National Strategy for Improving Indoor Air Quality

Report from the Johns Hopkins Center for Health Security
September 8, 2022, meeting in Washington, DC

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List of Abbreviations

Abbreviation	Full Description
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
COVID-19	Coronavirus Disease 2019
EPA	Environmental Protection Agency
HEPA	High Efficiency Particulate Air (filter)
GUV	Germicidal Ultraviolet
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy and Environmental Design
LMICs	Low- and Middle-Income Countries
MERV	Minimum Efficiency Reporting Value
PM	Particulate Matter
Q&A	Question and Answer
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
TVOC	Total Volatile Organic Compounds
US	United States
WHO	World Health Organization

Executive Summary

The Johns Hopkins Center for Health Security hosted a meeting, "National Strategy for Improving Indoor Air Quality," in Washington, DC, on September 8, 2022. The meeting featured a keynote speaker and four expert panels focused on the importance of indoor air quality (IAQ), challenges to providing healthy indoor air across the United States, international perspectives and strategies for healthy air improvements, and catalyzing needed science and technology innovation in the IAQ field. Dr. Ashish Jha, White House COVID-19 Response Coordinator, opened the meeting by reiterating the importance of IAQ to the Biden-Harris Administration.

Several themes stood out during the conference, including the need to:

- establish an easily measurable set of factors to determine IAQ
- improve minimum IAQ requirements
- set performance standards for building operation and maintenance
- incentivize building owners to improve IAQ.

Notably, participants highlighted the urgency of enacting major changes, before the COVID-19 pandemic fades from the public eye.

Introduction

The COVID-19 pandemic has highlighted the important role indoor air can play in infectious disease transmission, and this has led to encouraging steps toward improving indoor air quality (IAQ). In March 2022, the Biden-Harris Administration launched an initiative to improve indoor air quality—the Clean Air in Buildings Challenge—as a part of the National COVID-19 Preparedness Plan. As a component of the Challenge, the United States (US) Environmental Protection Agency (EPA) released a guidance document aimed at helping building operators improve indoor air quality to protect public health. To build on these successes and pave the way for more progress in making healthy indoor air available to everyone, the Johns Hopkins Center for Health Security hosted a meeting about national strategies for improving IAQ at Convene in Washington, DC, on September 8, 2022. This meeting covered topics such as the importance of IAQ, providing quality indoor air across the US and internationally, and catalyzing IAQ science and technology innovation. Each topic was covered in a panel format, with some of the leading experts in each field participating as speakers. The panels consisted of brief presentations by each speaker followed by a moderated discussion.

Keynote Address

Dr. Ashish Jha, the White House COVID-19 Response Coordinator, opened the meeting by underlining the importance of indoor air to public health. During his remarks, Dr. Jha called for IAQ to be at the top of the list of tools used for COVID-19 recovery, alongside vaccines, treatments, and testing. Observing that the most common routes of disease transmission are water and air, Dr. Jha noted that the long-term solution to achieving healthy water in the US involved population-based interventions such as providing good quality tap water to homes, not having each individual boil their own water. Dr. Jha acknowledged that although the issue of healthy water has not been fully resolved in the US, the systemic instead of individualistic approach helped reduce the incidence of waterborne illnesses nationwide. He emphasized the importance of taking a similar type of approach to improve IAQ in the US.

Dr. Jha also mentioned the importance of educating the public about IAQ issues. Most of the public might think only about pollutants or sick building syndrome when they hear IAQ, he said, noting many people have not fully considered the role improved IAQ could play in preventing the transmission of diseases such as influenza. Dr. Jha also discussed masks, likening their use to boiling water and noting that while masks have a role to play in preventing disease transmission, more systemic methods are needed to improve IAQ. He touched on several other topics, including the importance of IAQ for keeping kids in school, the need for systemic interventions in public health, and the responsibility of building owners to ensure IAQ in their spaces to reduce the risk of disease transmission. Dr. Jha concluded by noting US President Joe Biden planned to mention IAQ in a speech on COVID-19 later in the day and highlighting the federal government's work to develop a pledge program for IAQ improvements.

There was a brief question and answer (Q&A) session after Dr. Jha's remarks. Some questions related to US military policies on housing and how the Administration plans to protect soldiers and their dependents, some of whom are living under horrible conditions as discussed in a series of reports by the Reuters news service. Dr. Jha responded to these questions by noting President Biden's desire for safe buildings and their provision to members of the military, an issue crucial to national security. He stated that the General Services Administration (GSA) is looking into ways to improve IAQ in government buildings and that there are many efforts related to this topic.

Another member of the audience asked Dr. Jha about IAQ standards for public schools. He responded that the EPA is working to define those standards and that air quality monitors could push this effort along. Another member of the audience asked Dr. Jha about how to encourage school systems to uptake federal funds for IAQ improvements. He responded that he is working closely with the US Department of Education to properly explain existing benefits to school administrators, many of whom do not consider making IAQ improvements when they receive federal funds. Dr. Jha said he is attempting to simplify the process for administrators to improve IAQ in their facilities.

The final question of the session related to whether the government should begin requiring IAQ labeling on buildings. Dr. Jha noted he supports transparency and providing information to the public; however, in order to certify buildings' IAQ, consensus must first be reached on IAQ monitoring and evaluation. He emphasized that the qualities the field coalesces around should be easy to measure with existing technology. Dr. Jha also highlighted his preference that cities take on the responsibility of requiring IAQ labeling on buildings, with the hope that such programs would encourage other cities to follow suit out of a sense of local pride.

Panel 1 – Importance of Indoor Air Quality

For high standards of IAQ to become commonplace, it is first necessary for the public to care that IAQ affects them and to have easily identifiable means of assessing whether standards are being met. This session focused on public education programs about IAQ, incentive programs for building owners and operators, and improving IAQ in public schools. The session was moderated by Dr. Gigi Kwik Gronvall, Senior Scholar at the Johns Hopkins Center for Health Security. The panel speakers included Alejandra Nunez, Deputy Assistant Administrator for Mobile Sources for the Office of Air and Radiation at the US EPA; Dr. Kimberly Prather, Distinguished Chair in Atmospheric Chemistry at the University of California San Diego; Dr. Joseph Allen, Director of the Harvard Healthy Buildings Program; and Dr. Ana Rule, Assistant Professor of Environmental Health and Engineering at the Johns Hopkins Bloomberg School of Public Health.

Alejandra Nunez began the conversation by framing why indoor air issues are important. She mentioned that IAQ is critical for improving public health, but that role is not immediately apparent to the public. Ms. Nunez highlighted the need for more

investment in air ventilation and filtration on all levels and noted IAQ often is more important than outdoor air quality because people spend up to five times more time in indoor environments. She reminded the audience that improvements in air quality can lead to improvements in cognitive function. Ms. Nunez also declared that IAQ is an environmental justice priority at the EPA and for the Biden-Harris Administration and promoted the idea of looking at IAQ holistically. She reminded the audience that many Americans still die every year from radon exposure even though testing is widely available, that harmful particulate matter exposure can come from simple sources such as candles or cooking, and that asthma disproportionately impacts underserved communities. Additionally, Ms. Nunez called attention to the need to better understand how climate change impacts IAQ.

Dr. Kimberly Prather highlighted her role in helping one of the largest school districts in the nation, San Diego Unified School District, reopen while staying as safe as possible during the COVID-19 pandemic. Dr. Prather showed a picture of young students holding class outdoors during the 1918 flu pandemic to reiterate that humanity has known the value of good IAQ for some time. Efforts are needed to work toward having indoor air that is at least as good as outdoor air, she said. Declaring herself a proud aerosol activist, Dr. Prather remarked about the misleading emphasis and improper messaging on hand sanitizing and surface cleaning during the COVID-19 pandemic, because the primary transmission route of the virus is through aerosols. She discussed methods implemented to reopen San Diego Unified, including masking, upgrading air filters to higher-performing filters such as MERV 13, opening doors and windows to improve ventilation when possible, and using small cohorts to reduce exposure. Dr. Prather also talked about how Corsi-Rosenthal boxes—do-it-yourself box fan filters—are a great way to supplement filtration, noting that the boxes are less expensive and quieter than high efficiency particulate air filtration (HEPA) systems and can outperform HEPA systems. Dr. Prather concluded by posing the question: "It's not okay to eat dirty food, so why do we allow ourselves to constantly breathe dirty air?" She stated that Corsi-Rosenthal boxes could be one answer to that problem.

Dr. Joseph Allen underscored how buildings and building managers have not kept up with the growing understanding of how viruses spread indoors. Highlighting several successes, he noted that public awareness of IAQ issues is increasing due to COVID-19, long-standing medical knowledge is currently being rewritten, and IAQ conversations are finally being elevated to the federal level. He called on building managers to pursue four strategies to reduce risks posed by COVID-19: give buildings a tune-up, maximize ventilation, upgrade filters, and deploy portable air cleaners. He cautioned that health officials should avoid telling people to bring in more outdoor air without being able to mention specific targets, highlighting the role that climate change is playing in heating indoor air to extreme temperatures in buildings not designed for warmer temperatures. Noting that more people are looking to spend their time in healthy buildings rather than unhealthy ones—including prospective employees who make decisions on employers based on building conditions listed on websites like Glassdoor—Dr. Allen said building managers and businesses that undertake IAQ improvements could, in

turn, boost their earning potential. He concluded by highlighting the need for long-term epidemiological cohort studies on health and building quality.

Noting that the risk of infection with COVID-19 through fomites on a surface is low and that the chain of transmission can be broken through proper handwashing, Dr. Ana Rule discussed the impact of cleaning practices on human health and wellness and cautioned that many individuals may be overusing disinfectants. She remarked that initial COVID-19 prevention guidance from the US Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) involved cleaning surfaces. Dr. Rule noted there are 631 approved products on the EPA's List N of COVID-19 disinfectants, 297 of which contain quaternary ammonium compounds that could be harmful to humans. Quaternary ammonium products are biocides that can irritate the lungs and skin, are associated with a decrease in mitochondrial function, and can linger on surfaces for months, according to Dr. Rule. She noted that the people exposed to harmful chemicals include healthcare workers, public transit workers, food workers, and people in schools. Notably, children are particularly vulnerable to dangerous chemicals. She pointed out that there are many false arguments made in favor of quaternary ammonium cleaners, such as their widespread use, but she warned that widespread use does not mean they are necessarily safe. Dr. Rule specifically mentioned a website called Safer Disinfectants that lists 108 EPA-approved COVID-19 disinfectants on List N that are safer than quaternary ammonium compounds. She highlighted the best ways to reduce overexposure, including training individuals on best use practices for harmful products and considering changes to cleaning processes when appropriate.

Panel 2 – Providing Quality Indoor Air Across the US

This session explored various levers used to improve air quality across the US and potential mechanisms, like model legislation, that could be used to promote indoor air quality. Discussion topics included successful approaches, primary stakeholders who can ensure the success of local measures, and lessons learned. This session was moderated by Dr. Monica Schoch-Spana, Senior Scholar at the Johns Hopkins Center for Health Security. The panel speakers included Representative Donald Beyer, US Member of Congress from Virginia's 8th District; Dr. William Bahnfleth, Professor of Architectural Engineering at The Pennsylvania State University; Dr. Christopher Pyke, Senior Vice President, Product at Arc Skoru Inc.; and Dr. Kazukiyo Kumagai, Chief of the Indoor Air Quality Section at the California Department of Public Health.

Representative Donald Beyer opened by discussing the Airborne Act, legislation he introduced in the US House of Representatives in May 2022 that would allow a tax credit for certain IAQ assessments and improvements. Poor IAQ is one of the greatest risks to human health, Representative Byer stated, noting there are 23 federal agencies with some level of control over indoor air protocols. He underlined the importance of filtration and ventilation for controlling the spread of disease and called for more

efforts to improve IAQ as workers return to offices, including providing incentives for businesses to undertake such improvements. If passed, the Airborne Act would credit $1 per square foot of property to perform air quality assessments, $5 per square foot for qualified air filter upgrades, and $50 per square foot for a qualified HVAC upgrade; allow nonprofit organizations to transfer the credit directly to the company performing the assessment; and create a voluntary certification program. Representative Beyer noted he is gathering co-sponsors for the bill. He said he will attempt to attach the act to a tax extender bill in December and will reintroduce the bill in January if necessary. In response to a question, Representative Beyer said it is possible that the bill could include tax credits for UV light fixtures, adding that he will have his office investigate the matter.

Dr. William Bahnfleth underlined the importance of minimum standards and codes for IAQ. He encouraged the community to act now—because it will never be easier to implement a standard than directly following a respiratory pandemic—but cautioned that any enacted standard will become the minimum, so it is very important to get it right. Dr. Bahnfleth noted that a "carrot and stick" method could be used to improve IAQ, with funding and tax credits acting as the carrot and standards—such as the Leadership in Energy and Environmental Design (LEED) green building rating system—acting as the stick, since they can be measured and enforced. Dr. Bahnfleth said the biggest needs are higher minimum standards that are foundational to building codes, a national model IAQ standard, and minimum requirements for operations and maintenance. He stated that the process for developing standards can take years, and, in some cases, it could be easier for an outside organization to suggest them. Dr. Bahnfleth noted that achieving improvements in energy efficiency was a 50-year project that began with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publishing Standard 90 in 1975. With many US states and the federal government requiring builders to conform to some version of the ASHRAE 90 standard, energy use is down 50% from 1975, he noted. Dr. Bahnfleth called for a similar type of effort to improve standards and codes for the IAQ field. Like energy, IAQ suffers from poor maintenance, according to Dr. Bahnfleth, who mentioned that operations and maintenance exist in current IAQ standards but not in relevant codes. He concluded by noting that energy conservation should be considered as a model for improving IAQ and that standards and codes will do the heavy lifting for IAQ improvements.

Dr. Christopher Pyke discussed IAQ at scale, noting his main objective was to communicate that science is actionable, leadership is possible, and experiences across organizations are inconsistent and inequitable. Within the IAQ space, there are fewer differences between high-performing organizations but much larger deviances among underperformers, Dr. Pyke observed. He promoted the use of ASHRAE codes as a baseline but acknowledged they are not always great predictors of real-world outcomes, and he stated that organizations should be encouraged to outperform standards. Dr. Pyke then presented a case study that exemplified how inequitable experiences remain too common. In the case study, a school's carbon dioxide concentrations consistently remained within the 1,000-1,500 parts per million range, levels that do not reflect

science, standards, or leadership but instead reflect differences in management, execution, monitoring, and investment. Dr. Pyke described Arc Re-Entry, a tool designed to examine infection-control policies that was developed for buildings and recognized by LEED. He concluded that the tool can help improve IAQ management by collecting data about occupants' building experiences while also measuring carbon dioxide, relative humidity, particulate matter (PM) 2.5, and total volatile organic compounds (TVOC).

Dr. Kazukiyo Kumagai highlighted how COVID-19 revealed that many buildings are old and poorly maintained, noting several deficits in the IAQ space, including deficits of mandatory IAQ regulations and standards, enforcement of existing standards, budget, and public awareness. Dr. Kumagai discussed the California SMARTER Plan, comprising the state's strategies and systems to address COVID-19 and future public health emergencies. He said the plan will include IAQ innovation awards, enhanced IAQ communication and public education, reporting on IAQ and airborne pathogens, a roadmap for future California IAQ standard and regulation development, practical IAQ standards and regulations, and continuous and sustained IAQ improvement. Dr. Kumagai noted that the innovation awards under consideration include community education, workforce development, low-cost technology, innovation science, and school monitoring platforms. Presenting a brief history of California's IAQ standards and regulations, he specifically mentioned the 2017 California Department of Public Health Standard Method 01350 that has been cited in many certification programs. Dr. Kumagai concluded that the biggest missing piece for IAQ efforts in the US is operations and maintenance, pointing to Japan's 1970 Law for Environmental Health in Buildings and 2009 Standard for School Environmental Sanitation as model operations and maintenance examples.

Panel 3 – Providing Quality Indoor Air: International Perspectives

IAQ is an important issue globally, but each region of the world has different issues to consider when designing indoor environments. Different nations have had varying amounts of success enacting IAQ improvements. This session focused on levers used to improve air quality in other nations, as well as international standards. The session was moderated by Dr. Paula Olsiewski, Contributing Scholar at the Johns Hopkins Center for Health Security. The panel speakers included Luca Fontana, Technical Officer for the WHO Health Emergencies Programme at the WHO; Dr. Cath Noakes, Professor for the School of Civil Engineering at the University of Leeds; Dr. Pawel Wargocki, Associate Professor for the Department of Environmental Engineering and the Department of Civil Engineering at the Technical University of Denmark; and Dr. Lars Ekberg, Adjunct Professor at Chalmers University of Technology.

Luca Fontana noted that 99% of the world's population breathes air that has more pollutants than WHO air quality limits. Most people living in and around the

numerous cities that measure air quality breathe unhealthy levels of fine PM and carbon dioxide, with those in low- and middle-income countries (LMICs) suffering the highest exposures. He said the WHO is engaged in air quality improvements on several fronts, including quantifying and monitoring the effects of air pollution, promoting cooperation across sectors, providing country-level technical support to reduce air pollution and implement mitigation strategies, and developing guidance and training. Mr. Fontana discussed how COVID-19 highlighted the urgent need to improve knowledge of transmission mechanisms and enhance risk reduction measures. While the COVID-19 pandemic helped scientists better understand how pathogens spread through the air, that journey is not yet complete, Mr. Fontana said. He noted the WHO is working to improve risk assessment methods for airborne transmission in many indoor spaces to aid in the development of specific guidelines and standards.

Dr. Cath Noakes discussed how the COVID-19 pandemic improved our understanding of transmission mechanisms, risk across different settings, limitations of short-term action, and behavioral interfaces, as well as exposed strategic weaknesses. Dr. Noakes mentioned that while building design and standards can provide baseline conditions to manage risk and enable interactions, they cannot manage all human behaviors. Dr. Noakes noted that a lack of resilience in buildings can lead to disease transmission, loss of revenue, poor education, and health services strain. Additionally, buildings can have competing priorities during the design process, such as balancing ventilation and energy consumption, she said. Sir Patrick Vallance, the UK Government Chief Scientific Adviser (GCSA), commissioned Dr. Noakes's group and collaborators to conduct a two-part investigation to determine how buildings can be more resilient to disease transmission. Phase 1 involved determining actions to take before winter 2021-2022, and Phase 2 involved outlining longer-term challenges and strategies. The recommendations for Phase 1 included communicating to building owners and occupiers the importance of infection control, developing guidance on balancing risk with priorities and technology selection, and creating incentives to improve the poorest spaces. The recommendations for Phase 2 included developing standards for design, operations, and products; including health and wellbeing in building regulations; improving commissioning, testing, and enforcement for construction; establishing in-use regulations with local authorities; including infection resilience in major retrofits; improving communication to the public and building operators; developing strategic leadership within the government; and encouraging interdisciplinary research. Dr. Noakes concluded that there is no one-size-fits-all answer and called for an appropriate balancing of building design priorities.

Dr. Pawel Wargocki advised that the lack of a common metric for indoor environmental quality (IEQ)—which refers to a building's environmental quality related to the health of its occupants—is a significant barrier holding back innovation in the field. He discussed how the emergence of many undocumented IEQ measurement techniques is undervaluing the importance of both IEQ and IAQ. Dr. Wargocki proposed the TAIL system, a scheme his team developed to measure thermal quality, acoustic quality, IAQ, and light quality to determine an overall rating of IEQ using a green, yellow, orange, and

red ranking scale. The TAIL system measures ventilation rate; levels of carbon dioxide, formaldehyde, benzene, radon, and humidity; PM2.5; and visible mold to determine an IAQ score. Dr. Wargocki proposed that the TAIL system provides a complete tool for allowing the characterization of buildings' IEQ that could become a standard method for benchmarking IEQ in buildings. He encouraged those who are interested to begin using the TAIL system.

Dr. Lars Ekberg introduced the collaborative project, Buildings Post Corona. Prior to the COVID-19 pandemic, buildings tended to focus on temperature, air quality, function, and working to limit health risks, Dr. Ekberg noted, emphasizing that there has since been a shift toward focusing on disease transmission. Through Buildings Post Corona, Dr. Ekberg and collaborators are establishing and activating a network of partners, setting up and evaluating design methodology, and suggesting best practices for the design of good indoor environments. The Buildings Post Corona network comprises various organizations and industries, including trade organizations, real estate owners, industry, consultants, federal authorities of Sweden, and international authorities. Part of the effort includes a questionnaire that was sent to real estate owners, with the goal of determining the impact of actions implemented in response to the pandemic. The survey is ongoing, but Dr. Ekberg mentioned that initial results indicate guidance from trade organizations and authority organizations are of good value, with authority organizations having a higher perceived value. He called on the community to ensure buildings work as intended, promote innovation, harmonize guidance, educate, and motivate.

Panel 4 – Catalyzing IAQ: Science and Technology Innovation

The COVID-19 pandemic drew attention to the fact that many pathogens can be transmitted through the air. Some of the best mechanisms to prevent transmission of airborne disease and improve IAQ are engineering controls that do not rely on the actions of individuals to remain effective. This session focused on opportunities to drive innovation supporting high-quality indoor air and reductions in disease transmission. The session was moderated by Dr. William Bahnfleth, Professor of Architectural Engineering at The Pennsylvania State University. The panel speakers included Dr. Kerry Kinney, LP Gilvin Centennial Professor for the Department of Civil, Architectural, and Environmental Engineering at The University of Texas at Austin; Jason Wilbur, President of Omni CleanAir; Dr. Donald Milton, Professor of Environmental Health at the University of Maryland; and Dr. Brett Singer, Head of the Sustainable Energy and Environmental Systems Department and Co-lead of the Indoor Environment Group in the Energy Technologies Area at Lawrence Berkeley National Laboratory.

Dr. Kerry Kinney touched on how gaps in considerations and recommendations were common during the COVID-19 response among professional fields, including policymakers, healthcare professionals, scientists and engineers, and aerosol

specialists. Dr. Kinney echoed remarks made earlier by Dr. Prather, noting that people have understood the value of nonpharmaceutical interventions for airborne diseases—including wearing masks and improving air quality—for more than a century. Noting how misunderstandings among fields led to delays in recognizing the role of airborne transmission in the COVID-19 pandemic, Dr. Kinney discussed the continuing challenges to indoor health studies, such as viruses being difficult to measure in the field, assumptions about air mixing that do not capture real world complexities, and ventilation often being complicated in real buildings. Additionally, she said the IAQ community needs to conduct more studies on the effectiveness of indoor interventions on a broader range of health outcomes. Dr. Kinney expressed optimism that basic IAQ improvement recommendations are gaining attention. In conclusion, Dr. Kinney called on IAQ experts to engage in more cross-disciplinary efforts, conduct more health and built-environment studies, provide independent verification of treatment and ventilation technologies, focus on indoor air improvements in public and private spaces, and leverage technology and community engagement for rapid data collection and feedback.

Jason Wilbur discussed how Omni CleanAir has been working in the field of air purification for more than 30 years, noting that OmniTec works with construction applications, OmniClean works with applications for large communal facilities and hospitals, and AgriAir works with agricultural air quality products. Mr. Wilbur shared that his vision of industry's role in IAQ includes embracing sensible standards and regulations; educating, and not obfuscating; and developing innovation that drives affordability and sustainability. His vision also includes a regulatory landscape for IAQ similar to structured cabling, in which standards of "good" are universal, in which customers can easily understand the solution options, and reliable methods exist to validate whether solutions meet the objective criteria. He mentioned that IAQ customer experiences today include a marketplace that is crowded and confusing, a lack of transparency on basic performance specifications, and irrelevant or misleading marketing language. Mr. Wilbur concluded that the innovation challenge should be reducing up-front investment and total cost of ownership.

Dr. Donald Milton expressed concern that IAQ will lose progress after COVID-19 like it did after the 1918 influenza pandemic, but he added this could be avoided by engaging the medical community on IAQ issues, working on an influenza transmission study, and training infectious disease doctors to interface with the IAQ community. Dr. Milton mentioned that he was very happy to see two types of ultraviolet (UV) technology used at the conference, noting the community has a good understanding of the technology's germicidal effects. He discussed how UV technology can damage pathogens' DNA and RNA and prevent replication and noted the uses of UV technology for diseases such as influenza, measles, and tuberculosis. Dr. Milton specifically mentioned a 1957-58 Livermore Pandemic Influenza study that showed UV technology was 90% effective at preventing transmission. He also noted that germicidal UV (GUV) technology has been proven to suppress transmission of chickenpox and SARS-CoV-2.

Dr. Brett Singer outlined key underlying questions of research on infectious diseases in buildings, including those regarding emissions and susceptibility, spatial factors, and the effects of control. He also identified many research priorities, some of which include evaluating GUV and air cleaner effectiveness when deployed in high-risk settings, investing in population-based epidemiological studies of control effectiveness, identifying common challenges to implementation, and developing metrics and test methods for infectious aerosol inactivation. Dr. Singer remarked that the highest priority items for near-term impact include performing research to support setting- and scenario-specific guidance plus technical assistance for de facto space managers, quantifying the importance of imperfect mixing and the real-world effectiveness of approaches aimed at mitigating those impacts, and developing standards for GUV installations and performance evaluation. He concluded that the highest priority items for long-term impact include performing large-scale epidemiological studies to evaluate specific control approaches or packages, improving methods for in situ virus collection and quantification to scale up monitoring, and paying more consistent attention to maintenance and operations of building ventilation (air-moving) systems.

Conclusion

The Johns Hopkins Center for Health Security-hosted meeting, "National Strategy for Improving Indoor Air Quality," convened experts to share research, ideas, concerns, and aspirations regarding improvements for IAQ. Participants expressed an urgent need to develop and implement measurable and realistic performance-based building standards and codes for IAQ that would help reduce the risk of disease transmission in indoor spaces.

Discussions centered around the need to more clearly define IAQ minimum requirements, educate the public regarding the importance of healthy air, incentivize businesses and building managers to make improvements, create a consistent labeling method for building IAQ and IEQ, operationalize existing and emerging technologies to help monitor and enhance IAQ, and improve our understanding of climate change's impact on the indoor environment.

The Johns Hopkins Center for Health Security, which worked to promote indoor air improvements in schools during the COVID-19 pandemic, will continue to collaborate with these experts and others. As the Center for Health Security pursues additional projects to promote IAQ more broadly, taking action now to improve indoor air quality will significantly reduce disease transmission and protect human health for generations to come.

Appendix A: Participants' Professional Biographies

Joseph Allen, PhD

Dr. Joseph Allen is an associate professor at the Harvard T.H. Chan School of Public Health and the director of Harvard's Healthy Buildings Program. He is the coauthor of *Healthy Buildings: How Indoor Spaces Drive Performance and Productivity*, which was recognized as a Best Book of the Year by the *New York Times* and *Fortune* magazine. During the pandemic, Dr. Allen has served as Commissioner of The Lancet COVID-19 Commission and Chair of its Safe Work, Safe Schools, and Safe Travel Task Force.

An internationally renowned expert and sought-after advisor, Dr. Allen works with senior executives at Fortune 500 companies across major sectors of the economy to implement healthy buildings strategies. He has authored more than 80 peer-reviewed scientific papers and regularly contributes to the *New York Times, Washington Post*, and *The Atlantic*.

William Bahnfleth, PhD, PE

Dr. William Bahnfleth is a professor of Architectural Engineering at The Pennsylvania State University, University Park, PA. He is a Fellow of ASHRAE, the American Society of Mechanical Engineers, and the International Society for Indoor Air Quality and Climate. Dr. Bahnfleth holds a doctorate in Mechanical Engineering from the University of Illinois and is a registered professional engineer. His primary research interest is energy efficient control of indoor air quality with a focus on control of bioaerosols with germicidal ultraviolet light. Dr. Bahnfleth is the author or co-author of more than 180 journal articles and 15 books and book chapters. He has served ASHRAE in many capacities, including as 2013-14 Society President and Chair of the ASHRAE Epidemic Task Force. His ASHRAE awards include the Exceptional Service Award, the Louise and Bill Holladay Distinguished Fellow Award, the E.K. Campbell Award of Merit for teaching, and the F. Paul Anderson Award, ASHRAE's highest individual honor. His work as Chair of the ASHRAE Epidemic Task Force has been recognized with a letter of appreciation from the US Environmental Protection Agency (EPA) and the ASHRAE Presidential Certificate of Honor.

Congressman Don Beyer

Congressman Don Beyer is currently serving his fourth term in the US House of Representatives, representing Northern Virginia suburbs of the nation's capital. Rep. Beyer serves as Chair of the US Congress Joint Economic Committee, and he is a member of the House Committee on Ways and Means and the House Committee on Science, Space and Technology, where he chairs the Subcommittee on Space and Aeronautics. Previously, Rep. Beyer served as Lieutenant Governor of Virginia and Ambassador to Switzerland and Liechtenstein, and he has built a successful family business over the course of four decades.

Lars Ekberg, MSc, PhD

Dr. Lars Ekberg is an adjunct professor in Indoor Climate Technology at the Division of Building Services Engineering at Chalmers University of Technology in Gothenburg, Sweden. He also works as a consultant at one of the subsidiaries of Chalmers Industriteknik, CIT Energy Management AB.

Dr. Ekberg's research is focused on the chain of issues from human needs and wishes, via formulation of requirements to the design, construction, and management of healthy, comfortable, and energy-efficient buildings. He works over a wide spectrum, with residential buildings on one end, and advanced laboratories with very stringent requirements on the other.

Luca Fontana, MSc

Luca Fontana, an environmental toxicologist, epidemiologist working on health science and infection prevention and control, is currently Technical Officer, Emergency Programme, World Health Organization.

Since 2013, he has been contributing to preparedness and response for major outbreaks, including Ebola, Plague, Cholera, SARS-CoV-2, amongst others. His main expertise is the design and management of infectious disease treatment centers with a focus on engineering and environmental control measures. He led and contributed to several WHO publications including structural design of health facilities, the use of indoor ventilation as a risk reduction measure, and multiple IPC guidance focused on infectious diseases. One of his main areas of work is the strengthening of a multidisciplinary and holistic approach to emergency preparedness and response for infectious diseases by bridging engineering and building environment with the medical field.

Gigi Gronvall, PhD

Dr. Gigi Gronvall is a Senior Scholar at the Johns Hopkins Center for Health Security and an Associate Professor in the Department of Environmental Health and Engineering at the Johns Hopkins Bloomberg School of Public Health. She is an immunologist by training.

During the COVID-19 pandemic, she has led the Center's ongoing efforts to track the development and marketing of molecular and antigen tests and serology tests, as well as the development of national strategies for COVID-19 serology (antibody) tests and SARS-CoV-2 serosurveys in the United States. She also has written about the scientific response to the COVID-19 pandemic, the contested origin of SARS-CoV-2, and the implications for national and international security.

Dr. Gronvall is the author of *Synthetic Biology: Safety, Security, and Promise*. In the book, she describes what can be done to minimize technical and social risks and maximize

the benefits of synthetic biology, focusing on biosecurity, biosafety, ethics, and US national competitiveness—important sectors of national security. Dr. Gronvall is also the author of *Preparing for Bioterrorism: The Alfred P. Sloan Foundation's Leadership in Biosecurity*. Through her description of major grants that represented the foundation's investments in civilian preparedness, public health law, law enforcement, air filtering in buildings, influenza preparedness, and business preparedness, she constructed, for a nontechnical audience, a chronicle of early gains in US efforts to confront the threat of bioterrorism.

Dr. Gronvall is a member of the Novel and Exceptional Technology and Research Advisory Committee, which provides recommendations to the Director of the National Institutes of Health and is a public forum for the discussion of the scientific, safety, and ethical issues associated with emerging biotechnologies. From 2010 to 2020, Dr. Gronvall was a member of the Threat Reduction Advisory Committee, which provided the Secretary of Defense with independent advice and recommendations on reducing the risk to the United States, its military forces, and its allies and partners posed by nuclear, biological, chemical, and conventional threats. During 2014-2015, she led a preparatory group that examined the US government response to the Ebola outbreak in West Africa as a case study for the Department of Defense's strategic role in health security and made recommendations for future Department of Defense actions in response to disease outbreaks. She served as the Science Advisor for the Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism from April 2009 until the Commission ended in February 2010. She has testified before the US Congress about the safety and security of high-containment biological laboratories and served on several task forces related to laboratory and pathogen security. Dr. Gronvall has investigated and presented policy recommendations on the governance of science to the Biological Weapons Convention in Geneva, Switzerland.

In addition to being a life member of the Council on Foreign Relations, Dr. Gronvall is an Associate Editor of the journal *Health Security* and a founding member of the Johns Hopkins Center for Health Security. Prior to joining the faculty, she worked at the Johns Hopkins University Center for Civilian Biodefense Strategies. She was a National Research Council Postdoctoral Associate at the US Army Medical Research Institute of Infectious Diseases in Fort Detrick, Maryland.

Dr. Gronvall received a PhD from Johns Hopkins University for work on T-cell receptor/MHC I interactions and worked as a protein chemist at the Memorial Sloan-Kettering Cancer Center. She received a BS in biology from Indiana University, Bloomington.

Ashish Jha, MD

A practicing physician, Dr. Ashish K. Jha serves as the White House COVID-19 Response Coordinator, appointed by US President Joe Biden. In his former role, he served as Dean of the School of Public Health at Brown University. He is recognized globally as an expert on pandemic preparedness and response as well as domestic and global health

policy. Dr. Jha has led groundbreaking research on Ebola and has been a trusted voice on the COVID-19 response, leading national and international analysis of key issues and advising state and federal policymakers.

Dr. Jha joined Brown in 2020 after leading the Harvard Global Health Institute and teaching at the Harvard T.H. Chan School of Public Health and Harvard Medical School. He has practiced for nearly two decades at Veterans Affairs hospitals, providing direct clinical care to veterans.

Dr. Jha has published more than 250 original research publications in leading medical and health policy journals and is a frequent contributor to a range of public media. His research focuses primarily on the impact of public health policy on health outcomes and healthcare spending, both domestically and globally.

Born in Pursaulia, Bihar, India, Dr. Jha moved to Toronto, Canada, in 1979 and to the United States in 1983. He graduated magna cum laude from Columbia University with a BA in economics, earned his MD from Harvard Medical School, and received an MPH from the Harvard T.H. Chan School of Public Health. He has been a member of the National Academy of Medicine since 2013.

Kerry Kinney, PhD

Dr. Kerry Kinney is the LP Gilvin Centennial Professor in the Department of Civil, Architectural & Environmental Engineering at The University of Texas at Austin. She also has a courtesy appointment in the Department of Population Health at the Dell Medical School. Dr. Kinney's cross-disciplinary research in environmental engineering and molecular biology centers on the investigation of microorganisms and contaminants in engineered systems including buildings, residential water systems, and municipal wastewater systems. She has extensive experience working with multidisciplinary teams to investigate human exposure to microorganisms and contaminants in the indoor environment.

Over the last decade, Dr. Kinney's research group has explored the microorganisms, allergens, and contaminants found in schools, homes, and other buildings. These studies have led to a greater understanding of the conditions that promote fungal growth in buildings, new indoor sampling strategies (e.g., filter forensics), and insights into the relationships between indoor exposures and health.

Most recently, Dr. Kinney is working with researchers across UT Austin on the Whole Communities–Whole Health Bridging Barriers Initiative. She also serves on the steering committee for the Center for Health and Environment: Education and Research at Dell Med and is President Elect (and member of the Academy) of the International Society of Indoor Air Quality and Climate.

Kazukiyo Kumagai, PhD

Dr. Kazukiyo Kumagai is currently Chief of the Indoor Air Quality Section of the California Department of Public Health. Dr. Kumagai has worked for more than 20 years in the environmental science field, focused on air quality monitoring, human exposure to environmental and occupational pollution, exposure and/or effects of pollution on human health in indoor and controlled environments, and research driven by air quality policy.

His recent research support is from the Japanese government (specifically the Ministry of Land, Infrastructure, Transport and Tourism; Ministry of Economics, Trade and Industry; and Ministry of Health, Labour and Welfare of Japan), several foundations (including Nissan), Sumitomo Environmental, and more than 50 private Japanese companies.

Dr. Kumagai is also a guest professor at Kyushu University in Japan, as well as a member of the International Society of Indoor Air Quality and Climate; American Society of Heating, Refrigerating and Air Conditioning Engineers; and other major organizations focused on indoor and outdoor atmospheric environments.

Dr. Kumagai holds a BEng and MEng in architectural engineering from Tokyo University of Science, Japan; an MPH in environmental health from the Institute of Public Health, Japan; and a PhD in environmental science from the University of Tokyo.

Donald K. Milton, MD, DrPH

Dr. Donald K. Milton is a Professor of Environmental Health at the University of Maryland School of Public Health, with a secondary appointment in the University of Maryland School of Medicine's Department of Medicine. An internationally recognized expert on the aerobiology of respiratory viruses, Dr. Milton developed the concept of using indoor CO2 to directly measure rebreathed air and airborne infection risk. He is the Principal Investigator of the UMD StopCOVID study (investigating SARS-CoV-2 transmission) and of the newly NIH-funded Evaluating Modes of Transmission (EMIT-2) study, a 5-year, $15 million UMD-UMB collaboration to perform randomized controlled trials that will define the modes and mechanisms of influenza transmission.

Dr. Milton graduated from the University of Maryland, Baltimore County with a BA in chemistry in 1976 and obtained his MD from Johns Hopkins University in 1980. He went on to obtain a Master of Occupational Health and DrPH from the Harvard T.H. Chan School of Public Health in 1985 and 1989, respectively.

Cath Noakes, OBE, PhD, FREng, FIMechE, FIHEEM, FISIAQ

Dr. Cath Noakes is a chartered mechanical engineer, with a background in fluid dynamics. She gained her PhD in Computational Fluid Dynamics in 2000 from the University of Leeds, and has remained at Leeds since, becoming a Professor in the School of Civil Engineering in 2014. She leads research into ventilation, indoor

air quality, and infection control in the built environment using experimental and modelling-based studies. She is co-director of the EPSRC Centre for Doctoral Training in Fluid Dynamics and Deputy Director of the Leeds Institute for Fluid Dynamics. From April 2020-2022 she co-chaired the Environment and Modelling sub-group of the UK Scientific Advisory Group for Emergencies (SAGE), focusing on the science underpinning environmental transmission of COVID-19. She also has contributed to multiple working groups focusing on respiratory transmission, including for the WHO, the NHS, the UK and Scottish Governments, various professional bodies, the Academy of Medical Sciences, and the Royal Academy of Engineering.

Alejandra Nunez, SJD, LLM, LLB

Alejandra Nunez is the Deputy Assistant Administrator for Mobile Sources, Office of Air and Radiation at the US Environmental Protection Agency. Prior to being appointed to her current position at the EPA, she served as a senior attorney at the Sierra Club's Environmental Law Program, where her work focused on litigation and regulatory advocacy on federal greenhouse gas and corporate average fuel economy standards for light- and heavy-duty vehicles, carbon dioxide standards for new and existing power plants, state transportation and clean energy policies, and the integration of environmental justice in climate policy. Before Sierra Club, she worked as associate counsel at the World Bank's Legal Vice Presidency, where she advised on public-private partnerships in the energy and water infrastructure sectors, and was also an associate at Morrison & Foerster, where she represented clients on public trust issues, carbon sequestration projects, and conservation easements.

Paula Olsiewski, PhD

Dr. Olsiewski is a Contributing Scholar at the Johns Hopkins Center for Health Security. She is a pioneering leader in policy and scientific research programs in the microbiology and chemistry of indoor environments. Dr. Olsiewski leads the Center's work on indoor air quality policy to mitigate airborne disease and global catastrophic biological risks.

During her 2 decades at the Alfred P. Sloan Foundation, she led innovative and multidisciplinary programs that inspired, accelerated, and produced lasting impact. Her expertise in partnering with academic, governmental, and for-profit stakeholders fostered innovation and built research capacity through the creation of diverse stakeholder networks. Her accomplishments include the creation and direction of the microbiology of the built environment, chemistry of indoor environments, and biosecurity programs.

Dr. Olsiewski is recognized as a leading expert in biosecurity and is a member of the Council on Foreign Relations. She was Chair of the US Environmental Protection Agency (EPA) Homeland Security Research Subcommittee and was a member of the EPA Board of Scientific Counselors Executive Committee 2014-2022. She is a member of the Academy of Fellows of the International Society for Indoor Air Quality and Climate and Fellow of the American Association for the Advancement of Science in chemistry.

Dr. Olsiewski's acumen in board governance, recruitment and development, and fundraising has helped both scientific and philanthropic organizations improve their operational efficacy and programmatic outcomes. Early in her career, Dr. Olsiewski was Vice President of Product Development at Enzo Biochem and President of Neo/Tech Corp. She is an active board member of the Critical Path Institute, an independent nonprofit organization dedicated to improving the drug development and regulatory process. She is also Vice Chair of the Spondylitis Association of America and was board chair of Asphalt Green—a not-for-profit organization in New York that encourages a lifetime of participation in sports and fitness.

Dr. Olsiewski received a PhD in biological chemistry at the Massachusetts Institute of Technology (MIT). As an alumna, she was a member of the MIT Corporation and President of the MIT Alumni Association, earning her the association's top honor: the Bronze Beaver award. Dr. Olsiewski was a member of MIT's Initiative for Faculty Race and Diversity Advisory Committee and is an advocate for diversity and ongoing supporter of MIT's Women in Chemistry. She also received a BS in chemistry, *cum laude*, from Yale University.

Kimberly Prather, PhD

Dr. Kimberly Prather is an Atmospheric Chemist, Distinguished Chair in Atmospheric Chemistry, and a Distinguished Professor at the Scripps Institution of Oceanography and the Department of Chemistry and Biochemistry at the University of California San Diego. Her work focuses on how human emissions are influencing the atmosphere, climate, and human health. In April 2020, she was elected to membership in the National Academy of Sciences in honor of outstanding contributions to aerosol chemistry. In 2019, she was elected as a member of the National Academy of Engineering. She is an elected Fellow of the American Geophysical Union, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences.

Dr. Prather is working to understand the health and environmental impacts of ocean-derived pollutants and toxins in run-off and outfalls. Her work focuses on studying the ocean-to-atmosphere transfer of pollutants and subsequent atmospheric transport and extent of human exposure. Her research specifically focuses on measurements of the concentration of particles that are small enough to be fully inhaled and impact human health. This new area of research can be used for alerting the public and predicting days with heavier airborne pollution and bacterial loads, especially during storm events that wash contaminants into coastal oceans, where they can then become airborne. She is working collaboratively with a team of interdisciplinary scientists to study the potential health effects of these ocean-derived natural microbes and anthropogenic pollutants under changing climate conditions.

Chris Pyke, PhD

Dr. Chris Pyke is an environmental scientist and the Senior Vice President for Arc Skoru—part of the US Green Building Council family of organizations. Arc helps spaces, buildings, and places in more than 132 countries benchmark real world sustainability performance. Prior to joining Arc, Dr. Pyke led research for the US Green Building Council, served as Chief Strategy Officer for Aclima, and contributed to the global growth of GRESB as Chief Operating Officer. Dr. Pyke is on the faculty of the Urban and Regional Planning Program at Georgetown University. He holds a PhD and MA from the University of California, Santa Barbara.

Ana María Rule, PhD, MHS

Dr. Ana María Rule is an Assistant Professor at the Johns Hopkins Bloomberg School of Public Health, where she obtained her Master of Occupational Health in 1996 and her PhD in Environmental Health Sciences in 2005. Dr. Rule is an expert in exposure assessment of airborne environmental and occupational hazards, including in agricultural, urban, and nosocomial environments. She has led projects to evaluate exposures to biological aerosols, electronic cigarettes, as well as indoor and outdoor air pollution. Dr. Rule's main research goal is the development and evaluation of novel sampling and analysis strategies for the assessment of exposure to air pollutants. She is currently Director of the Environmental Exposure Assessment Lab, where she develops and applies methods for the assessment of exposures to adult and pediatric populations. She has experience working in multidisciplinary projects that involve collaboration with researchers from other disciplines and is passionate about addressing the root-causes of environmental justice.

Monica Schoch-Spana, PhD

Dr. Monica Schoch-Spana, a medical anthropologist, is a Senior Scholar with the Johns Hopkins Center for Health Security and a Senior Scientist in the Department of Environmental Health and Engineering at the Johns Hopkins Bloomberg School of Public Health. Since 1998, she has focused her public health career on generating and applying evidence to advise policymakers and practitioners on how to collaborate with private citizens, businesses, and faith- and community-based groups in efforts to manage catastrophic health events, both effectively and equitably. Her areas of expertise include community resilience to disaster, public engagement in policymaking, crisis and emergency risk communication, and public health emergency management (readiness/response/recovery).

During the COVID-19 pandemic response, Dr. Schoch-Spana has worked diligently to translate social scientific insights into actionable recommendations for policymakers and practitioners, including most recently as co-Principal Investigator for CommuniVax—a national ethnographic research coalition whose expert advisory group and 6 local teams are partnering with communities of color to tackle COVID-19 vaccine access and acceptance issues and to put equity at the center of the pandemic recovery

process. She has also collaborated in generating an ethical framework for the allocation of COVID-19 vaccines, advanced understanding of the pandemic's mental health challenges, contributed to decision-making guidance for governors on safe reopening strategies, consulted on crisis standards of care and their communication to the public, and spotlighted the need for a transformative pandemic recovery process focused on the whole person.

Dr. Schoch-Spana's national advisory roles include currently serving on the Homeland Security Subcommittee of the Board of Scientific Counselors for the US Environmental Protection Agency and on the Resilient America Roundtable of the National Academies of Sciences, Engineering, and Medicine (NASEM), which she also formerly cochaired. She also serves on the NASEM Committee on Community Engagement in Southeast Texas: Pilot Project to Enhance Community Capacity and Resilience to Floods and on the NASEM Committee that planned the March 2022 workshop, "Building Public Trust in Public Health Emergency Preparedness and Response (PHEPR) Science."

Dr. Schoch-Spana has helped guide the direction of policy and practice in public health emergency management such that planning and operations are more behaviorally realistic and contribute to health equity; public health communicators are better equipped to meet the population's informational needs in an emergency; citizens have more venues to contribute their practical, intellectual, and ethical inputs to readiness and response endeavors; and national and local communities are striving to withstand and learn from disasters, rather than merely respond to them.

From 2003 to 2017, Dr. Schoch-Spana worked at the University of Pittsburgh Medical Center's Center for Health Security; prior to that she worked at the Johns Hopkins University Center for Civilian Biodefense Strategies, starting in 1998. She received her PhD in cultural anthropology from Johns Hopkins University and a BA from Bryn Mawr College.

Brett Singer, PhD

Dr. Brett C. Singer is the Head of the Sustainable Energy and Environmental Systems Department and Co-lead of the Indoor Environment Group in the Energy Technologies Area of Lawrence Berkeley National Laboratory. Dr. Singer has more than 25 years of experience conceiving, conducting, and leading research studies of air pollutant emissions and the physical-chemical processes and controls that impact exposures in varied building types. A major focus of Dr. Singer's work has been the goal of accelerating new building standards and retrofit practices to decarbonize the sector and improve energy performance, resilience, and indoor environmental conditions. His research also addresses low-energy systems for filtration, smart ventilation, and exposure mitigation. Dr. Singer earned MS and PhD degrees in civil and environmental engineering from the University of California, Berkeley and a BS in engineering from Temple University.

Pawel Wargocki, PhD

Dr. Pawel Wargocki is an Associate Professor in the Department of Environmental Engineering and the Department of Civil Engineering at the Technical University of Denmark, DTU. He has more than 25 years of experience in research on human requirements in indoor environments. He is best known for his seminal work demonstrating that poor indoor environmental quality affects the performance of office work and learning. Other work influenced requirements for ventilation and air cleaning. Recent research includes studies on human emissions, sleep quality, the development of the IEQ rating schemes, and the performance of green buildings.

Dr. Wargocki has collaborated with leading research institutions, universities, and industrial partners worldwide, such as the National University of Singapore, Jiaotong University in Shanghai, Syracuse Center of Excellence, United Technologies, and Google. He was President and a long-standing Board Member of the International Society of Indoor Air Quality and Climate (ISIAQ); President of ISIAQ Academy of Fellows (previously Academy of Indoor Air Sciences); Vice President of the Indoor Air 2008 conference; and Chair of ASHRAE committees. He has received several awards for his work, including the Rockwool Award for Young Researchers, ASHRAE Ralph Nevins Award, ISIAQ's Yaglou Award, and the Indoor Air Journal Best Paper Award. He is published extensively. Dr. Wargocki received his PhD from the Technical University of Denmark in 1998 and graduated from Warsaw University of Technology in Poland.

Jason Wilbur, MSc, MBA

Jason Wilbur is the Executive Vice President and Co-Founder of Silver Falls Capital and President of Omni CleanAir. Omni CleanAir is critically focused on eliminating illnesses caused by unhealthy air through scientifically proven air purification solutions for indoor commercial spaces (medical facilities, office spaces, educational facilities), industrial environments (abatement, construction), and indoor agricultural environments. For more than 30 years, Omni CleanAir has kept professionals safe from the most dangerous airborne pathogens and pollutants and continues to develop innovative solutions to clean the air we breathe.

Mr. Wilbur has a degree in mechanical engineering from the University of Iowa, a Master of Engineering degree from the California Institute of Technology, and an MBA from Arizona State University. Prior to Omni CleanAir, Mr. Wilbur worked for several Fortune 100 public companies, including Honeywell and Danaher.

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