

The importance of maintaining suitable Indoor Air Quality in working places

Impact of indoor air quality in workplaces

Indoor environments harbour numerous pollutant sources, increasing concerns about health issues linked to poor indoor air quality in recent years¹. Additionally, indoor air pollutants are reported to be 2–5 times higher than outdoor pollutants, with human exposure potentially exceeding outdoor levels by over 100 times². This elevated exposure is attributed to the accumulation of pollutants from finishes, furnishings, and daily activities within homes³. Consequently, indoor air quality (IAQ) is acknowledged as a critical factor affecting occupants' health and comfort, especially given that the majority of people now spend over 90% of their time in artificial environments⁴.

In 1983, the World Health Organization (WHO) coined the term "Sick Building Syndrome" (SBS) to describe clinical features observed in building occupants due to indoor air pollution⁵. Numerous studies have linked exposure to CO, O₃, and PM to an increased risk of SBS⁶. These studies also emphasise the impact of indoor air quality on the development of nonspecific symptoms characterising SBS, affecting the skin, upper and lower respiratory tract, eyes, and the nervous system⁷. Some studies have even suggested that exposure to HCHO and TVOCs may elevate the risk of allergic diseases.

In addition to the symptoms of SBS, certain diseases like Legionnaire's disease, extrinsic allergic alveolitis, asthma, and atopic dermatitis may be associated with indoor environments, a concern amplified in industrialised countries where citizens spend the majority of their time indoors⁸. Consequently, the symptoms and diseases linked to "sick buildings" pose a growing public health problem, correlated with lower productivity and increased absenteeism. The causes of SBS and building-related diseases encompass various factors such as chemical contaminants, biological agents, psychological factors, electromagnetic radiation, lack of sunlight, humidity, poor acoustics, inadequate ventilation, and poor ergonomics⁹.

Monitoring Indoor Air Quality for Enhanced Occupational Health

Ventilation in buildings aims to create thermally comfortable environments with acceptable IAQ, regulating parameters like air temperature, humidity, air speed, and chemical concentrations¹⁰.

¹ [10.1126/science.6857273](https://doi.org/10.1126/science.6857273)

² <http://www.epa.gov/region1/communities/indoorair.html>

³ [10.4236/ojap.2014.32004](https://doi.org/10.4236/ojap.2014.32004)

⁴ [10.1126/science.6857273](https://doi.org/10.1126/science.6857273)

⁵ PMID: 26221153

⁶ [10.1016/j.buildenv.2014.11.026](https://doi.org/10.1016/j.buildenv.2014.11.026)

⁷ [10.1111/j.1398-9995.2004.00652.x](https://doi.org/10.1111/j.1398-9995.2004.00652.x)

⁸ [10.4168/oaair.2014.6.6.517](https://doi.org/10.4168/oaair.2014.6.6.517)

⁹ [10.4103/0019-5278.43262](https://doi.org/10.4103/0019-5278.43262)

¹⁰ [10.1108/F-07-2014-0061](https://doi.org/10.1108/F-07-2014-0061)

Numerical modelling is commonly used to study airflow patterns and contaminant particle transport in occupied areas.

An IAQ assessment system is crucial for detecting and improving IAQ, with local and distributed assessment of chemical concentrations vital for safety, security, and efficient control of heating, ventilation, and air conditioning¹¹. Monitoring systems used to be often expensive and limited to collecting random samples, highlighting the need for more accessible and continuous monitoring solutions in the built environment¹².

In recent times, there has been a surge in the development of new systems dedicated to monitoring environmental parameters, all with the overarching goal of enhancing IAQ efficiency¹³. The prevalence of cost-effective, low-power, and compact embedded processors, radios, sensors, and actuators—often integrated on a single chip—has paved the way for the utilisation of wireless communications and computing in various applications, including air quality control¹⁴. The parameters monitored include humidity, temperature, and carbon dioxide, showcasing the continuous evolution of IAQ management.

From the COVID-19 pandemic, there has been an increasing of awareness about the importance of assessing and monitoring IAQ at indoor spaces, and particularly workplaces. And this is especially important at schools and hospitals, due to the vulnerability of people who spend the majority of time in these places.

Indoor Air Quality at hospitals

Air quality in hospitals poses a substantial risk to both staff and patients, given the potential health consequences associated with the indoor environment. Infections are prevalent in hospital settings, prompting numerous studies to examine bioaerosol levels, sources, and characteristics^{15 16}. However, medical activities, treatments, and cleaning practices can also impact IAQ. The use of cleaning solutions and detergents to reduce infection risks, for example, can elevate levels of total volatile organic compounds (TVOCs)¹⁷. Medical treatments and the use of formaldehyde (HCHO) solutions may contribute to higher HCHO levels in the air¹⁸. Building decorations and human activity indoors, such as walking, are additional sources of TVOCs, HCHO, and particulate matter (PM). Additionally, outdoor air introduces pollutants like carbon monoxide (CO), PM, and ozone (O₃) that impact IAQ. Additionally, IAQ can vary across different areas of a hospital due to diverse medical activities and materials¹⁹. Ventilation systems, categorised as natural or mechanical, further influence IAQ. Central air conditioning with a filtration system is generally employed to remove outdoor air pollutants and enhance IAQ. In

¹¹ [10.1016/j.proeng.2011.12.021](https://doi.org/10.1016/j.proeng.2011.12.021)

¹² [10.1109/I2MTC.2013.6555624](https://doi.org/10.1109/I2MTC.2013.6555624)

¹³ [10.1155/2015/14097](https://doi.org/10.1155/2015/14097)

¹⁴ [10.1016/j.procs.2013.09.072](https://doi.org/10.1016/j.procs.2013.09.072)

¹⁵ [10.1016/j.scitotenv.2009.02.024](https://doi.org/10.1016/j.scitotenv.2009.02.024)

¹⁶ [10.1016/j.buildenv.2007.11.015](https://doi.org/10.1016/j.buildenv.2007.11.015)

¹⁷ [10.1016/j.scitotenv.2005.09.004](https://doi.org/10.1016/j.scitotenv.2005.09.004)

¹⁸ [10.1016/j.buildenv.2007.11.011](https://doi.org/10.1016/j.buildenv.2007.11.011)

¹⁹ [10.1016/j.buildenv.2007.11.015](https://doi.org/10.1016/j.buildenv.2007.11.015)

hospitals, the type of air conditioning can impact the transmission and distribution of infectious agents. Ventilation is found to be significantly associated with microbiologic pollutant levels, emphasising its role in IAQ²⁰.

Consequently, understanding the characteristics of non-biological pollutants in hospitals as well as the assessment and monitoring of IAQ becomes imperative.

Indoor Air Quality at schools

The assessment and monitoring of IAQ in schools play a pivotal role in safeguarding the health, well-being, and performance of students and staff. Prolonged exposure to poor IAQ can have adverse effects on students' and staff's health and well-being. There is evidence indicating an increase in respiratory symptoms among teachers in classrooms with excessively high or low indoor air relative humidity, as well as in settings with poor building conditions, dampness, and mold exposures^{21 22}. Additionally, poor IAQ could also affect academic performance, by reducing cognitive function, concentration and learning efficiency²³.

In the last years, important technological advancements and awareness initiatives have improved the monitoring of IAQ at schools. Regarding sensor technologies, more accurate and affordable IAQ sensors have been developed, allowing for real-time monitoring of various pollutants such as PM, VOCs, carbon dioxide, among others. Moreover, schools are increasingly adopting sensor networks that enable comprehensive monitoring across different areas within the school premises and which provide a holistic view of IAQ patterns. Many of these monitoring systems leverage cloud-based platforms, enabling remote access to real-time data and consequently, facilitating efficient management, analysis and reporting of data^{24 25}. Coming back to the importance of ventilation, systems in schools currently include occupancy sensors to adjust ventilation rates according to the number of people in the room.

Regarding awareness about IAQ, due to the increase in the research studies focused on health impact, there is a growing awareness of the importance of maintaining suitable IAQ in educational settings, and this is leading to increased initiatives for monitoring and improving indoor environments at schools²⁶. Moreover, as a consequence of increased awareness, some regions are implementing or updating regulations related to IAQ in schools, emphasising the need for regular assessments and monitoring²⁷.

Conclusion

²⁰ [10.1111/j.1600-0668.2007.00480.x](https://doi.org/10.1111/j.1600-0668.2007.00480.x)

²¹ [10.1007/s00420-016-1111-0](https://doi.org/10.1007/s00420-016-1111-0)

²² [10.1111/j.1600-0668.2004.00291.x](https://doi.org/10.1111/j.1600-0668.2004.00291.x)

²³ [10.1016/j.jeem.2014.11.002](https://doi.org/10.1016/j.jeem.2014.11.002)

²⁴ [10.1016/j.dibe.2023.100266](https://doi.org/10.1016/j.dibe.2023.100266)

²⁵ [10.1016/j.scitotenv.2020.138385](https://doi.org/10.1016/j.scitotenv.2020.138385)

²⁶ [10.1016/j.jobbe.2022.104908](https://doi.org/10.1016/j.jobbe.2022.104908)

²⁷ [10.1111/j.1746-1561.2010.00502.x](https://doi.org/10.1111/j.1746-1561.2010.00502.x)



Regular assessment and monitoring of IAQ at working places contribute to creating healthy indoor environments, ensuring compliance with regulations, and addressing potential issues before they have an impact. However, while initiatives in some working places such as schools and hospitals are increasing, all these measures and good practices should be adopted in all other indoor workplaces to protect health and well-being of their occupants.