CDC and ADA recommendations. (1,5) This includes training on proper use of PPE, standard fit tests and references to user fit checks for face filtering respirators (FFRs) for each use. A face shield and surgical mask or N95 and goggles is recommended; N95 or better FFRs will filter particles down to 1 micron. However, although the dose required for transmitting COVID-19 is unknown, since the SARS-CoV-2 is so small, from 0.125 to 0.6 microns, many outpatient and dental practices are opting for a higher level of protection, namely N99 or N100, or even powered air purifying respirators. (25,28)

Since OSHA does not specifically address standards for dental offices, the recommendation is that AGPs should be undertaken within an air intake isolation room (AIIR). CDC interim guidance for dental settings suggests this AIIR, particularly when treating COVID-19 positive patients. Because of the variability of room sizes, configurations, and airflow within dental and other outpatient healthcare offices, neither the AIIR or the highest-level PPE may be practical, affordable, or accessible solutions to mitigate risk from aerosols and AGDPs. (1)

It is clear however, that a Respiratory Protection Program must include additional safeguards, namely administrative and engineering controls, which, according to the NIOSH Hierarchy of Controls (See Diagram Page 4, Hierarchy of Controls), offer higher levels of infection prevention and protection than PPE.

Given the efficacy of engineering controls, the CDC and the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) issued a joint statement with general recommendations for reducing disease transmission from airborne particles. It suggests that improvements to engineering controls using building ventilation systems be considered. This may include one or both of the following activities:

- Increase ventilation rates
- Increase the percentage of outdoor air that circulates into the system

ASHRAE has issued the following two statements regarding transmission of SARS-CoV-2 and the operation of HVAC (Heating, Ventilation and Air Conditioning) systems during the COVID-19 pandemic:

> “*Changes to building operations exposure, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.*
>
> *Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air. Unconditioned spaces can cause people thermal stress that may lower resistance to infection or be directly life threatening. In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus.* (29)

## 2.1 Air Quality and Flow Issues

When generating AGDPs, air flow as measured in total room air exchanges per hour, should be addressed in combination with temperature and humidity. The total room air exchanges will determine the time required between patients. (29)

As stated above, the precise risk of contracting HAIs or nosocomial infections through AGDPs is not known; however, air flow issues play a role in transmission of SARS-CoV-2. An outbreak investigation in an air-conditioned restaurant in China involving three family clusters, suggested that air flow direction resulted in transmission of SARS-CoV-2. People seated downwind from the table with source infected patients became infected, while those at tables outside the air flow path, did not. (25) This paper implies that adequate ventilation and higher air exchange rates are important in reducing risks of aerosol transmission of SARS-CoV-2.

Finally, Santarpia et al notes that 80% of air handling grates are contaminated with SARS-CoV-2, and 100% of areas under hospital beds are contaminated in quarantine units where COVID-19 patients were housed. (30)

The consensus supported by the CDC, is to have the head of the dental operatory or other patient care chair supplied with clean air that flows toward the foot of the chair. (1)

Filters with Minimum Efficiency Reporting Value (MERV) ratings of around 13 are optimal with an air exchange of 10-12 per hour. In general, filters with higher MERV ratings have smaller openings, which allow the higher MERV filters to capture more and smaller airborne particles. However, this can have the effect of restricting the airflow passing through them.

Increasing filter efficiency means increased resistance or pressure within HVAC, resulting in a drop in airflow velocity across the filter itself. This can lead to an overall drop in total airflow, unless a large fan can overcome increased resistance. While larger systems may be able to compensate, the limited fan horsepower of most smaller air handling unit systems used in residential, multi-family, and light commercial buildings (where small dental and medical offices are often located), cannot. Therefore, adding some types of High Efficiency Particulate Air (HEPA) filtration, could compromise air flow. (29)

# 3.0 Current Air Quality Control Approaches

The CDC goal is to reduce infection transmission from airborne particles by increasing outdoor air ventilation and filtration efficiency. CDC's June 18, 2020 interim guidelines on engineering controls for dental settings (5) recommend the following for maintaining air quality within the dental office:

- Consider the use of a portable HEPA air filtration unit while the patient is undergoing an AGP and immediately following.
  - Select a HEPA air filtration unit based on its Clean Air Delivery Rate (CADR). The CADR is an established performance standard defined by the Association of Home Appliance Manufacturers and reports the system's cubic feet per minute (CFM) rating under as-used conditions. The higher the CADR, the faster the air cleaner will work to remove aerosols from the air.
  - Rather than just relying on the building's HVAC system capacity, use a HEPA air filtration unit to reduce aerosol concentrations in the room and increase the effectiveness of the turnover time.
  - Place the HEPA unit near the patient's chair, but not behind the Dental Healthcare Personnel (DHCP). Ensure that DHCP are not positioned between the unit and the patient's mouth. Position the unit to ensure that it does not pull air into or past the breathing zone of the DHCP.
- Consider the use of upper-room ultraviolet germicidal irradiation (UVGI) as an adjunct to higher ventilation and air cleaning rates.
  - Limit the use of demand-controlled ventilation (triggered by temperature setpoint and/or by occupancy controls) during occupied hours and when feasible, up to 2 hours post occupancy to assure that the ventilation rate does not automatically change. Run bathroom exhaust fans continuously during business hours. (1)

The Filtration and Disinfection section of the ASHRAE COVID-19 resource webpage has recommendations on disinfection, as well as use of infection control risk assessment (ICRA) specialists for surfaces and materials in the building. This suggests ideal humidity in the 40-60% range and a balance of indoor and outdoor air. (29)

# 3.2 Other Emerging Infection Control with Administrative/Engineering Controls

A recent article in JAMA highlights the need for air disinfection due to SARS-CoV-2. However, their review of potential air disinfection methods failed to include the full range of options, including CASPR technology. (28) Air disinfection is warranted by the scientific data and environmental air and surface sampling.

Additional information on alternative methods for air disinfection is supplied below:

## Foggers

ASHRAE Standard 170-2017: Ventilation of Health Care Facilities is the standard for foggers. Located within air-handling units or ductwork, this permits the use of adiabatic high-pressure atomizing humidifiers.

Other requirements include a humidity sensor positioned at a suitable distance downstream from the injection source; controls to limit duct humidity to a maximum value of 90% Relative Humidity (RH), when the humidifier is operating; duct takeoffs not located within the humidifier's absorption distance; humidifier control valves designed to remain off whenever the air-handling unit is not in operation; moisture elimination must be addressed to prevent infection risks.

## HEPA filters

While portable room air cleaners with HEPA filters may provide added protection for indoor occupants, their use may negatively affect the performance of the existing HVAC systems; in some cases decreasing air exchange rates. A regular maintenance schedule and use of appropriate PPE is essential when changing filters. Some HEPA filters may have a limited capacity, less than 1000 cubic feet.

## Ultraviolet Light

A type of ultraviolet light with wavelengths between 200 – 280 nm, called UVC is another option. Light in the UVC wavelength can be used for water and surface disinfection as well as air purification. Research shows that Ultraviolet germicidal irradiation (UVGI) at the UVC range in both the upper-room and in-duct configurations can inactivate some disease-transmitting organisms. Either option takes time to plan and install. (29) Disadvantages include: personnel cannot remain in the room when UVC light is being used; UVC installed in ductwork keeps the ducts and coils clean, but when air stream velocity is high, the air passes through too quickly to be adequately treated. (31)

Alternative room air disinfection methods have not been fully evaluated for efficacy and safety of personnel. The June 18, 2020 CDC interim guidelines for dental settings state, "The efficacy of alternative disinfection methods, such as ultrasonic waves, high intensity UV radiation, and LED blue light against COVID-19 virus is not known. United States Environmental Protection Agency (EPA) does not routinely review the safety or efficacy of pesticidal devices, such as UV lights, LED lights and ultrasonic devices. Therefore, EPA cannot confirm whether, or under what circumstances, such products might be effective against the spread of COVID-10." (1)

# 4.0 Enter CASPR Continuous Air & Surface Pathogen Reduction

CASPR is a continuous disinfection technology that provides around-the-clock disinfection of air and surfaces. This engineering solution provides a higher level of control than PPE and administrative controls alone.

The CASPR Medik technology engineering solution is an innovation that further reduces the risks of transmitting diseases in medical and dental facilities. CASPR Medik systems have been successfully deployed in hospitals, with high-performance units placed in the ventilation ducts of preexisting air management or HVAC systems.

A cost-effective stand-alone version of CASPR Medik, the CASPR Compact, continuously circulates air in the working area. It should be noted that CASPR is not a filtration technology, does not vaporize any disinfection fluids, and is not intended to decompose pathogens in the unit or device. Rather, it produces gaseous oxidizing molecules in a catalytic process from ambient air. This enhanced air is continuously dispensed into the environment. The CASPR Medik technology is safe for both equipment and continuous use in occupied spaces.

To be most effective, CASPR Compact should be placed at countertop level or higher, away from air returns, not on the floor. The continuously circulated ambient air enriched by gaseous oxidizing molecules, decomposes airborne pathogens from AGPs, including aerosols and droplets of all sizes transported by the air flow and on surfaces.

Using air disinfecting technology creates a safer environment for HCPs, DHCPs and patients alike during AGMPs and AGDPs by providing an extra layer of respiratory protection on top of full PPE.

It should be noted, that the CASPR Medik technology is not intended to replace existing cleaning and disinfection or personal protection measures and protocols.

## 4.1 CASPR Origins – NASA and Beyond

The genesis of CASPR's proprietary technology was the development of a catalytic process by the National Aeronautics and Space Administration (NASA) for purifying the air in the Space Station.

In the 1990s, researchers at the Wisconsin Center for Space Automation and Robotics, a NASA research partnership center at the University of Wisconsin in Madison, developed an air purifier that eliminates pathogens in the ambient air of spacecrafts. The device draws air through thin tubes of titanium dioxide ($TiO_2$) that are exposed to ultraviolet light, performing a photo-catalytic oxidation (PCO) process that decomposes ethylene – the decaying gas produced by plants in greenhouse experiments in space.

The first device was used aboard Space Shuttle mission STS-73 in 1995, and since then in numerous International Space Station expeditions. (32) CASPR Medik, the next evolution of this technology, takes the original concept and improves the output of oxidizing molecules and overall effectiveness in reducing harmful viruses and bacteria in the air and on surfaces. This new, smaller footprint device is ideal for private practice health and dental settings. The CASPR Medik technology has proven highly effective at reducing pathogens by more than 99.96% in multiple clinical and laboratory tests.

## 4.2 Hospital Success Stories for Reduction of HAIs

In a clinical trial evaluating the CASPR Medik technology in a hospital environment, the continuous application of low levels of oxidizing molecules was found to exert significant reductions of 78% in the average bacterial and 97% in fungal micro-burden found on the surfaces (1415 cfu/100"2 and 328 cfu/100"2 for Bacteria and Fungi, respectively). The incidence of MRSA and VRE was reduced by 63% and 70%, respectively.

An exciting bi-product of the CASPR Medik technology clinical trial was a 44% reduction in employee absenteeism over four months from Nov 2018 – Feb 2019, compared with the same period in the previous year. (See also, Section 5.3) Therefore, employee absenteeism from sickness was less when using CASPR Medik technology

# 4.3 Mechanism of Action – Getting Technical

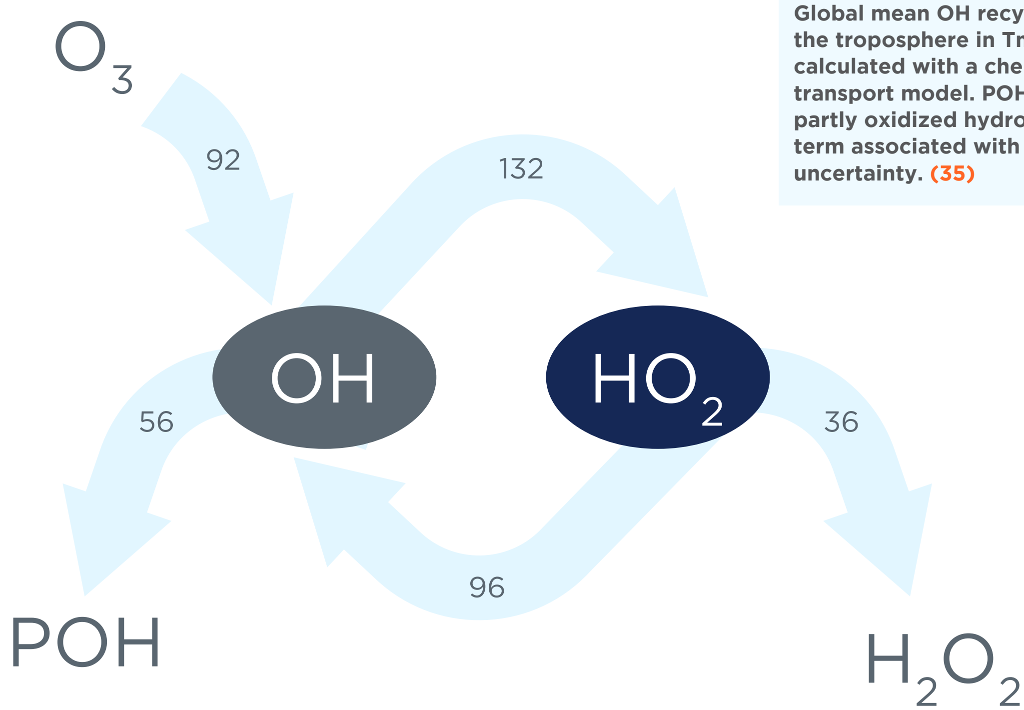
As discussed above, even at low concentrations hydrogen peroxide, $H_2O_2$ in its aqueous form is a powerful disinfectant. Trace amounts of gaseous oxidizing molecules, such as HP, are very efficient in decomposing pathogens.

## The Detergent of the Atmosphere

Paul J. Crutzen, a 1995 Nobel Prize winner in Chemistry (33) described the oxidizer cycling, namely the hydroxyl radical, HO as the "detergent of the atmosphere", cleansing it of greenhouse gases carbon monoxide, CO and other carbon-based molecules, such as methane and CH4 by decomposing its chemical structure. (33) These oxidizers are formed in the atmosphere when ultraviolet light (UV) from the sun strikes ozone in the presence of water vapor, H2O. Radicals are highly reactive due to unpaired electrons which tend to transfer to other molecules, so their lifespan is only a few seconds. However, complex photochemical processes cause them to form other oxidizers, e.g. the much more stable HP (see figure below).

The reduction/oxidation potential (ROP) is a measure of the reduction or oxidation tendency/power of a substance. HP for example, has an ROP of 1.77V on the scale between zero for hydrogen H2, and the strongest oxidizer, fluorine, F at 2.87V.

To understand the air cleaning mechanism resulting from humidity, H2O and oxygen, O2 in the sunny daylight, meteorologists have measured the concentrations of gaseous HP in the atmosphere. They found with few exceptions, concentrations less than 10 parts per billion by volume (ppbv), which denotes 10 parts per 1,000,000,000 parts, or 10 parts of HP molecules in 109 gas molecules of ambient air (34). For example, their study based in North Carolina found gas-phase HP concentrations ranged from less than 0.05 to about 1.0 ppbv and from less than 0.05 to 2.0 ppbv in urban and rural sites respectively. A clear diurnal and seasonal trend is observed.




**Global mean OH recycling in the troposphere in Tmol/yr, calculated with a chemistry-transport model. POH means partly oxidized hydrocarbons, a term associated with substantial uncertainty. (35)**

# 4.0 Enter CASPR Continuous Air & Surface Pathogen Reduction

Although these ranges represent a very low trace concentration of HP in air, a concentration of 2 ppbv at sea level pressure, is equivalent to about 54 billion HP molecules per cubic centimeter, cm3. In other words, at this concentration, the average distance between two HP molecules in air is in the order of magnitude of 2.6 micrometer, Qm.

## Safe in Occupied Spaces

At low concentrations, HP is a safe oxidizer and disinfectant that can be found in many medical and household products, e.g. cosmetics, toothpastes, and deodorants.

The Summary Risk Assessment Report, Hydrogen Peroxide, 2003 Special Publication I.03.148 of the Institute for Health and Consumer Protection European Chemicals Bureau of the European Commission states that HP is a reactive, short-lived polar substance that has no expected bioaccumulation. In a risk evaluation, the EPA assumes a maximum half-life of 0.5 hours for residual HP vapor. (36)

Although OSHA has set a permissible exposure limit (PEL) for HP in workplaces at 1 ppm, the EPA Risk Assessment and Science Support Branch (RASSB) assesses the inhalation risk-based level for concern at 7 ppbv, i.e. 0.7% of the OSHA PEL, based on a 2006 toxicological review. (37) However, this appears to be a theoretical consideration, since the most sensitive OSHA validated analysis methods for HP have a detection limit for the overall procedure of 10.8 ppbv and a reliable quantitation limit of 36.6 ppbv (OSHA Sampling and Analytical Methods: Method number: 1019, Version: 1.0).

## The CASPR Medik technology

CASPR Medik technology employs gaseous HP utilizing a proprietary photocatalytic conversion process. Activated by multiple wavelengths of blue and ultraviolet light, oxygen and humidity are extracted from the air to create a composition of powerful oxidizing molecules, including traces of gaseous HP. Enhanced quality air is dispensed continuously in the room environment.

The stand-alone CASPR Compact with Medik inside is comprised of the Medik photocatalytic converter and a fan to circulate ambient air through the device. Multi-wavelength blue/ultraviolet light illuminates a honeycomb matrix surface coated with reactive metals to enhance the overall catalytic effect.

The light in the blue/ultraviolet range emits photons at a frequency that, when absorbed, has sufficient energy to ionize atoms or molecules and break chemical bonds. When applied to oxygen, $O_2$ and water, $H_2O$, this is a precondition to the production of hydrogen/oxygen species that chemically adsorb as intermediates on the catalyst surface. Cycling through dissociation and recombination of those species, the photocatalytic process allows for the synthesis of HP, $H_2O_2$.

The concentration emitted by CASPR Medik's catalytic converters has been tested in an exemplary setting and measurements taken by an accredited laboratory for industrial hygiene. Results showed an HP concentration of less than 10 ppbv.

## Low Concentration Provided by CASPR is Highly Effective

Although the CASPR Medik photocatalyst cell synthesizes and dispenses just traces of HP to the room environment, the anti-microbial impact is highly effective. Testing results in a controlled environment with a prototype of the CASPR Compact situated on a tabletop inside a modular room 8 ft from various pathogen carriers, indicate that CASPR devices materially reduce or eliminate microorganisms on surfaces. Results from a testing cycle of up to 24 hours show:

- bacteria on carrier surfaces was reduced over 99.998%,
- fungi were reduced over 95%,
- Methicillin Resistant Staphylococcus (MRSA) was reduced over 99.98%
- Influenza A (H1N1) was reduced over 99.93%, and
- MS2 (virus) was reduced over 99.993%.

Although not tested specifically on the novel coronavirus (COVID-19), the CASPR technology has demonstrated effectiveness against SARS-CoV-2-like viruses on hard, nonporous surfaces.

## 4.5 Why Continuous Disinfection is a Highly Effective Approach

Simply put, CASPR Medik reduces the bioburden of pathogenic aerosols by cleaning and disinfecting environmental air and surfaces. Studies currently being conducted using CASPR Medik catalytic converter decontamination in hospital patient rooms indicate an average eight to ten-fold reduction in environmental micro-burden over pre-activation baseline samples of high-touch points. Independent clinical studies of the effectiveness of the continuous disinfection technologies have shown at least a >3 log10 reduction in clinically relevant pathogens associated with environmental contamination.

# 5.0 CASPR Medik in the Era of COVID-19: What You Need to Know

CASPR Medik provides both air and surface disinfection on a continuous basis, including the decomposition of pathogens that remain after large droplets settle from the air or after environmental cleaning and disinfection.

CASPR Medik's no-touch disinfection technology works without an operator to provide continuous facility-wide reduction of micro-burdens. The system is proven in independent lab tests to effectively reduce clinically relevant pathogens like MRSA, Norovirus, *Aspergillus Niger*, VRE, *C. difficile,* before they spread.

Summary of CASPR Compact with Medik inside attributes:

- Safe to use in occupied spaces
- Works on all surfaces, including floors
- Requires no operator and minimal maintenance
- Affordable and easy to install in dental practices
- Effectively treats 1,500 square feet
- Unit specific targeting of pathogens
- Dimensions 12"H x 12" W x 9" D
- Weighs 10 pounds

When used in conjunction with proper PPE and environmental cleaning and disinfection, CASPR Medik technology provides an extra margin of safety from AGDPs generated in the dental setting.

The stand-alone, CASPR Compact to CASPR Compact Medik closer to an air supply vent than an air return. This allows the oxidizing molecules to circulate through the room most efficiently.

Since room air is pulled into the back of the CASPR Compact Medik to pass through the reactor where oxidizing molecules are created, an unobstructed airflow is needed on both the front and the back of the unit. Allow at least six inches from the back of the unit to the wall. If placed on a shallow shelf, turn the unit sideways to accommodate the airflow.

The manufacturer describes the requirements for effective operation of the unit as follows:

- For optimal performance, ensure air flow and circulation by leaving doors open.
- Leave as much space as possible in the front and back of the CASPR Compact to enable the most efficient processing of the air.
- Never place the CASPR Compact on the floor. It must be positioned on a shelf or countertop at least 36 inches from the floor.
- Electrical 120/220 VAC, 50/60 HZ 70 watts
- Mechanical adjustable fan 460 cfm
- Max temp 150 °F
- Ensure a humidity level of at least 20% for the technology to work efficiently.

## 5.1 Why CASPR Medik is the Most Well-Rounded Method of Continuous Disinfection

In hospital studies, CASPR Medik reduced average bacterial and fungal micro-burdens by up to 80%, while significantly eliminating the incidence of MRSA, VRE and other HAIs.

## 5.2 Wellness and preventing of absenteeism

A systematic review of respiratory infections among healthcare personnel (HCPs) shows that many of them contract illnesses from their work environment. (38) Additional research demonstrates that 89% of HAIs occur in rooms with a burden of more than 500 colony-forming units (CFUs)/100cm. Illness among HCPs is a leading cause of absenteeism, although dental employee absenteeism is not tracked.

As referenced above (See Section 4.2), a clinical trial of CASPR technology in the ICU of a 527 bed hospital including patient rooms, nursing stations, and work areas saw absenteeism reduced over four months by 550 hours from 1313 to 762 for the same period the previous year. The decrease represented a 42% reduction and a gain of over 80% of an FTE (full time equivalent). While this has not been studied in the dental environment, it is expected to have a similar impact on absenteeism from illness due to pathogens in AGDPs. It is known that respiratory infections are common, and that hydrogen peroxide mist is effective in reducing spores. (17,22) Among microorganisms, spores are the most difficult to kill; this is often the criteria distinguishing sterilants from high-level disinfectants.

## 5.3 Where to Locate CASPR Compact

Many offices report that having enhanced infection control, reducing AGDPs, and including the CASPR Compact in each operatory or examination room is significantly reducing risks.

CASPR Compact should also be considered for doffing areas where dispersion may occur once contaminated PPE is removed, and beyond the operatory where the autoclave is located. When the autoclave is vented, additional humidity may build up and cause aerosols from AGDPs to linger. Analysis of air flow, year-round temperature and humidity, and existing filters will help in determining where the CASPR Compact is required.

# 6.0 Conclusion/Summary

The Department of Labor has ranked 966 categories of workers for risk of contracting COVID-19. Dental hygienists were ranked the highest, followed closely by dental assistants, general dentists and oral surgeons. (www.onet/dol.org)

OSHA, CDC, ADA and CDC/NIOSH have released various safety guidelines and all strongly recommend the implementation of infection prevention programs and protocols, particularly wherever AGPs are being produced.

Many of the suggested safety options (e.g. AAIRs or increasing room air exchange rates) for a dental clinic or operatory, are complicated and expensive.

The CASPR Compact Medikt with Medik Inside is convenient, cost effective and proven to kill pathogens. As an engineering control measure, it provides an additional level of safety and infection control and can be a key component of any successful plan reducing the transmission of diseases. Its unique engineering technology leverages the sterilizing and disinfecting qualities of HP to destroy pathogens from aerosols in the air and on surfaces, significantly reducing the risks associated with AGDPs from respiratory and waterborne pathogens.

Used in conjunction with PPE, CASPR Compact Medik ensures greater respiratory protection, creating a safer environment for the dental team and patients alike. (39-42)

# About Dr. Margaret Scarlett

A dentist, clinician, and author, Margaret Scarlett DMD is an infectious and chronic disease prevention and policy leader. For thirty years, Dr. Scarlett has provided expert guidance as a consultant to the Centers for Disease Control and Prevention (CDC), the World Health Organization, the Pan American Health Organization, the United States Agency for International Development, the American Red Cross and many consumer health companies. Author of CDC's very first infection control guidelines for dentistry in 1986, she is considered an expert on infection control, leading efforts to incorporate infection control training into dental practices and dental schools for five years for CDC worldwide. As a Senior Policy Advisor to the Surgeon General for two years, she addressed policy, based on science, at HHS from 1998-2000.

Retired from the US Public Health Service as a CAPTAIN (0-6) after more than twenty years, including two years in the US Army Dental Corps, Dr. Scarlett proudly served as "disease detective/epidemiologist" at CDC. During the Ebola outbreak of 2014-2015, Dr. Scarlett provided expert infection control guidance for CDC to train health workers and Public Health Service officers deployed to West Africa. Since 2005, Dr. Scarlett provides expertise and leadership to CDC on pandemic preparedness and response, working with CDC's emergency operations center, various CDC centers and institutes, and various private and public sector partners to mitigate epidemic impact on daily life and the workplace.

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