Ultraviolet light and indoor air disinfection to fight pandemics: A technology long overdue—Part 2

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This is the second of a two-part article. Part one can be read here.

Many researchers investigating the germicidal qualities of ultraviolet radiation in schools were unable to reproduce the data that Drs. Mildred and William Wells had obtained, often achieving mixed results, leading to apprehension about accepting those conclusions. These problems were predominately due to the erroneous design of these later studies, which did not take into account the activity of children in other shared spaces for hours where UV radiation was not utilized, like school buses, that exposed them to measles.

At the same time, the advent of vaccines and antibiotics drove the incidence of these diseases down, leading public health experts to dismiss the benefits of disinfecting the air. Additionally, health concerns over exposure to ultraviolet light, the need for continuous irradiation and questions over its germicidal properties contributed to essentially abandoning the technology and forgetting about it.

Throughout the rest of the 20th century and up until the COVID-19 pandemic, the conceptions advanced by Charles Chapin remained dominant, erroneously stressing the predominance of contact infection rather than airborne transmission. Foremost in promoting Chapin's conceptions was public health officer Dr. Alexander Langmuir, who served in the US Army during World War II working to prevent infectious diseases among soldiers.

The experience of the 1918 influenza pandemic, which spread like wildfire through the barracks and the battlefields, left an indelible impression on the military organizations. Langmuir and other military researchers failed to recognize in their studies on airborne infection the physical laws that governed the spread and exposure to infectious pathogens. As Dr. Jimenez and colleagues wrote on Langmuir's investigation of airborne infections, "They viewed the world through the lens of Chapin's theories."

Here, it is worth quoting Jimenez in full:

> However, Langmuir's work renewed interest in the physics of airborne infection, as he concluded that weapons of airborne disease can be created, which became a topic of intense interest during the cold war. Based on studies of occupational exposure, he learned that aerosols smaller than five microns can penetrate deeply into the lung, all the way into the alveolar region. Infectious disease aerobiology was extensively developed during this period as part of the US and Soviet Union bioweapons programs. However, most of the work remained classified even after the weapons were banned, and thus that body of work had little influence on the general medical and infection control communities.

In 1945, William Wells, in an article titled "Sanitary Ventilation by Radiant Disinfection," lamented:

> The ultimate goal of sanitation set by Lemuel Shattuck a century ago is to guarantee to members of society the same freedom from communicable disease enjoyed by isolated individuals. Water purification, milk pasteurization, and pure food administration during the present century have added several years to the expectancy of life at birth. Does the control of respiratory infection by sanitary ventilation seem more difficult to sanitary science that the conquest of intestinal and insect-borne parasites seemed at the turn of the century?

In 1954, William Wells recruited his former student Richard L. Riley, an expert in lung physiology at the Johns Hopkins School of Hygiene and Public Health, to study the transmission route of tuberculosis (TB) at Baltimore's veterans hospitals where it was disproportionately infecting the patients. At the time, TB was a major global scourge killing millions annually without any effective treatment.

Many in the medical community continued to conceive of TB transmission via droplets, even though Chapin himself had acquiesced to describing it as a uniquely airborne disease. Wells formulated the idea that if the route of spread was determined, then appropriate measures could be taken to prevent the disease.

After gaining permission from hospital administrators, Wells and Riley proceeded to build an air-tight ventilation system on top of one of the veterans hospitals that was connected to a tuberculosis ward. Some 150 guinea pigs, ideal TB animal models because of the array of respiratory symptoms they could produce, were placed in the exposure chamber far removed from the patients. A second group of guinea pigs acting as controls were exposed to similar air. However, the air ducts were irradiated with UVC lamps that killed the TB bacilli. While around three guinea pigs per month in the untreated air contracted TB, none of those breathing in irradiated air were infected.

The researchers had not only proven the airborne nature of TB, but they also recognized that the tried-and-true contact tracing used in person-to-person contact was impossible for airborne transmission as one person could infect far more people, and the links between infected and contacts were difficult to establish. Most importantly, they showed that ultraviolet radiation can disinfect the air in a room sufficiently to prevent infections.

In 1955, Wells was to publish his authoritative *Airborne Contagion and Air Hygiene: an ecological study of droplet infections*. Near the end of his life, Wells suffered from prostate cancer that metastasized to his spine,

leaving him an invalid. Before his own death in 2001, Riley wrote on the occasion, “Wells died in 1963 after months of physical restraint. Thus ended the career of a truly ‘mad genius’ who gave us the droplet nucleus hypothesis and changed our thinking about aerial transmission of infection. He never saw the final confirmation [of the study’s publication]. To my eternal shame, his name was not included among the authors of the final paper.”

Riley would go on to assume the chair of the Department of Environmental Medicine from 1960 to 1977, while warning of the dangers posed by airborne diseases. As Bloomberg School historian Karen Kruse Thomas noted, Riley also patented UVC technology for air purification systems that were installed in health care facilities, factories and even NASA space capsules. He devoted a significant part of his work on the study of indoor air circulations and room conditions on the efficacy of UVGI (ultraviolet germicidal irradiation). This became known as upper-room UVGI because of the location of the irradiation equipment, usually in ceiling fixtures. Many of the current standards set for air exchanges and power required for these lamps are based on his calculations and experiments.

By the 1980s, the emergence of the HIV pandemic and rise in antibiotic-resistant TB led to renewed interest in UVGI. Dr. Edward Nardell, Harvard professor in the Departments of Environmental Health and Immunology and Infectious Diseases, working as a TB control officer with the Boston City Health Department, became interested in airborne infection and its control when an outbreak of drug-resistant TB occurred in a large homeless shelter in Boston in 1983.

On pondering how to stop the TB transmission, Nardell recalled a lecture he attended given by Riley on the use of UVGI. During that lecture, Riley explained that unlike UV light from the sun, the wavelength of UVGI (258 nm) did not have long-term severe side effects though it could cause mild skin or eye irritation.

Nardell decided to contact Riley to help him with the homeless shelter. This led to an 18-year-long collaboration during Riley’s retirement, in which the pair studied and wrote extensively on UV air disinfection. Nardell spent the better part of his professional career working in countries (predominately South Africa) where the incidence of TB is high, and the only practical solutions are air disinfection through upper-room UVGI.

In high-income countries, the standard form of air purification remains the use of advanced heating, ventilation and air conditioning (HVAC) units, particularly in office buildings, factories, hospitals and schools.

As Nardell has noted on several occasions, the principles of bringing fresh air into a room and filtering it with HVAC systems remain not as effective in combatting airborne pathogens as compared to UV radiation, which can do equivalents of multiple air exchanges compared to HVAC systems. However, Nardell also observed, “Lighting experts may know about UV, but they’re not involved in public health issues. This technology is not taught to engineers, so it really has fallen between disciplines, and a lot of people don’t know about it.”

Nardell has since developed the first international post-graduate course for engineers, architects and public health workers on design and engineering strategies to prevent airborne infections. In March 2021, he authored an important review in the journal Photochemistry and Photobiology on why air disinfection with germicidal UV for airborne infection control, specifically COVID-19, was essential. He also collaborates with the World Health Organization (WHO) and was the lead speaker on a webinar conducted by the international health agency on UV technology in December 2021.

Far-UVC at 222 nm: The sweet spot?

The use of Far-UVC, specifically at the 222 nm wavelength for disinfecting indoor spaces, is recent, encompassing the last two decades of work in this field. A more extensive discussion on the current state of knowledge of Far-UVC radiation is available in a comprehensive White Paper written by the International Ultraviolet Association (IUVA) Task Force. It was recently posted and linked here, with summaries of the mechanisms for disinfection, safety profile with regards to skin and cornea exposure, as well as consideration of ozone production with these units.

Much of the work confirming the safety of continuous Far-UVC technology was conducted in the last decade by the team led by Drs. Manuela Buonanno, David Welch and David Brenner at the Center for Radiological Research at Columbia University Medical Center in New York City. In particular, as discussed by Dr. Brenner during a TED talk in 2017, the impetus for the work was the death of a close colleague from sepsis caused by a virulent antibacterial-resistant pathogen. According to Brenner, he wanted to investigate the potential UVC offered in reducing the burden of infections acquired in health care systems.

Unlike UVGI, which uses 258 nm wavelengths and is considered potentially harmful to the skin and eyes of people and requires careful placement, filtered Far-UVC at 222 nm can be used to disinfect the air throughout occupied rooms. To place this in perspective, Dr. Ewan Eadie of the National Health Service of Scotland, remarked, “Far-UV exposure for 30,000 hours or 3.5 years is equivalent to 10 minutes in the sun.”

The UV radiation at these wavelengths is nearly completely absorbed in the stratum corneum (dead skin layers) and tear-film layer of the eyes and unable to cause any damage or mutation to regenerating cells.

At the same time the radiation can easily penetrate the minute structures of viruses (influenza, tuberculosis, measles and coronaviruses) and bacteria (Staphylococcus aureus and Escherichia coli), specifically their genetic molecules and the proteins that make up the structure of these pathogens. As the figure below shows, there is higher protein absorption at the 222 nm wavelength compared to 254 nm.

In 2018, Buoanno, Welch and Brenner also published a report in *Nature* that because Far-UVC could efficiently inactivate bacteria without the concerns for skin cancer and cataract development with conventional UVC light sources, it could be used to eliminate airborne pathogens. They showed that low-dose rates of Far-UVC inactivated more than 95 percent of aerosolized H1N1 influenza virus.

The emergence of the COVID-19 pandemic and the recognition by many scientists that airborne transmission was the dominant mode of infection prompted Brenner and his group at Columbia University to investigate the rationale for Far-UVC light at 222 nm against airborne human coronaviruses, similar in size to SARS-CoV-2 but implicated in causing common colds. Using chambers to create a working model of two aerosolized human coronaviruses, they were able to inactivate 99.9 percent of all viral particles within 25 minutes using a low-dose rate (within current regulatory dose limits) of Far-UVC.

The most recent evidence for the benefit of Far-UVC at 222 nm was the publication in *Nature* of a collaborative proof of concept study conducted by Columbia University, University of St. Andrews, Scotland and the National Health Service of Scotland in March 2022. Using a room-sized chamber that allowed three Air-Changes-per-Hour (ACH) and five filtered Far-UVC lamps, they continuously released aerosolized staphylococcus aureus into the space and conducted samplings of the air.

The figure above using five lamps at levels set by the current American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values can reduce the pathogen load in the room by 98.4 percent in minutes, an equivalent of around 180 air exchanges per hour. Notably, the ACGIH raised their threshold limits in January 2022 for skin and eye exposure to 222 nm radiation based on updated safety analysis.

As Dr. David Brenner noted in his commentary on the study:

> [The equivalent ACH = eACH] numbers are significantly larger than are achievable with most other air-cleaning technologies. The bottom line is that particularly for highly transmissible viruses such as the SARS-CoV-2 Omicron variant, the higher the eACH that can be achieved, the more protection the room occupants will receive from disease transmission.

Given that a virus is smaller than a bacteria like Staphylococcus aureus, the authors have noted that the effect against a SARS-CoV-2-like virus would result in even higher clearance of the pathogen.

One aspect that lighting engineers and radiation scientists need to consider and address is the production of ozone molecules, or as Dr. Jose-Luis Jimenez called it, "indoor smog."

In a study published in December 2022, the authors explained that 222 nm light can directly produce small amounts of such pollutants, and indoor spaces with UV lamps must be adequately ventilated to keep concentrations below set standards. They cautioned that the ozone production can oxidize volatile organic compounds indoors, and these factors need to be accounted for and studied further in terms of cost-benefit analysis.

It is also important to note that Far-UVC lamps require that the light generated be filtered, meaning that these lamps can produce additional wavelengths of light besides 222 nm. The lower wavelengths can contribute to higher ozone generation and the higher wavelengths may cause biologic harm, as previously discussed, so the construction and use of these devices must be carefully regulated and monitored. It is also necessary to train workers in the maintenance and upkeep of these instruments and building of floor plans to incorporate them.

A thorough review of ozone generation by ultraviolet lamps is provided for interested readers here by Holger Claus, the vice president of technology at Ushio America Inc., with a Master's degree and Ph.D. in lighting from the Technical University Ilmenau in Germany. He is also a member of IUVA Task Force and reviewed his findings at length in their White Paper linked again here [section: Ozone generation by Far UVC Lamps].

Who is using Far-UVC?

On several recent occasions, photographs of White House COVID Response Coordinator Dr. Ashish Jha giving lectures with Far-UVC devices in the background have circulated widely on social media. However, at the recent White House Indoor Air Summit held on October 11, 2022, neither Jha nor any other speaker delved into the technology, other than a brief reference under the heading of "New Technologies." One must ask why, if Dr. Jha depends on this technology so much, did he choose to remain silent on it?

While these devices have only recently appeared in public, the White House was informed about the potential benefits of Far-UVC technology more than two years ago at the very beginning of the pandemic.

On June 1, 2020, a paper co-authored by Dr. Nardell was published in *JAMA Network*. It noted, "An April 2, 2020, expert consultation from the National Academies of Sciences, Engineering, and Medicine to the White House Office of Science and Technology Policy concluded that available studies are consistent with the potential aerosol spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), not only through coughing and sneezing, but by normal breathing."

They added that if recommendations for the use of face covering by the public and N95 respirators for health care workers were being considered, "should not air disinfection be deployed in intensive care units, emergency departments, waiting rooms, and ambulatory clinics? This approach may be especially important to prevent spread from asymptomatic persons with infection, who may be sources of transmission in selected public settings."

The report emphasized the limitations of obtaining adequate air exchanges with ventilation alone and underscored the important benefits of using upper-room UVGI. They provided historical evidence for airborne transmission, noting the transmission of SARS-CoV-1 on airplanes and in apartment buildings in 2003, laboratory evidence of aerosol spread of influenza, and the infamous Washington state choir rehearsal super-spreader event.

[As an aside, it appears likely that former President Trump's gaffe at the April 23, 2020 televised COVID-19 briefing, when he made remarks to the effect that people could inject themselves with disinfectants and UV lights to ward off COVID-19, was brought on by a complete misunderstanding or misrepresentation of the content of Dr. Nardell's letter.]

During the WHO webinar in December 2021, Nardell reiterated his concerns:

> Natural ventilation is unreliable and mechanical ventilation [HVAC] and room air cleaners are flow-limited. It is important to compare air disinfection strategies in terms of equivalent Air Changes per Hour (eACH). The CDC recommends 6-12 ACH but it has to do with the infectiousness of [the pathogen]. The greater the infectiousness, the greater the eACH needed for protection. UV is efficient because it treats a large volume of air at once. Whole room Far UV, importantly, treats the air immediately around occupants and does it safely. Over 5 million people have died from COVID, and many more are left with serious or debilitating consequences. It is unlikely that anyone has ever suffered any serious medical consequences of UVC exposure properly deployed for air disinfection.

Even at this point in the pandemic, the WHO has not admitted that the coronavirus is airborne and only a whisper of it was made in late December 2021 under growing public pressure and the unprecedented spread of the Omicron variant.

Flying under the radar of public consciousness and media scrutiny, in August 2020, in the pre-vaccine phase of the COVID-19 pandemic, the US Department of Defense (DOD) reported that the Arkansas Air National Guard's 189th Airlift Wing, in coordination with their innovation team, was installing 50 Far-UVC lights throughout their campus. P.J. Piper, CEO of Missouri-based Far UV Technologies and David Brenner were on the project.

A follow-up report more than a year later in October 2021 noted that "approximately 175 cutting-edge 222-nm ultraviolet lights" had been installed since the project had been initiated. The report also noted that due to the success of reducing the spread of COVID, the UV lights "were quickly adopted by other wings around the Air Force as well as the Pentagon and internationally." These lights were also placed in government vehicles.

The article published in the *189th Airlift Wing* then proceeds to make the important connection that placing such lights in buses and classrooms would be a step forward in mitigating the spread of COVID-19. It quotes Major Justin Fitzpatrick stating:

> I think we as a wing did an excellent job being the pioneers for

> large-scale Far UV installations. We worked through the challenges, became subject-matter experts, helped other units implement the light installation and now we have the opportunity to share this critical technology with the school systems, our kids and families are part of when they need it most. This represents our first real offensive weapon against the airborne spread of COVID-19 and pathogens.

Meanwhile, CDC Director Rochelle Walensky, President Joe Biden, Dr. Anthony Fauci and then-White House COVID Response Coordinator Jeff Zients all remained silent on airborne transmission. Just months prior, Biden lied directly to a second grader at a CNN town hall, saying, "You're not likely to be able to be exposed to something and spread it to mommy or daddy."

Thus, while officials covered up the science of airborne transmission, behind the scenes they knew full well the benefits of cleaning indoor air. For the vast majority of the American and world population, schools and public buildings, including health care systems, remain unprotected and continue to be vectors for the spread of COVID-19.

Conclusion

As historians look back on the COVID-19 pandemic, one of the fundamental issues that they will have to reckon with is the paradox that from the very beginning of the pandemic every tool that could be used to eradicate the virus was in our possession.

Due to the mass infection policies implemented by capitalist governments throughout the world, SARS-CoV-2 has become entrenched in many animal reservoirs, making the eradication of the virus far more complex. Still, the global elimination of the virus among human populations remains entirely within reach and must be upheld as the goal of scientists, public health professionals and workers internationally.

The tools to fight the pandemic include an array of technologies whose deployment must be coordinated globally: vaccines, mass testing, rigorous contact tracing, the isolation of infected patients and quarantining of exposed people, and high quality N95 or better respirators. Mankind has also established pathways and countermeasures to treat and manage patients afflicted with COVID-19.

Central to any effort to stop the pandemic is the understanding of the airborne nature of viral transmission and the need to clean the air in all indoor spaces, through the improvement of ventilation to bring in fresh air, filtration of the air with HEPA filters, and disinfection through UV irradiation. The combination of these measures, particularly in densely-occupied and critical facilities like hospitals, would drastically reduce the spread of COVID-19 and numerous other pathogens.

Despite the existence of these tools, world leaders responsible for protecting the lives and welfare of their populations have allowed millions of people to perish and hundreds of millions more to suffer the long-term consequences of their infections. The pandemic has revealed the contempt of the ruling elites for the working class. Every day, countless people continue to die or be sickened needlessly while the capacity to end the pandemic remains at the ready.

This reality raises the fundamental point that it is not just the physical properties of the coronavirus that give it such strength and persistence. Rather, it is the policies derived from the capitalist social order that subject the population to the repeated dangers posed by the virus. In order to end the pandemic, it is necessary to address the politics that prevent an effective strategy for these pressing concerns.

It takes more than simply acknowledging that respiratory pathogens are airborne. In order to harness the entire cumulative knowledge that human scientific inquiry has acquired, a fundamental restructuring of society along socialist lines must be undertaken. The trillions of dollars squandered on war and the personal enrichment of the financial oligarchy must be reallocated towards infrastructure investments to ensure that every indoor space is provided with clean air, in order to save millions of lives.

Such funds must also be applied to further research into making UV and other new technologies even cleaner and more efficient. Real-life clinical trials, such as those begun by Wells, are needed to ensure the practical, society-wide utilization of the technology.

Going forward, the fight for a socialist public health program will remain a critical component of the class struggle led by the international working class, in alliance with scientists and progressive layers of the middle class. The cognition of the material world and our ability to fashion it to our purpose, based on scientific understanding, is precisely what is at stake. We have to fight for the air we breathe.

Concluded