CO_2 MONITORING FOR BUSINESS ENVIRONMENTS

A tool for analyzing specific indoor air-quality conditions, to help individuals determine air ventilation needs

Honeywell

TABLE OF CONTENTS

INTRODUCTION

During the COVID-19 pandemic, a large population has become more acutely aware of the air they breathe. This is due to certain infectious viruses being proven to spread most commonly through airborne transmission. When an infected person talks, coughs, sneezes, yells or sings, droplets or tiny particles (aerosols) can carry a virus into the air from the individual's nose and/or mouth.

The quality of indoor air, especially, is a topic of serious concern - particularly air quality in public spaces, such as retail stores, offices, municipal buildings, hospitals, hotels and educational institutions.

This white paper focuses on air quality in small to medium size offices, restaurants, or fitness facilities and presents a case for using carbon dioxide monitoring with one goal in mind:

TO HELP BUSINESSES CREATE AN AIR QUALITY ENVIRONMENT THAT SUPPORTS STAFF AND CUSTOMER ACTIVITY.

THE PURPOSE OF CO_2 MONITORING IN PROFESSIONAL AND RECREATIONAL ESTABLISHMENTS

Multiple studies suggest that insufficient ventilation increases viral transmission.[1]

The Centers for Disease Control (CDC) recommends "a layered approach to reduce exposures to SARS-CoV-2, the virus that causes COVID-19. This approach includes using multiple mitigation strategies, including improvements to building ventilation, to reduce the spread of disease and lower the risk of exposure".[2]

HIGH CO_2 LEVELS INDICATE POOR VENTILATION

CARBON DIOXIDE (CO_2) IS OFTEN USED AS AN INDIRECT MEASURE OF VENTILATION. When a building is occupied, the CO_2 concentrations indoors are elevated by occupants exhaling. When occupants leave and no other CO_2 sources are present (e.g. combustion sources, etc.), the rate of decay of the carbon-dioxide concentration can be used to estimate how fast air from outdoors (at approximately 400 ppm CO_2) replaces the indoor volume of air.[3]

CARBON DIOXIDE (CO_2) SENSORS HAVE BECOME BETTER AND LESS EXPENSIVE IN THE RECENT YEARS. Technology advancements have increased the sensing and data capabilities for CO_2 monitoring, while also allowing real-time displays with refresh data that offer actionable information. CO_2 monitoring products can provide information on the specific air-quality conditions inside a classroom or other enclosed spaces. These measurements can then be leveraged to assist with ventilation analysis and adjustments.

The CDC recommends using a portable CO_2 monitor and installing it near the breathing zones in occupied areas of each room.[2] This allows collection of data regarding air quality. Based on these measurements and occupancy levels, the intake of outdoor air can be adjusted to increase interior flow of air.[4]

TWO KEY BENEFITS OF CO_2 MONITORING

Benefit #1: Alert Users to the Presence of Air Conditions That May Increase the Risk of Potential Exposure to Airborne Viral Transmission

A PROMINENT RESEARCH STUDY[5] CONFIRMED THAT CO_2 MONITORS CAN ALERT USERS TO THE PRESENCE OF AIR CONDITIONS THAT MAY INCREASE THE RISK OF POTENITAL EXPOSURE TO AIRBORNE VIRAL TRANSMISSION.

OBJECTIVE OF THE STUDY

Zhe Peng and Jose-Luis Jimenez, two University of Colorado scientists, researched whether exhaled CO_2 can be used as a COVID-19 infection risk proxy for indoor environments and activities. According to a summary of the overview from the University of Colorado[6], the scientists relied on a simple fact already accepted by other researchers for more than a decade: Infectious people exhale airborne viruses at the same time as they exhale CO_2.

METHODS

In this study, the researchers derived analytical expressions of the probability of indoor COVID-19 infection through room-level aerosol transmission only (i.e., assuming social distance is kept so that close proximity aerosol and droplet pathways are eliminated; fomite transmission is not included), human-exhaled CO_2 concentration and subsequently a few CO_2-based quantities as infection risk proxies. Based on available data, these expressions were applied to common indoor settings to meet the objective mentioned above.

The University of Colorado summarizes methods as follows[6]: Jimenez and colleagues turned to commercially available carbon dioxide monitors, which can cost just a few hundred dollars. First, laboratory testing confirmed that the detectors were accurate. Then, a mathematical "box model" was created to reproduce how an infected person exhales viruses and CO_2, the manner in which others in the room inhale and exhale, and how the viruses and gas accumulate in the air of a room or are removed by ventilation. The model takes into consideration infection numbers in the local community, but does not detail air flow through rooms, as modeling at that level of detail requires expensive, custom analysis for each room.

WHAT IS CONSIDERED AN AVERAGE LEVEL OF INDOOR CARBON DIOXIDE?

The Harvard study specifies that a CO_2 level of approximately **950** ppm (parts per million) is common in indoor spaces and mentions that this level satisfies the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) ventilation rate guidance for acceptable indoor air quality.[3]

RESULTS AND CONCLUSIONS

The study's scientists reported the following key findings[5,6]:

- **HIGHER CO_2 LEVELS INDICATE HIGHER RISK:** Thus, keeping CO_2 as low as feasible in a space allows optimization of the protection provided by ventilation. (The researchers also showed that the carbon-dioxide level corresponding to a given absolute infection risk varies by greater than 2 orders of magnitude for different environments and activities.)
- **INFECTION TRANSMISSION IS MORE DANGEROUS INDOORS:** Transmission is much easier indoors than outdoors, which is most consistent with aerosols. As individuals spend more of their time in indoor environments, where air volumes are limited and virus-laden aerosols may easily accumulate, mitigation of indoor COVID-19 transmissions is a subject of high interest. Practical, affordable and widely applicable measures to monitor and limit indoor transmission risks are urgently needed.
- **DIRECT MEASUREMENTS OF VIRUS-CONTAINING AEROSOLS ARE NOT PRACTICAL.** These types of measurements are extremely difficult and slow.
- **CO_2 MONITORING IS PRACTICAL:** CO_2 concentration was suggested as an indicator of indoor space ventilation quality in the 19th century, and more recently as a practical proxy of respiratory infectious disease transmission risk, because pathogen-containing aerosols and carbon dioxide are co-exhaled by those infected. Also, since background (ambient) CO_2 levels are almost stable and indoor excess CO_2 is usually only from human exhalation, measurements of indoor carbon-dioxide concentration by low-cost CO_2 sensors can often be strong indicators of infection risk and suitable for mass deployment.
- **FORTUNATELY, CO_2 CAN BE MEASURED EASILY:** Carbon dioxide CO_2 is the only known quantity that can be easily measured by fast, low-cost sensors as an infection risk proxy.
- **THE GOAL IS TO KEEP THE CO_2 LEVEL LOW:** Regulatory authorities may derive carbon-dioxide thresholds for different types of indoor spaces. However, even when parameters are unknown, the University of Colorado study suggests that simply maintaining the CO_2 level, and the physical intensity and vocalization activity levels, as low as practically feasible in indoor environments will still reduce transmission risk.

GYMNASIUMS MAY BE ESPECIALLY PRONE TO HIGHER RISK

Outdoor CO_2 levels are usually at 400 parts per million and it's best not to be in spaces that exceed 1,000 parts per million.[5,6] Even then, someone who is in a gym — with people breathing heavily and often — will be at a higher risk than someone sitting in a library. "But if you can lower the CO_2 level as much as possible, it can be much safer than it usually is," [7] said Zhe Peng, one of the University of Colorado scientists who conducted the study mentioned above. Peng and co-author Jose-Luis Jimenez recommend using an activity-dependent approach, which means keeping physical intensity and vocalization activities as low as practically feasible.

Benefit #2: Enhance cognitive function

A study by the Harvard T.H. Chan School of Public Health[8] showed that higher ventilation rates and lower CO_2 levels can positively affect cognitive function and performance.

The study demonstrated that people who work in well-ventilated environments with below-average levels of indoor pollutants and CO_2 have significantly higher cognitive functioning scores in crucial areas such as responding to a crisis or developing strategy than similar individuals who work in offices with typical pollutant and CO_2 levels.

In fact, the study's participants had significantly improved cognitive function scores when working in well-ventilated environments compared with scores obtained when working in a conventional environment.

OBJECTIVE OF THE STUDY

The researchers simulated indoor environmental quality (IEQ) conditions in "Green" and "Conventional" buildings to evaluate the impacts on an objective measure of human performance: high-order cognitive function.

METHODS

Twenty-four participants spent six full workdays (0900-1700 hours) in an environmentally controlled office space, blinded to testing conditions. On different days, they were exposed to IEQ conditions representative of Conventional [high concentrations of volatile organic compounds (VOCs)] and Green (low concentrations of VOCs) office buildings in the United States. Additional conditions simulated a Green building with a high outdoor air ventilation rate (labeled Green+) and artificially elevated CO_2 levels independent of ventilation.

During the study, the researchers tested the nine cognitive function domains listed in Table 1.

TABLE 1. DESCRIPTION OF THE COGNITIVE DOMAINS TESTED

Cognitive Function Domain	Description
Basic activity level	Overall ability to make decisions at all times
Applied activity level	Capacity to make decisions that are geared toward overall goals
Focused activity level	Capacity to pay attention to situations at hand
Task orientation	Capacity to make specific decisions that are geared toward completion of tasks at hand
Crisis response	Ability to plan, stay prepared, and strategize under emergency conditions
Information seeking	Capacity to gather information as required from different available sources
Information usage	Capacity to use both provided information and information that has been gathered toward attaining overall goals
Breadth of approach	Capacity to make decisions along multiple dimensions; use a variety of options and opportunities to attain goals
Strategy	Complex thinking parameter that reflects the ability to use well-integrated solutions with the help of optimal use of information and planning

RESULTS

On average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional building day ($p < 0.0001$). The study independently associated VOCs and CO_2 with cognitive scores.

The researchers found that the largest improvements occurred in these three crucial cognitive function domains:

- √ Crisis Response: Ability to plan, stay prepared and strategize under emergency conditions
- √ Strategy: Complex thinking parameter that reflects the ability to use well-integrated solutions with the help of optimal use of information and planning
- √ Information Usage: Capacity to use both provided information and information that has been gathered toward attaining overall goals

CONCLUSIONS

Cognitive function scores were significantly better under Green+ building conditions than in the Conventional building conditions for all nine functional domains. Exposure to CO_2 and VOCs at levels found in Conventional office buildings was associated with lower cognitive scores than those affiliated with levels of these compounds found in a Green building.

KEY TAKEAWAY: These findings have wide-ranging implications because this study was designed to reflect conditions that are commonly encountered daily in many indoor environments.

Additional information about how poor indoor air quality affects cognitive function can be found in APPENDIX B.

AN EFFECTIVE EASY TO USE CO_2 MONITORING SOLUTION

Honeywell partners with business owners to create an air quality environment that supports staff and customer activity.

Employees and customers deserve to work and relax in an environment with suitably monitored air quality. The Honeywell Transmission Risk Air Monitor can be one of the key components in achieving that goal. The device is ideal for indoor CO_2 monitoring in small to medium size offices, restaurants, and fitness facilities.

WHAT IS IT?

The Honeywell Transmission Air Monitor is a cost-effective, user-friendly solution to monitor indoor environments in real time, analyzing specific air-quality conditions and alerting users to the risk of potential exposure to airborne viral transmission.

HOW IS IT USED IN BUSINESSES?

An easy-to-deploy, portable device, the Honeywell Transmission Air Monitor measures CO_2 and features a proprietary risk alerting system based on activity levels within a room. These alerts, combined with other situational factors, can help business owners and other staff members determine whether to take ventilation actions to:

- Potentially enhance employees' cognitive function, as described in the study above
- Help reduce the risk of potential exposure to airborne viral transmissions

HOW DO I USE IT?

Honeywell can provide guidance and technical support regarding how to set up and use the Honeywell Transmission Air Monitor device.

The Honeywell Transmission Risk Air Monitor helps you monitor indoor environments in real time for the presence of conditions that may increase the risk of potential exposure to airborne viral transmission.

RESEARCH BASED, EXPERTLY ENGINEERED

The Honeywell Transmission Air Monitor was designed and created utilizing the University of Colorado research study described earlier, on page 5.

DEVICE INDICATION

	GREEN	YELLOW	RED
Low activity setting	<800 ppm 0.043 % infection risk	800 ppm 0.043 % infection risk	1100 ppm 0.051 % infection risk
Medium activity setting	<700 ppm 3.40 % infection risk	700 ppm 3.40 % infection risk	1000 ppm 5.41 % infection risk
High activity setting	<500 ppm 7.32 % infection risk	500 ppm 7.32 % infection risk	800 ppm 25.25 % infection risk
Custom setting	The end user can also choose custom settings on the device to set the alarm threshold levels based on the user's parameters and local, regional and state requirements. **Note: If custom settings are used, the user is solely responsible for validating that those alarm settings meet their specific requirements.**		
Recommended action	–	▪ Open windows ▪ Turn on HVAC fan ▪ Move out of room ▪ Additional actions as needed	▪ Ventilate room immediately ▪ Reduce activities ▪ Move out of room ▪ Additional actions as needed
Alarm	–	One beep	Two beeps

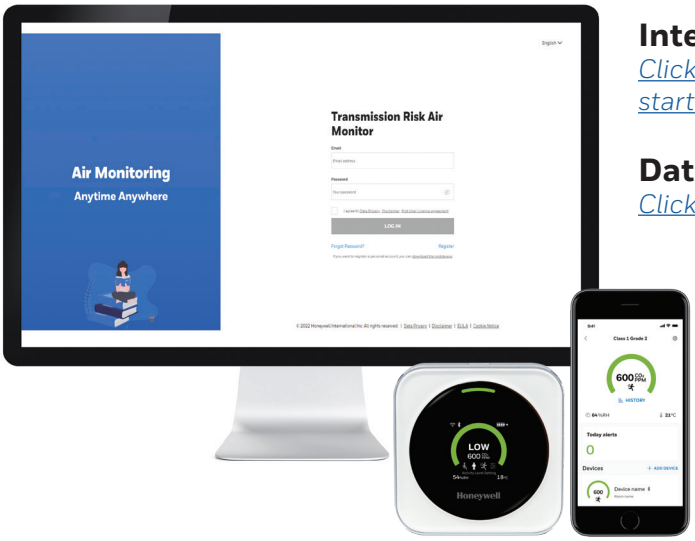
1. The HTRAM's preset PPM measurements for each Activity Level are subjective standards based on Honeywell's assessment of U.S. state statutory limits and scientific studies, including the "2020 COVID-19 Aerosol Transmission Estimator" and the "Exhaled CO_2 as a COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities" article from the University of Colorado-Boulder (see https://docs.google.com/spreadsheets/d/16K1OQkLD4BjgB dO8ePj6ytf-RpPMU6aXFg3PrIQBbQ/edit#gid=519189277 and https:// pubs.acs.org/doi/10.1021/acs.estlett.1c00183, respectively) . The user must verify applicable standards or regulations and adapt the product's thresholds to such standards and regulations as required for its usage intended by the user.

2. Please note: A Green designation does not mean no risk for transmission. An increase from Green to Yellow, Yellow to Red or Green to Red does not indicate a linear increase in potential transmission risk within one Activity Setting. Any increase in potential transmission risk across multiple Activity Settings is also not linear. Numerous factors, including without limitation, interaction among individuals in a room, the number of infected individuals present, and the wearing of Personal Protective Equipment (PPE) such as masks and gloves, will affect the potential transmission risk. Users should not rely solely on this device to make a determination of safety.

3. Percent of infection risk calculation is based on the following assumptions and is only intended as guidance: Total number of people: 20, Infected: 1; Time duration: 30 mins and room size: 900 sq ft.

4. Percent of infection risk calculation is based on the following assumptions and is only intended as guidance: Total number of people: 20, Infected: 1; Time duration: 45 mins and room size: 900 sq ft.

5. Percent of infection risk calculation is based on the following assumptions and is only intended as guidance: Total number of people: 20, Infected: 1; Time duration: 60 mins and room size: 900 sq ft.



Integrated Software

Click here to download the user quick start guide

Datasheet

Click here to download

CONCLUSION

Carbon dioxide (CO_2) monitoring can be used to alert employees to the presence of air-quality conditions that, according to the studies above, may potentially have two possible negative implications: increased risk of exposure to airborne viral transmission, and an adverse effect on cognitive function.

One simple and cost-effective solution for detecting elevated CO_2 levels is to use reliable, portable CO_2 monitors, which can be used to measure and monitor CO_2 levels in populated areas in real time. By using portable CO_2 monitors in this manner, business owners and other staff members can monitor indoor air quality related to CO_2 and use that data, along with other situational information, to evaluate whether improved air exchange is advisable.

The HTRAM analyzes specific air quality conditions and alerts the user when conditions are present that may increase the risk of potential exposure to airborne viral transmission. The device does not prevent or reduce virus transmission nor mitigate viruses that may be present, nor does it detect or warn against the presence of any virus, including but not limited to COVID-19. Even at lower risk levels caution is required to prevent viral transmission. The HTRAM does not repel or destroy any microorganism, viruses, bacteria, or germs.

- It is buyer's sole responsibility (1) to determine the suitability of the HTRAM for use in its application, (2) to operate the HTRAM in accordance with the user manual and any other instructions provided by Honeywell and in compliance with all applicable laws, rules and regulations and (3) to determine, based on buyer's experience, expertise and other available tools, the suitability of any product or service it may offer or recommend to the end user.
- Buyer is responsible for determining whether the product is appropriate for use under certain international, federal, state or local guidelines and is likewise responsible for determining whether the HTRAM is subject to any government programs, including without limitation, reimbursement plans.
- Any recommendations or assistance provided by Honeywell regarding the use or operation of the HTRAM – through our literature, the Honeywell website, or otherwise – shall not be construed as representations or warranties of any kind, express or implied, and such information is accepted at buyer's own risk and without any obligation or liability to Honeywell.
- The HTRAM does not detect for levels of CO_2 that would make for an unsafe or unsuitable breathing environment.
- The information we supply in this white paper is believed to be accurate and reliable as of this writing. However, specifications may change without notice, and Honeywell assumes no responsibility for its use.
- For more information and the most recent User Manual, go to https://airmonitoring.honeywell.com/#/doc/help

SOURCES

1 Natural Ventilation for Infection Control in Health-Care Settings, World Health Organization (2009)

2 Ventilation in Buildings, CDC (2021)

3 How School Buildings Influence Student Health, Thinking and Performance, Harvard T.H. Chan School of Public Health (Joseph Allen et al., 2020)

4 Key Considerations for CO_2 Monitoring in Educational Settings, Honeywell Safety and Productivity Solutions

5 Exhaled CO_2 as a COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities, Environmental Science and Technology Letters (Zhe Peng and Jose L. Jimenez, 2021)

6 Carbon Dioxide Levels Reflect COVID Risk, Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder (2021)

7 CU Boulder Study Links CO_2 Levels to Coronavirus Risk, Boulder Daily Camera (2021)

8 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; Harvard Library Office for Scholarly Communication

THE FUTURE IS WHAT WE MAKE IT

For more information
safety.honeywell.com

Honeywell