AHLA htng MOVING HOSPITALITY FORWARD

INDOOR AIR QUALITY EXECUTIVE SUMMARY

Version 1.0

January 25, 2023

About HTNG

Hospitality Technology Next Generation (HTNG) is a non-profit association with a mission to foster, through collaboration and partnership, the development of next-generation systems and solutions that will enable hoteliers and their technology vendors to do business globally in the 21st century. HTNG is recognized as the leading voice of the global hospitality community, articulating the technology requirements of hotel companies of all sizes to the vendor community. HTNG facilitates the development of technology models for hospitality that will foster innovation, improve the guest experience, increase the effectiveness and efficiency of hotels, and create a healthy ecosystem of technology suppliers.

TABLE OF CONTENTS

1 AHLA Executive Summary

1.1 KEY POINTS

Hotel managers have long appreciated the value of assessing and addressing indoor air quality (IAQ) for their properties. But the COVID-19 pandemic has brought even greater attention to the importance of IAQ. While IAQ systems are not new to the industry, the pandemic has increased focus on solutions that prevent and remediate the problems associated with poor IAQ.

Additionally, the benefits of good IAQ extend far beyond COVID-19. SARS-CoV-2, the virus that causes COVID-19, is just one of many pathogens that can be transmitted through the air, not to mention pollutants and other physical threats to health surrounding individuals day-to-day. Good IAQ not only helps to reduce the spread of other respiratory infections, such as the common cold or flu, but can also improve respiratory symptoms[1], reduce allergy[2] and asthma symptoms[3], improve mental health and well-being outcomes (such as cognition and mood)[4,5,6,7,8] and improve employee workplace satisfaction and productivity[9]. In light of the preceding, we recommend the following for consideration:

1. Continuing the collaboration with the American Hotel & Lodging Association (AHLA) through AHLA's groundbreaking Safe Stay Guidelines
2. Increasing focus on IAQ as a means of enhancing safe operations for hotels, instilling confidence among guests and employees, and building resiliency for the future
3. Implementing IAQ solutions such as ventilation, filtration, and air cleaning (as described in detail below) to improve IAQ
4. Considering expert advice and focusing on cost-effective solutions when evaluating IAQ solutions in terms of their operational feasibility for a particular venue, affordability, and energy efficiency
5. Communicating the benefits of AHLA's Safe Stay Guidelines to attract more guests

[1] U.S. Environmental Protection Agency. Volatile Organic Compounds' Impact on Indoor Air Quality. https://www.epa/gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality. Accessed May 21, 2019.
[2] Hay fever – Symptoms and causes. Mayo Clinic. https://www.mayoclinic.org/diseases-conditions/hay-fever/symptoms-causes/syc-20373039. Accessed September 19, 2019.
[3] Allergies and asthma: Double trouble. Mayo Clinic. https://www.mayoclinic.org/diseases-conditions/asthma/in-depth/allergies-and-asthma/art-20047458. Accessed December 6, 2019.
[4] C. Vert et. Al., "Effect of long-term exposure to air pollution on anxiety and depression in adults: A cross-sectional study." In. J. Hyg. Environ. Health, vol. 220, no. 6, pp. 1074-1080, Aug. 2017, doi: 10.1016/j.ijheh.2017.06.009
[5] Y. Kim et al., "Association between air pollution and suicide in South Korea: a nationwide study," PIoS One, vol. 10, no. 2, p. e0117929, 2015, doi: 10.1371/journal.pone.0117929.
[6] J.G. Allen, P. MacNaughton, U. Satish, S. Santanam, J. Vallarino, and J.D. Spengler, "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments," Environ. Health Perspect., vol. 124, no. 6, pp. 805-812, Jun. 2016, doi: 10.1289/ehp.1510037.
[7] W.J. Fisk. Health and Productivity Gains from Better Indoor Air Environments and Their Relationship with Building Energy Efficiency. Annual Review of Energy and the Environment. 2000; 25: 537-586.
[8] Allen J, Macomber J. Healthy Buildings: How Indoor Spaces Drive Performance and Productivity. Harvard University Press; 2020.
[9] Seppanen O, Fisk W. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research. 2006; 12(4):957-973. doi: 10.1080/10789669.2006.10391446

1.1 THE IMPORTANCE OF INDOOR AIR QUALITY (IAQ) FOR THE INDUSTRY

This executive summary provides supplemental advice to help hotel brands, property managers, and hospitality partners better understand the risks posed by aerosol transmission of infectious pathogens, why good IAQ in hotels is so important, and what evidence-based solutions are available to address key IAQ issues.

The disease may be spread by infectious pathogens (bacteria, viruses, fungi, and more) through contact (surface, droplet, or waterborne) or through respiratory tract entry (aerosol). There are three main SARS-CoV-2 transmission routes: 1) inhalation of very fine respiratory droplets and aerosol particles (airborne transmission), 2) deposition of respiratory droplets and particles on exposed mucus membranes in the mouth, eyes, or nose (droplet transmission), and 3) touching mucus membranes after contact with contaminated surfaces (surface transmission)[10]. Mounting evidence has shown that airborne transmission poses the most significant SARS-CoV-2 transmission risk. While larger respiratory droplets quickly fall onto surfaces, smaller exhaled aerosolized particles containing viral pathogens can travel considerable distances in indoor spaces and remain suspended in the air for prolonged periods (up to several hours)[11,12,13,14,15].

Hotels have invested heavily in surface cleaning protocols, which provide many positive effects. Now that more information about how the SARS-CoV-2 virus transmits, it is time to increase the focus on IAQ to address the risk of airborne transmission. Deploying IAQ solutions helps protect the health and well-being of guests and employees and may drive revenue growth by increasing consumer confidence, enhancing the guest experience, and improving the hotel's reputation.

Good indoor air quality is potentially a marketable strategy to bring guests back to hotels and improve employee retention rates, with benefits extending beyond COVID-19.

[10] U.S. Centers for Disease Control and Prevention. Scientific Brief: SARS-CoV-2 Transmission. Updated May 7, 2021. Accessed March 9, 2022. https://www.cdc.gov/coronavirus/2019-ncov/science-briefs/sars-cov-2-transmission.html
[11] World Health Organization. Transmission of SARS-CoV-2: implications for infection prevention precautions. Accessed September 25, 2020. https://www.who.int/publications/i/item/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations
[12] Allen JG, Marr LC. Recognizing and controlling airborne transmission of SARS-CoV-2 in indoor environments. Indoor Air. 2020;30(4):557-558. doi: 10.1111/ina.12697
[13] Morawska L, Milton DK. It is Time to Address Airborne Transmission of COVID-19 [published online ahead of print, 2020 Jul 6]. Clin Infectt Dis.2020;ciaa939. doi 10.1093/cid/ciaa939
[14] Lednicky JA, Lauzardo M, Hugh Fan Z, et al. Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients [published online ahead of print, 2020 Sep 16]. Int J Infect Dis. 2020;S1201-9712(20)30739-6. doi: 10.1016/j.ijid.2020.09.025
[15] The American Societ of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). ASHRAE Position Document on Airborne Infectious Diseases.; 2020:22. https://www.ashrae.org/file%20library/about/position%20documents/airborne-infectious-diseases.pdf

Some hotel environments feature a range of shared spaces and facilities (such as conference/event rooms, lobbies, gyms, and even elevators) and thus have a higher potential for pathogen transmission through the air; but countermeasures are not "one size fits all," and hotels may need to consider several factors before deploying solutions. Many factors influence IAQ, and the diversity of indoor spaces, airflow, temperature, humidity, number of people in the area, and mask-wearing influence how to measure and mitigate airborne threats. Improving IAQ may compete with the ability to address other indoor environmental factors, such as achieving optimal thermal comfort, ranked as one of the most important contributing factors to our overall satisfaction with the indoor environment.[16]

Furthermore, in addition to pathogens in the air, other pollutants can impact the health, well- being, and overall satisfaction of guests and employees. For example, fine particulate matter ($PM_{2.5}$) are particles so small that once inhaled; they can penetrate the lungs and even enter the bloodstream - resulting in both short-term and long-term health concerns.[17] Allergens such as dust, pollen, pet dander, saliva, and pest waste can cause allergic reactions in some individuals and potentially trigger asthma symptoms.[18] Mold and mildew, common in damp indoor environments such as bathrooms, pools and spas, are known to be asthma triggers that may cause allergic reactions[19].

Volatile organic compounds (VOCs) are emitted as gasses from certain complex chemicals found in commonly used products, and exposure to certain VOCs may have detrimental effects on human health[20]. Carbon dioxide, which humans produce through respiration, can be an indicator for many aspects of IAQ, from ventilation effectiveness to the risk of airborne infection transmission.

With so many IAQ solutions on the market, selecting solutions that best fit the needs of any space can be challenging and should be done in consultation with experts. Below are five key strategies to help reduce harmful pollutants and pathogens within indoor air.

1.1.1 VENTILATION

Ventilation is one of the best-known IAQ control strategies that can be essential in diluting pollutant concentrations built up indoors by supplying fresh air from outdoors. Mechanical systems can provide ventilation or naturally through open doors and windows. However, ventilation use has limitations. Outdoor air is not always free of pollution and can impact thermal comfort. Additionally, installing or retrofitting ventilation systems usually takes a long time and can be a costly investment, and conditioning outdoor air requires a significant amount of energy.

---

[16] Frontczak M. Wargocki P. Literature survey on how different factors influence human comfort in indoor environments. Build Environ. 2011;46(4):922-937. doi: 10.1016/j.buildenv.2010.10.021.
[17] U.S. Environmental Protection Agency. Health and Environmental Effects of Particulate Matter (PM). 2017.
[18] Mayo Clinic: Allergies and asthma: Double trouble. Accessed December 6, 2019. https://www.mayoclinic.org/diseases-conditions/asthma/in-depth/allergies-and-asthma/art-20047458
[19] World Health Organization (WHO). WHO Guidelines for Indoor Air Quality: Dampness and Mould. 2009. WHO Regional Office for Europe. Accessed November 12, 2020. http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf
[20] U.S. Environmental Protection Agency. Volatile Organic Compounds' Impact on Indoor Air Quality. US EPA. Published August 18, 2014. Accessed June 25, 2020. https://epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality

1.1.2 FILTRATION

Filtration uses air filters to capture and remove the pollutants from the air to deliver filtered, cleaner air into the space and thus can help to mitigate disease transmission by reducing airborne particles that carry viruses and bacteria. Filtration can be achieved by Heating, Ventilation, and Air Conditioning systems (HVAC) filters, in-duct air purifiers, and portable air purifiers.

Central HVAC Filters and **in-duct air purifiers** utilize filters installed directly in the HVAC system. They help to reduce indoor air pollutants by filtering recirculated air whenever the HVAC system fan is operating. Unfortunately, increasing the removal efficiency of the filters can also cause an increased pressure to drop across the filters, leading to a reduced flow rate and higher energy consumption.

Portable air purifiers refer to plug-and-play wall-mounted or standalone units that can reduce indoor air pollutants without requiring more extensive upgrades or renovations to existing HVAC systems. There is a large and firmly supported body of scientific research that shows the effectiveness of portable air purifiers in reducing indoor air pollutants, including particles that carry infectious agents, and improving the health of occupants[21,22,23,24].

While HVAC filters and in-duct air purifiers work to dilute the concentration of airborne pollutants in the entire space, portable air purifiers can be moved to address pollution sources directly. Additionally, HVAC systems are often not visible. The visible nature of portable air purifiers can provide peace of mind for guests and employees that their air is being cleaned. The CDC also highlights that using portable filtration systems can enhance air cleaning.[25]

1.1.3 HVAC MAINTENANCE

Hotels should evaluate the condition of their HVAC systems and make necessary adjustments if required. Routine HVAC maintenance can help to ensure your system is operating at its peak performance and efficiency. Hotel HVAC systems are believed to operate below their rated efficiencies because of faults introduced during installation or developed during operation. Common HVAC faults include stuck dampers, leaky valves, sensor drift, simultaneous heating and cooling, and improper refrigerant charge. Implementing fault detection and diagnostics (FDD) tools can help to address this problem. FDD tools can reduce equipment downtime, energy consumption, and maintenance costs and improve occupant comfort and indoor air quality.

---

[21] Jia-Ying L, Zhao C, Jia-Jun G, Xiao L, Bao-Qing S. Efficacy of air purifier therapy in allergic rhinitis. Asian Pac J Allergy Immunol. 2018;36(4):217-221. doi 10.12932/AP-010717-0109
[22] Bräuner EV, Forchhammer L, Møller P, et al. Indoor particles affect vascular function in the aged: an air filtration-based intervention study. Am J Respir Crit Care Med. 2008;177(4):419-425. doi 10.1164/rccm.200704-632OC
[23] Curtius J, Granzin M, Schrod J. [Preprint] Testing movile air purifiers in a school classroom: Reducing the airborne transmission risk for SARS-CoV-2. medRxiv. Published October 6, 2020:2020.10.02.20205633. doi: 10.1101/2020.10.02.20205633
[24] Morishita M, Adar SD, D'Souza J, et al. Effect of Portable Air Filtration Systems on Personal Exposure to Fine Particulate Matter and Blood Pressure Among Residents in a Low-Income Senior Facility: A Randomized Clinical Trial. JAMA Intern Med. 2018;178(10):1350. doi: 10.1001/jamainternmed.2018.3308
[25] The Centers for Disease Control and Prevention. Ventilation in Buildings. Updated June 2, 2021. Accessed March 28, 2022. https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html

1.1.4 IAQ MONITORING

IAQ monitors can track the levels of several types of air pollutants (e.g., $PM_{2.5}$, PM_{10}, TVOCs) and other air quality parameters (CO_2, temperature, humidity). Depending on the IAQ issues identified, hotels can work to determine what IAQ remediation efforts are needed to optimize their air quality. IAQ monitors can also serve as a visual cue to show guests and employees that they are breathing cleaner air to demonstrate further your hotel's commitment to prioritizing their health, safety, and well-being. Fortunately, many consumer-grade and easy-to-use monitors are available in the market.

1.1.5 OTHER AIR CLEANING TECHNOLOGIES

Ultraviolet Germicidal Irradiation (UVGI) is electromagnetic radiation that can destroy the ability of microorganisms to reproduce. UVGI radiation can effectively inactivate microorganisms such as viruses, bacteria, and fungi with proper dosage. UVGI can be implemented in various ways, including in-duct disinfection, upper-room disinfection, and portable room disinfection.

Unfortunately, inappropriate use of UVGI applications can present human health and safety issues, lead to insufficient deactivation of infectious agents, material degradation, the release of harmful chemicals (if the mercury lamp breaks) and potentially generate harmful byproducts such as ozone[26].

While other emerging air cleaning technologies (such as bipolar ionization, photocatalytic oxidation (PCO), and plasma) are also available on the market, many scientific and regulatory institutions (such as the U.S. EPA) urge caution when considering these technologies due to the absence of an established body of peer-reviewed evidence showing proven efficacy and safety under as-used conditions. The ability to measure how a particular intervention strategy for IAQ is a complex undertaking, usually requiring expert guidance.

The pandemic has reimagined the guest experience and the hotel industry. Prioritizing IAQ in hotels is crucial to help protect the health and safety of guests and employees, offer a competitive advantage, and help hotels continue to recover and grow. It is important to note that while the recommendations provided above are based on existing scientific evidence, these recommendations do not guarantee that any indoor environment will be completely free from pathogens or harmful pollutants. It is critical to select IAQ solutions that stay true to their claims on safety, efficacy, and performance. It is recommended that hotels consider science-backed research and third-party validation in their selection processes.

[26] CIE Position Statement on Ultraviolet (UV) Radiation to Manage the Risk of COVID-19 Transmission. 2020

2 What is Indoor Air Quality?

Indoor air quality (IAQ) refers to the types and concentrations of airborne contaminants within buildings, which can impact the wellness and comfort of people.[27]

Exposure to indoor air pollutants may cause immediate health effects such as irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue, and long-term health effects such as chronic respiratory diseases, heart disease, and cancer.[28] Studies also show that poor indoor air quality can contribute to decreased learning and working outcomes, performance, and productivity.[1]

Airborne contaminants include biological pollutants such as bacteria, viruses, and mold capable of causing disease and discomfort in occupants. Exposure to these pollutants can trigger allergic reactions such as hypersensitivity pneumonitis and asthma. Additionally, infectious diseases such as influenza and measles can be transmitted through the air via respiratory droplets.

2.1 WHY MONITOR IAQ?

Monitoring is a general term for collecting and using measurement data to assess performance against a standard or status for a specific requirement. Monitoring IAQ allows occupants and building managers to keep track of the pollutant conditions, identify areas that may need improvements, and take controlling and remediation actions to help reduce risks of indoor health concerns.

2.2 MAJOR INDOOR AIR POLLUTANTS AND THEIR THRESHOLDS

While temperature and humidity can affect the thermal comfort of occupants, airborne particulate matter, including biological and non-biological particles and harmful gasses, are the primary sources contributing to poor IAQ. Listed below are some common IAQ monitoring parameters and their acceptable thresholds:

- **Temperature and Relative Humidity:** Low indoor air temperature has been linked to respiratory and cardiovascular problems, including increased blood pressure and asthma symptoms. High air temperature can be similarly detrimental and result in heat cramps, heat exhaustion, and heatstroke. Humidity refers to the amount of water vapor in the air. Low humidity can promote the movement of viruses and other pathogens in the air and dry out nasal passages, reducing our immune defense mechanisms in protecting us against pathogens. High humidity can encourage the growth of mold, fungi, and bacteria. In addition, temperature and relative humidity also affect a person's perception of comfort in an indoor environment.
    - Temperature: 68.5°F - 74°F (winter); 75°F - 80.5°F (summer)[29]
    - RH: 30% - 50%[30]

[27] Weekes D, Lapotaire JP, Persily A, Siegel J, Stephens B, Walker I, Wargocki P, White B. ASHRAE Position Document on Indoor Air Quality. ASHRAE. Published July 1, 2020. Accessed October 21, 2022. https://www.ashrae.org/file%20library/about/position%20documents/pd_indoor-air-quality-2020-07-01.pdf.
[28] U.S. Environmental Protection Agency. Introduction to Indoor Air Quality. Accessed October 21, 2022. https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality
[29] ANSI/ASHRAE Standard 55-2017: Thermal Environmental Conditions for Human Occupancy
[30] WELL Building Standard V2 https://v2.wellcertified.com/en/wellv2/overview

- **Particulate Matter**: Particulate matter refers to a mixture of solid or liquid matter that can stay suspended in the air. PM_{10} refers to coarse inhalable particles that are less than 10 micrometers in diameter, and $PM_{2.5}$ refers to fine inhalable particles that are less than 2.5 micrometers in diameter (these are a subset of PM_{10}). Smaller inhalable particles can get deep into a person's lungs, and some may even get into the bloodstream, posing severe health concerns.
    - PM_{10}: less than 50 µg/m³ (24-hour mean)[31]
    - $PM_{2.5}$: less than 15 µg/m³ (annual mean, averaged over three years)[32]
- **Volatile Organic Compounds (VOCs)**: VOCs are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. VOCs are emitted as gasses from certain solids or liquids through a process called "chemical off-gassing." Some VOCs, such as formaldehyde, have short- and long-term adverse health effects. Total volatile organic compounds (TVOCs) refer to the total concentration of multiple airborne VOCs present simultaneously in the air in a given space rather than the concentration of any individual VOC.
    - Formaldehyde: less than 27 ppb[33]
    - TVOCs: less than 220 ppb[7]
- **Carbon Monoxide (CO)**: CO is an odorless, colorless, and toxic gas. Because it is impossible to see, taste, or smell toxic fumes, CO is one of the most dangerous gasses in the indoor environment. The effects of CO vary from dizziness to death depending on its concentration and length of exposure.
    - CO: less than 9 ppm (8-hour mean)[5]
- **Ozone**: Ozone, composed of three atoms of oxygen, is a gas that occurs both in the Earth's upper atmosphere and at ground level, but only ground-level ozone is harmful. Ozone is created by chemical reactions between nitrogen oxides and VOCs. It can be emitted by cars, fossil fuel burning devices, or generated in the home from printers and certain types of air purifiers. Exposure to ozone can damage the respiratory and cardiovascular systems.
    - **Ozone**: less than 51 ppb (8-hour mean)[5]
- **Radon**: Radon is a colorless, odorless, radioactive gas released from the breakdown of radioactive elements in rocks and soil and typically enters the home through cracks and other holes in the foundation. According to EPA estimates, radon is the number one cause of lung cancer among non-smokers and is the second leading cause of lung cancer in the U.S after smoking.

[31] World Health Organization. WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. Geneva: World Health Organization; 2005, 9,14.
[32] U.S. Environmental Protection Agency. National Ambient Air Quality Standards. 40 CFR Part 50. Revised October 2011. Updated December 14, 2012. Accessed September 16, 2014. https://www.epa.gov/criteria-air-pollutants/naaqs-table
[33] U.S. Green Building Council. LEED v4: Reference Guide for Building Design and Construction. Washington D.C.: U.S. Green Building Council; 2013: 37, 43-44, 541-552, 567, 605, 623, 645-53, 658-61, 682-3, 685-6, 723-4.

  - Radon: less than 0.148 Bq/L [4 pCi/L] in the lowest occupied level of the project[34]
- **Carbon Dioxide (CO_2)**: CO_2, which is a constituent of normal air that can be increased in an enclosed area via respiration, such as through human occupants' breathing. CO_2 levels can indicate adequate ventilation (outdoor air) in a space and serve as a proxy for other pollutants and pathogens in the air. CO_2 can also proxy indoor airborne transmission risk for COVID-19 and other respiratory diseases. This is because CO_2 is co-exhaled with aerosols containing pathogens – such as SARS-CoV-2, the virus that causes COVID-19 – by infected individuals.[35] Emerging evidence also indicates that CO_2 may be linked more directly to human cognitive performance if present at high levels.[36]
  - CO_2: below 800 ppm[37]
- **Biological Contaminants**: Biological contaminants such as bacteria, viruses, mold, dust mites, pollen, and animal danger are created by living things. Many of these pollutants are small enough to be inhaled by occupants. Controlling relative humidity can help to minimize the growth of some sources of these pollutants.[38] The health risks associated with exposure to biological pollutants depend on the pollutant's type, the occupants' susceptibility, and the magnitude and duration of exposure.

2.3 TYPES OF IAQ MONITORING METHODS

Based on the measuring process, there are two common IAQ monitoring methods, spot testing, and continuous monitoring.

For **spot testing**, air samples of the indoor space are collected by professionals onsite and analyzed by various instruments for different pollutant types. Reference grade instruments that are characteristically used in spot testing have cost limitations, the complexity of operation and maintenance, and require skilled personnel to operate such instruments. Spot testing is not a continuous monitoring process. Since indoor air quality varies significantly over time due to season, weather conditions, and human activities, spot testing may be limited in its practical application.

Air quality sensors are installed strategically across the applicable indoor space for continuous monitoring. These sensors collect real-time air quality data at regular intervals and simultaneously provide readings of multiple parameters. Although usually conducted with means of lower precision than the reference grade instruments used in spot testing, continuous monitoring tracks the IAQ consistently in the

[34] U.S. Environmental Protection Agency. A Citizen's Guide To Radon: The Guide to Protecting Yourself And Your Family From Radon. Published May 2012. Accessed September 16, 2014. http://www.epa.gov/radon/pdfs/citizensguide.pdf
[35] Peng Z, Jimenez JL. Exhaled CO2 as a COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities. Environ Sci Technol Lett. 2021;acs.estlett.1c00183. Published 2021 Apr 5. doi: 10.1021/acs.estlett.1c00183
[36] Jacobson TA, Kler JS, Hernke MT, Braun RK, Meyer KC, Funk WE. Direct human health risks of increased atmospheric carbon dioxide. Nature Sustainability. July 2019:1. doi: 10.1038/s41893-019-0323-1.
[37] Illinois Department of Public Health. Illinois Department of Public Health Guidelines for Indoor Air Quality. Updated May 2011. Accessed September 15, 2014. http://www.idph.state.il.us/envhealth/factsheets/indoorairqualityguide_f
[38] U.S. Environmental Protection Agency. Accessed October 14, 2022. https://www.epa.gov/indoor-air-quality-iaq/biological-pollutants-impact-indoor-air-quality#:~:text=Biological%20contaiminants%20include%20bacteria%2C%20viruses,of%20biologicals%20can%20be%20minimized

long term. Thus, continuous monitoring provides a thorough and representative assessment of the building's indoor air and enables IAQ problems to be detected and addressed more quickly and rapidly.

Air monitors themselves can be divided into three categories according to their performance and accuracy: **reference grade monitors**, which are primarily utilized for project commissioning, calibration, site audits, and pollutant source detection; **commercial grade monitors**, which balance performance and cost to enable building IAQ automation and provide occupants with high-quality data; **consumer-grade monitors**, which are more affordable but less precise.[39] Spot testing mainly utilizes reference-grade monitors, while continuous monitoring primarily utilizes commercial and consumer-grade monitors.

2.4 WHAT TO LOOK FOR IN AN IAQ MONITOR?

There are several parameters to consider when purchasing an IAQ monitor, including:

- **IAQ Measurements**: IAQ monitors can help users identify indoor air quality issues. Consider selecting monitors that measure multiple IAQ parameters, including particulate matter ($PM_{2.5}$ and PM_{10}), TVOC, CO_2, temperature, and relative humidity (RH).
- **Detection Range**: Ideally, the IAQ monitors should measure the target pollutants over a wide range of concentrations to reflect pollutant levels commonly found in indoor environments.
- **Detection Limit**: The detection limit is the lowest concentration of a target pollutant that an IAQ monitor can detect. Selecting an IAQ monitor with a low detection limit can help to ensure that pollutants at lower concentrations are detected.
- **Accuracy**: Sensor accuracy refers to the maximum difference between the actual value and the indicated value at the sensor's output. Before buying an IAQ monitor, you should check the reported sensor accuracy in the specifications. It should be noted that sensor accuracy can change over time.
- **Calibration**: Calibration refers to the adjustment or set of adjustments performed on a sensor or instrument to make that instrument function as accurately, or error-free, as possible. It compares the sensor value to a reference value. Before buying an IAQ monitor, check whether the manufacturer calibrates it or not. Also, check how long the calibration will last after the IAQ monitor is used. IAQ monitors need to be recalibrated to maintain their accuracy.
- **Power Sources**: IAQ monitors may require different power sources such as charging cables, low voltage wires, or batteries. Consult the manufacturer and/or the product specifications to determine the required power sources. It can be costly and time-consuming to bring power to locations that do not have the necessary infrastructure.
- **Display:** IAQ monitoring can be used as a tool to help educate the general public on the importance of IAQ. Additionally, IAQ monitoring allows users to identify existing IAQ issues which can help them select suitable IAQ solutions, such as air purification. The display of an IAQ monitor is significant for achieving these benefits. Some questions to consider include:

[39] RESET Air Standard For Accredited Monitors V2.0

What data is being displayed? How user-friendly is the display?

- **Communication**: IAQ monitors may communicate their collected data to a cloud-based interface using different technologies (e.g., Wi-Fi, LoRa, Ethernet). Consult the manufacturer to determine specific requirements, such as network limitations and area coverage.
- **Cost**: The cost of IAQ monitors may change depending on the number and type of pollutants they measure, sensing technology, the accuracy of the measurements, and other features of the device, including the app or web interface, built-in data storage, etc.
- **Certifications**: It is recommended that the IAQ monitors comply or align with applicable certification standards, such as the WELL Building Standard and the RESET Standard.
- **Placement**: IAQ monitors should ideally be placed in the breathing zone (a height range between 3 and 6 ft above the floor). Placement in this zone will ensure that the device collects samples from the air building occupant's breath. They should also be placed away from doors, windows, fresh air diffusers, air purifiers, and pollutant sources to collect a more representative measure of indoor air quality. The placement should also ensure unrestricted airflow around the monitors.

Abbreviations

- ppb – Particles per billion
- ppm – Particles per million
- µg/m³ - Micrograms per cubic meter
- Bq/L – Becquerels per liter
- pCi/L – Picocuries per liter
- RH – Relative humidity (measured as a percentage)

3 What Is Ventilation?

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) defines ventilation as “the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space.” This is required so that indoor air containing pollutants generated by occupants, processes, and the building can be exhausted from the space and exchanged with fresh air from outside.

Outdoor air can be brought into a space in two ways - mechanically through the HVAC system or naturally through building openings like operable windows and doors. The code requirements around how ventilation air is brought into a space and in what quantities vary by space type are typically in line with ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality.

3.1 WHY IS VENTILATION IMPORTANT?

Ventilation is the primary means of mitigating two critical indoor air pollutants: the carbon dioxide generated by occupants and the aerosolized chemicals and odors generated inside the building. Additionally, increased ventilation rates have been shown to reduce indoor particulate matter levels and the risk of airborne disease transmission.

Ventilation is often a code-required building feature. Additionally, insufficient ventilation has related to various adverse health effects, including reduced productivity, fatigue, and respiratory irritation.[1] The scientific evidence of the benefits of ventilation is strong enough that building rating systems such as LEED and WELL reward buildings for increasing ventilation rates beyond code minimums.

3.2 WHAT SHOULD I LOOK FOR?

Hotels have various space types, each with its unique ventilation requirements. Many ventilation solutions will be components of the HVAC system, so it will always be best to review your existing systems and capabilities with your building engineer and then consult a Professional Engineer as needed when considering system retrofits, upgrades, etc. Here are a few key topics for consideration:

- **Outdoor Air Quality and Filtration:** Ventilation brings outdoor air inside the building, so the quality of that outdoor air must be considered. In some cases, increasing ventilation without proper filtration may degrade IAQ by introducing particulate matter. Ask your engineer about ASHRAE 62.1-2019 Section 6.1.4.
- **Temperature and Humidity Control:** Outdoor air must be conditioned to make it comfortable and dry before introducing it into the building. To maintain guest comfort and humidity control, ensure your engineer validates the HVAC system has enough capacity to support any proposed ventilation rate changes.
- **Energy Conservation and Demand Controls:** Outdoor air conditioning is an energy-intensive process, and changes to ventilation rates should be considered holistically with operating costs and sustainability metrics. However, solutions exist to mitigate or eliminate energy and operational cost penalties associated with increased ventilation. Ask your design engineer about energy recovery devices that passively condition outside air and demand-based controls that vary ventilation rates based on IAQ sensors.

- **Building Maintenance**: Consistent preventative maintenance of your HVAC equipment, including filters, dampers, coils, controls, etc., is critical to indoor air quality. Many systems are designed to introduce outside air into the building at specified rates but may function differently due to poor and/or deferred maintenance. Systems that are well maintained and in good operating condition will help improve IAQ and may be candidates for control upgrades to enhance IAQ further. For example: If you have an outdoor “package” type air handler, there is a good chance it has an economizer feature that introduces outside air to the building. But does it work properly? Such systems require dampers, motors, and controls, working collectively for the system to function correctly. If the system is solely controlled by temperature, it may retrofit to include CO2 controls. This is just one example of many where your hotel may have existing systems and equipment that can be used to improve IAQ.

https://9foundations.forhealth.org/

4 Air Purification Technologies

This document provides additional information on air purifiers (also known as air cleaners) – both portable and in-duct – as a critical strategy to improve indoor air quality (IAQ) and reduce the risk of transmission of airborne pathogens such as SARS-CoV-2 (the virus that causes COVID-19).

Although ventilation is one of the best-known IAQ control strategies, it is not without its limitations. Outdoor air is not always free of pollution and can impact thermal comfort. Additionally, outdoor conditioning air requires a significant amount of energy. Using portable air purifiers and upgrading HVAC systems with in-duct air purifiers are effective supplements to ventilation and can help improve IAQ by reducing the concentration of indoor air pollutants.

This document will provide an overview of different air-cleaning technologies and critical factors to consider when selecting a portable or in-duct air purifier, including performance, sizing, placement, and noise.

4.1 CLEANING TECHNOLOGY

The types of air cleaning technologies employed in portable and in-duct air cleaning devices can be divided into two broad categories: mechanical air filters and electronic air purifiers.

Mechanical air filters consist of porous media which contain fibers or membrane material to remove particles from the air as it passes through the filter. Electronic air purifiers utilize electric charge in a variety of ways in an attempt to remove pollutants from the air and include ionizers, electrostatic precipitators (ESPs), photocatalytic oxidation (PCOs), hydroxyl generators, ultraviolet germicidal irradiation (UVGI), and plasma devices. Ultraviolet Germicidal Irradiation (UVGI), for example, is an air-cleaning technology used to reduce the number of viable airborne microorganisms such as fungal spores, bacteria, and viruses. It has a UV lamp to kill or deactivate airborne microorganisms or on surfaces such as cooling coils and drain pans.

Reliable deactivation of microorganisms requires a sufficiently high lamp power and prolonged exposure time.

Electronic air purifiers that utilize ions and reactive oxygen species (ROS) were heavily marketed during the COVID-19 pandemic. However, many scientific and regulatory institutions (such as the U.S. EPA[40]) consider these emerging technologies and urge caution due to the absence of an established body of peer-reviewed evidence showing proven efficacy and safety under as-used conditions. Performance test reports should be carefully reviewed when selecting these technologies.

[40] U.S. Environmental Protection Agency. Can air cleaning devices that use bipolar ionization, including portable air cleaners and in-duct air cleaners used in HVAC systems, protect me from COVID-19? Accessed October 21, 2022. https://www.epa.gov/coronavirus/can-air-cleaning-devices-use-bipolar-ionization-including-portable-air-cleaners-and

Additionally, many emerging air cleaning technologies may generate harmful by products like ozone. It is essential to ensure that the device is certified to meet UL 867 (the Standard for Safety for Electrostatic Air Cleaners) for producing acceptable levels of ozone, or preferably UL 2998 standard, Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners.

Another air purification technology is adsorption, which uses a very high surface area of sorbent media to capture gaseous air pollutants. Adsorbents attract gaseous air pollutants to their surface. However, they have a finite capacity for gaseous adsorption. Thus, the device must have a sufficient amount of sorbent media. Activated carbon is the most common adsorbent used in portable and in-duct air purifiers.

4.2 PORTABLE AIR PURIFIERS

Portable air purifiers are standalone units that can filter and disinfect the air in a specific area. These devices can easily be moved to a place where localized air cleaning is required. Portable air purifiers typically have a filter and a fan that moves the air through that filter, and some may also utilize other air-cleaning technologies described above.

4.2.1 PERFORMANCE

The performance of portable air purifiers depends on several parameters, including filter efficiency, airflow rate, location of the device, and running time.

The single-pass efficiency of a filter is a measure of its ability to reduce the pollutant concentration in the air that passes through it. The most commonly used filter efficiency metric is MERV (minimum efficiency reporting value), based on the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standard 52.2. MERV values range from 1 to 16, and the higher the MERV rating, the higher the particle removal efficiency. Another popular filter efficiency metric is HEPA (high-efficiency particulate air). Based on the HEPA standard set by U.S. regulators, a HEPA filter can remove at least 99.97% of particles with a size of 0.3 microns. Particles that are larger or smaller than 0.3 microns are typically captured with even higher efficiency by HEPA filters. Portable air purifiers which exceed the HEPA particle removal efficiency requirement are recommended.

Note that a HEPA filter does not guarantee HEPA efficiency outcomes in portable air purifiers. There is a clear distinction between a HEPA filter in isolation versus a portable air purifier that meets or exceeds HEPA filtration efficiency outcomes in a real-world setting. What matters most is the performance of the device in its entirety, not a rating applied solely to the filter within the device. So, it is also recommended that any HEPA or other performance testing results be evaluated to determine if the testing was performed on the filter itself or the total device and whether any testing was conducted in a real-world setting.

Another common metric for characterizing the performance of portable air purifiers is the clean air delivery rate (CADR), which shows the amount of contaminant-free air delivered by the unit, expressed in cubic feet per minute (cfm). The CADR is the product of the single-pass efficiency of the filter and the airflow rate through the device. A higher CADR relative to the room size will increase the effectiveness

of a portable air purifier. A CADR can theoretically be generated for either gases or particles; however, current test standards only rate CADRs for removing particles. Some manufacturers report CADRs for capturing three specific types of pollutants: tobacco smoke, dust, and pollen. A unit with a high CADR value for tobacco smoke is recommended to capture small particles.

4.2.2 SIZING

The CADR value of a portable air purifier can be used to size the number of units for a given space properly. The higher the CADR, the more particles the system can filter and the larger the area it can serve. The following formula can be used to calculate the required CADR to reach the desired air changes per hour (ACH):

$$\text{CADR (cfm)} = [\text{ACH} \times \text{space volume (ft}^3\text{)}] \div 60 \text{ (min/hr)}$$

The ideal exposure reduction target for a space recommended by most experts is 5 to 6 ACH. This can be achieved by combining ventilation and supplementary air cleaning with portable and/or in-duct air purifiers. Multiple units can be used for large spaces to achieve the recommended ACH. For example, if space requires 1,000 cfm of clean air, two 500 cfm units can be used. Another factor to consider is that using multiple smaller units is more effective than one large unit in addressing the nonuniformity of air pollutants across the space.

Filter maintenance is also essential for the performance of portable air purifiers. Always refer to the manufacturer's instructions for guidance on cleaning and maintaining your air filter.

4.2.3 PLACEMENT

The location of the unit is an essential factor in its performance. Portable air cleaning units should be placed close to occupants to supply clean air directly to their breathing zone. It is also necessary to ensure that the airflow is clear from other objects in the space.

4.2.4 NOISE

Some portable air purifiers may generate high noise levels, which can adversely impact occupant comfort levels and deter occupants from running the unit. Noise levels change based on the fan speed settings. For reference, the noise level generated by a modem refrigerator is approximately 50 decibels (dB).

4.2.5 IN-DUCT AIR FILTERS

Replacing the air in a space with clean air is a vital strategy to help control pollutant levels. But because of poor outdoor air quality and the heating, cooling, and humidity requirements needed to maintain thermal comfort, it is not always feasible or even beneficial to supply 100% outdoor air to a space. This means that air in a space will often have to be recirculated, but by using filtration, the pollutant levels in the recirculated air can be reduced. Therefore, it is recommended that the air provided to a space be a combination of as much outdoor air as the HVAC system can handle and filter recirculated air to help improve IAQ.

High-efficiency filters are essential in HVAC systems to remove outdoor and recirculated air pollutants. It is recommended that filters with at least a MERV 13 rating, or equivalent, be used where possible. Otherwise, use the highest-rated filter that your HVAC system can handle.

Filters with MERV 13 equivalent particle removal efficiency can remove ≥85% of particles 1-3 microns in size.

Increasing the filter efficiency generally results in a higher pressure drop across the filter, which means greater energy consumption. Upgrading to higher efficiency filters may require replacing the HVAC system fan motor and/or blower to accommodate the increased pressure drop.

Ensure your HVAC system can handle filter upgrades without negatively impacting the air flow rate. Many different types of filters are available on the market and can come in various sizes and configurations: select filters with higher particle removal efficiencies and lower pressure drop. Also, ensure new filters can be sealed well to ensure the airflow passes through the filter and not around it due to any leaks.