Whitepaper

Why buildings need UV-C

A conversation with germicidal UV expert Richard Vincent

In early 2023, we spoke with germicidal UV expert Richard Vincent. Richard works at the Icahn School of Medicine at Mount Sinai, Department of Medicine, Division of General Internal Medicine in New York City. He also worked on the Community Medicine and TB/UV Studies at the Brickner Research Unit in New York.

The following is an edited transcript of our conversation.

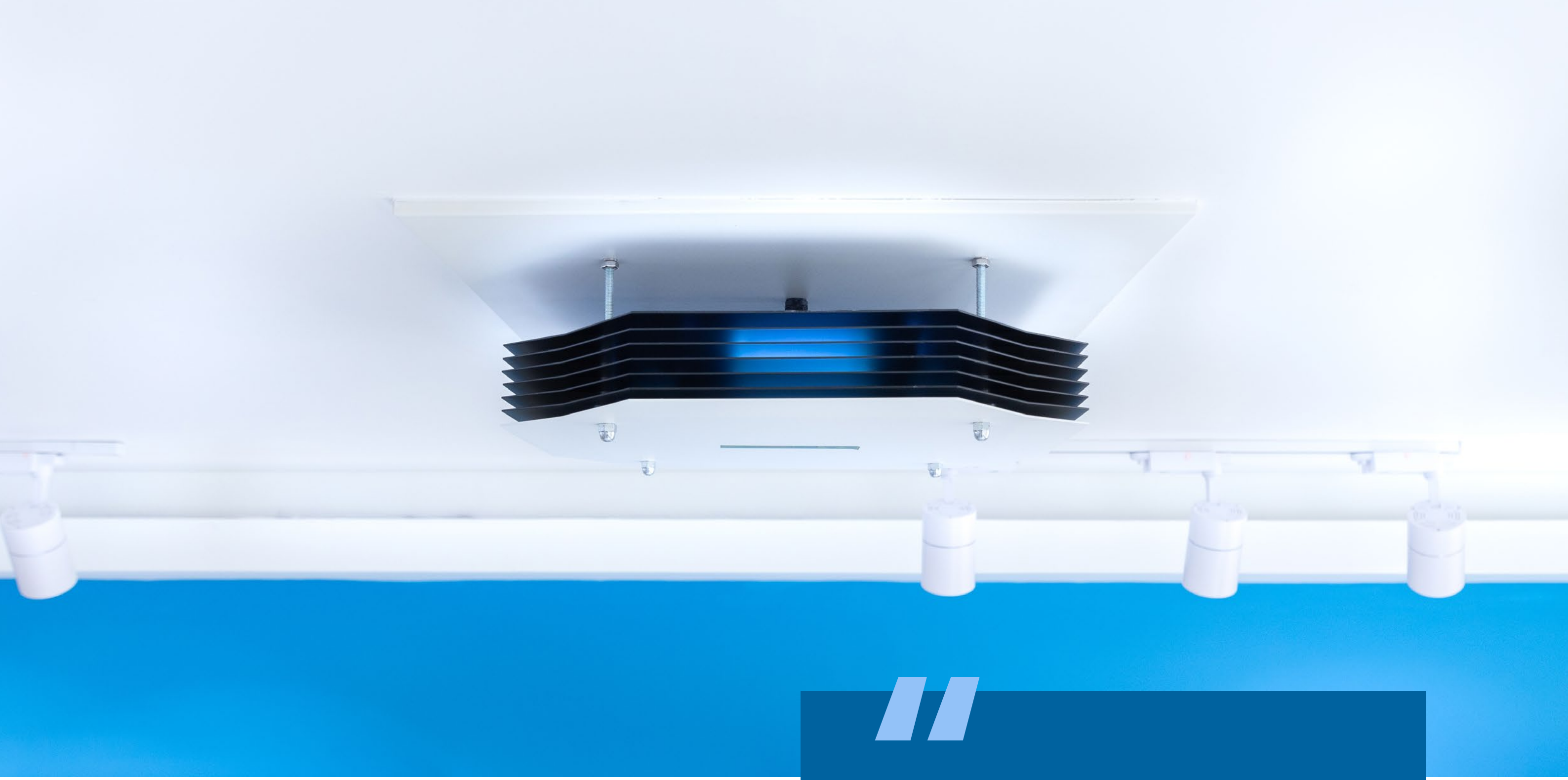
What is UV-C?

There are different forms of ultraviolet (UV) light. For germicidal purposes, we're really looking at what's called the UV-C part of the spectrum, which the CIE defines as the range from 180 nanometers (nm) all the way up to 400 nm. For germicidal effectiveness, the range is between 200 nm to about 280 nm.

UV works by disrupting the DNA and RNA of microorganisms. The UV photons break the molecular bonds when absorbed by these molecules. When the RNA and DNA chains are broken, the microorganism becomes harmless and it can't replicate inside the human body.

Air disinfection is especially effective because it can hit microorganisms in three dimensions. The rays emitted by the UV source have many opportunities to intercept microbes as they float on the air current.

The beauty of UV disinfection is that it doesn't matter whether the organisms mutate. They can always be inactivated or destroyed by the application of sufficient germicidal UV.



Where has UV-C been used?

A lot of the UV that has been globally applied has been for water treatment. In many cases the particulate matter is cleaned out first, and then the water is exposed to intense UV-C. This is an approach used in New York State, for example, where I work.

Other applications are primarily for building HVAC systems. To cut down on microbial growth, UV-C light sources can be placed in air handling units or drain pans where liquid can collect in the dark and grow mold. Bioburden can build up on the cooling coils in an air conditioning unit, affecting the unit's efficiency. Also, microbes can be dislodged and travel throughout the building, causing health issues.

UV-C can also be placed in the ventilation system for cleaning the air stream on the fly as it comes in from the outside. It's also been used as a countermeasure against biological agents that might be inserted into a building through the air conditioning units. And of course, it's been used in hospitals, where air must be recirculated up to 15 times an hour. Having UV-C in the air stream is a way of ensuring biological security, to inactivate pathogens that could otherwise be circulated throughout the building.

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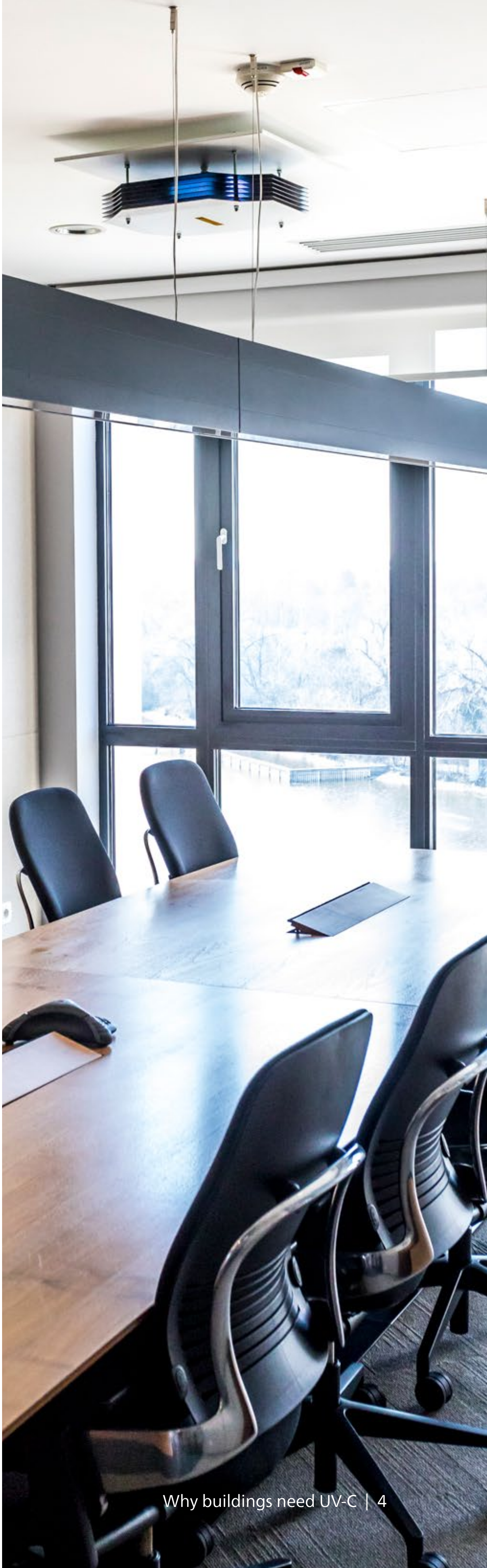
In the occupied spaces of buildings, upper air UV-C has been used over the last 70 years to deal with the release of organisms into the air from humans who may be sick. Tuberculosis (TB) continues as a major global concern, and added into the mix is a renewed focus on coronaviruses, influenza, measles, or other infectious agents that can be aerosolized. Small particles of these microorganisms can float on the air currents for a number of hours and be inhaled. Lessons learned from controlling TB with UV-C are being applied to deal with these airborne infectious agents. UV-C systems designed for TB will easily inactivate SARS-CoV-2, influenza virus, and measles virus even when all are circulating in the environment at the same time.

Is UV-C potentially dangerous to humans?

Depending on the wavelength, UV light exposure above established limits can cause what's called photokeratitis, which can irritate the eyes. Photokeratitis is like getting grit in your eyes, but it resolves within 24 to 48 hours with no long-lasting effects. People can also develop erythema with exposure above established limits, which is a reddening of the skin that also resolves in a similar period of time with no lasting effects.

The UV-C light that we're talking about here, however, is not like solar UV, where you have to be concerned about deep penetration of the wavelengths from sunlight into the skin. UV-C light is mainly blocked by the stratum corneum, the dead outer layer of the skin, so it doesn't get down into the germinative layer where new cells are being formed. UV-C around 222 nm is now being explored, because it can have a germicidal effect but is not as potentially irritating to the eye and skin.

Upper room air disinfection minimizes risks to humans. The idea of upper room disinfection is to cleanse large volumes of air quickly using UV-C sources installed to create a disinfection zone, directed above occupants' heads to avoid direct exposure. Airborne infectious microorganisms continuing to pass through the disinfection zone are inactivated and return to the breathing zone to dilute remaining microorganisms.



Why is indoor air quality important?

Ventilation is necessary in buildings for human health. The purpose of ventilation is to bring in outside air so that's there's enough oxygen in the building. It's also used to remove a series of pollutants like CO2 and volatile organic compounds (VOC) from the building. Filtration is also used to remove particulate matter and microbes from the air in a building. Pathogens can also be filtered out through the ventilation circuit.

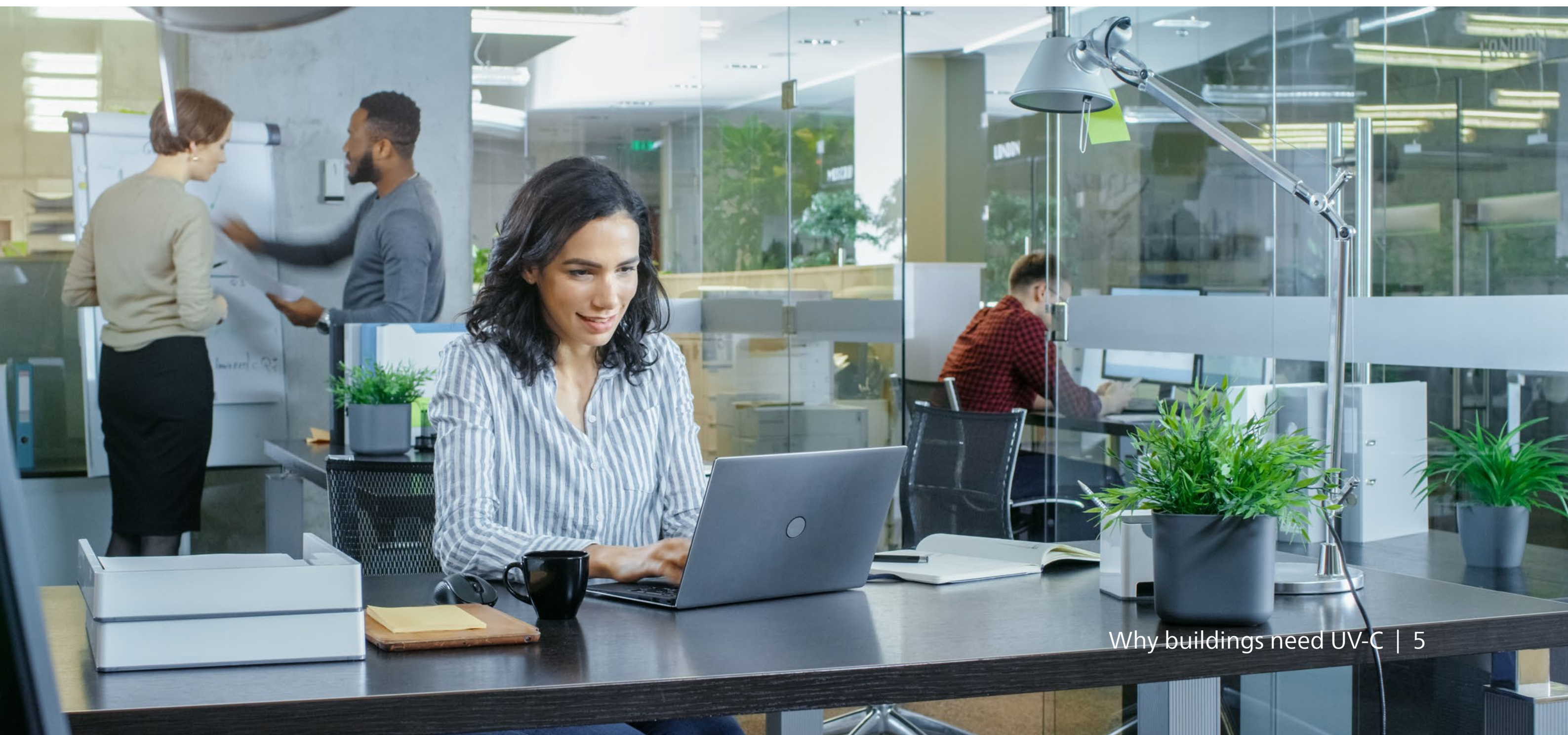
The goal is to maintain a good level of indoor air quality in a building to support the health of people who occupy the spaces inside. We spend the majority of our time indoors, so good, breathable air is an important aspect of indoor air quality.

Indoor air quality is often measured in air changes per hour (ACH). One complete air change occurs when the entire volume of air in a room is vented out and new air is supplied. One complete air change removes around 63% of pathogens and microbes from a room.

Ventilation is necessary for comfort, humidity control, sufficient oxygen, and to remove particulates from indoor spaces. But there are limitations as to how much air removal can actually be done in a space. Some spaces are ventilated to 3 ACH, so you'd remove 63% of pathogens and microbes on the first air change, 63% of the remainder on the second air change, and another 63% of what's left on the third. That means that some percentage of the original amount is left over.

From an air disinfection standpoint, then, ventilation alone is often not sufficient to effectively and rapidly deal with disinfection of all the microbes that may have been released into an occupied space. This is where the killing power of upper-room UV-C comes into play to augment existing ventilation.

In a classic study done by Richard Riley, MD, in the 1970s, a 17-watt UV-C lamp was suspended from his office ceiling and a bioaerosol of BSG was used to test effectiveness. His experiment resulted in inactivation rates equivalent to adding 10 ACH to the natural decay of organisms at the rate of about 2 ACH. The total of about 12 ACH is the high end of current recommendations by the CDC in healthcare facilities.



What's the difference between ventilation and disinfection?

These are sometimes combined in the consumer's mind, but they're different. Disinfection via UV-C augments the ventilation for a space but does not eliminate the need for ventilation.

If you have a very low ventilation rate but you want to rapidly reduce transmission of infectious particles in the space, UV-C with air-mixing can do that effectively without increasing the ventilation rate, which can be costly. It's expensive to redesign a building to achieve necessary air changes per hour. You might need to install bigger fans in the ventilation system that uses more dense filtration to capture microorganisms, and these sorts of changes have an impact on energy consumption. In many buildings, it's just not feasible to change the ventilation. So UV is a way of augmenting what's already there.

You could remove infectious particles if you have enough air exchanges in a space and proper filtration, but can be very energy intensive and costly to do it that way. Some studies have been done, by the US DoE and others, comparing the amount of electricity consumed for a UV system versus the electricity consumed if you increased ventilation rates alone. Different approaches have been used in different parts of the world, but UV disinfection is widely considered beneficial electrification. **As a way of enhancing biosecurity while reducing energy consumption, it's really a win-win to add the technology to existing buildings.** Integrating UV-C into new buildings right from the beginning could also be a great energy benefit.

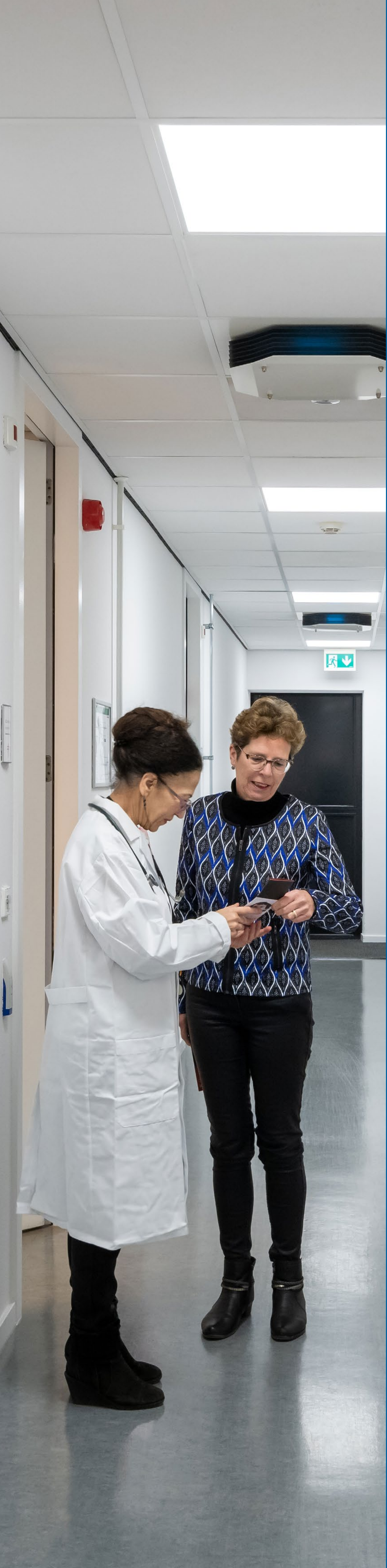
How effective is UV-C?

Nothing is 100% effective. Two studies were done with patients in active TB wards, one in Lima, Peru, and one in South Africa. In the Lima study, a naturally ventilated space with mixing fans, the air that the patients were breathing was siphoned off into colonies of guinea pigs. UV would be on in the ward some days and off on other days. Over a period of time, the study showed that the risk of TB transmission to the guinea pigs was reduced by between 70% and 80% when UV was on even with high relative humidity. That's a great reduction, and although it was greater than what you would get wearing a mask, for example, it wasn't a reduction of 100%.

The South Africa study involved mechanical ventilation, UV, and some mixing fans. Further it showed that UV could reduce the risk of transmitting TB through the air from humans to animals by about 70% to 80%.

These results became part of the rationale for the World Health Organization (WHO) to update their guidance on TB IPC (infection prevention and control) in 2019. WHO did a systematic review of the literature and concluded that germicidal UV was an effective environmental control. As a result, upper-room UV became part of the WHO'S recommendation for treating areas of high risk of transmission of TB.

Some airborne pathogens are more resistant to UV than others, but that resistance can be overcome with a high enough dose of UV energy over a sufficient amount of time. An anthrax spore, for example, has a hard outer shell, but with enough energy and time UV can penetrate that shell and inactivate the spore. Viruses with cell walls around them are a little bit more resistant than naked viruses, but this difficulty can easily be overcome.



Has UV-C been adopted in commercial buildings and other public spaces?

Since the pandemic, we've seen adoption in schools, houses of worship, restaurants, gymnasiums and other hospitality spaces. Boeing has been looking at using UV in the bathrooms on their aircraft.

In offices, UV-C is primarily used in the ventilation circuit or air handling unit, where nobody's really aware of it. I've looked at some opportunities to put upper-air UV-C into offices, but customers really want to understand better how it can be applied, how safe it is, and how you can tell if it's working.

We've looked at different strategies to help end-users understand that UV is working in a space. Various companies offer dosing dots that show that the UV is actually working. I've been experimenting with a self-contained microbial marker device that can be exposed and then incubated to find out what kill level the UV-C is providing in the space.

It has been challenging to get UV-C into offices and other commercial spaces. It's a different approach needed than for ventilation. Everybody just accepts that air is moving in a building until it doesn't, and then they complain. People don't always understand when UV is present, or why. When we install UV systems, we can say that the space is being protected and the air is being cleaned, so it becomes a positive public message. Often, the messages you see when UV is in place are warnings, but we also need to be able to balance the message that UV sources are sanitizing the air for health.

I think there will be opportunities for deploying UV throughout buildings, but it has to be done strategically. I'm not necessarily recommending that you cover every space with UV but you want to look at the opportunities. Look for common areas where people gather, lobbies, conference rooms, employee cafeterias, elevator lobbies, auditoriums, etc. You then have to perform an analysis to be strategic about where, when, and how to apply UV and always in conjunction with ventilation.

At some point, though, I believe that having germicidal UV incorporated into a building design will be as expected and universal as lighting itself.

Is UV-C being incorporated into healthy building standards?

The American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) is including technical information on UV-C applications in its handbooks, standards, and guidelines as well as sponsoring UV-related research. As a part of this leadership, guidelines are being developed such as ASHRAE GPC 37, Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens.

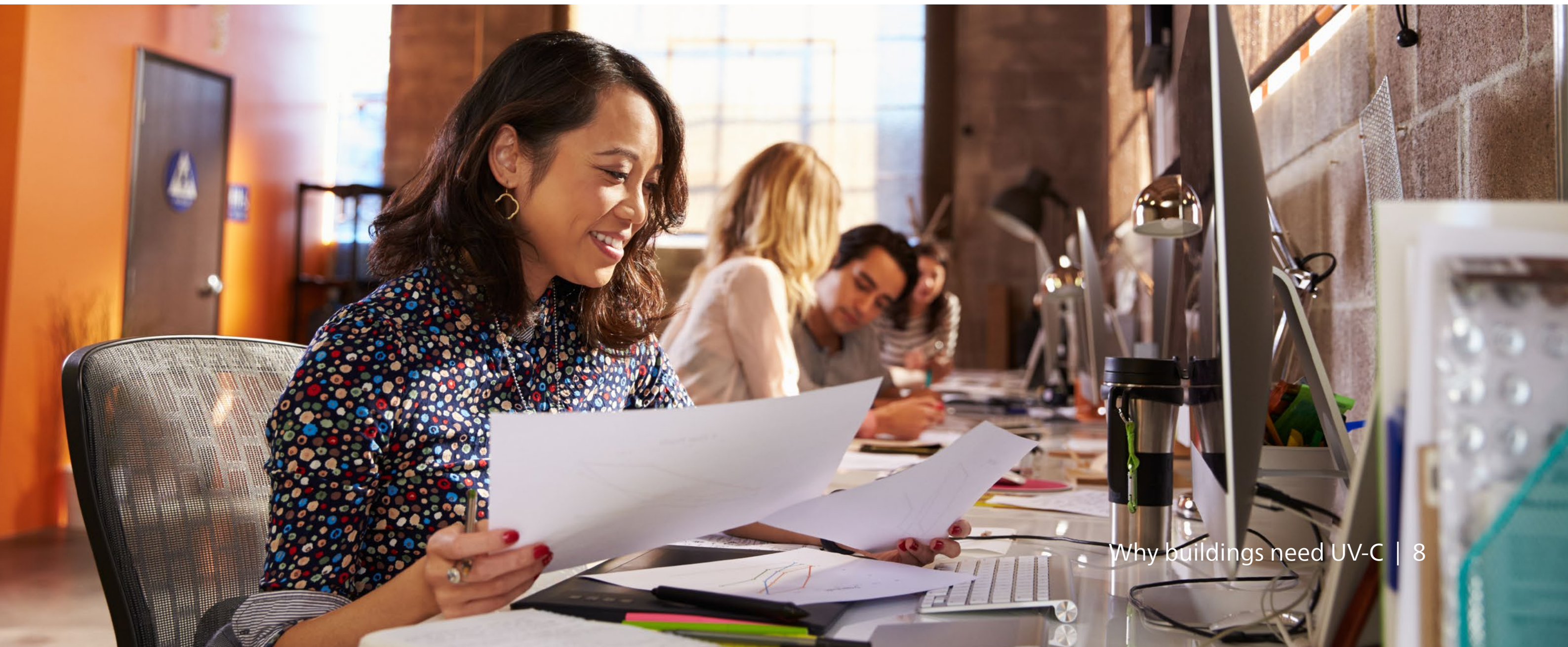
ASHRAE, the American Institute of Architects (AIA), the Illuminating Engineering Society (IES), and other accredited societies want to bring UV systems into their standards and develop consensus guidelines. But there's some missionary work we have to do to bring the UV-C message to them, to help them understand how the technology can be applied, and how they can inform their community about it.

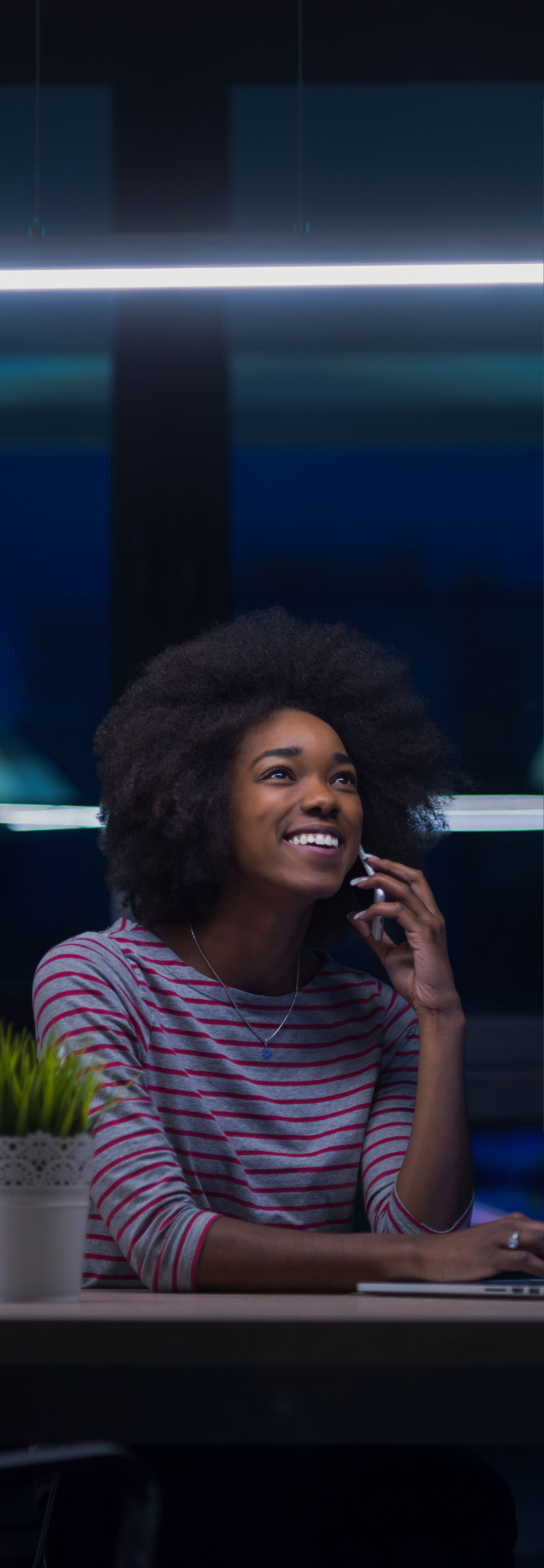
I think the real estate industry really needs convincing, because they're all about the bottom line. We need to help them understand that UV-C can improve indoor air quality and public health. UV-C application could be a differentiator, that there's more value in a building that offers UV for biosecurity and health than a building that doesn't. Part of the reason why standards like LEED and WELL are in place is so that the real estate industry can differentiate their buildings.

One reason we decided to put UV in the ASHRAE handbooks and guidelines is because there is a natural symbiotic relationship between UV and ventilation. You need to have moving air in order for UV to be most effective, and so ASHRAE has identified UV as one of its top priorities for research, even though it's not their primary focus.

When I was getting my LEED certification, I was looking at indoor air quality. With LEED, you can get points for employing different design strategies on a project. UV is one of those strategies, but you have to jump through a lot of hoops to convince them that it's worthwhile giving a LEED rating to a building because of UV. But that may be changing now.

When I talked with the WELL people last year, they were aware of UV and had already started incorporating it in their standard. They will continue to track ASHRAE's UV guidance. They've left the door open for us to have further conversation in this area.





What about UV-C and public health guidelines?

After 2009, when we had TB outbreaks in the United States, the National Institute for Occupational Safety and Health (NIOSH) put together guidelines on TB control, and upper room UV was included as an environmental control.

The World Health Organization (WHO) is also aware of it, at least within their TB group. But WHO is a big organization, and they often lean toward using pharmaceuticals and other types of approaches to health. However, **the fact is that pharmaceuticals will fail us, and vaccines will fail us, but UV is going to continue to be effective no matter how organisms mutate.** One clear message is that it doesn't matter what happens if vaccines require time to be safely deployed if you have other airborne infection control practices with UV in place. It can provide a level of risk reduction in public spaces no matter what happens with the pathogens.

How can we get the message out there?

Basic awareness is a major issue. A lot of places where we've worked with UV internationally, such as India, South America, Africa, and parts of Asia, have real difficulty with TB transmission. Prior to COVID-19, TB was the number one killer of people among infectious diseases transmitted through the air. UV disinfection is effective at neutralizing both.

I think it's very helpful to have some good public service messages of enhanced sanitation out there that are simple and understandable. We have spokespeople for shoes who get millions for endorsements. Maybe UV needs something like that, or maybe just simple public service messages that really bring the benefits of germicidal UV to the fore. You could put simple plaques within buildings that say the air is being treated by a UVC for a cleaner and healthier environment.

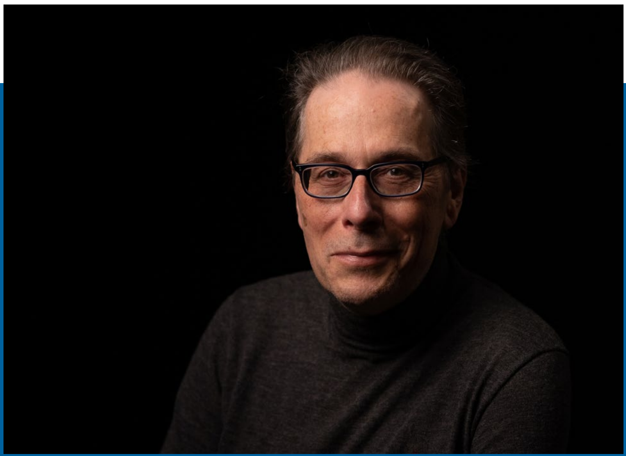
I think we really have to get both positive health and safety UV messaging to building facilities managers, so that they can understand the benefits. Often, decisions are made at the CEO level, especially in a hospital. It may be challenging to talk to the CEO of a hospital about UV if they don't believe in it, but sometimes a hospital's head of infection control is a good place to start.

I'm doing UV experiments at my own hospital right now. To get them running, I had to overcome hurdles of skepticism from safety officers and the like. But if a study is completed successfully and then receives positive publication, it becomes easier for the hospital to accept that this is something worth doing.

Part of it is education, and part of it is getting the engineering and specification community to understand UV better. One of the things we're doing right now through the National Association of Lighting Maintenance Companies (NALMCO) in the US is to develop a certification course where people can get trained knowledgeably and get hands-on experience on how to install, test, and maintain UV systems. There are just a handful of people who have this expertise today, and wider adoption in the engineering and lighting community will really help.

At the upcoming 2023 Lightfair trade show in New York, we will conduct a workshop on germicidal UV to get people interested. I think it would be a good idea for lighting companies to have sections dedicated to UV at trade shows to help people learn about and apply the technology. Like everybody, lighting companies are looking for new ways to grow their business. UV could be great for that.

Getting the message out to the specifier community is important. We need a combination of public awareness, regulatory awareness, and specifier awareness. Positive messaging is key.



Richard L. Vincent

Richard L. Vincent, MS, BS Arch, FIES, LEED AP, is a Manager at the Icahn School of Medicine at Mount Sinai in New York City.

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