Schnackel University

Schnackel engineers

ENHANCED HVAC INFECTION CONTROL: IONIZATION

WHITE PAPER JUNE 2020

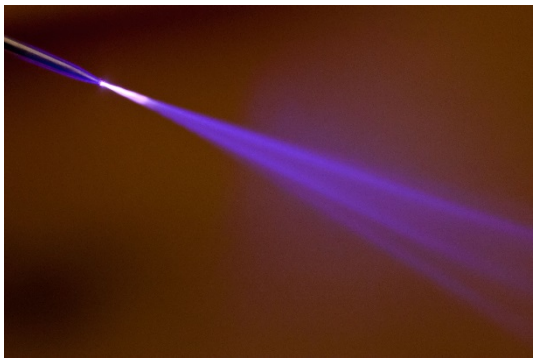
This is the fourth in a series of white papers covering the topic of infection control in buildings through enhanced HVAC strategies.

Introduction

In addition to the mechanical filtration and UV-C disinfection methods discussed in our previous white papers, there are a number of other technologies commercially available that claim to disinfect the air or improve the overall air quality. In this white paper we look at one category of those technologies - ionization based air purification systems.

Background

Ionization air purification involves the use of a high voltage conductor (wire, plate, needle, etc.) to create air molecules with a negative (or positive) charge by adding (or removing) one electron to (or from) the air molecules, thereby creating N_2^- and O_2^- (or N_2^+ and O_2^+) molecules. These charged molecules (anions and cations respectively) attract impurities in the air by electrostatic attraction. Once they bond with the impurities in the air they are attracted to either positively charged surfaces (plates) in the device itself, or grounded surfaces in the nearby area like walls, floors and ducts.



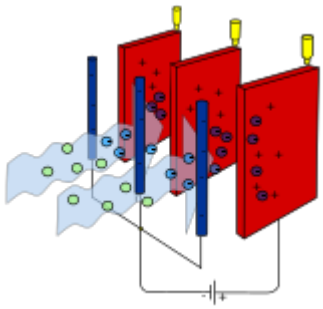
Corona Discharge from a Needle

Ionization via corona discharge occurs when a conductor of sufficiently high voltage causes the fluid (air) around the wire to become conductive (ionized) without resulting in an electrical breakdown or arc to adjacent surfaces. This process creates a region of plasma (conductive gas) around the conductor. This plasma region generates the negatively or positively charged ions that are attracted to dust, bacteria and viruses in the airstream. With sufficiently high voltages, other products of corona discharge can include ozone (O_3), nitric oxide (NO), nitrogen dioxide (NO_2) and nitric acid (HNO_3) if water vapor is present

Electronic Precipitation Systems

Today there are many different technologies that rely on the ionization of air to promote air cleaning. The "electronic air cleaner" or "electrostatic precipitator" is one common type of ionization device that has been in commercial production since the mid-1950s. This device is a self-contained unit, typically installed in an air handling unit equipped with pre-filters and final filters to ensure longer life and reduced maintenance of the precipitator. Some freestanding room air purifiers also include electronic precipitators in their design.

These devices use thin corona wires charged to a very high voltage to create negatively charged ions that bond with airborne particles. These charged particles are immediately trapped by positively charged plates downstream of the corona wires.



Electronic Air Cleaner or Electrostatic Precipitator

These devices became fairly popular in the 1970s and 1980s however their popularity has waned as a result of two main factors. First, as the collector plates become dirty with captured particulate matter their effectiveness drops dramatically. Over time the surfaces of the collector plates corrode and the filter no longer performs as well as it did when it was new. Replacement cells are expensive, so they tend to be simply turned off. Second, it was soon discovered that these devices generate significant amounts of ozone (O_3) as a byproduct of the

ionization process, due to the operation of the corona wires.

Ozone Generators

Personal ozone generators became quite popular in the late 1990s and early 2000s with introduction of the Sharper Image "Ionic Breeze" product. The product was claimed to improve indoor air quality by reducing a multitude of airborne contaminants. The claims were found to be misleading. In addition, the early models of this product were designed to intentionally produce ozone as the primary "purification" method. Ozone has been determined to be a severe lung and eye irritant and, in sufficient concentrations, can be toxic.

The Occupational Safety and Health Administration's (OSHA) maximum Permissible Exposure Limit (PEL) for ozone in the workplace is 100 parts per billion (ppb) averaged over an 8-hour work period. The National Institute for Occupational Safety and Health (NIOSH) recommends exposures of no greater than 100 ppb over a 15-minute period and California Ambient Air Quality Standards' threshold is 70 ppb maximum over an 8-hour exposure period. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends no more than 10 ppb as a "safe" level and states that it should be maintained "as low as reasonably achievable."

Even the best ionization systems today can generate some trace amounts of ozone. Systems that generate as little as 2.2 mg/hr have been found to result in a 40 ppb concentration in a ventilated office space. Ozone, even at very low concentrations can be extremely detrimental to your health and should be avoided at any level.

Bipolar Ionization Systems

This technology also uses electrodes designed to create reactive ions in the air, however they are designed to create both positive and negative ions simultaenously by applying an alternating current (AC) to a tube with two electrodes in a process called cold plasma discharge. When voltage is applied to the electrodes, an ionization field is created around the tubes, creating both positive and negative ions (cations and anions) of oxygen.

Bipolar ionization systems differ significantly from previous ionic air cleaning technologies because rather than attempting to capture the particles on collection plates at the device itself, the ions are dispersed into the airstream to bond with air particles (dust, allergens, bacteria and viruses) agglomerating them into larger particles that fall to the ground or are more easily captured by the HVAC system's filtration systems. Since the cations and anions have a half-life of only about 30 seconds their effective range in the air is fairly limited.

The positive and negative ions also react with water vapor and oxygen in the air to create free radicals, primarily OH. A free radical is a molecule, atom, or ion that has an unpaired valence electron, making them highly chemically reactive. They are inherently unstable and are "looking for" an H^+ molecule to become chemically stable again. These free radicals can kill microorganisms, including viruses, by disrupting their ability to reproduce. They can bond to bacteria and viruses, robbing them of hydrogen molecules on their surface, thereby disrupting their ability to reproduce or infect. OH radicals, have a very short lifespan, less than 1 second, so any biological neutralization will occur at or near the unit equipment and not within the occupied space, as often claimed. The effectiveness of OH radicals as an airborne (gaseous) cleaner has not been proven conclusively in any peer-reviewed scientific study.

The cations, anions and free radicals generated by bipolar ionizaiton units also react with VOC's in the air, breaking down the molecules into less harmful compounds like carbon dioxide and water, usually only in trace amounts.

The ionizing tubes of a bipolar ionization system can be installed withing the discharge plenum of the air handler or into the main supply air duct. Bipolar Ionization in its current form has been available in the United States since the early 2000s. As a result, there is very little conclusive independent scientific research available.

Bipolar Ionization Module

Needle Point Bipolar Ionization Systems

One variant of bipolar ionization is Needle Point Bipolar Ionization (NBPI). In this case, instead of ionizing tubes, the systems use what the manufacturers call "needles" to do the ionization. The needle point electrode module is a fraction of the size of the tube type units, with a cross sectional area of only 0.50" x 3.25" compared to a 9" x 4.25" cross sectional area of the tube type module. These are compact modules that the manufacturer claims can be installed in ductless air conditioners. The manufacturers of both tube type and NBPI systems claim their process differs from corona discharge systems because the power output at the electrodes is low enough to not produce ozone as a by-product.

Needlepoint Bipolar Ionization Module

Photocatalytic Oxidation Systems

This technology uses ultraviolet radiation combined with a catalyst, usually Titanium Dioxide (TiO_2), to generate free hydroxyl (OH) radicals, ionized hydro-peroxides and super-oxide ions (O_2^-) that kill biological contaminants and VOCs. The UV radiation reacts with the Titanium Dioxide causing it release electrons. The electrons react with water vapor in the air producing the OH radicals and with oxygen to produce the O_2^- ions. These OH radicals then attack the micro-organisms in much the same manner as the Bipolar Ionization technology discussed previously. There are significant drawbacks to this technology, including the production of small amounts of ozone during the Titanium Dioxide ionization process, as well as the potential for a byproduct of formaldehyde due to incomplete oxidation of airborne VOCs from paint, carpets, furniture, etc.

Due to the very short life of the OH radicals produced, the biological neutralization process occurs primarily on the surface of the catalyst, not in the airstream or in the occupied space, limiting the effectiveness of this process to the air that comes in direct contact with the catalyst. Therefore they are typically only effective in relatively small systems and spaces.

Photocatalytic Oxidation Module

Summary

Unlike the previously addressed filtration and UV sterilization methods, there are very few independent, peer-reviewed scientific studies covering these ionization technologies in detail. Consequently, most of the available information comes from the manufacturers themselves or from studies sponsored by the manufacturers of this equipment. ASHRAE cautioned as recently as 2018 that: *"Convincing, scientifically rigorous, peer-reviewed studies do not currently exist on this emerging technology. Manufacturer data should be carefully considered."*

Before considering the installation of any of these products, check the available literature for any independent scientific test data regarding the generation of undesirable by-products, such as ozone or formaldehyde. Ozone is considered hazardous to your health, even at concentrations as low as 10 ppb, so any device that generates even trace amounts of ozone should be avoided. Formaldehyde is a highly toxic systemic poison that should never be introduced into occupied spaces under any circumstances.

Electronic Precipitators carry a significant risk of ozone generation as well as degraded performance over time without continuous maintenance of the collection plates. For these reasons, they have fallen out of favor and should be avoided.

Ozone Generators are a definite no, since ozone is a known severe respiratory and eye irritant.

Bipolar Ionization appears to be a viable option for the overall improvement of air quality, however the manufacturers' advertising claims appear to be a bit overstated due to the short life span of the ions and free

radicals produced by these systems. The claimed agglomeration and biological neutralization "throughout the occupied space" do not seem to be supported by the reaction times of the charged particles generated, ranging from well under 1 second to a maximum of about 30 seconds. In addition, any particles that are "dropped from the air" as claimed are subject to disturbance and reentry into the occupied zone if not cleaned up soon after they are precipitated.

Photocatalytic Oxidation may have specific limited applications, however these units tend to be only moderately effective in smaller rooms and carry with them the potential for the generation of small amounts of ozone during the ionization of the catalyst material by the UV lights. Incomplete oxidation of VOCs can also potentially lead to the formation of formaldehyde, depending on which VOCs are present in the airstream.

Final Considerations

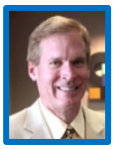
When considering these relatively new technologies, we must be sure that in our quest to clean the air we do not end up introducing equally or potentially more dangerous agents than the ones we are trying to eliminate. Any technology that utilizes ozone as its primary method of sterilizing the air should be strictly avoided due to the known health risks of breathing ozone. Even the best ionization systems still generate trace amounts of ozone as a byproduct of the ionization process and should be carefully considered based on the amount of ozone generated. Depending on the size of the space served and the amount of outdoor air introduced for dilution, any ozone production above about 2.2 mg/hr is considered too high and should be avoided.

Lastly, these technologies should always be used in tandem with the appropriate mechanical filtration to physically remove the *potentially neutralized* contaminants from the air to avoid redistributing them, which could occur with systems that claim to drop them on surfaces within the occupied space.

About Pedro:

Pedro Ferrer, P.E., has been involved in the design of mechanical systems for malls, mixed-use developments, corporate offices, national retail roll-outs, commercial and institutional buildings for over 26 years with Schnackel Engineers.

About Gregory:



Gregory Schnackel, P.E., LEED AP has been involved in the design of mechanical, electrical, plumbing, fire protections and information technology systems for malls, mixed-use developments, corporate offices, national retail roll-outs, schools, hospitals, medical facilities, commercial and institutional buildings for over 40 years with Schnackel Engineers.

RESOURCES	
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