A Review of Enhancements to HVAC Systems Marketed to Address COVID-19 and Improve Overall Air Quality

By

Wonder Makers Environmental & Mathias Environmental

October 2020

ABSTRACT

The continuing threat of SARS-Cov-19, the virus that causes the COVID-19 disease, has brought increased attention to the role that the heating ventilation and air conditioning systems (HVAC) can have in dealing with a pandemic. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) offered general guidance in a paper published at the start of the pandemic that anticipated the later confirmation of airborne transmission of the virus.[1] Those experts offered a number of suggestions for improving the environment to minimize transmission of the virus, including enhanced filtration on HVAC systems, and a discussion of ultraviolet germicidal radiation (UVGI).

From the very beginning of the pandemic, numerous manufacturers were promoting their technology and products as enhancements to HVAC systems to reduce or eliminate viral particles. In addition to the ultraviolet light systems mentioned in the ASHRAE report, manufacturers of electrostatic precipitators, polar and bipolar ionization units, hydroxyl radical generators, ozone generators, and combination units began marketing their products to building managers and HVAC engineers as the "solution" to controlling the transmission of the virus. However, the ASHRAE paper noted that *While UVGI is well researched and validated, many new technologies are not* (page 6).

The confusing nature of the marketing claims in regards to different technologies advertised to assist with HVAC control of the virus led to the development of this white paper. A review of a large number of product claims and supporting research was conducted in order to classify the types of technologies being promoted to HVAC installers, provide a simple explanation of their method of operation, and summarize the benefits and concerns of each type of technology. The

conclusions are summarized in a simple chart to help interested parties understand the basic functioning of the various products. Although the research evaluated the marketing claims of multiple specific manufacturers of each technology, it was beyond the scope of this effort to provide a detailed evaluation of each manufacturer and model, à la Consumer Reports. Nevertheless, the overall discussion of the technologies should help building owners, facility managers, and HVAC engineers choose products that best meets the needs of a specific facility.

INTRODUCTION

A number of global conditions has brought increased public interest in indoor air quality and the role that microscopic air contaminants play and degrading air quality. Some of these recent situations include:

- Extensive wildfires in Australia in the spring of 2020
- Massive wildfires across the Pacific Coast of the continental United States in the summer and fall of 2020
- Mold contamination in buildings damaged by hurricanes
- Ongoing efforts to protect individuals working in essential industries
- The return-to-work individuals who had been restricted from gathering, in an effort to minimize the spread of COVID-19
- Efforts to reopen public indoor spaces safely while under pandemic restrictions

In response to these conditions, many products are being marketed heavily to the owners and managers of properties, claiming significant efficacy in combating airborne pollutants for a low investment cost. Although there is tremendous interest in stand-alone room air purifiers as a supplement to HVAC filtration of the air, this report focuses on products designed to be installed as part of the ventilation system for a building. Although there is a substantial number of products marketed to improve HVAC performance in regards to indoor air quality, this paper provides information on six specific technologies:

1. traditional filtration
2. ultraviolet light (UV) - also known as ultraviolet germicidal irradiation (UVGI)
3. polar/bipolar ionization
4. electrostatic precipitators
5. hydroxyl radical generators
6. ozone generators

For each of the technologies, this paper provides a summary of the technology in layperson’s language, a review of the general claims of various technologies being marketed to assist in controlling the SARS-CoV-2 virus, and a comparison of those claims to information from independent sources, when such materials were found through a basic Internet search. The goal of the paper is to provide an unbiased overview to individuals working to provide enhanced indoor air quality by helping them better understand and compare some of the "new technologies" referenced by ASHRAE.

To this end, it is critical to state that neither Wonder Makers nor Mathias Environmental has any financial ties to manufacturers or distributors of products discussed in this report. In summary, this paper is designed to provide practical information and advice from experts in the field of indoor air quality to an industry struggling to sort the facts and reasonable expectations from marketing hype.

TRADITIONAL FILTRATION

Filtration of outdoor air being brought into a building by a mechanical air handling system has been in place since the first forced air heating systems were installed in buildings in the 1920s. The rapid adoption of combination heating and cooling systems in the 1950s increased the need for basic filtration to keep cooling coils operating properly. Primarily, these filters were designed to protect the mechanical components of the HVAC system by keeping debris and large particles from entering the fans, coils, and other components.

By the 1980s, the role of the HVAC system expanded beyond providing thermal comfort. As both medical and scientific materials documented the negative impacts of elevated levels of particulates, volatile organic compounds (VOCs), and other indoor contaminants on occupants HVAC systems were seen as the primary means of addressing acceptable indoor air quality. This led to a substantial shift in thinking away from: filtration as a means of protecting the mechanical components, to filtration as a means of protecting the occupants. In 1987, ASHRAE developed a report to describe the effectiveness of air filters by rating them according to their Minimum Efficiency Reporting Value, commonly known as *MERV*. The MERV evaluation grades filters with a numerical value from 1 to 20; with 1 representing the lowest filtration efficiency, and a filter rated at 20 providing the greatest filtration (see attached chart following the end notes). The typical, one-inch fiberglass, furnace filter has a MERV rating from 1 to 4. Most typical new HVAC systems accepts medium level 1 to 2-inch pleated filters in the 6 to 8 range on the MERV chart.

The pandemic forced people to take a good look at the filtration provided by their HVAC systems. With the current virus being an average size of approximately 0.1 microns (µ), such particles were not getting screened out in any meaningful way by even medium level filters. Even medium efficiency filters (MERV rating of 12) only screen about 20% of the contaminants at the smallest measured particle size (0.3 to 1.0 µ) with every pass through the system. That is why ASHRAE made a recommendation in their report, regarding the pandemic, encouraging building owners to: *Improve central air and other HVAC filtration to MERV-13 (ASHRAE 2017b) or the highest level achievable; and keep systems running longer hours (24/7 if possible)*. This recommendation is based on the fact that filters rated at MERV 13 or higher screens out sub-micron particles at 75% or better.

While filtration is desirable, it generally has limitations and comes at a cost. Traditional filtration methods use smaller and smaller pore sizes on the filter media to trap small particulates; oftentimes by stacking multiple layers or pleats in sequence. However, this filtration efficiency creates greater and greater resistance to the airflow and increases the energy necessary to run the fans. A more significant limiting factor is the fact that traditional filter material with a greater capture efficiency

creates a pressure differential in the HVAC system, which often exceeds the design capacity and puts the entire system at risk of failure.

In response to the ASHRAE recommendation, numerous products have been offered to increase HVAC filter efficiency without creating adverse pressure differentials. Two types of filter media have been promoted extensively to assist in improving HVAC filtration: 1) tackified filter media, and 2) media that is created with a static electric charge. Tackified filter media typically is a non-woven polyester fabric with a sticky substance applied to one side of the filter. This oil or glue residue leaves the surface "tacky" and increases the rate of particle capture without significantly restricting the airflow. Working in a fashion similar to tackified filter media (as the name implies), electrostatically-charged media is made so that the fibers carry an electrical charge, which tends to attract particles as the air passes through. Although both of these techniques can improve filtration efficiency without significant addition to the pressure differential, the filter lifespans tend to be significantly shorter than more traditional filter media. For example, some electrostatically-charged media may only have a lifespan of 1 to 3 weeks before the charge dissipates and small particles pass through unimpeded.

Over the past five years, several new styles of filter media have been developed that addresses these concerns by, reportedly, providing up to MERV level 16 filtration with very low air resistance[2]. The current drawbacks to such a filtering material involve the price (up to $20 to $450 per square foot, which for large commercial units would add thousands of dollars to the cost of filter replacements), limited availability, and limited independent testing to confirm the manufacturer's claims.

Although not part of the HVAC system, a number of stand-alone air purifiers which incorporate filtration as their only, or primary, means of enhancing the quality are being marketed to deal with the pandemic situation. In addition to filtration, many of the independent room air purifiers also incorporate additional technology as discussed below, in an effort to improve the effectiveness. In general, the same benefits and concerns regarding the various types of technology that are discussed for use in air handling systems can be applied to those portable units.

ULTRAVIOLET LIGHTS

Ultraviolet light (UV) is a form of electromagnetic radiation. It cannot be seen with eyes because the wavelength is from 10 nanometers (nm) to 400 nm (shorter than that of visible light). UV radiation is present in sunlight and can also be produced by electric arcs and specialized lights, such as mercury-vapor lamps, tanning lamps, and black lights. In addition to the heating surfaces, UV light reacts with a number of chemical and biological molecules. The ability of UV rays to cause damage to skin and eyes prompted the investigation of its effect on microorganisms. As an outgrowth of that line of inquiry, ultraviolet light has been in use as a disinfectant since the late 1800s[3], with a 1903 Nobel prize awarded for work using UV light to control the spread of tuberculosis. Only more recently, with the advent of smaller, less maintenance intensive, and survivable bulbs, the technology has become more widely usable as a broad purpose indoor air quality enhancement product.

Using ultraviolet light to control infectious agents has been of such interest to the healthcare industry that such technology has developed into a specialty subsection of the use of ultraviolet light, called ultraviolet germicidal irradiation (UVGI). Installation of ultraviolet lights in HVAC systems (and as stand-alone units in critical areas of medical facilities) has been proven to reduce infections[4]. This extensive research has indicated that the effectiveness of such systems is based on multiple factors; including the specific wavelength of light utilized, the intensity of the light (which is what is determined by the strength of the bulb and the proximity of the contaminant to the source of the light), and the amount of time that the light interacts with the microbial contaminant. Therefore, it is important to note that the ASHRAE recommendation to *Add duct- or air-handling-unit-mounted, upper room, and/or portable UVGI devices in connection to in-room fans in high-density spaces such as waiting rooms, prisons, and shelters* is based on the assumption that such systems will be designed and installed properly to address the COVID pandemic, rather than for other purposes, such as preventing bio-film buildup on cooling coils or drip pans.

ASHRAE's approach is supported by the Food and Drug Administration in their recent guidance document related to ultraviolet lights as part of a response to the pandemic[5]. As part of their summary, the FDA notes: *UVC lamps used for disinfection purposes may pose potential health and safety risks depending on the UVC wavelength, dose, and duration of radiation exposure. The risk may increase if the unit is not installed properly or used by untrained individuals.* Some of these specific concerns listed include: damage to skin and eyes for individuals exposed to UV light, production of ozone as a byproduct of the operation of the system, degradation of materials subjected to exposure to UV light, and potential exposure to mercury if the UV bulb is broken. The FDA document further notes that the virus *will not be inactivated if it is covered by dust or soil, embedded in porous surface or on the underside of a surface.* The FDA also encourages the use of UVGI systems that employ bulbs which operate at a very specific, safer, wavelength[6].

Overall, the evidence makes it clear that the use of ultraviolet light systems inside existing HVAC units, or as stand-alone shielded units, mounted toward the ceiling in occupied spaces can make a positive difference in controlling the spread of infectious aerosols. Even so, to provide a measurable positive impact, the UV light system has to be sized and installed properly in HVAC systems, so that contaminants passing through the area of the ductwork illuminated by the lamp(s) provide the proper dose and duration to inactivate viral particles. Because of these variables, marketing claims indicating that a small UV bulb added to HVAC ductwork will be effective in minimizing the transmission of the virus responsible for COVID-19 should be met with significant skepticism.

POLAR-BIPOLAR COLD PLASMA AIR IONIZATION

An ionizer is an electronic device that imparts an electrical charge to particles that pass near the ionizer. Air ionization systems share many similarities with electrostatic precipitation, in that the primary operative process of the system is to use electrically-charged fields to interact with the air passing by in an otherwise unimpeded space. Electrostatic precipitation uses strong currents to charge particles, and then intentionally attracts them to surfaces with an opposite electric charge. In contrast, air ionization systems use a substantially lower amount of electricity, with the primary

intent to impart an electrical charge, or ionize, small molecules of material, as well as larger particles; referred to collectively as aerosol contaminants.

Ionization systems have a variety of different names, depending on the specific type of electric charge they impart, to aerosol contaminants and the way that the charge is created. Polar ionization systems adjust the existing electrical condition, leaving the impacted aerosols with only one type of charge: positive (+) or negative (-). Bipolar systems also impart an electrical charge to the aerosol contaminants, but those systems create both (+) and (-) charged ions. Cold plasma is typically a term used for equipment that produces positive and negative ions in a way that the electrical charge impacts the gaseous parts of the air, as well as the aerosol contaminants.

The overall benefit of ionizing aerosol contaminants (and even the gases of the air that they float in) is that the charged aerosols are attracted to one another, forming larger particles, which either drop out of the air or are easier to capture. An additional benefit is that many microorganisms are damaged when they are exposed to electrical charges after coming in contact with an ionized aerosol. There is also a proven impact that ionized aerosols have on VOCs. Volatile organic compounds are typically made up of long chains of atoms, which are broken apart upon contact with the ionized aerosols. The broken parts of the VOCs are called reaction byproducts. If the concentration of ionized particles is great enough, then the reaction byproducts are further broken down, until they reach a state of stable, basic elements, like water or CO_2. However, until that process reaches an end stage, both the existing VOCs in the building and the fragments of the original molecules (created by contact with the ionized particles) can cause ill health effects.

The positives of these systems, as aids to the HVAC equipment, revolve around their ease of installation at a relatively low cost. Despite those benefits, there are concerns over the efficacy and application of HVAC ionization systems because of the difficulty in proving their effective reach. Currently, relatively inexpensive meters make it possible to measure ionized particle concentration in the ambient air. Such measurements in real-life applications need to be evaluated carefully, as there are many sources of ionized particles in most buildings, including ambient radon levels, cooking, evaporating water, computers, copiers, certain light fixtures, and even faulty wiring. With this in mind, measuring the true impact of an HVAC system ionizer can be difficult to do with precision.

The science of the potential benefits of ionized aerosols is clear from decades of laboratory studies. Translating those benefits into workable systems, in dynamically occupied buildings, with a wide variety of HVAC components, is challenging as the positive impact of ionizers is dependent upon the type of electrical charge and volume of ionized aerosols that are produced. While most of the advertisements for such systems tout the health benefits of being exposed to an increased level of ions (especially negative ions), there are limited medical studies validating the claims. A recent medical study looked at the overall health impacts of using ionizers that impart a negative charge on the aerosols and concluded: *Our findings suggest that negative ions, possibly along with their reaction products with the room air constituents, adversely affect health. The downsides do not support the use of NIAPs (*negative ion air purifiers*) as a health-based mitigation strategy to reduce*

*$PM_{2.5}$ (*small particulate*) exposure*[7]… Even though that study (completed in August of 2020) focused on ionizers as HVAC aids to control airborne particulates, those potential adverse health effects need to be balanced against the improvement of the air quality that such systems may offer, in regards to a reduction of viral contaminants.

ELECTROSTATIC PRECIPITATION

Electrostatic precipitation systems bridge the gap between traditional particulate collection filtration, and the use of electrical currents to actively clean the passing air. First employed in large scale industrial applications to entrap soot and other byproducts from large furnaces and boilers, with a very low pass-through impedance, such systems have now been adapted to commercial and residential HVAC, and even stand-alone room air purifiers. As discussed in the previous section, the process works with electrical current to generate magnetic fields that charge the passing aerosol contaminants (primarily the larger particles). After the particles pass through the section of the precipitator where they are charged, the second section contains a surface that is charged to the opposite polarity, to attract those now charged particles.

One drawback of electrostatic precipitation or devices is, at the collection part of the apparatus, it needs periodic cleaning; a process which should be done more frequently with smaller HVAC add-on units, or stand-alone room size devices. Another concern is that in order to reach truly purifying levels of efficiency, electrostatic precipitation devices need to be operated at energy levels that results in Corona discharge. This intense electrical discharge ionizes the air to the point where water atoms are separated, resulting in the production of ozone. The ozone byproduct is the primary reason that a number of room air purifiers using electrostatic precipitators were taken off the market. Both the FDA in multiple states now control how much ozone is allowable, as a byproduct of air purifying devices.

HYDROXYL GENERATORS

Hydroxyl radicals are unstable molecules that are typically formed in the air when one of the oxygen atoms is stripped away from a water molecule. This process changes a single stable H_20 molecule into a highly reactive single oxygen atom, and equally reactive oxygen/hydrogen molecule; known as a hydroxide ion or hydroxyl radical (*i.e.* $H_2O = O + HO$). The production of hydroxyl radicals occurs naturally in the upper atmosphere, and leads to the natural breakdown of chemical and biological pollutants.

Since both the oxygen atom and hydroxyl radical are unstable and seek to reconnect with other materials in the air, they are extremely short-lived, usually lasting less than a second. While they exist, hydroxyl radicals function as potent oxidizers, breaking down chemical compounds and organic matter. Perhaps more importantly, the hydroxyl radicals "kick start" what can become a cascade of chain reactions, as different chemical compounds form, only to react with another near-by compound. These newly created intermediary compounds may also be short-lived and trigger additional reactions; or may live longer, lasting hours or more.

Hydroxyl radical generators mimic the natural production of these reactive molecules. The two main technologies utilized in such equipment both involve ultraviolet light. Some units shine specific UV wavelengths on special catalyst materials (frequently titanium dioxide) to produce the hydroxyl radicals. Other devices use a different UV wavelength to break down some of the ambient humidity in the air. The systems that use a catalyst are not as dependent on an adequate supply of moisture in the air; making them simpler to install in HVAC systems, without having to add humidifiers, steam jets, or other sources of water.

One of the advantages that hydroxyl radical generators offers to the facilities manager or the homeowner, is that the basic hydroxyl generation system can be made fairly small and easily installed in HVAC systems. They can also be built into small portable units. Some hydroxyl radical generators have been miniaturized to the point where they can be plugged into an outlet and be left there much like a nightlight.

Hydroxyl radical generators are frequently advertised as being safe for "people, pets, and plants." While there is a significant amount of medical data supporting the safety of the actual hydroxyl radicals (primarily because of their extremely short life span), the safety question needs to consider both the unintended creation of ozone and the "cascade effect." Depending on the technology used to create the hydroxyl radicals, such generators can generate small amounts of ozone. Generally, this secondary generation of ozone is well below the current occupational permissible exposure limits (PEL), but cannot be fully dismissed as a health concern, as hydroxyl radical generators installed inside HVAC units may run on a continuous basis.

Numerous studies have documented that as the hydroxyl radicals break down larger chemical molecules, the resulting materials may well have toxic properties that are as significant, or even more serious, then the original contaminant. The type and level of potentially dangerous compounds produced by the impact of hydroxyl radical generators are difficult to document, as they are unique to each particular environment. Even so, studies from the restoration industry indicate that when hydroxyl radical generators are used in environments with significant airborne contamination (such as fire residue), the level of dangerous compounds produced during the air cleaning process can be significant. This risk of producing unknown, potentially dangerous, byproducts from the hydroxyl radical cascade effect has been shown to be negligible in commercial and residential applications where off-gassing of new building products has dissipated.

OZONE GENERATORS

Ozone is an unstable, form of oxygen that has three oxygen atoms bonded together, rather than two (*i.e.* ozone is O_3 rather than O_2). Ozone is formed naturally in the upper atmosphere from the oxygen in the air and is impacted by the electric discharge from lightning or exposure to ultraviolet radiation. Ozone is also produced in the lower atmosphere by the reaction of certain pollutants to sunlight.

Because the ozone is a highly reactive molecule, it has been used extensively to deodorize air, purify water, and treat industrial wastes. Portable units that generate ozone on demand through the

use of electric discharge has been used for over 20 years in the restoration field, or merely to deodorize smoke-impacted contents after a fire. The benefits of ozone centers around the proven efficacy and potency of this unstable gas to break down and rapidly oxidize most organic compounds. This ability to reliably create reactions leads to a track record of successful use.

Unfortunately, along with a history of use comes a history of documented health and occupancy risks. Ozone is known to be dangerous to human lung tissue, as well as a strong corrosive agent on oxidizable metals. It also has the ability to rapidly break down rubber and latex products. In response to these known hazards, OSHA has set limits to the amount of ozone workers can be exposed to, which can make such equipment difficult to employ in work place settings. Generally, ozone generators are not to be operated in occupied spaces, which makes it inappropriate for use in HVAC systems, or as stand-alone room air purifiers. The Environmental Protection Agency has multiple warnings regarding the use of ozone generators for air purifiers[9].

CONCLUSIONS

Our understanding of what a "clean" indoor environment is has undergone a radical transformation in both the professional and public sphere over the course of recent events. Concerns ranging from global pandemics to local fires and chemical crowd-control have brought heightened public scrutiny to the need for consistently clean air inside buildings. Many facility owners and managers have begun searching for options to keep occupants safe as part of their re-opening plan. This increased demand for "healthy air" to let everyone return to "normal" safely has seen a multitude of products being advertised as effective improvements to the building HVAC systems; sometimes with dubious health claims. Today, as never before, there are many questions for the HVAC community to address from the perspective of occupant and public wellbeing, rather than the perspective of a product manufacturer.

For many situations, traditional filtration methods are still the most demonstrably effective tool. They work reliably and can be made to fit almost any space. Upgrading the filtration level of existing HVAC equipment has the simple benefit of being able to work in combination with additional technologies, as further evidence proves what sort of equipment could offer additional protection for a specific facility. As has been found time and again, as the HVAC industry has grappled with issues of indoor air quality and airborne contaminants, the best solution is always to eliminate the exposure to the hazard by physically removing the hazard. This helps to explain the new industry guidance which is recommending MERV-13 filtration for HVAC units; an uncommon level of filtration for commercial and residential systems before the declaration of a pandemic.

Along with enhanced filtration, there is also proven applicability for UVGI systems in addressing the virus that causes COVID-19. These systems have already shown efficacy in medical and mass housing applications, primarily in the prevention of tuberculosis and hospital-acquired infections. Substantial information is available that allows worthwhile UV equipment to be installed in HVAC systems in a fashion that provides real improvements in the indoor air quality. Unfortunately, such detailed planning and proper installation are not being explained by equipment manufacturers,

many of whom are advertising that residential and commercial HVAC units can be upgraded with a UVGI light as easily as changing the filter.

Air ionization systems have been advertised for over a decade, as devices that can improve air quality by reducing the level of airborne particulates. These well-documented benefits have been supplemented with claims regarding the deactivation of airborne microbiological contaminants. The effectiveness of these claims depends on the type of electrical charge and volume of ionized aerosols that are produced. The claimed safety and benefits of adding such equipment to HVAC systems has been challenged by independent studies, which raised questions about the negative health effects of the ions themselves, as well as the byproducts they create. Independent research on the efficacy and potential health impacts is needed to clarify and verify the claims made by the manufacturers.

Electrostatic precipitators seem to be a solution best suited for industrial-scale application where pollution capture is completed in air streams that are not supplying occupied areas. Concerns about secondary ozone generation by electrostatic precipitator air cleaners (particularly when collection plates are not properly cleaned) should be evaluated carefully before installation of such systems in commercial or residential HVAC units.

Hydroxyl generators have yielded promising results for killing airborne contaminants. This does not come without some hesitation in using these systems in close proximity to building occupants. The tendency of some of these systems to inadvertently produce ozone is a reasonable cause for concern. Additionally, while hydroxyl radicals do not linger, many of the byproducts of the chain reaction produced by the introduction of hydroxyl radicals into the air have a longer lifespan, as well as known toxicity. Even hydroxyl radical generators that do not produce ozone as a byproduct should not be used in areas with significant off-gassing of VOCs; either because of the presence of new building products, or because of commercial or industrial processes in the building. Therefore, hydroxyl radical generators (as part of an HVAC system) seem best suited to address microbiological contaminants in ambient air conditions that do not have a substantial concentration of volatile organic compounds.

Many of the technologies discussed in this paper are not yet "well researched and validated," as ASHRAE noted. In contrast, ozone generators as air purifiers have been thoroughly researched and found to be far more harmful to the occupants than helpful to the environment. To both protect health and avoid liability, ozone generators should not be installed in HVAC systems.

In contrast to ozone generators, other technologies, such as electrostatic precipitators, ionizers, and certain types of hydroxyl radical generators (that are prone to producing ozone as a byproduct) should be evaluated very carefully before connecting them to HVAC equipment and only consider units which are California compliant; as they have to submit test data which verifies their claims regarding residual ozone production.

Just as the ozone issue was addressed by customer demand for verified testing results under real-world conditions and regulatory intervention, this may also be the case for HVAC enhancements

that generate ionized particles or hydroxyl radicals. Until such testing where an independent validation is available, individuals responsible for evaluating, installing, and operating supplemental equipment in connection with an HVAC unit have an obligation to research products carefully to help protect the health of the occupants. This means that such professionals should look beyond marketing materials, to understand the different technologies advertised, and address the current pandemic before they make a selection to add any supplemental process to HVAC equipment.

More importantly, HVAC design, installation, and repair professionals should never recommend supplemental equipment that is untested or of questionable use, simply to calm fears of owners or occupants without knowing the complete picture of the full effects of the add-on equipment. In each situation that arises for the building manager or HVAC professional, education on how a system works is paramount to understanding if that system is right for their application. As one safety and health expert who specializes in infection control put it when explaining how HVAC systems could be helpful in addressing COVID-19 [10]: *It is critical to remember that each indoor environment is unique; conditions within each indoor environment are dynamic, and there is not a one-size-fits-all strategy for infection control.*

END NOTES

1. ASHRAE Position Document: https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf
2. Two notable examples of new filter media with high capture efficiency and low static pressure: https://www.sandersfilters.com/containment-filters and https://www.dynamicaqs.com/commercial/products/v8-air-cleaning-systems
3. A summarized history of ultraviolet light for disinfection: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2789813/
4. Aerosol Susceptibility of Influenza Virus to UV-C Light: https://aem.asm.org/content/78/6/1666.full
5. The Food and Drug Administration (FDA) provides an objective summary of ultraviolet light as a means of dealing with the COVID-19 pandemic: https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/uv-lights-and-lamps-ultraviolet-c-radiation-disinfection-and-coronavirus#:~:text=A%3A%20UVC%20radiation%20is%20a,often%20called%20%22germicidal%22%20lamps.
6. Report about a safer UV light for COVID-19: https://www.sciencedaily.com/releases/2020/09/200917105345.htm
7. Medical study about the health effects of negative ion air purifiers: https://pubmed.ncbi.nlm.nih.gov/32757287/
8. Electrostatic precipitators most effective against microorganisms at power levels which create a Corona discharge: https://www.researchgate.net/publication/26790816_Airborne_Virus_Capture_and_Inactivation_by_an_Electrostatic_Particle_Collector
9. EPA information on ozone generators that are sold as air purifiers: https://www.epa.gov/indoor-air-quality-iaq/ozone-generators-are-sold-air-cleaners
10. Summary article on managing indoor air quality on the COVID-19: https://www.randrmagonline.com/articles/89119-how-to-manage-indoor-air-quality-amid-covid-19

AUTHORS

Michael Pinto is the chief executive officer of Wonder Makers Environmental. For over 40 years, Michael has provided professional safety and industrial hygiene services related to asbestos, lead, IAQ, mold, chemical exposures, infectious agents, and noise. Mr. Pinto is the author of over 230 published articles and several books. He currently serves as a Restoration Industry Association (RIA) representative on a joint task force, with members from the Institute of Inspection, Cleaning and Restoration Certification (IICRC), and American Industrial Hygiene Association (AIHA), providing education and guidance regarding the provision of restoration services during the COVID-19 pandemic.

Dave Heydinger is the President and founder of Mathias Corporation, a twenty-five year old construction and construction management firm, and Mathias Environmental, an indoor air quality consulting firm and solution provider for significant facilities seeking to reopen safely in the current pandemic. Dave has a Civil & Environmental Engineering Degree from Vanderbilt University. He has extensive experience in the construction, renovation, and operation of major mechanical operating systems in diverse facilities over the past 33 years.

Jacob Kooistra is an Environmental Specialist with Wonder Makers Environmental, Inc., a manufacturing and environmental consulting firm that specializes in identification and control of all types of indoor contaminants. For 10 years, Jacob has worked in the property restoration industry, specializing in mold remediation and caring for sensitized individuals. In his current position, Mr. Kooistra assists building owners and occupants when they face indoor air challenges related to mold, lead, asbestos, and chemicals.

COMPANY INFORMATION

Wonder Makers Environmental

Since 1988, Wonder Makers Environmental, Inc. is a manufacturing and environmental consulting firm whose focus has been on improving conditions inside buildings. We specialize in identification and control of asbestos, lead, IAQ, mold, industrial hygiene, and chemical problems. Traditionally, this has involved the inspection, assessment, and control of hazardous contaminants, such as asbestos, lead, chemicals, radon, mold, and multi-faceted situations that fall under the heading of indoor air quality (IAQ). Wonder Makers Environmental provides the expertise to evaluate the conditions, conduct risk assessments, and develop recommendations and/or specific work plans for control of the hazards. to protect the owners.

CONTACT INFORMATION:
Website: www.wondermakers.com
Email: info@wondermakers.com
Phone: 269-382-4154

Mathias Environmental

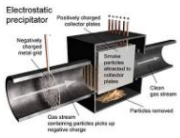
Mathias Environmental provides expertise to commercial and public facilities to evaluate, design and implement effective indoor air quality strategies to battle the spread of pathogens. These include the SARS-CoV-2 novel coronavirus and the H1N1 Flu virus. Our mission is to significantly improve the indoor air quality in our clients' facilities and help protect those that use them.

CONTACT INFORMATION:
Website: www.mathiasenvironmental.com
Email: dheydinger@mathiascorp.com
Phone: 706-705-6322

Chart Of Minimum Efficiency Reporting Values (MERV) By Particle Size

MERV Rating	Air Filter will trap Air Particles size .3 to 1.0 microns	Air Filter will trap Air Particles size 1.0 to 3.0 microns	Air Filter will trap Air Particles size 3 to 10 microns
MERV 1	< 20%	< 20%	< 20%
MERV 2	< 20%	< 20%	< 20%
MERV 3	< 20%	< 20%	< 20%
MERV 4	< 20%	< 20%	< 20%
MERV 5	< 20%	< 20%	20% - 34%
MERV 6	< 20%	< 20%	35% - 49%
MERV 7	< 20%	< 20%	50% - 69%
MERV 8	< 20%	< 20%	70% - 85%
MERV 9	< 20%	Less than 50%	85% or Better
MERV10	< 20%	50% to 64%	85% or Better
MERV 11	< 20%	65% - 79%	85% or Better
MERV 12	< 20%	80% - 90%	90% or Better
MERV 13	Less than 75%	90% or Better	90% or Better
MERV 14	75% - 84%	90% or Better	90% or Better
MERV 15	85% - 94%	95% or Better	90% or Better
MERV 16	95% or Better	95% or Better	90% or Better
MERV 17	99.97%	99% or Better	99% or Better
MERV 18	99.997%	99% or Better	99% or Better
MERV 19	99.9997%	99% or Better	99% or Better
MERV 20	99.99997%	99% or Better	99% or Better

Condensed Fact Sheet

ITEMS						
DESCRIPTION	**Traditional Filtration**	**Electrostatic Percipitators**	**Polar/Bipolar Ionization**	**Ultra Violet Light**	**Hydroxyl Radical Generation**	**Ozone Generation**
HOW IT WORKS	•A mesh or weave of various opening sizes sifts the air passing through the filter and catching airborne particulate •Can be enhanced with Tackified media or charged media	•Positive plates charge particles •Negative plates attract positive particles	•Positive and/or negative discharge points create charged molecules •Charged molecules cause chemical reactions and collide with one another	•Specialized bulbs generate specific spectrum light •This light is damaging to cells, including airborne bio-contaminants	•Specialized bulbs and specific coatings create Hydroxyl gas •Some systems forego the coatings in favor of stronger bulbs •Hydroxal gas oxidizes the air it interacts with	•Controlled electrical discharge breaks down oxygen in the atmosphere •Ozone gas is a strong oxidizer that interacts with the air around it.
GOOD POINTS	•Simple to understand •Easy to modify the system to suit the space •High degree of provable efficacy •Portable additive systems are readily available	•Very low pass through impedence •Scalable to large or small spaces •High degree of provable efficacy	•Simple installation process •May be safe for occupied spaces •Low cost of operation	•Multiple flexible installation options •Low health hazards when installed correctly •Proven kill claims	•Multiple plug and play options for room based solutions •Proven kill claims •Effects spread widely	•Proven kill claims •Strong odor indicator that a space is “clean” •Effects spread widely
ISSUES	•Upgrading existing systems can be expensive •Plug and play systems can be expensive and bulky	•Larger systems can have high power demands •Collection elements need regular cleaning to remain effective	•There is a lack of data on the long term health effects from exposure •Kill claims are still being evaluated •May generate ozone as a byproduct	•Can cause damage to eyesight if the bulbs are looked at directly •In order to ensure effective kill of bio-contaminants, close contact is required •Many publicly marketed systems may not be strong enough for the spaces they are employed in	•There is lack of data on the long term health effects from exposure •Produces some amount of ozone as a byproduct •Intermediate stage byproducts can be hazardous	•Ozone is a known health hazard •Ozone breaks down natural rubber and latex
EXAMPLES	•**Sanders filters:** Containment Media 150 •**Honeywell:** Home Filter systems •**True blue:** Basic Blue	•**Cosatron:** Model LC1750	•**Global Plasma Systems:** GPS-FC-3-BAS •**Plasma Air:** PlasmaPURE 600 Series •**Phenomenal Aire**: R6.0 - R Series 6.0 Cold Plasma Generator	•**International Ozone Systems:** Interceptor RIUV-A18 •**Bioshield:** 50-BUVAS-E	•**Odorox:** Oasis+ •**International Ozone Systems:** Titan 1000	•**International Ozone Systems:** Total Zone TZ-1 •**Odor Free**: Autel 1000