Causing more harm than good? No evidence bipolar ionization inactivates SARS-Cov-2 in HVAC systems, limited evidence of effective particle reduction, and concerning evidence of creation of hazardous chemical byproducts in air

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There is no peer reviewed science documenting the effectiveness of bipolar ionization to clean the air in an indoor space of SARS-CoV-2, the virus that causes COVID19. Yet there is aggressive marketing by many vendors to install these units in schools, offices and other spaces. The theory of bipolar ionization sounds elegant and plausible – positive and negative ions that are added to the air stream in an HVAC duct cause particles to glom or stick together, easily removed by a MERV8 filter. How does the technology work? Ionized particles introduced by corona discharge based bipolar ionization devices strip electrons from gas molecules like O_2 , creating ions that react with particles (dust, pollen, bacteria, virus, volatile organic compounds [VOC's]) to form bigger and heavier ions that can then be filtered out or simply settle out in the chamber due to gravity (Kim et al. 2017). There is little noise and after the substantial installation costs, the units are relatively low maintenance. However, for this technology to work to decrease particles, there needs to be a stable and wide ion field generated to have sufficient contact time in air (Kim et al. 2017). The scientific studies that have investigated the benefits of bipolar ionization to reduce particles and VOC's do not convincingly show there is actually any net benefit to using the technology compared to other methods such as filtration. In fact, bipolar ionization is associated with more problems than benefits as scientists have measured the creation of hazardous gas byproducts and noted negative health effects as well. This white paper reviews and outlines the current and most recent scientific literature on bipolar ionization, explaining the problems associated with this technology and demonstrating that marketing claims regarding 99.4% inactivation of SARs-CoV-2 are just that – marketing claims. There is no peer reviewed study that demonstrates this result in a laboratory duct system or real world HVAC system.

Researchers that investigated positive and negative ionizers' impact on 3 test microbes (Escherichia coli (E. coli), Salmonella typhimurium (S. typhimurium), and Staphylococcus epidermidis (S. epidermidis)) in a laboratory based duct study found the technology highly susceptible to humidity changes, which decreased disinfection efficiencies (Nunayon et al. 2019). Additionally, the disinfection efficiency decreased as the air velocity increased. Increasing the air velocity from 3 to 6.5 m/s (described as typical expected flow rates) substantially decreased the disinfection efficiency for both the positive and negative ionizer. For the positive ionizer, the increase from 3 to 6.5 m/s reduced disinfection efficiency from 89 to 44% (E.Coli); 49 to 39% (S. typhimurium); and 35 to 20% (S. epidermidis) (Nunayon et al. 2019). For the negative ionizer, the increase from 3 to 6.5 m/s decreased the disinfection efficiency from 63% to 35% (E.Coli); 52 to 30% (S. typhimurium); and 43% to 30% (S. epidermidis) (Nunayon et al. 2019). To recap, disinfection efficiencies overall, regardless of type of microbe or positive or negative ionizer, were dramatically decreased to the 44% to 20% reduction range with an increase in air velocity that is typical of those found in HVAC systems (Nunayon et al. 2019).

These low microbe disinfection efficiencies contrast markedly with claims that bipolar ionization can inactivate 99.4% of SARS-COV-2. A closer examination of the test methods of the 3rd party lab Innovative Analysis, commonly cited for the result of 99.4% inactivation of SARS-COV-2, reveals why. Unlike the Nunayon et al. (2019) study, which evaluated disinfection under the dynamic conditions of air flow in a duct system, the Innovative Analysis methodology uses a static chamber study. The test was conduct in a chamber that is only 1 ft3 in volume (12" x 16.5" x 9"). A stable ion level was first achieved, the ionizers turned off, and then differed sealed petri dishes inoculated with cells infected with SARS-COV-2 virus were exposed for 10, 15, and 30 minutes. After 30 minutes of the petri dish sitting in a small space with a highly charged ion atmosphere, 99.4% disinfection was achieved. The test conducted by Innovative Analysis is actually demonstrating that bipolar ionization can deactivate the virus on surfaces after 30 minutes of exposure, and it is not a test of the inactivation of the virus in a moving air stream. It is a surface disinfection test in a small space. It is not at all similar to the peer reviewed and accepted methods used by other building air quality scientists and engineers evaluating bipolar ionization performance in HVAC systems and cited in this document.

In addition to the issue of marketing claims versus scientific evidence for virus removal, there remains elevated concern of hazardous chemical byproducts created by bipolar ionization technology. A recent study by Zeng et al. (2021) included a careful review of the effectiveness of bipolar ionization to remove particles and impact on unintended VOC byproducts. The study included 2 phases: a large chamber in a laboratory under controlled conditions and testing bipolar ionization installed in a real world office building. The researchers in the chamber study set up a small office in the chamber, with furniture and books, and ensured the air exchange rate was stable and the bipolarization achieved a steady state before measuring pollutants including particles/particulate matter (PM), ozone, NOx, VOC's in air (via EPA Method TO-15) and aldehydes and carbonyls (via EPA Method TO-11).

PM was introduced into the chamber via incense. The results indicated that the PM2.5 concentration when the ionizer was off was hardly different from the PM 2.5 concentration when the ionizer was on. In short, the ionizer reduced PM2.5 by only 5% (Zeng et al. 2021). While the total organic compounds (the sum of every identified VOC) was reduced by 19% with the ionizer in "on" operation, the study found that certain VOC's like acetone increased by 73%. Concentrations of toluene and butylaldehyde also increased; the authors suggest that these chemicals might have been produced by the ionizer (Zeng et al. 2021). To summarize, the chamber experiments suggest no benefit from biopolar ionization because there were no significant decreases in PM2.5 and increases in certain harmful VOC's.

The field study in Zeng et al. (2021) evaluated particle number concentrations and the size distribution of the particles upstream and downstream of a installed bipolar ionization unit in the HVAC duct of an office building. Researchers found no change in the number concentration or size distribution of particles comparing upstream versus downstream, suggesting no particle agglomeration occurred. The creation of charged particles that glom together is the very claim central to the effectiveness of the technology yet no evidence was found that this occurred. The measurement of VOC's in the duct found some decreases but also increases in VOC's such as acetone, isopropanol, methyl methacrylate, and toluene. Comparing the chamber versus the in duct study, no benefit from bipolar ionization was determined, and the authors caution more study, as there was formation of unintended VOC byproducts.

Crawford et al. (2019) conducted a study in a New York state classroom with a bipolar ionization unit installed in the duct. The team measured ozone, total VOC's, particles, and carbonyls. They added 1 ml of limonene as a VOC introduction challenge. The class room conditions remained stable at 70 o F and RH ranged from 51 to 74%. Both formaldehyde and acetone increased by 2 to 5X when the ionizer was in operation (Crawford et al. 2019). Particle number count was also highest during the unit operation. Therefore again, in a real world classroom, no net benefit was demonstrated by use of the bipolar ionization technology.

Liu et al. (2020) determined increased oxidative stress (measured with a biomarker malondialdehyde in urine) in young healthy adults after exposure to negative ions (~60,000 ions/cm3). The researchers concluded that the benefits of PM reduction that were demonstrated did not offset the adverse negative health effects of exposure to negative ions (Liu et al 2020).

In another study involving the use of ionizers to purify air in classrooms (11 to 14 year old students) in Beijing China, researchers found that PM2.5 was reduced by 44% and PM 0.5 was reduced by 48%, and exhaled NO was decreased by 15% (Dong et al. 2019). However, heart rate variability was negatively impacted, and the authors recommended more investigation into use of bipolarionization on health effects is needed due to this result (Dong et al. 2019).

The overall science on bipolar ionization is far from settled. Health effects studies involving people in spaces where bipolar ionization is used do not support there are health benefits, or are at best, indicate mixed results to health. There is no evidence supporting the marketing claims of 99.4% SARS-CoV-2 reduction, and the reduction of typical particles in a real world setting is often far less than 50%. Bipolar ionization also appears to create unintended

VOC byproducts, with unclear health impacts. In general, there is not much recommending bipolar ionization with respect to cleaning the air of COVID19. Tried and true technologies, including filtration and UV-C, that have been studied for decades with a wealth of scientific evidence to support them, should be deployed to clean the air and reduce risk of exposure to COVID19.

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