

INDOOR AIR QUALITY AND HEALTH AND SAFETY

Health Risks, Vulnerable Populations,
and Policy Challenges in Hong Kong



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LIST OF ACRONYMS

Acronyms	Meaning
IAQ	Indoor Air Quality
IAP	Indoor Air Pollutants
VOCs	Volatile Organic Compounds
PM	Particulate Matter
MVAC	Mechanical Ventilation and Air-Conditioning
COPD	Chronic Obstructive Pulmonary Disease
SARS	Severe Acute Respiratory Syndrome
MERS	Middle East Respiratory Syndrome
SBS	Sick Building Syndrome
DALYs	Disability-Adjusted Life Years
HCHO	Formaldehyde
TVOCs	Total Volatile Organic Compounds
SDUs	Subdivided Units

PROJECT FOREWORD

Indoor air quality (IAQ) in Hong Kong remains a critical yet under-addressed public health issue. Despite decades of progress in outdoor air pollution control, IAQ has not received equivalent levels of attention. Scientific evidence shows that poor IAQ contributes to serious health risks, including respiratory diseases, cardiovascular conditions, and cognitive impairments, especially among vulnerable groups such as children, the elderly, and those with chronic illnesses.

This report is part of a broader 24-month initiative led by Clean Air Network (CAN) to address the growing concern of IAQ in Hong Kong. The project combines a Study Program and a Key Sector Engagement Program, designed to build awareness, consolidate knowledge, and drive systemic change in IAQ management.

The Study Program includes five research components, with this Study Component focusing on consolidating international and local research on the correlation between indoor air quality (IAQ) and health and safety outcomes, providing a scientific basis to enhance public awareness and inform policy.

This study serves multiple purposes:

- **Knowledge Consolidation:** integrating international and local research findings on the sources of poor IAQ in Hong Kong and their associated physical, cognitive, and economic impacts.
- **High-Risk Identification:** identifying high-risk indoor locations (such as schools, offices, and high-density residences) and vulnerable populations (such as children, the elderly, and chronic disease patients) within Hong Kong's specific environment.
- **Public & Policy Advocacy:** enhancing public awareness of the importance of IAQ and providing a scientific and systematic knowledge base for the Hong Kong government to formulate relevant policies.

Ultimately, this study program lays the foundation for larger-scale research, cross-sector partnerships, and policy reform- positioning Hong Kong as a leader in IAQ innovation for dense urban environments.

EXECUTIVE SUMMARY

This report aims to highlight the critical issue of IAQ in Hong Kong by consolidating international and local research through a literature review. Despite receiving less attention than outdoor air quality concerns, evidence reveals that poor IAQ has significant adverse effects on the physical and cognitive health of the Hong Kong population, in addition to imposing substantial burdens on the economy and productivity.

Key insights include:

- **Key Pollutant Sources:** Combustion (cooking, incense), VOCs from building materials, furniture and chemical products, and biological contaminants, amplified by urban density and humidity.
- **Major Health Impacts:** Poor IAQ is strongly linked to increased risks of chronic diseases, cancer, and infectious diseases, as well as impaired cognitive function.
- **Significant Economic Burden:** Estimated 32.56 billion HKD annual loss, with 86.12% from non-occupational environments.
- **Vulnerable Populations:** Key groups including women, children, elderly, and some staff and workers are identified as more susceptible to IAQ effects.
- **High-Risk Environments:** Poor IAQ concentrated in Subdivided Units (SDUs), schools, offices, hospitals, and elderly homes.

The report advocates for the following:

1 Enhance public awareness of the importance of IAQ through public education



2 Establish real-time monitoring and public reporting of IAQ data for public places



3 Establish mandatory IAQ standards for public places and residential buildings



4 Promote local IAQ-related research in Hong Kong



For more information on indoor air quality and ongoing initiatives, visit: hongkongcan.org/indoor-air-quality



BACKGROUND

IAQ is a critical global public health issue, with the WHO reporting that poor IAQ from household environments alone causes about 3.2 million deaths annually. In Hong Kong, this public health challenge is further amplified by the city's unique high-density urban environment and humid climate, making IAQ a critical public health issue with significant health and economic implications.

However, despite significant government achievements in managing outdoor air quality, there is a significant gap in policy planning and data monitoring for indoor air. A vicious cycle exists where a lack of evidence leads to low government priority, which in turn prevents research and data collection.

This report aims to break this cycle by consolidating international and local research on the correlation between indoor air quality (IAQ) and health and safety outcomes, providing a scientific basis to enhance public awareness and advocate for policy change.

Key objectives include:

- Analyze key pollution sources affecting Hong Kong's IAQ.
- Evaluate the full scope of adverse impacts, including the physiological, cognitive, and economic burdens of poor IAQ.
- Analyze Hong Kong's specific context to identify high-risk environments and vulnerable populations.
- Assess Hong Kong's current IAQ management policies and research.

Scope and Limitations

The information in this report are primarily sourced from academic databases such as PubMed, Web of Science, and Google Scholar, as well as information platforms of official organizations and government agencies from various countries and regions. Due to a lack of recent studies, especially local ones, this report includes literature from the past 25 years. As a result, some of the evidence presented may not be current.

1

SOURCES OF POOR INDOOR AIR QUALITY

OVERVIEW

Poor IAQ is primarily caused by indoor air pollutants (IAP) as well as physical factors such as humidity, temperature, and ventilation.

INDOOR AIR POLLUTANTS (IAP)

1 | Combustion and Heating Activities

Sources	Examples	IAP Released
Cooking appliances	Gas stoves, Woodstoves	CO, CO ₂ , NO _x , SO _x , VOCs, PM
Heating appliances	Space heaters, Water heaters	CO, CO ₂ , NO _x , SO _x , VOCs, PM
Tobacco & other smoking products	Cigarettes, cigars, hookah/ shisha	CO, CO ₂ , NO _x , SO _x , VOCs, PM
Burning incense & candles	Scented candles, joss sticks, aromatherapy incense	NO ₂ , VOCs, PM

2 | Building Materials, Furnishings, and Renovation

Sources	Examples	IAP Released
Building materials	Granite countertops (radon), engineered wood flooring, PVC pipes	Rn, VOCs
Furniture	Wooden cabinets, particleboard desks, wall-to-wall carpets	VOCs
Paints, Solvents, Adhesives	Interior wall paint, varnish, glue for flooring	VOCs
Aging of above materials	Crumbling plaster, deteriorating paint, worn-out carpet fibers	VOCs, PM

INDOOR AIR POLLUTANTS (IAP) (CONT')

3 | Chemical Product Use

Sources	Examples	IAP Released
Household chemicals	Cleaners, Disinfectants, Pesticides	VOCs
Personal care products	Soaps, Body & face lotions, Hair styling products, Deodorant, Sunscreen, Nail polish, Perfume	VOCs

4 | Human, animal, and microbial activity

Sources	Examples	IAP Released
Human activities	Coughing, sneezing, cleaning, vacuuming	CO ₂ , Bacteria & viruses, Allergens (Dander), PM (Resuspended dust)
Household pets	Cats, dogs, birds	CO ₂ , Bacteria & viruses, Allergens (Dander), PM (Resuspended dust)
Pests	Cockroaches, rodents, dust mites	Allergens, Bacteria & viruses, PM (Fragments, droppings)
Mechanical Ventilation & Air- Conditioning (MVAC) Systems	Contaminated HVAC ducts, poorly maintained air filters	Bacteria & viruses, Mold & fungi

5 | Outdoor pollutants entry

Sources	IAP Released
Vehicle exhaust	CO, Nox, SO _x , PM
Industrial emissions	CO, Nox, SO _x , PM
Soil gas emissions	Rn
Outdoor plants	Allergens (Pollen), PM (Pollen)

PHYSICAL FACTORS

Beyond IAP, IAQ is also significantly affected by humidity, temperature, and ventilation. Some countries have incorporated these factors into the IAQ standards.

1 | Temperature

- It directly influences the emission rate of pollutants from indoor materials and products.
- It also affects how pollutants diffuse through the air. A quantitative study found that a 10°C rise in temperature can increase the diffusion coefficient by approximately 6%.
- Indoor temperature is determined by factors like ambient (outdoor) temperature, indoor heat sources, the building's heat conduction, and its ventilation or cooling systems.

3 | Ventilation

- Ventilation is strongly linked to IAQ.
- Strong ventilation generally leads to better IAQ, as outdoor air often has lower pollutant concentrations than indoor air.
- Poor ventilation can be caused by various factors, including terrain, building layout, nearby pollution sources, interior design, and the performance of mechanical ventilation equipment.

2 | Moisture (Humidity)

- Moisture primarily degrades IAQ by promoting biological pollutants.
- A humid environment creates ideal conditions for the survival and growth of microorganisms like bacteria, fungi (mold), and viruses. These can cause infections or produce irritating toxins and allergens.
- Dampness also attracts pests such as dust mites, insects, and rodents, which are sources of germs and allergens.
- Common sources of indoor moisture include water leaks (from roofs, walls, pipes), infiltration of humid outdoor air, and inadequate ventilation in high-humidity zones like kitchens and bathrooms.

PHYSIOLOGICAL IMPACTS

Category	Specific Health Outcomes	IAP
Cardiovascular System Diseases	• Hypertension • Atherosclerosis • Heart attack • Stroke • Arrhythmia • Congestive heart failure • Coronary artery disease • Angina	• Gaseous • VOCs • PM
Respiratory System Diseases	• Chronic Obstructive Pulmonary Disease (COPD) • Type II respiratory failure • Respiratory infections • Asthma • Allergic rhinitis	• Gaseous • VOCs • PM • Biological
Infectious Diseases	<i>Viral:</i> • Influenza • SARS • MERS • Measles • Adenovirus disease <i>Bacterial:</i> • Tuberculosis • Diphtheria • Pharyngitis • Staphylococcal infection <i>Others:</i> • Psittacosis • Aspergillosis	• Virus • Bacteria • Fungus • Other Microorganisms

PHYSIOLOGICAL IMPACTS (CONT')

Category	Specific Health Outcomes	IAP
Cancer	• Lung cancer • Oral cancer • Laryngeal cancer • Nasopharyngeal cancer • Breast cancer	• Rn • VOCs • PM
Sick Building Syndrome (SBS)	<i>Irritation Symptoms:</i> • Irritation in eyes, nose, throat and skin • Odor and taste complaints <i>Neurotoxic symptoms:</i> • Headache • Dizziness • Nausea • Lethargy • Drowsiness • Mental fatigue • Reduced memory • Reduced Concentration	• Gaseous • VOCs • PM • Biological

FACTBOX

"Sick Building Syndrome" symptoms emerges once residents spend a certain amount of time in the building and it gradually subsides and disappear once they leave the building.

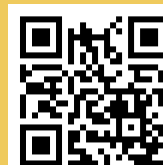


COGNITIVE IMPACTS

IAP		Impacts
Gaseous	CO, CO ₂ , O ₂ , O ₃	• Decreased memory • Difficulty concentrating • Prolonged reaction time • Decreased work accuracy • Fatigue • Dizziness, headache • Decreased cognitive level • Decreased productivity
VOCs	Aromatic hydrocarbons (benzene, toluene, xylene, ethylbenzene) Aldehydes (formaldehyde) Terpenes Alcohols	• Fatigue • Dizziness, headache • Decreased cognitive level • Decreased productivity
PM	PM _{2.5} , PM ₁₀	• Decreased cognitive level • Decreased productivity



To understand more about the impacts of poor IAQ on health, visit: hongkongcan.org/indoor-air-quality.



OVERVIEW

Poor IAQ's negative effects on health and cognition lead to broad societal and economic problems, resulting in significant financial burdens from increased healthcare costs and productivity losses.

INTERNATIONAL IAQ ECONOMIC BURDEN ESTIMATION

Some international studies and organizations have quantified these multifaceted economic impacts, employed diverse methodologies and focused on various pollution and outcome scopes.

As the table shows, although these studies vary in methodology, scope, and year, they all reach a consistent conclusion: for decades, poor indoor air quality has been internationally recognized as a major economic problem costing tens or even hundreds of billions of dollars.

Region	Pollution scopes	Economic burden	Outcome scopes	Year
France	IAQ	€20 billion	Total economic cost	2004
America	IAQ	\$168 billion	Total economic cost	2004
California	IAP	\$45 billion	Total economic cost	2005
America	Household damp and mold	\$3.5 billion	Total economic cost	2007
Indonesia	IAP	\$1.4 billion	Value of the lost health	2010
Philippines	IAP	\$86–435 million	Value of the lost health	2010
Timor-Leste	IAP	\$5–20 million	Value of the lost health	2010
Developed country	IAP	\$150,000 per DALYs*	Value of the lost health	2018

* DALYs: Disability-Adjusted Life Years, years of life lost due to ill-health, disability, or early death.

ESTIMATE THE ECONOMIC IMPACT OF POOR IAQ IN HONG KONG

1 | Total Economic Burden

Based on the analysis, the total economic burden of poor indoor air quality (IAQ) in Hong Kong is estimated to be 32.56 billion HKD per year.

This total loss is divided into two main categories:

- Non-occupational environments (homes, schools, restaurants, shopping malls): 28.04 billion HKD.
- Occupational environments (offices): 4.52 billion HKD.

This estimate shows a substantial increase from the 12.2 billion HKD estimated in 1995. Notably, this IAQ burden is close to the 41.8 billion HKD loss attributed to outdoor air pollution in 2024 by the Hedley Environmental Index.

2 | Methodology

This study's estimate is based on the health impacts of six key air pollutants: CO, PM2.5, NO2, O3, HCHO, and TVOCs. The total economic burden was calculated by combining two components:

- Cost of Health Loss: This is the economic value of healthy life years lost to disease (DALYs). And the cost per DALYs is composed of the cost of a life year and productivity loss.
- Cost of SBS: The cost associated with productivity loss from SBS symptoms in the workforce.

Limitation: Due to local data limitations, the associated medical costs for the diseases were excluded from this analysis. Therefore, the 32.56 billion HKD estimate is likely an underestimate of the true economic burden.

4

HIGH-RISK POPULATION AND BUILT ENVIRONMENTS IN HONG KONG

HIGH-RISK POPULATION

1 | Elderly

As a large and growing population in Hong Kong, the elderly typically spend more time indoors. Their reduced physiological functions and weaker immune systems make them particularly vulnerable to the harmful effects of poor IAQ. Relatively higher rates of smoking and incense burning also expose them to more IAPs.

Locally Identified Sources

- Cooking
- Tobacco Smoke
- Incense burning
- Heating equipment
- Outdoor air pollution
- Poor ventilation
- Decoration materials and furniture
- Household chemicals
- Damp environments
- Cleaning activities

Additional International Sources

- Building materials (Radon)
- Solid Fuel combustion (wood, candle burning)
- Air conditioning system and humidifier
- Transmission of infectious diseases
- Hygiene and healthcare products

2 | Children

Children are highly sensitive to poor IAQ because their developing organs, especially the lungs, are vulnerable to severe and lasting harm. Their higher breathing rates also cause them to inhale more pollutants per unit of body weight. Furthermore, they spend substantial time indoors at home and school, and this cumulative exposure is significantly worsened by Hong Kong's high-density living and classroom environments.

Locally Identified Sources

- Cooking Activities
- Heating
- Environmental Tobacco Smoke
- Incense Burning
- Poor Ventilation
- Air Conditioning
- Outdoor Air Pollution Infiltration
- Building Characteristics and Materials
- Household Background Emissions
- Damp environments

Additional International Sources

- Household products
- Personal care products
- Office products
- The combustion of solid fuels and kerosene
- Soil and rock
- Indoor heavy metal dust
- Pesticides
- Pets
- Occupant activities
- Dust mites and pests

HIGH-RISK POPULATION (CONT')

3 | Women

Women may have distinct IAQ exposure patterns due to traditional household roles. In Hong Kong, women are often primarily responsible for cooking, leading to higher exposure to cooking fumes. They may also face increased exposure to VOCs from the frequent use of household cleaning agents and personal care products. Furthermore, pregnant women are an exceptionally sensitive group, as pollutant exposure can affect both their own health and that of the developing fetus.

Locally Identified Sources

- Cooking Activities
- Environmental Tobacco Smoke
- Incense Burning
- Poor Ventilation
- Household Background Emissions
- Damp environments
- Building Characteristics and Materials

Additional International Sources

- Household products
- Personal care products
- Office products
- The combustion of solid fuels and kerosene
- Soil and rock
- Indoor heavy metal dust
- Pesticides
- Pets
- Occupant activities
- Dust mites and pests

4 | Staff and workers

Staff and workers face significant IAQ risks due to extended exposure durations in occupational settings. In Hong Kong's service-based economy, a large workforce is based in offices. Local reports show these offices often fail to meet IAQ standards, leading to SBS and reduced productivity. Furthermore, workers in specific occupations, such as restaurant and e-waste recycling, face unique and severe exposure risks.

Locally Identified Sources

- Office Equipment
- Building Materials and Furniture
- Outdoor Air Pollution Infiltration
- Mechanical Ventilation and Air-Conditioning (MVAC) Systems
- Damp Environments
- E-Waste Recycling
- Commercial Kitchen

Additional International Sources

- Flame retardants

BUILT ENVIRONMENTS

1 | Schools

Schools face unique IAQ risks as pollutants from teaching and student activities are significantly amplified by high student density within classrooms. This environment is particularly concerning as it can potentially impact students' cognitive function and learning performance.

Category	Specific Sources and Pollutants
Internal Activities	• Respiration (CO₂) • Student activity (Particle resuspension) • Cleaning activities (VOCs) • Science labs (Chemicals vapors) • Art supplies, chalks, glues and markers (VOCs, PM) • High-density electronic products (VOCs)
Building Materials	• New wooden desks and chairs (VOCs) • Granite, concrete (Radon)
Ventilation Systems	• MVAC Systems (Mold, Dust, Bacteria)
Outdoor infiltration	• Vehicle exhaust, industry emission (Gaseous, PM, VOCs) • Pollen (Biological) • Soil gas (Radon)



BUILT ENVIRONMENTS (CONT')

2 | Elderly Homes

Elderly homes house an exceptionally vulnerable population in a high-density living environment. The primary IAQ risks are unique to their care operations, arising from the heavy, frequent use of disinfectants and cleaning agents, and the circulation of bioaerosols from residents.

Category	Specific Sources and Pollutants
Internal Activities	• Respiration, coughing (Bioaerosols, Viruses) • Bed-making, sweeping (Particle resuspension) • Disinfectants and cleaning agents (Chemicals, VOCs) • Air fresheners (VOCs) • Personal care products (VOCs) • Pesticides (VOCs)
Building Materials	• Paint, wooden furniture (VOCs) • Aging materials (PM) • Granite, concrete (Radon)
Ventilation Systems	• MVAC Systems (Mold, Dust, Bacteria)
Outdoor infiltration	• Vehicle exhaust, industry emission (Gaseous, PM, VOCs) • Pollen (Biological) • Soil gas (Radon)



BUILT ENVIRONMENTS (CONT')

3 | Offices

Offices pose a significant IAQ risk in Hong Kong's service-based economy, primarily due to high occupant density and heavy reliance on MVAC systems. This environment facilitates the accumulation of pollutants from office equipment operation and occupants activities, leading to the prevalence of SBS and reduced worker productivity.

Category	Specific Sources and Pollutants
Internal Activities	• Respiration (CO₂) • Food heating in pantries (PM, VOCs) • Printers, photocopiers (Ozone, VOCs, Dust) • Cleaning activities (VOCs) • Humidifiers (Aerosols, Bacteria) • Air purifiers (Ozone)
Building Materials	• Paint, wooden furniture, carpets (VOCs) • Granite, concrete (Radon)
Ventilation Systems	• MVAC Systems (Mold, Dust, Bacteria)
Outdoor infiltration	• Vehicle exhaust, industry emission (Gaseous, PM, VOCs)



BUILT ENVIRONMENTS (CONT')

4 | Subdivided Units (SDUs)

SDUs pose one of Hong Kong's most acute IAQ challenges. Structural deficiencies, such as partition walls and minimal or no windows, result in severely restricted ventilation. This allows pollutants from high-risk activities, particularly cooking fumes from open kitchens, to accumulate within the confined living space.

Category	Specific Sources and Pollutants
Internal Activities	• Open kitchens cooking (Gaseous, PM) • Indoor clothes drying (VOCs)
Building Materials	• Paint, wooden furniture (VOCs) • Cheap construction materials (VOCs)
Ventilation Systems	• Air conditioner (Dust, CO, VOCs) • Partition walls, minimal windows (Poor ventilation)
Outdoor infiltration	• Vehicle exhaust, industry emission (Gaseous, PM, VOCs)

5 | Hospitals and Medical Institutions

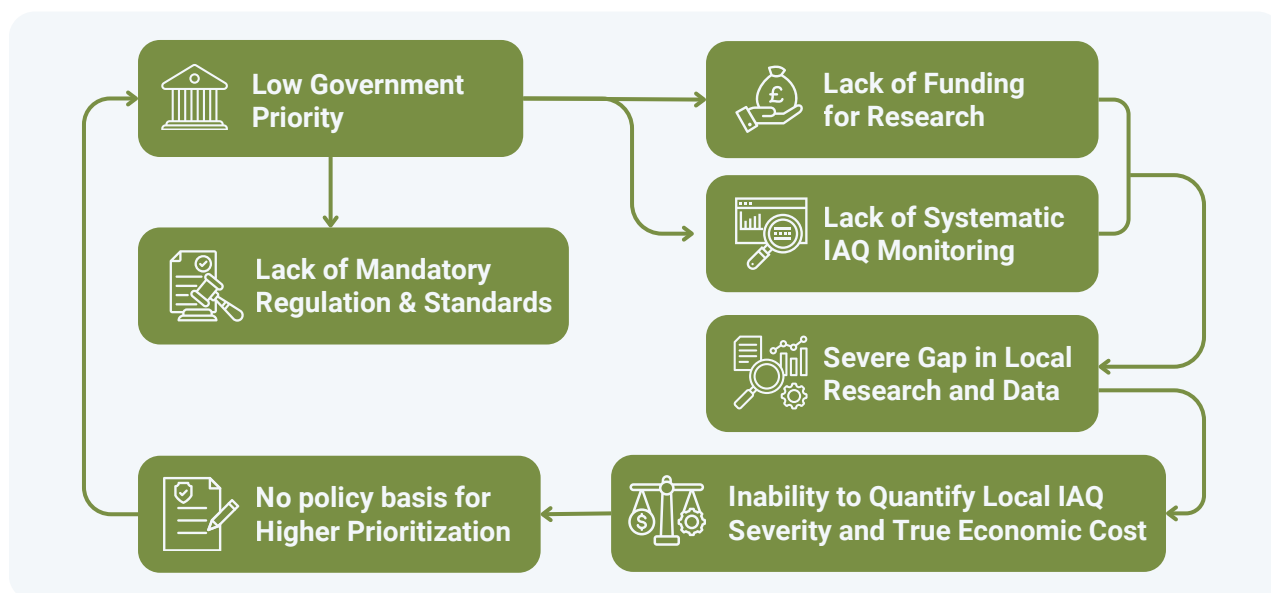
Hospitals serve a patient population highly vulnerable to poor IAQ. Meanwhile, they face risks from VOC pollution caused by the heavy use of disinfectants and the spread of biological contaminants (bacteria and viruses) carried by patients.

Category	Specific Sources and Pollutants
Medical Activities	• Disinfection and cleaning (VOCs) • Anesthesia, laboratory and imaging Procedures (NO₂, Chemicals, VOCs, Radioactive gases) • Aerosolized Medications (Chemicals)
Biological Sources	• Patients (Airborne pathogens) • Water Systems (Legionella and other Bacteria)
Building Materials	• Paint, PVC flooring (VOCs) • Granite, concrete (Radon)
Ventilation Systems	• MVAC Systems (Dust, CO, VOCs, Biological)
Outdoor infiltration	• Vehicle exhaust, industry emission (Gaseous, PM, VOCs)

5

CHALLENGES IN HONG KONG'S IAQ MANAGEMENT

VICIOUS CYCLE FOR IAQ MANAGEMENT IN HONG KONG



RECOMMENDATIONS

1 | Policy and Regulatory

- Expand the coverage of current IAQ guidelines to include high-risk environments, such as Subdivided Units (SDUs) and hospitals.
- Establish mandatory IAQ regulations to govern standards in key public and residential buildings.

3 | Research and Funding

- Allocate government funding to local universities and research institutions to systematically study IAQ sources and impacts in Hong Kong.
- Promote local epidemiological studies to quantify local health risks and the economic cost related to poor IAQ.

2 | Data Collection and Monitoring

- Modify the existing voluntary certification scheme to shorter inspection intervals and employ spot-checks rather than passive testing.
- Establish a long-term, systematic IAQ monitoring network across Hong Kong.
- Ensure regular public reporting of IAQ monitoring results.
- Establish an IAQ portal with real-time data display.

REFERENCE

This concise report summarizes key findings and recommendations. Readers seeking comprehensive references, methodology, and additional discussion are encouraged to consult the full report by scanning the QR code or visiting: <https://shorturl.at/ek1ze>



To explore more insights and updates on indoor air quality in Hong Kong, scan the QR code or visit: hongkongcan.org/indoor-air-quality



PHOTO SOURCE

[1] Manning, K. (2025). *White and green signage* [Photograph]. Unsplash. <https://unsplash.com/photos/sOCT5bSYxrU>

