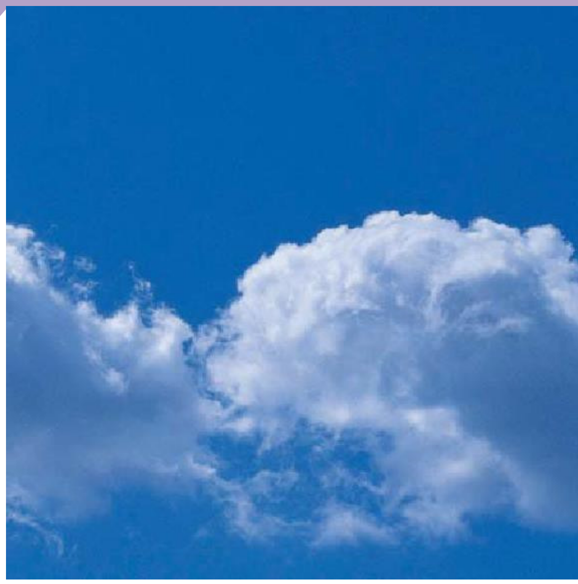
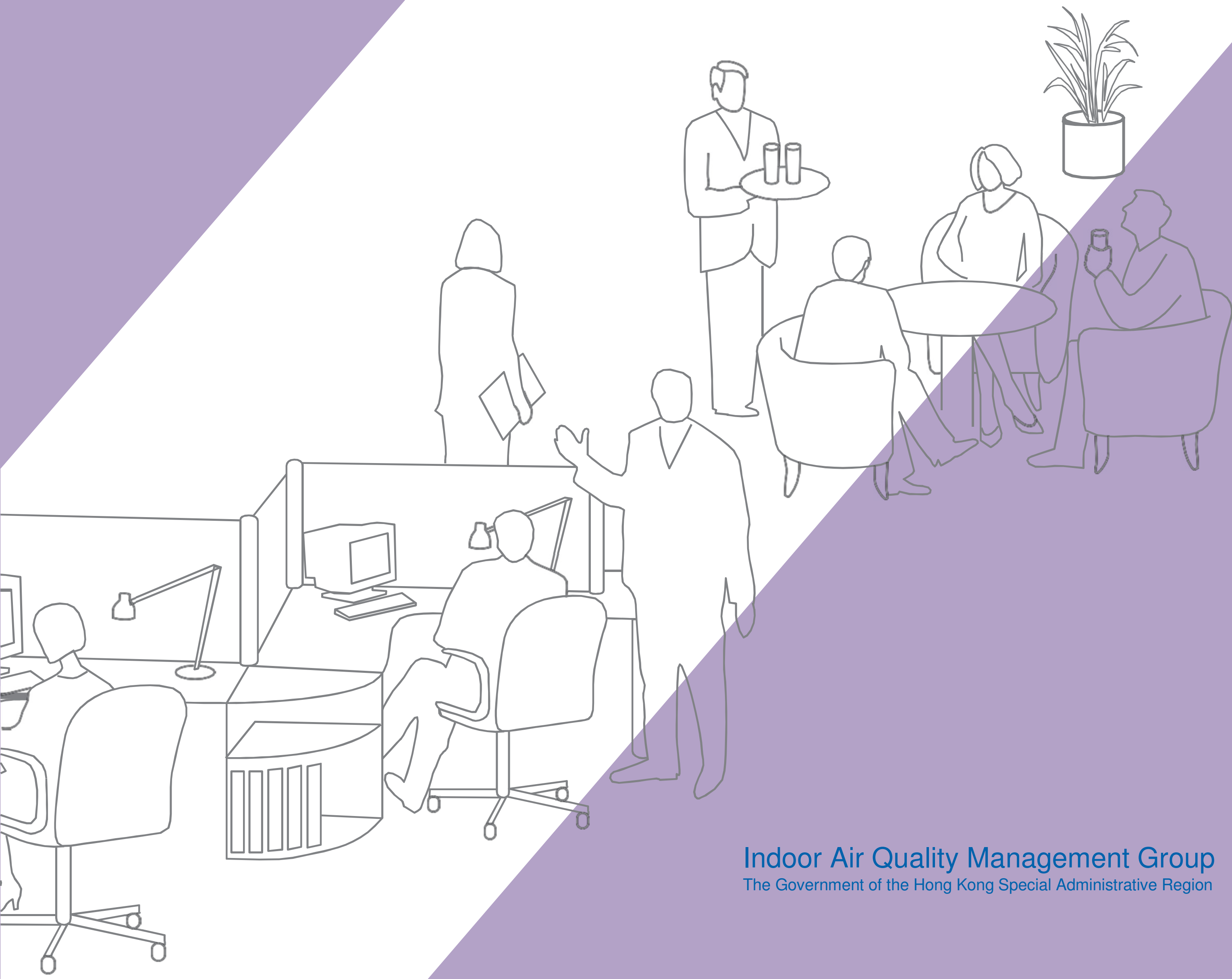
Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places





Indoor Air Quality Management Group
The Government of the Hong Kong Special Administrative Region

Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places

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FOREWORD

In modern city life, the quality of air in the indoor environment has a significant impact on human health and comfort. People spend most of their time at homes, offices and other indoor environment. Poor indoor air quality (IAQ) can lead to discomfort, ill health, and, in the workplace, lead to absenteeism and lower productivity. Good indoor air quality safeguards the health of the building occupants and contributes to their comfort and well-being.

Indoor air pollution has received little attention in the past compared with air pollution in the outdoor environment. It has now become a matter of increasing public concern, prompted partly by the emergence of new indoor air pollutants, by the isolation of the indoor environment from the natural outdoor environment in well-sealed buildings, and by the investigation of so-called Sick Building Syndrome. The World Health Organization (WHO) also recognises that biological and chemical indoor air pollution as public health risks.

The health effects of individual indoor air pollutants are studied extensively. For example, the health impact of formaldehyde is well documented. Two guidelines were published by WHO in 2009 and 2010 respectively on mould and dampness, and selected indoor air pollutants. On the other hand, the health effects of a combination of indoor air pollutants are much less well understood and more difficult to tackle. This is due to the shortage of reliable data on the effects on human health; difficulties in accurately measuring air pollutants at low levels; potential interactions between pollutants; and wide variations in the degree to which building occupants are susceptible to air pollutants. There are also many external factors which may obscure the relationship between IAQ and its impact on the building occupants.

IAQ is not only technically complex, it is also complex from an administrative point of view. The many factors to be taken into consideration and strategies required to maintain good IAQ cut across a variety of disciplines—public health, occupational hygiene, employment practice, engineering standards, and government departmental responsibilities. In Hong Kong, ventilation systems and some other factors affecting IAQ are already subject to legislation. IAQ is also touched on in certain regulations and ordinances, most noticeably the Smoking (Public Health) Ordinance (Cap. 371) that prohibits smoking in all indoor workplaces and public places. But Hong Kong does not have, or plan to introduce, legislation specifically addressing the issues of IAQ because it is considered that self-regulation can be effective and, given the complexities and uncertainties which still surround IAQ, is preferable to comprehensive regulation. Most of the countries/regions concerned with IAQ, such as the United States, Singapore, Canada and those European countries, have adopted the same approach. The self-regulatory approach is consistent with Hong Kong’s principle of small government.

To coordinate the development on the control of IAQ in Hong Kong, the Government has set up an inter-department IAQ Management Group. Its membership comprises representatives from five government bureaux and fourteen departments:

- Civil Service Bureau
- Education Bureau
- Environment Bureau
- Food and Health Bureau
- Transport and Housing Bureau
- Architectural Services Department
- Buildings Department

- Customs and Excise Department
- Department of Health
- Electrical and Mechanical Services Department
- Environmental Protection Department (the Chairman)
- Fire Services Department
- Food and Environmental Hygiene Department
- Government Property Agency
- Housing Department
- Labour Department
- Marine Department
- Social Welfare Department
- Transport Department

The following Guidance Notes has been developed and endorsed by the IAQ Management Group to help the community to understand and manage this complex subject. This Guidance Notes is based on international standards on ventilation design and on other aspects affecting IAQ where these exist, and insofar as their provisions are applicable to Hong Kong.

This Guidance Notes provides comprehensive guidelines for the total management of IAQ and covers a wide range of issues including ventilation, scientific assessment and communication strategies. It is designed to enable owner/management of premises/building to prevent and successfully manage most of the common IAQ problems encountered in buildings in Hong Kong, for the health and well-being of all.

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ABBREVIATIONS USED IN THIS GUIDANCE NOTES

Abbreviations

ACGIH	– American Conference of Governmental Industrial Hygienists
ACM	– asbestos-containing material
ASHRAE	– American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BRI	– building related illnesses
CIB	– IAQ Certificate Issuing Body
EPD	– Environmental Protection Department
GN	– Guidance Notes
HEPA	– high efficiency particulate air
IAQ	– indoor air quality
MSDS	– material safety data sheet
MVAC	– mechanical ventilation and air conditioning
SBS	– sick building syndrome
TVOC	– total volatile organic compounds
USEPA	– US Environmental Protection Agency
VOC	– volatile organic compound
WHO	– World Health Organization

1. INTRODUCTION

1.1 Application

The primary objective of this Guidance Notes (GN) is to give background information and practical guidelines to enable users to prevent indoor air quality (IAQ) problems, and to solve problems promptly if they arise.

This GN applies to all buildings or enclosed areas served with mechanical ventilation and air conditioning (MVAC) system for human comfort except:

(a) domestic buildings
(b) medical buildings
(c) industrial buildings
(d) any area or any part of the building which is constructed, used or intended to be used for domestic, medical or industrial purposes

This GN does not apply to any part of a building which is enclosed but not served by MVAC system such as store rooms, plant rooms and switch rooms.

This GN also does not cover underground or multistorey car parks, tunnels, public transport interchanges, public transport facilities, or other partially enclosed areas. However, professional practice notes have been issued for some of these facilities/buildings by the Environmental Protection Department. Guidelines for managing air quality in air-conditioned public transport facilities in respect of buses and railways in the form of professional practice notes were also issued in 2003, whereas the practice note for ferries was issued in 2015. A list of these practice notes is given in Appendix A.

1.2 Definitions

"mechanical ventilation and air conditioning (MVAC) system" means the equipment, distribution network and terminal that provide, either collectively or individually, the processes of heating, cooling, humidification, dehumidification, ventilation or air-purification or any other associated processes to a conditioned space except window-type air conditioners or split-type air conditioners.

"domestic building" means a building constructed, used or intended to be used for habitation but excluding the use of it for a hotel, guest-house, boarding-house, hostel, dormitory or similar accommodation and the expression "domestic purposes" is construed accordingly.

"industrial building" means

(a) a godown; or
(b) a building in which articles are manufactured, altered, cleaned, repaired, ornamented, finished, adapted for sale, broken up or demolished, or in which materials are transformed; and the expression "industrial purposes" is construed accordingly.

"medical building" means a building constructed, used or intended to be used as clinic, infirmary or hospital and the expression of "medical purposes" is construed accordingly.

"buildings" means buildings and premises.

1.3 Scope

This GN should be used as a general guidance document in:

- formulating IAQ policies
- designing buildings and building services for acceptable IAQ
- setting operation and maintenance procedures
- investigating IAQ complaints
- mitigating IAQ problems if they arise

This GN is not a ventilation standard or a detailed manual for assessing indoor air contaminants. Detailed designs are also outside the scope of this GN. However, references to standards for specific designs are provided where applicable. This GN provides guidelines on the IAQ objectives for different levels of comfort and optimal health required for offices and public places so that building owners and managers can, with advice from relevant experts, select the objective most appropriate to the needs of the occupants, and minimise the costs of implementation.

This GN should be used in conjunction with acceptable guidelines for ventilation such as the latest version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *Standard 62.1, Ventilation for Acceptable Indoor Air Quality*.

Apart from this GN, the Environmental Protection Department has launched a voluntary IAQ Certification Scheme for Offices and Public Places. Please refer to *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)*[1] for details.

1.4 Structure of the Guidance Notes

The structure of this GN and sequence of information is designed to provide a basic understanding of the principles behind good IAQ before giving practical guidance on how to achieve and maintain it.

Section 2: *Background:* explains why IAQ has become a concern; and describes the dangers posed to IAQ by different indoor air contaminants.

Section 3: *Indoor Air Quality Objectives:* seeks to establish acceptable IAQ, and provides recommended maximum concentrations of air contaminants (IAQ objectives) for maintaining good IAQ; and describes the parameters for IAQ certification.

Section 4: *Strategies to Achieve Indoor Air Quality Objectives:* describes building design, construction, ventilation, and maintenance practices which will help keep air contaminants below recommended levels.

Section 5: *Overall Indoor Air Quality Management Strategy:* advises building managers on how to develop a comprehensive strategy for maintaining good IAQ and managing IAQ problems.

Section 6: *Communication:* covers consultation at the design stage, and strategies to foster the cooperation of contractors and tenants in preventing IAQ problems in the occupied building; and advises building managers on how to handle IAQ complaints and emergencies.

Section 7: *Investigation:* describes the tools for investigating an IAQ complaint, including on-site

[1] Published by the Indoor Air Quality Management Group, The Government of the Hong Kong Special Administrative Region.

inspection, information gathering, environmental monitoring and hypothesis testing.

Section 8: *Mitigation:* provides general guidance on remedial measures, criteria for selecting the most appropriate strategy in each case, and on evaluation of the success of mitigation measures

Section 9: *Professional Assistance:* describes situations where outside assistance may be needed and factors to consider when hiring external consultants; and also covers the IAQ Certificate Issuing Bodies (CIBs) for IAQ certification.

1.5 Legal Status of the Guidance Notes

This GN is designed to establish an effective self-regulatory system for the maintenance of IAQ. It is not legally binding and should be treated as a voluntary guideline and a set of common objectives of IAQ by the parties involved. Compliance with this GN does not in any way provide exemption from existing legal obligations relating to IAQ.

1.5.1 Legislation, Departmental Guidance Notes, and Codes of Practice

Legal provisions on ventilation and certain other factors affecting IAQ in buildings are contained in the following Ordinances and Regulations:

- Building (Planning) Regulations, Cap. 123F, and Building (Ventilating Systems) Regulations, Cap. 123J
- Ventilation of Scheduled Premises Regulation, Cap. 132CE
- Places of Public Entertainment Regulations, Cap. 172A
- Air Pollution Control Ordinance, Cap. 311
- Smoking (Public Health) Ordinance, Cap. 371
- Consumer Goods Safety Ordinance, Cap. 456
- Ozone Layer Protection Ordinance, Cap. 403
- Pesticides Ordinance, Cap. 133
- Occupational Safety & Health Ordinance, Cap. 509

Some government departments (Architectural Services Department, Electrical and Mechanical Services Department, Environmental Protection Department, Food and Environmental Hygiene Department, and Labour Department) have introduced general specifications and/or guidance notes on subjects covered in this GN. These are referred to in the text at the appropriate points and relevant departments should be consulted as necessary. A full list of relevant regulations, and departmental guidelines and codes of practice is given in Appendix A.

Every effort has been made to avoid inconsistencies between this GN and current legislation. Should any inconsistencies arise, the legal provisions shall prevail.

1.6 Intended Users

This GN is written primarily for building owners (proprietors), building tenants who have installed their own ventilation systems, and building managers. The building proprietor, since he normally has legal control of building facilities, retains primary responsibility for IAQ. The duties of the owner may, however, be modified by contractual agreements such as lease agreements made with building tenants. The building manager is usually the legal representative of the owner.

Some factors affecting IAQ fall outside the direct control of building owners and managers. In these cases this GN also provides guidelines for professionals such as building designers, architects and engineers. Each of these groups has a responsibility to prevent, directly or indirectly, IAQ problems in the design, construction or operational phase of a building (Table 1-1).

Table 1-1: Responsibilities for Achieving and Maintaining IAQ

Party	Activities/Responsibilities	Parts of GN which refer
Developers/ Building Owners	Authorisation of the MVAC system, selection of building and ventilation design and installation, construction, decoration standards, decisions on occupancy distribution and density. Preparation of buyer's contracts/tenancy agreements along with technical guidance to the buyers/ tenants to achieve the desired IAQ.	Sections 4, 5
Building Proprietors	Comply with the terms and conditions listed in the purchasing/ tenancy agreement related to internal decoration and control of IAQ. Commission of internal IAQ control policies and IAQ complaints handling. Communication with the Building Facilities Manager/ Building Management.	Sections 4, 5
Building Facilities Managers/ Building Management	Day-to-day management of the MVAC system, supervision of housekeeping, maintenance to ensure the compliance of all licensing conditions. Communication and IAQ complaints handling. Ensure the compliance of the buyer's contracts/ tenancy agreement by the Building Proprietors. Investigation and mitigation of IAQ problems with respect to the central MVAC System.	Sections 4–9
Architects	Design of building envelope, choice of building material, air intake and exhaust position.	Section 4
Interior Designers	Internal layout, choice of materials and furnishings.	Section 4
Registered Professional Engineers	Design, supervision of installation, inspection, witness commissioning test and certification of the MVAC system.	Sections 4, 9
Ventilation Consultants and Contractors	Advice on the relationship between ventilation and IAQ. Installation, repair and maintenance of the MVAC system.	Sections 4, 9
Manufacturers and Suppliers of Appliances	Information on emission rates of office equipment.	Section 4
Manufacturers and Suppliers of Building Materials	Information on emission rates of building materials.	Section 4
Contractors for other works in buildings	Control of pollution-emitting activities.	Section 6
Environmental, Health and Safety Consultants	Analysis and advice on IAQ problems.	Sections 7–9
Environmental Monitoring Laboratories	Monitoring and testing IAQ parameters.	Sections 3, 8, 9
Building Tenants and Other Occupants	Housekeeping, cleaning, notification of problems and pollution-emitting activities.	Sections 4–6, 8

Additional obligations, under the legislation outlined in Section 1.5.1, are largely confined to owners of ventilation systems or building owners. This does not in any way imply that building tenants and other occupants are exempt from relevant obligations as prescribed in the legislation.

2. BACKGROUND

2.1 Understanding Indoor Air Quality

Problems related to poor IAQ have existed ever since human beings started building shelters to protect themselves from the harshness of the natural environment.

In the past, resources and attention have been focused on controlling air pollution in the outdoor environment. The development of research into IAQ only emerged, from work to prevent occupational diseases in the industrial workplace, in the late 1970s. Since then, there has been growing public concern about the impact of indoor pollutants in non-industrial buildings. This follows changes in building technology and design, increased public exposure to indoor air in buildings, and publicity surrounding cases of Sick Building Syndrome (SBS).

Following the oil crisis in the late 1970s, new energy conservation building methods were developed to reduce the amount of outside air supply. These, together with the tighter sealing buildings and near universal adoption of air conditioning in Hong Kong, have increasingly isolated the occupants of modern buildings from the outside environment. In particular, they have limited the amount of outside air that can be brought into the indoor environment to dilute the air pollutants which may accumulate there.

In the "Second Review of the 1989 White Paper on Pollution in Hong Kong" completed in November 1993, the Government identified the health risks and other problems associated with indoor air pollution. The Government indicated that appropriate measures would be taken to address the issue. Meanwhile, inside office buildings, the potential sources of such air pollutants have multiplied. Materials and objects that may emit air polluting substances include:

- modern office equipment, such as computers, high-capacity photocopiers, laser printers, photographic processing equipment
- synthetic building materials, such as formaldehyde emitting particle boards, glues using organic solvents
- a wide range of plastic materials
- chemical based cleaning agents
- sources outside the building such as vehicle exhausts and chimneys

Nonetheless, changes in building design, equipment and office consumable provide only part of the explanation why office air quality has become such a significant public issue. The other reason is the expansion of office working in Hong Kong. As a result of growth in the service sector, majority of our workforce is now working in indoor environment. This trend, and the large amount of time which people spend indoors generally, has increased the social and economic importance of good IAQ.

Research has shown that, if health and well-being are jeopardised by poor indoor environment, productivity will also be affected.[2] This may take the form of high absenteeism, more sick leave being taken, and lower worker efficiency (quality of work). Apart from costs to individual businesses through lost productivity, poor IAQ imposes costs on the larger community through direct medical costs, as well as the cost of damage, such as mould contamination, to building materials and equipment due to poor air quality. Many studies have estimated the cost of IAQ to varying degrees.

For the property managers, increased energy costs from IAQ improvements are offset not only by

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[2] Wyon, D., *The effects of indoor air quality on performance and productivity*, Article in Indoor Air 14 Suppl 7, 2004.
Kosonen, R. Tan, F,.*The effect of perceived indoor air quality on productivity loss*, Energy and Buildings, Vol. 36, Issue 10, p981-986, 2004.
Wargocki, P., Wyon, D. P., and Fanger, P. O., *Proceedings of Healthy Building*, Vol 1, p635, 2000.

reduced absenteeism and improved productivity, but also by reduced liability exposure and increased competitiveness in the leasing market.

Public awareness on IAQ has been growing and the participation to the IAQ Certification Scheme for Offices and Public Places has remarkable growth since its implementation. There are expectations for owners and managers of buildings to improve the IAQ of their buildings to safeguard the health of the occupants. As such, it requires a good understanding of IAQ. Building owners and managers should seek to approach the subject with accurate scientific information, logical reasoning, good communication with all parties involved, and a high degree of sensitivity towards the affected building occupants.

2.2 Definition of Acceptable Indoor Air Quality

Acceptable IAQ is defined by ASHRAE and World Health Organization (WHO) as follows:

ASHRAE Standard 62.1-2016 *Ventilation for Acceptable Indoor Air Quality*

"Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

WHO

"The physical and chemical nature of indoor air, as delivered to the breathing zone of building occupants, which produces a complete state of mental, physical and social well-being of the occupants, and not merely the absence of disease or infirmity."

2.3 Complaints and Illnesses

There is an increasing amount of scientific evidence indicating that a range of health problems and complaints are associated with poor IAQ. The problems range from transient sensory irritation of the respiratory tract to diseases that can be life-threatening. These problems can be generally divided into the following two categories[3]:

- Sick Building Syndrome
- Building Related Illnesses

Sick Building Syndrome (SBS) is the name given to a range of non-specific symptoms associated with occupation of a particular building. The symptoms include:

- irritation and itching of the eyes
- nose and throat irritation
- runny or congested nose
- other flu-like symptoms
- chest tightness
- itchy skin occasionally with the development of rash
- headaches
- lethargy
- poor concentration
- irritability

[3] European Communities (1989). European Concerted Action Indoor Air Quality and its Impact on Man, Report No. 4 *Sick Building Syndrome*, G.J.Raw (1992). *Sick Building Syndrome: A review of the evidence on causes and solutions*' Health and Safety Executive research report no. 42/1992, HMSO, London.

These symptoms appear to occur more often in air-conditioned buildings than naturally ventilated buildings. They tend to abate or disappear entirely when the affected personnel leave the building. At the moment, the causal links between poor IAQ and SBS are still not conclusive. Some studies suggest that inadequate ventilation rates could be a major cause of SBS. There are many difficulties in establishing unquestionable proof because of the technical problems of quantifying low-level air pollutants in mixture, the non-specificity of the symptoms, and the many factors in the indoor environment such as noise, lighting, and work stress which may compound the effects. It is more likely that SBS has multiple causes, with poor IAQ being one of the major contributing factors.

Though SBS is not life-threatening or permanently disabling, it has a significant impact on both the affected building occupants and the organisations they work for. SBS has often resulted in lower work performance, higher absenteeism and amount of sick leave taken, increased staff turnover, companies having to allocate more resources to resolving complaints, and poorer industrial relations.

The second group of health problems associated with IAQ is Building Related Illnesses (BRI). These are clinically diagnosed illnesses which can be readily attributed to specific or well established causes associated with indoor air pollutants in buildings. Allergic reactions such as hypersensitivity pneumonitis caused by certain species of fungi, and infectious diseases such as Legionnaires' disease and humidifier fever (an influenza-like illness) are typical examples of BRI in office and public buildings. Other health effects such as allergic reactions to formaldehyde, long-term cancer risk from exposure to indoor radon also fall within this category.

Apart from the two broad categories discussed above, there are other types of indoor air problems related to the thermal comfort of the building occupants. Thermal comfort is mainly determined by temperature, humidity, and air movement. Though thermal environment in air-conditioned buildings does not usually cause serious ill health, it has a very significant impact on the general well-being and work performance of building occupants. Poor thermal environment may also affect occupants' perception of the IAQ.

2.4 Factors Affecting Indoor Air Quality

The overall quality of indoor air is influenced by thermal comfort and air contaminants. This chapter provides a brief description of the factors affecting thermal comfort, i.e.:

- temperature
- humidity
- air movement

and the more common air contaminants including:

- airborne particles
- volatile organic compounds
- asbestos
- formaldehyde
- radon
- combustion gases
- ozone
- respiratory products and body odours
- microorganisms

As smoking is prohibited in all indoor working places and public places[4] since 1 January 2007 in accordance with the Smoking (Public Health) Ordinance (Cap. 371), tobacco smoke is no

[4] Designated no smoking areas are listed in Part 1 of Schedule 2 of the Smoking (Public Health) Ordinance (Cap.371).

longer a concern of indoor air contaminant for the types of premises applied by this GN. As such, IAQ issues relating to smoking is not covered in this GN.

Guidelines on the objectives necessary to ensure acceptable IAQ for the main air contaminants are provided in *Section 3* below.

2.5 Thermal Comfort

Thermal comfort refers to the condition of mind that expresses satisfaction with the thermal environment. It is a subjective perception that can be influenced by one's metabolic rate, clothing insulation, air temperature, mean radiant temperature, air movement and relative humidity. The guidelines to determine optimum temperature, relative humidity and air movement settings of MVAC system for occupants in air-conditioned offices and public places is included in Appendix B.

2.5.1 Temperature

Air temperature has the most direct effect on thermal comfort. The air temperature of the indoor environment is influenced by factors such as the temperature control of the air conditioning, solar heat gain, other heat sources such as lighting, electrical equipment, computers and water heaters, as well as humidity and air movement. Consideration should also be given to variations in temperature within rooms served by a single thermostat. Temperature between rooms or locations within a room may vary due to large window areas, or large vertical surfaces (which may create convection currents resulting in cold air at floor level), for example causing discomfort for some occupants. The temperature level at which people feel comfortable will depend on activity levels, age and natural body temperature which will vary from individual to individual, as well as one's clothings, and on seasonal temperatures.

2.5.2 Humidity

Humidity influences thermal comfort by affecting the human body's ability to lose body heat through perspiration. In humid conditions it is more difficult to lose heat—the effect is therefore the same as raising the temperature and a "sticky" feeling is usually described by people. High humidity also encourages the growth of mould on building fabric and furnishings. Low relative humidity causes eyes, noses and throats to dry which may lead to discomfort, irritation and increased susceptibility to infection. Extremely low humidity can cause static electricity which is uncomfortable for occupants and can affect the operation of computers.

2.5.3 Air Movement

A certain amount of air movement around the human body is essential for thermal comfort. It is also important in dispersing air pollutants. The required level of airflow depends on the air temperature and humidity. In the hot and humid summer months, for example, greater air movement can help produce a more comfortable environment.

Airflow is determined by ventilation and convection currents (created by hot air rising and cool air falling) in a room. Blocked or unbalanced ventilation systems, or too low pressure levels in ventilation ducts may restrict air movement, producing a "stuffy" atmosphere which makes occupants feel uncomfortable. Airflow is also sensitive to changes in room occupancy; installation or removal of partition walls; the size, quantity and arrangement of office equipment and furniture; and building use. Too much air movement results in draughts and excessive cold.

2.6 Air Contaminants

Air contaminants include an enormous range of substances and biological organisms generated by building materials, human activities, office equipment, and also activities outside the building from the outdoor environment.

2.6.1 Respirable Suspended Particulates (PM_{10})

Respirable Suspended Particulates (PM_{10}) describe a variety of particulates with a nominal aerodynamic diameter of 10 micrometers (μm) that are small enough to be suspended in air. Sources of these airborne particles can be categorised as microbial particulates (e.g. bacteria, virus, mould, and spores), animal and plant particulates (e.g. pollen, insect parts and by-products), mineral particulates (e.g. asbestos and man-made mineral fibres), combustion particulates (e.g. emissions from cooking, heating appliances, and incense burning), and radioactive particulates (e.g. radon decay products attached to other larger particles).

The health hazards which particulates present depend on the size, shape, density and chemical reactivity of the particles. For example:

- smoke particles from combustion could cause respiratory irritation and infection, and aggravation of existing respiratory or cardiovascular disease
- general household dust could cause nasal and eye irritation and contact lens problems
- asbestos fibre exposure for prolonged periods increases the risk of lung cancer and mesothelioma
- fibre glass dust could cause itching and irritation to the skin, eyes and the upper respiratory system

2.6.2 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are chemical compounds that contain one or more carbon atoms and tend to evaporate at room temperature and normal atmospheric pressure[5]. They exist in the indoor environment as colourless gases. US Environmental Protection Agency (USEPA) (1989) detected and identified over 900 different VOCs in indoor environment at concentrations higher than 1 ppbv[6].

VOCs may enter from the outdoor environment, or be emitted from building materials, cleaning agents, cosmetics, waxes, carpets, furnishings, laser printers, photocopiers, adhesives and paints used indoors. They could create an IAQ problem if they temporarily or permanently exceed normal background levels.

The WHO Working Group Consensus of Concern About Indoor Air Pollutants at 1984 Levels of Knowledge listed out the VOCs commonly present in indoor environment[7]. In 2010, WHO published the *WHO Guidelines for Indoor Air Quality: Selected Pollutants* which provided numerical guidance levels for certain commonly found indoor air pollutants of known hazard, supported by toxicological and epidemiological data to human health. Among others, these indoor air pollutants including six individual VOCs, namely benzene, formaldehyde, naphthalene, polycyclic aromatic hydrocarbons, trichloroethylene, and tetrachloroethylene. These VOCs are commonly found indoors and their indoor sources are shown in Table 2-1.

Exposure to VOCs at high levels in the industrial environment has been shown to have toxicological effects on the central nervous system, liver, kidney and blood of the human body. Hypersensitive individuals can have severe reactions to a variety of VOCs at very low concentrations. These reactions can occur following exposure to a single sensitising dose or sequence of doses, after which a much lower dose can provoke symptoms. Chronic exposure to low doses can also cause reactions. Some studies have linked exposure of VOCs commonly found indoors to the following symptoms of SBS:

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[5] VOCs are defined by the WHO as compounds with a boiling-point range of 50°C -100°C as the lower limit, and 240°C -260°C as the upper limit. (WHO (1989). *Indoor air quality: organic pollutants*. Report on a WHO Meeting.

[6] USEPA (1989). *Report to Congress on Indoor Air Quality*, EPA Office of Air and Radiation / Office of Research and Development (EPA/400/1-89/001).

[7] WHO (1984). *Working Group Consensus of Concern about Indoor Air Pollutants at 1984 Levels of Knowledge*. WHO.

- eye irritation: burning, dry, gritty eyes; watery eyes
- throat irritation: dry throat
- respiratory problems: shortness of breath; bronchial asthma
- headaches; poor concentration; dizziness, tiredness, irritability

Exposure to certain compounds, such as benzene—a known human carcinogen, for long periods may increase the risk of cancer. Because the available knowledge of toxicological and sensory effects of VOCs and their mixtures is incomplete, reduction of overall exposure to VOCs is desirable.

Table 2-1: VOCs Commonly Found Indoors and Their Indoor Sources

Pollutant	Indoor Sources
Formaldehyde*	Germicide, pressed-wood products, urea-formaldehyde foam insulation (UFFI), plywood, medium-density fibreboard, adhesives, particle boards, laminates, paints, carpeting, upholstered furniture coverings, gypsum boards, joint compounds, ceiling tiles and panels, non-latex caulking compounds, acid-cured wood coatings, wood panelling, plastic/melamine panelling, vinyl floor tiles, parquet flooring, sealants, varnishes and lacquers, cleaning agents, nail polish and hardeners, insecticides
Benzene*	Furnishing materials, polymeric materials (vinyl, PVC, rubber floorings), nylon carpets, particle boards, plywood, fibreglass, flooring adhesives, wood panelling, caulking compounds, paint removers, solvents, paints, stains, varnishes, fax machines, computer terminals and printers, joint compounds, floor tile adhesives, spot/textile cleaners, styrofoam, synthetic fibres
Carbon Tetrachloride	Solvents, refrigerants, aerosols, fire extinguishers, grease solvents, cleaning agents
Trichloroethylene*	Solvents, dry-cleaned fabrics, upholstered furniture covers, printing inks, paints, lacquers, wood stains, varnishes, lubricants, adhesives, fax machines, computer terminals and printers, typewriter correction fluid, paint removers, spot removers
Tetrachloroethylene*	Dry-cleaned fabrics, upholstered furniture coverings, spot/textile cleaners, fax machines, computer terminals and printers
Chloroform	Cleaning agents, solvents, dyes, pesticides, fax machines, computer terminals and printers, upholstered furniture cushions, chlorinated water
1,2-Dichlorobenzene	Dry cleaning agents, degreasers, insecticides, carpeting
1,4-Dichlorobenzene	Deodorant, mould and mildew control agents, air fresheners/deodorisers, toilet bowl and waste-can deodorisers, mothballs and moth flakes
Ethylbenzene	Cleaning products, paints, styrene-related products, synthetic polymers, solvents, fax machines, computer terminals and printers, polyurethane, furniture polishes, joint compounds, caulking compounds, floor tile adhesives, carpet tile adhesives, lacquered hardwood parquet flooring
Toluene	Solvents, perfumes, nail polishes, detergents, dyes, water-based adhesives, edge-sealing, moulding tapes, wallpaper, joint compounds, calcium silica sheets, vinyl-coated wallpaper, caulking compounds, paints, carpeting, pressed-wood furnishings, vinyl floor tiles, paints (latex and solvent-based), paint thinners, adhesives, grease solvents, printer
Xylenes	Solvents, dyes, insecticides, polyester fibres, adhesives, joint compounds, wallpaper, caulking compounds, varnishes, resin and enamel varnishes, carpeting, wet-process photocopying, pressed-wood products, gypsum boards, water-based adhesives, grease solvents, paints, carpet adhesives, vinyl floor tiles, polyurethane coatings, synthetic fragrance
Naphthalene*	Paints, insecticides, moth repellents and disinfectants, deodorizers
Polycyclic Aromatic Hydrocarbons*	Cooking, domestic heating with fuel stoves and open fireplaces, incense and candle burning

* Quantitative guidance levels were recommended in the "*WHO guidelines for indoor air quality: Selected Pollutants*". WHO (2010).

2.6.3 Formaldehyde

Formaldehyde is a VOC of major health concern. It is a chemical ingredient used in many building materials and fabrics, cleaning fluids and adhesives. The most common sources of formaldehyde emissions in buildings are plywood, particle board, carpets and urea-formaldehyde foam insulation as summarised in Table 2-1. The level of formaldehyde concentration depends on the age of the source, air flow, temperature and humidity, and may vary during the course of a day or from season to season. In very high concentrations it gives off a strong chemical smell.

Unusually high concentrations of formaldehyde are known to cause eye, nose and respiratory irritation and sensitisation. Formaldehyde is a known human carcinogen.

2.6.4 Asbestos

Asbestos is a collective term referring to a group of naturally occurring hydrated silicate minerals crystallised in the form of long, strong and flexible fibres which can be separated into bundles of fibrils. It is commonly found in buildings and building installations in the form of asbestos spray, asbestos-textured paints, ceiling tiles, pipe lagging, vinyl floor tiles, flexible joints in air handling units, insulation boards and arc chutes in electrical switch boxes, and brake lining in lift brake drums.

The immediate health hazard of asbestos-containing material (ACMs) lies in its friability (the ease of crumbling when dry). The more friable the ACM is, the more susceptible it is to damage and the more likely it is to release asbestos fibre to the environment. ACM is only hazardous when it is damaged or in poor physical condition so that the asbestos fibre could be emitted into the air. Inhalation of asbestos fibres has been linked to asbestosis (a scarring of lung tissue), lung cancer and mesothelioma (a cancer of the lining of the chest or abdominal cavity). More information on asbestos is provided in Appendix C.

2.6.5 Radon and its Decay Products

Radon is a radioactive gas that has no taste, smell nor colour. It is formed when radium found in soils and rocks, particularly granite, disintegrates radioactively. As radon further decays, a series of tiny radioactive particles are formed. When either the gas or these particles are inhaled, some will be deposited in the lung and will continue to emit radiation.

Granite is very widely used in concrete for building construction in Hong Kong and hence may have the potential of radon emission. If a building is not well ventilated, the emitted radon will become trapped and accumulated. In addition, radon can diffuse into the indoor air from building materials or from soil gas seeping up through cracks or openings in the ground.

Radon has been found to cause lung cancer in underground miners, and is the second main cause of lung cancer in the United States after smoking. There is concern that exposure to radon in the modern indoor environment can increase the cancer risk of building occupants.

The Environmental Protection Department has published a *Practice Note for Professional Persons—Control of Radon Concentration in New Buildings* to provide guidance to the professional persons on the reduction of non-occupational radon exposure in new buildings and set out i) the radon concentration limit for protection of the public health; ii) factors to be considered for the design of new ventilation systems and buildings and mitigation measures; and iii) the measurement protocols.

2.6.6 Combustion Gases

The burning of gas, for example in gas cooking and space heating, releases a range of gases and vapours into the indoor environment. These so-called ‘combustion gases’ are a result of incomplete combustion. Another important source of combustion gases in the indoor environment is vehicle exhaust fumes entering the building from the outside environment or indoor car parks. The gases which carry the most serious risk to the health of building occupants are:

- carbon monoxide
- nitrogen oxides (NO and NO_2)

Carbon monoxide is an extremely toxic gas which interferes with the oxygen transport capacity of blood. It can cause cardiovascular diseases and symptoms such as dizziness, headaches, concentration problems, nausea, fatigue, rapid breathing, chest tightness and impaired judgement. It can be lethal when the carboxyhemoglobin[8] (COHb) concentration reaches more than or equal to 40%[9]. Oxides of nitrogen are potent eye and respiratory irritants.

2.6.7 Ozone

Ozone can be produced by equipment that utilises ultraviolet light or causes ionisation of air. This includes photocopiers, laser printers and ionisers. Ozone is highly reactive and could cause serious damage to the lung if inhaled in high concentrations. It also irritates the eyes and respiratory tract. However, because it is so reactive, it is only found in substantial concentrations near the source, and generally does not tend to accumulate in the indoor environment.

2.6.8 Respiratory Products and Body Odours

Human respiratory products such as carbon dioxide (CO_2) and body odours can also affect IAQ. The concentration of CO_2 in exhaled human breath is typically around 3.8% (38,000 ppmv) generated at a rate of 0.005 L/s for office work. The levels of CO_2 concentration encountered in non-industrial environments are usually far below the prescribed health and safety standards and do not present a health risk. CO_2 concentration is nonetheless important to IAQ management and is commonly adopted as a surrogate in measuring air freshness. The lower the concentration of CO_2 the fresher the air supply is likely to be. Body odours can be unpleasant. Care should be taken in using chemical deodorisers or perfumes to mask body odours as they may create more pollution problems than they solve.

2.6.9 Microorganisms

Microorganisms are another potential source of indoor air pollution, and can cause more serious problems than some chemical air contaminants. The three main types of microbiological contaminants are bacteria, fungi (moulds) and viruses.

Bacteria. In air-conditioned buildings, water or condensation in ventilation systems can act as breeding grounds for harmful bacteria which are then dispersed through the ventilation process. The health effects vary. Where high counts of environmental bacteria such as *Staphylococcus epidermidis*, *Micrococcus*, and *Flavobacterium* shed from skin flakes can be regarded as indicators of inadequate ventilation. Investigators suggested that if gram-negative bacteria, such as *Pseudomonas aeruginosa*, or other bacteria such as thermophilic actinomycetes, *Streptomyces albus*, *Bacillus subtilis*, and complex communities of microorganisms in biofilms are etiologic agents of hypersensitivity lung disease. It should be emphasised, however, that the presence of bacteria in the environment does not necessarily imply that human infections will occur. In indoor environment, bacterial counts are naturally higher in crowded places and it is not meant to be a direct indicator of health risk but serve as screening tests for further investigation.

In addition, several infectious agents, such as *Legionella pneumophilia*, *Mycobacterium tuberculosis*,

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[8] Carboxyhemoglobin is formed when carbon monoxide is combined with hemoglobin and thus preventing the blood from carrying oxygen.

[9] Lethal concentrations of carbon monoxide are 1700 ppm (10 minute), 600 ppm (30 minute), 330 ppm (1 hour), 150 ppm (4 hour) and 130 ppm (8 hour). (National Research Council (2010). *Acute Exposure Guideline Levels for Selected Airborne Chemicals Volume 8*. Committee on Acute Exposure Guideline Levels, Washington, D.C.).

and *Corynebacterium diphtheria* are of important IAQ concern. Outbreaks of Legionnaires' disease in the past have occurred in buildings that had evaporative cooling towers and humidifiers in air-conditioning systems[10].

Endotoxins are lipopolysaccharide compounds present in the outer cell wall of gram-negative bacteria and blue-green algae. They are associated with byssinosis and with sick building syndrome, both of which are predominately caused by airway inflammation and affect the immune system[11].

Fungi. A group of microscopic fungi is commonly known as mould which lives on dead organic matter. Mould growth, is promoted by high humidity and materials with a high moisture content. The Hong Kong climate with its high temperatures and relative humidity is particularly favourable to mould growth. The most common causes of mould growth in buildings are condensation on improperly insulated air ducts, and water damage on carpets. Other common causes include rain entering an inadequately sealed building and accumulation of moisture on building surfaces. Mould requires nourishment as well as moisture to proliferate. They can obtain nutrients from almost all common construction materials and also from dust on surfaces. Dust is an important source of nutrient as it contains biological particles other than inorganic particles that serve as food for mould. It can also gain water from air when relative humidity is high. It is recommended that proper control of indoor air temperature and relative humidity (not exceeding 70%), and limiting dust accumulation are important to prevent indoor mould growth.

Fungal spores, especially *Cladosporium* and *Alternaria*, are common in outdoor air during the growing season. The species of fungi that have the physiological ability to grow and accumulate indoors or in air handling equipment are quite different from the common plant and leaf fungi. Once fungi/mould growth occurs, it can damage food, textile, leather, carpet and various building materials. Furthermore, some toxigenic fungi, which produce certain mycotoxins, have been shown to induce SBS-type symptoms. If fungi/mould are allowed to proliferate they may produce VOCs, usually noticeable as a mouldy smell. The VOCs involved are thought to contribute to SBS. Chronic exposure to mould can induce allergic or asthmatic reactions in mould-sensitised individuals. Symptoms other than allergic and irritant types are not common. At present, it is impossible to derive thresholds for the health effects of moulds because exposure to different fungi would likely result in different consequences and everyone has different sensitivity to moulds. However, it is advisable to remove all visible mould growth to minimise the risk of exposure. Toxigenic fungi species found in indoor environments include *Stachybotrys atra*, toxigenic *Aspergillus,* and *Penicillium aurantiogriseum* and *Fusarium* species; pathogenic fungi include *Aspergillus fumigatus, Histoplasma* and *Cryptococcus*.

Viruses. Viruses do not survive long in MVAC systems and do not replicate inside the system. Viral infections such as colds or influenza are normally transmitted from person to person via aerosols of body fluids.

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[10] Electrical and Mechanical Services Department (2016). *Code of Practice for the Prevention of Legionnaires' Disease*.

[11] Rylander, R., and Snella, M.C. (1983). *Endotoxins and the Lung : Cellular Reactions and Risk for Disease.* Clin. Allergy 14:109-112.

3. INDOOR AIR QUALITY OBJECTIVES

3.1 IAQ Certification Scheme

To improve IAQ and promote public awareness of the importance of IAQ, the Government has implemented an IAQ Management Programme. One of the core elements of the Programme was the launching of a voluntary Indoor Air Quality Certification Scheme for Offices and Public Places (hereafter refers as "IAQ Certification Scheme") in 2003.

Key features of the IAQ Certification Scheme are—

(a) a 2-level IAQ objectives (Excellent Class and Good Class) is used as the benchmark to assess IAQ of premises/buildings;
(b) a voluntary and self-regulatory approach is adopted for annual certification;
(c) participation is free but premises/building owners or management are responsible for all expenses, including but not limited to, employing accredited IAQ Certificate Issuing Body (CIB) to assess IAQ of their premises/buildings against the IAQ objectives;
(d) CIB will issue an IAQ certificate for premises/building owners or management to register with the IAQ Information Centre if the IAQ objectives are complied with. The certificate and the IAQ labels provided by the IAQ Information Centre should be put up at a prominent location for the public information;
(e) the certificate is valid for 12 months. For certificate renewal, a full set of parameters on IAQ objectives shall be measured/assessed once every 5 years, and for the 4 years in between, only carbon dioxide, respirable suspended particulates and mould need to be measured/assessed annually if certain conditions are met;
(f) certification is generally made on the basis of a building as a unit. Nevertheless, premises/building owners or management can choose to certify certain parts or certain floors of a building; and
(g) premises/building owners or management have to manage post-certification IAQ to ensure IAQ is maintained at the certified level.

On certification requirements and measurement methods for participating in the IAQ Certification Scheme, please refer to *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)*. The Guide is available at http://www.iaq.gov.hk.

This chapter sets out the objectives to achieve the desired IAQ under the IAQ Certification Scheme. Since the participation of this IAQ Certification Scheme is voluntary, premises/building owners or management who do not wish to participate in this IAQ Certification Scheme are also encouraged to make reference to the IAQ objectives set out in this chapter in managing their IAQ.

The IAQ objectives have reflected international health-based air quality standards and good practice modified, where necessary, to suit local circumstances. Continuous achievement of the objectives should protect the majority of the community from ill health and discomfort arising from working in or visiting public places and office buildings. However, there may be a small proportion of the population who are extremely sensitive to certain air contaminants may experience some discomfort or ill health even where a building complies with the tightest IAQ objectives set out below.

3.2 Comparison of Indoor Air Quality Objectives with Occupational Health Standards

Occupants of modern buildings are concerned not only about their health but about their comfort and well-being. This poses a different starting point for the development of environmental and health policies for offices compared to those for industrial buildings. While the emphasis of traditional occupational health standards is on protection of workers from occupational diseases, the IAQ objectives provided in this GN are intended both to minimise ill health and to promote the comfort and well-being of all building occupants. They are more stringent than the corresponding occupational health standards because:

- IAQ objectives are intended to protect a more diverse target population which include the young and the elderly;
- IAQ objectives for higher class buildings also apply to the more vulnerable populations, such as individuals with chemical hypersensitivity and being immuno-compromised, as well as those susceptible to certain microbial exposures;
- IAQ objectives are based on health-based air quality standards, such as WHO's guidelines, some of which have taken into consideration the synergistic effect of some common air pollutants; and
- IAQ objectives take into consideration comfort (odour and sensory irritation) other than health effects.

In Hong Kong, statutes and government regulations, including the Building (Planning) Regulations (Cap. 123F), Places of Public Entertainment Regulations (Cap. 172A), and the Public Health and Municipal Services Ordinance (Cap. 132), stipulate the requirement of provision of ventilating system and/or the amount of fresh air supplied to certain buildings under certain circumstances. Where the objectives in this GN differ from the standards laid down in legislation, the legislative provisions should be complied with as a minimum standard, and the guidelines set out in this GN should be followed as good practice.

3.3 Outdoor Air Quality

In order to maintain the best IAQ, the fresh air intake of the ventilation system should be located away from local pollution sources. Guidelines on choosing the fresh air intake locations are in *Section 4.4.1.2*. The quality of the fresh air should, as far as practicable, conform to the relevant parameters of the prevailing Hong Kong Air Quality Objectives. The latest Air Quality Objectives as of the publication date of this GN are set out in Table 3-1.

Table 3-1: Relevant Parameters in Hong Kong (Ambient) Air Quality Objectives

Pollutant	Concentration in $\mu g/m^3$ Averaging Time			
	1 hr	**8 hrs**	**24 hrs**	**1 yr** [i]
Respirable Suspended Particulates (PM_{10}) [ii]			100 [iii]	50
Nitrogen Dioxide [iv]	200 [v]			40
Carbon Monoxide [iv]	30,000 [vi]	10,000 [vi]		
Ozone [iv]		160 [iii]		

i. Arithmetic means.
ii. Respirable suspended particulates means particles suspended in air with a nominal aerodynamic diameter of 10 μm or less.
iii. Not to be exceeded more than nine times per year.
iv. Measured at 293°K (25°C) and 101.325 kPa (one atmosphere).
v. Not to be exceeded more than eighteen times per year.
vi. No exceedance allowed

Ambient air quality can usually be estimated using data provided by the Environmental Protection Department, academic institutions or environmental consultants. If data are unavailable, the specified pollutants should be monitored according to established environmental monitoring standards by a suitably qualified professional. If the surrounding outdoor environment suggests the existence of certain unusual outdoor pollutants, these pollutants should be monitored.

3.4 IAQ Objectives

A set of 2-level IAQ objectives is established to act as the benchmark for evaluating and assessing IAQ under the IAQ Certification Scheme. These objectives are comparable to the international health-based air quality standards, including WHO's guidelines, which are intended to protect a more diverse target population including the young and the elderly, and can encourage building owners to aim at the best IAQ. They are classified as follows:

"Excellent" Class — represents an excellent IAQ that a high-class and comfortable building should have

"Good" Class — represents the IAQ that provides protection to the public at large including the young and the elderly

The IAQ objectives are designed for the IAQ inside the entire building and are applicable for all occupants inside the buildings. The rationale of providing different sets of objectives is to minimise the cost of implementation for the achievement of different degrees of the desired "optimal health". The IAQ objectives are not meant to be exhaustive to avoid all IAQ problems. However, if all the parameters are met, the likelihood of indoor air pollution leading to health problems or discomfort in the building should be remote. Building owners and employers therefore should endeavour to achieve the IAQ objectives as far as practicable.

Since the launch of the IAQ Certification Scheme in 2003, the WHO has published two IAQ guidelines in 2009 and 2010[12] respectively on dampness and mould, and selected pollutants (viz. formaldehyde, radon, carbon monoxide, nitrogen dioxide, benzene, naphthalene, polycyclic aromatic hydrocarbons (PAHs), trichloroethylene and tetrachloroethylene). Taking into account local circumstances and the practicability of adopting the latest WHO's IAQ guidelines, the IAQ objectives adopted in 2003 under the IAQ Certification Scheme have been revised for implementation starting from 1 July 2019. Table 3-2 sets out the latest IAQ objectives while the previous IAQ objectives adopted in 2003 are listed in *A Guide on IAQ Certification Scheme for Offices and Public Places*[13]. The IAQ parameters selected for the latest IAQ objectives include carbon dioxide, carbon monoxide, respirable suspended particulates, nitrogen dioxide, ozone, formaldehyde, total volatile organic compounds, radon, total airborne bacteria and mould. Table 3-3 also sets out the recommended objectives for individual VOCs, which serve as an alternative option for TVOC compliance checking.

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[12] The two guidelines are *WHO Guidelines for Indoor Air Quality—Dampness and Mould* and *WHO Guidelines for Indoor Air Quality—Selected Pollutants* published in 2009 and 2010 respectively.

[13] Indoor Air Quality Management Group, the Government of Hong Kong Special Administrative Region: *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places*, 2003.

Table 3-2: IAQ Objectives for Office Buildings and Public Places (Effective on 1 July 2019)

Parameter			Excellent Class	Good Class
Pollutant	**Averaging Time**	**Unit**		
Carbon Dioxide (CO_2)	8-hour	mg/m^3	1,440	1,800
		ppmv	800 [a]	1,000 [a]
Carbon Monoxide (CO)	8-hour	µg/m^3	2,000 [b]	7,000 [c]
		ppmv	1.7	6.1
Respirable Suspended Particulates (PM_{10})	8-hour	µg/m^3	20 [d]	100 [d]
Nitrogen Dioxide (NO_2)	8-hour	µg/m^3	40 [c]	150 [e]
		ppbv	21	80
	1-hour	µg/m^3	100 [c]	200 [c]
		ppbv	53	106
Ozone (O_3)	8-hour	µg/m^3	50 [b]	120 [f]
		ppbv	25	61
Formaldehyde (HCHO)	8-hour	µg/m^3	30 [b]	100 [b]
		ppbv	24	81
	30-minute	µg/m^3	70 [c]	100 [c]
		ppbv	57	81
Total Volatile Organic Compounds (TVOC)	8-hour	µg/m^3	200 [b]	600 [b]
		ppbv	87	261
Radon (Rn)	8-hour	Bq/m^3	150 [g]	167 [c]
Airborne Bacteria	8-hour	cfu/m^3	500 [h,i]	1,000 [h,i]
Mould	---	---	Assessment in form of prescriptive checklist (refer to *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)* [j]	

Legends:

a. USEPA (2017), *Facilities Manual Volume 2: Architecture and Engineering Guidelines.* A more stringent value is set for Excellent Class than the recommended time weighted average in this manual.

b. Finnish Society of Indoor Air Quality and Climate (2001), *Classification of Indoor Climate 2000: Target Values, Design Guidance and Product Requirements.*

c. WHO (2010), *WHO guidelines for indoor air quality: Selected pollutants*. A more stringent level is set for Excellent Class 1-hour NO_2 and 30-minute HCHO than the guidance level in this guideline. The Excellent Class objective of 8-hour average NO_2 is made reference to the corresponding WHO annual level. The WHO 24-hour averaging reference level for CO has been adopted as the 8-hour objective in the above table. Information from WHO has been taken into account for radon value in the above table, though WHO has no 8-hour averaging reference level for radon.

d. WHO (2006), *Air Quality Guidelines Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. The Excellent and Good Class objectives of PM_{10} in the above table are made reference to WHO annual and 24-hour averaging reference level for PM_{10} respectively.

e. EPD (1987), Hong Kong Air Quality Objectives under the Air Pollution Control Ordinance (Cap. 311).

f. WHO (2000), *Guidelines for Air Quality*.

g. USEPA (2016): A Citizen's Guide to Radon. (Note: 4 pCi/L or 150 Bq/m^3 is EPA Action Level).

h. ACGIH (1986), ACGIH committee activities and reports "Bioaerosols: Airborne viable microorganisms in office environments: sampling protocol and analytical procedures", Applied Industrial Hygiene.

i.. The exceedance of bacterial count does not necessarily imply health risk but serve as an indicator for further investigation.

j. WHO (2009), *WHO guidelines for indoor air quality: dampness and mould*.

Table 3-3: IAQ Objectives for Individual VOCs (Effective on 1 July 2019)

Compound	**8-hours Average**
Benzene	5.3 ppbv [a] (17 μg/m^3)
Tetrachloroethylene	37 ppbv [a] (250 μg/m^3)
Trichloroethylene	43 ppbv [a] (230 μg/m^3)
Naphthalene	1.9 ppbv [a] (10 μg/m^3)
Polycyclic Aromatic Hydrocarbons (as benzo(a)pyrene)	1.2 x 10^{-4} ppbv [a] (1.2 ng/m^3)

Legends:

a. WHO (2010). *WHO guidelines for indoor air quality: Selected pollutants*. Information from WHO has been taken into account for values of benzene, tetrachloroethylene, trichloroethylene, naphthalene and benzo(a)pyrene in the above table, though WHO has no 8-hour averaging level for these chemicals. The objectives are applicable to both Excellent and Good Classes. Compliance with the respective objective of the five individual VOC species is regarded as meeting Good Class TVOC objective. If at the same time the sum of the five individual VOC is less than or equal to 200 μg/m^3 (the Excellent Class TVOC objective level), it will be regarded as complying with the Excellent Class TVOC objective.

Note: All conversion calculations are based on data from NIST Standard Reference Database 69—October 2018 Release: *NIST Chemistry Webbook.*

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3.4.1 Selection of Relevant Objective

Owners of buildings often require different levels of comfort and cleanliness. To reflect these variations, there are 2-level objectives: "**Good**" and "**Excellent**" Classes. Owners should select the most suitable level in consultation with building designers, architects and engineers. Building owners and management are encouraged to endeavour to achieve the corresponding IAQ objectives as far as practicable.

3.5 Assessment of IAQ Parameters

For assessing the IAQ parameters with quantitative standards, there are basically two types of methods, namely real-time measurements and integrated sampling with subsequent laboratory analysis. Real-time monitors can be used for detection of pollutant sources and provide information on the variation of pollutant levels throughout the day. Integrated samples, normally obtained during operating hours for offices and public places, can provide information on the total exposure level of a particular pollutant. Regardless of the choice of the method, it is very important to ensure proper operating of the equipment and handling of the samples, as well as to have stringent quality assurance procedures including equipment calibrations in accordance with the manufacturer's recommendations, duplicate samples, and field and shipment sample blanks. A reasonableness checklist should be formulated for the instrument operator in the field so that any abnormality readings could be detected instantly.

The following sections provide general information about the assessment of individual parameters of the IAQ objectives. For details on the measurement/assessment for individual IAQ parameters, including sampling criteria and locations, and measurement methodologies, please refer to *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019).*

3.5.1 Carbon Dioxide (CO_2)

Carbon dioxide has been commonly adopted by IAQ researchers as an indicator with levels above 1,000 ppmv in indoor environments indicating that the ventilation rate is low and that other airborne contaminants are accumulating. For example, levels of carbon dioxide are normally highest in the late morning and late afternoon and vary with occupancy during the day in offices. Also, fresh air intake is usually at a minimum during the peak heating and cooling seasons.

Measurements should be taken at the fresh air intake, places of high occupancy density, and locations where there are complaints of poor air quality. Carbon dioxide level can be measured using real-time monitors, such as Non-Dispersive Infra-Red (NDIR) analysers or electrochemical oxidation devices. The user should select monitors with appropriate start-up and response time as some of them are designed for continuous monitoring and require longer time to reach equilibrium before operation.

3.5.2 Carbon Monoxide (CO)

The level of carbon monoxide may increase if vehicle exhausts are trapped, location of fresh air intake is in close proximity to roads of heavy traffic, car park or industrial exhaust, or where source of combustion is present indoors. Carbon monoxide level can be measured by real-time monitors, such as Non-Dispersive Infra-Red (NDIR) analysers or electrochemical oxidation devices.

3.5.3 Radon (Rn)

Radon and/or its progeny concentration measurements can be performed from very short-term to long-term depending on the purpose. Long-term measurements (typically 1 year or several months) can provide the best estimates of the average value while short-term (typically from 1 to 10 days) can be used for screening purpose. Very short-term or grab sampling (typically several minutes or tens of minutes) are generally used for building diagnosis and identification of hot spot.

For long-term exposures, a testing device called an "Alpha track detector" is commonly used. The principle of such detector is by using materials called Solid State Nuclear Track Detectors (SSNTDs), the primary damage caused in them by the passage of alpha particles remains fixed and a visible track is produced by means of a suitable etching procedure which can be identified by a human microscopist or by means of an automatic computerised image analysis system. Both short-term and long-term samplers are available for alpha track detector.

For short-term measurements up to a little over one week, charcoal canister is recommended to be used. The gamma radiation emitted by radon and its ingrown decay products can be adsorbed by activated charcoal, which can then be measured by means of a gamma ray detector such as Sodium Iodide. Normally a diffusion barrier is used between the charcoal and the air so that the rate of radon adsorption is proportional to its concentration in the air.

Other less common methods are available for radon measurement including scintillation cells and electronic monitors for grab and continuous measurement, as well as electret detectors for integrated measurement.

3.5.4 Formaldehyde (HCHO)

Formaldehyde has a pungent odour which often indicates its presence at a concentration greater than 200 ppbv. High level of formaldehyde may be present if there are renovation and/or refurbishment (e.g. new carpets, particleboard, fabrics and new wooden furniture) within past 3 months of the survey, or locations where substantial volume of cleaning fluids and adhesives are being used.

Formaldehyde level can be determined by active or passive sampling followed by analysis method such as High Performance Liquid Chromatography (HPLC) or colorimetry. These include: (i) active sampling and analysis by HPLC based on the USEPA TO-11A method; or (ii) passive sampling and analysis by colorimetry based on the American Society for Testing and Materials (ASTM) method D5014-94; or (iii) passive sampling and analysis by HPLC based on the method with the desorption of hydrazone and analysis via HPLC. Real-time measurement of formaldehyde could also be used.

3.5.5 Nitrogen Dioxide (NO_2)

Similar to carbon monoxide, high level of nitrogen dioxide may exist if there is combustion source indoor, vehicle exhausts are trapped, or location of fresh air intake is in close proximity to roads of heavy traffic, car park or industrial exhaust. Nitrogen dioxide level can be quantified by collecting air samples in a Tedlar bag with subsequent analysis by a chemiluminescence based nitrogen dioxide analyser that complied with USEPA designated methods in accordance with Title 40, Part 53 of the Code of Federal Regulations (40 CFR Part 53) or equivalent. Alternatively, the level can be quantified by passive sampling and analysis by spectrophotometric method or by real time portable analysers.

3.5.6 Ozone (O_3)

Offices with high densities of ozone-emitting office equipment, such as photocopying machines, laser printers, fax machines, and computer terminals, and/or use of air cleaners such as electrostatic precipitators, and/or deficiencies in ventilation systems may lead to high levels of ozone. Ozone level can be determined by real-time instruments such as heated metal oxide semiconductors, electrochemical, UV photometric or chemiluminescence detectors. These methods could also be used for general testing purpose.

3.5.7 *Respirable Suspended Particulates (PM_{10})*

Respirable suspended particulates (PM_{10}) refer to particles in air with a nominal aerodynamic diameter of 10 µm and smaller. High indoor PM_{10} level could be due to the trapping of vehicle exhausts, the location of fresh air intake being close to roads with heavy traffic, car park or industrial exhaust, or the presence of combustion source indoors, as well as poor housekeeping. The PM_{10} level can be determined by gravimetric analysis method based on the IP-10A method of the USEPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air (EPA/600/4-90/010). Alternatively, a real-time monitoring method with analysers, such as optical scattering or piezoelectric monitors, can also be used.

3.5.8 *Total Volatile Organic Compounds (TVOC)*

TVOC records total VOCs present in the indoor environment. TVOC level in air can be determined by analytical methods with whole air sampling by passivated canisters or solid sorbents and followed by direct flame ionisation detection based on the USEPA compendium method TO-12. For real-time measurement, photo-ionisation detectors (PIDs) and flame ionisation detectors (FIDs) are useful devices for identification source locations and pollution migration routes in form of TVOC. FID is perhaps the most widely used detector because of its high sensitivity, large linear response range, low noise, and convenience. However, when a real-time PID instrument is used, the measurement could be interfered by the presence of other non-VOC compounds, such as anaesthetic or disinfecting gases.

If the level of TVOC is higher than the recommended level as given in Table 3-2, the source of the individual VOC could be identified first by observation or by making reference to Table 2-1. The contamination could be either eliminated by removal or isolation of the sources, or by improving ventilation to dilute the contaminants. Measurement of individual VOC can be carried out by passivated canister sampling or solid sorbent sampling followed by gas chromatography flame ionisation detection (GC/FID) or gas chromatography mass spectrometric (GC/MS) analysis based on the USEPA's organic (TO) compendium procedures to determine whether the contamination situation has been improved. Infrared detectors can also be used for monitoring individual VOCs but are less sensitive compared to gas chromatography (GC) analysis and are subject to possible interference when several VOCs are present together.

3.5.9 *Airborne Bacteria*

Various factors can result in high bacterial counts. High counts serve as an indicator for poor ventilation and inadequate maintenance of the MVAC system, or use of water damaged carpet, etc. Further investigation should be carried out to identify the root causes so as to facilitate formulation of appropriate improvement measures. The presence of bacteria in indoor environment does not necessarily imply that human infections would occur.

Airborne bacteria have been quantified traditionally in "Colony-Forming Units" per cubic metre (cfu/m^3) of air. They are measured by collecting bacteria and allowing them to grow on suitable culture medium. For bacterial analysis, general purpose media such as tryptic soy agar, aerobic plate count agar and nutrient agar incorporated with an antifungal agent are suitable. Sampling instruments including Andersen multihole impactors, Reuter Centrifugal Sampler (RCS), Surface Air System (SAS) bioaerosol sampler, and cyclone scrubber can be used, and reference can be made to the *Field Guide for the Determination of Biological Contaminants in Environmental Samples* published by the American Industrial Hygiene Association in 1996.

3.5.10 *Mould*

Mould patches are usually dark in colour but can be in any colour. They could be detected by their "musty" or "damp" smell. Moulds can grow under sufficient moisture, presence of nutrients and suitable temperature. Mould growth can occur in hidden areas, such as behind wallpapers, under the carpet, or inside ventilation ducts. Maintaining relative humidity below 70% and avoid water damage (e.g. water condensation, and leakage or spills), regular housekeeping (including carpet cleaning), and routine inspection are important to prevent and control mould growth.

At present, it is impossible to derive thresholds for the health effects of moulds because exposure to different fungi would likely result in different consequences and further, everyone has a different sensitivity to moulds. However, the area of mould growth is an important indicator of the potential level of exposure for occupants. Since threshold exposure limits for air contaminants of fungal origin have not been established, it is advisable to remove all visible mould growth and apply remediation measures irrespective of the extent of mould growth. WHO recommends conducting thorough inspection to assess the dampness and mould problems. The assessment can be done by conducting a walkthrough inspection to inspect all accessible areas for possible mould growth and identify the factors, including dampness and dust, to facilitate mould growth. Reference can be made to the assessment checklist in the *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)*.

4. STRATEGIES TO ACHIEVE INDOOR AIR QUALITY OBJECTIVES

4.1 Introduction

To achieve acceptable IAQ, it needs to be considered at every stage of a building's life—from design and construction to operation and maintenance. Strategies to promote good air quality and prevent indoor air pollution problems should be formulated and implemented in the following areas:

- Building design and construction
  - Architectural design
  - Selection of building and furnishing materials
  - Selection of office equipment
- Building uses and layout
- Mechanical ventilation and air conditioning (MVAC) system
  - Design of MVAC system
  - Operation and maintenance of MVAC system
- Renovation works
- Pest control
- Housekeeping and cleaning

IAQ will be determined by all these factors combined and it is important that none of them should be ignored. It is hard and sometimes impossible to compensate fully for poor IAQ performance in one area, e.g., the poor IAQ caused by extensive use of pollution-emitting materials in buildings and furnishings cannot be compensated by improving the IAQ at other areas with better ventilation.

Achievement of the Excellent and Good Classes of IAQ objectives (Table 3-2 refers) is largely a matter of common sense. At current levels of knowledge, and given the range of factors involved, it is not possible to say exactly what design or standard of equipment will deliver a particular IAQ outcome. Finland has produced guidelines[14] which attempt to match particular standards of construction cleanliness and finishing materials to different standards of indoor air cleanliness. Nonetheless, there is enough available information, e.g. about the efficiency of different MVAC systems or filters, or the risks of pollution emissions from different building materials, for building owners/designers to strongly influence the IAQ outcome at the design and construction stage. To achieve the Excellent Class IAQ objectives for an office building, for example, owners/designers will want to select a better and more efficient filtering system, and impose stricter limitations on the use of pollution-emitting furnishing and building materials, than they would need to achieve the Good Class IAQ objectives.

4.2 Building Design and Construction

Appropriate design and selection of materials and products which have low emissions of pollutants will be one of the most effective ways to assure adequate quality of indoor air.

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[14] Finnish Society of Indoor Air Quality and Climate (2008). *Finnish Classification of Indoor Environment 2008: Target Values, Design Guidance and Product Requirements*.

4.2.1 Architectural Design

Architects can have an important and direct impact on IAQ for improving design of buildings. Design and construction of the building envelope plays a critical role in reducing the potential for moisture accumulation, and reducing air infiltration. In warm humid climates, there is a high risk that any air (as well as water) entering through breaks in the building envelope, will cause condensation and microbial growth. From an IAQ perspective, therefore, it is important to have a tightly sealed building, with a continuous and durable air barrier system.

Doors leading to car parks or other sources of pollution could contaminate the indoor air. It is therefore advisable to enclose lift lobbies of car parks in office or other buildings with self-closing, well-sealed doors, and to maintain positive air pressure inside the building. Besides, water supply, drainage, sewerage and other installations should be designed and installed in a way that can minimise the risk of leaks.

During the construction period, duct insulation and liner should be protected from moisture and not be exposed to the action of weather. If they are exposed to water, they should be discarded and replaced rather than dried and disinfected.

After construction is completed, the construction area should be purged by running the MVAC system at rates suitable for occupation for at least 48 hours before occupation to purge the contaminants of indoor air, e.g. solvents and dust. Maintaining a higher rate of ventilation during the first few months of occupation will also help to reduce air contaminant levels in new, renovated or newly refurbished buildings. Also, the air ducting system of the building is usually not very clean and contains piles of dusts and debris inside after construction. It is therefore recommended to conduct an air duct cleaning operation before the purging.

Centrally air conditioned building should be provided with:

(a) A supplementary central outside air supply system for supplying additional outside air to areas with above-average occupant density such as classroom, conference room, canteen, etc.
(b) Supplementary central exhaust system for handling local exhaust from tenant areas such as kitchenette, canteen, printing room, toilet, etc.

Where possible, rooms with significant sources of emission should be maintained under slight negative pressure, to minimise migration of the pollutants to nearby occupant which could result in cross- contamination, including:

- cooking-related exhaust (e.g. kitchen, canteen)
- sanitary-related exhaust (e.g. toilet, bathroom)
- office processes exhaust (e.g. printing room, photocopying room)

4.2.2 Selection of Building and Furnishing Materials

Building and furnishing materials may be sources of indoor air pollutants. To achieve IAQ objectives for chemical emissions, building designers should limit the use of high emitting building and furnishing materials. Materials with the lower emission rates should be selected provided that they meet all relevant statutory requirements, e.g. fire resisting properties, etc. This is particularly important when a large amount of the material is used in an area.

Natural materials, such as marble, glass, ceramic tiles, brick, metal surfaces and untreated wood, have no or negligible emissions of air contaminants: However, according to some overseas study, untreated wood furnishings may not be a panacea for IAQ problems associated with furnishing emissions, as even these products are not always completely free of emissions. A variety of VOCs in untreated wood (e.g. alkaloids, catechols, phenols, terpenes, etc.) could act as sensitisers or irritants that potentially affect human health.

For manmade or treated materials, such as plywood panels, particle boards, carpets, paints, varnishes and adhesives, rates of emission of formaldehyde and VOCs are sometimes available for products imported from other areas, such as United States and European Countries. There is currently no international consensus on testing methods, so product standards may vary slightly from country to country.

Although Hong Kong has not adopted or developed emission standards for building and furnishing materials of its own. The Environmental Protection Department published a guideline, "New Furniture and Indoor Air Quality"[15], on how to choose low VOC-emitting furniture and related materials. The guideline recommends consumers to select products that meet the standards commonly adopted on the products provided to Hong Kong. Besides, the Government has implemented the government green procurement policy requiring government bureaux and departments to take into account environmental considerations when procuring goods and services, including the formaldehyde emission limits for furniture. There are also three labelling schemes providing standards for product certification on a voluntary basis, namely the Green Council's Hong Kong Green Label Scheme (HKGLS), Hong Kong Green Building Council's Green Product Accreditation and Standards (HK G-PASS) and Hong Kong BEAM Society's BEAM Plus Interiors. They are local voluntary programmes that provide guidance on indoor air pollutant emission requirements for whole furniture and related materials such as paints/coatings, adhesives, and renovation materials.

Professionals in the building design industry should make use of whatever product information is available including from other countries and, if it is insufficient, carry out their own emission tests on the product. The manufacturer/supplier of materials and furnishings may follow the testing method adopted predominantly in the market e.g. European Union standards. Manufacturers and suppliers of materials and furnishings are encouraged to reduce the levels of emissions from, and to provide relevant information about, their products so that people can choose to buy or specify the materials which they want. Suppliers of building materials should also pass on manufacturers' information on emission rates to customers where such information is available. If the information is not available, suppliers should encourage manufacturers to provide it. Emission standards of building and furnishing materials adopted by other countries can also serve as guidelines for emission testing e.g. European E1 standard, China GB18580-2017, and the Japan F-Two Star for formaldehyde emission of wood panels. Other guidelines on emission testing are contained in:

- US Environmental Protection Agency Air Emissions Measurement Center[16]
- US Environmental Protection Agency, (2013), *Summary of EPA Emission Test Methods*, Title 40, Office of Air Quality Planning and Standards[17]
- U.S. Department of Housing and Urban Development, (2013), *Manufactured Home Construction and Safety Standards*, Fed. Reg. Vol. 78 No. 236
- European Commission Directorate-General for Science, Research and Development, (1995), *Determination of VOCs emitted from indoor materials and products – Second interlaboratory comparison of small chamber measurements*, Environment and Quality of Life: Report No. 16

Building materials containing any fibrous forms of asbestos should not be used in the indoor environment. Although materials containing asbestos may not present a health risk when they are in good condition, they may release fibres into the air as they age or after wear and tear. See Appendix C for details of statutory controls on the use of asbestos in Hong Kong.

The rate at which building materials and furnishings emit harmful substances reduces over time.

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[15] EPD (2019). *"New Furniture and Indoor Air Quality"*.

[16] US Environmental Protection Agency's Air Emission Measurement Center (refer to: https://www.epa.gov/emc)

[17] US Environmental Protection Agency (2013). *Summary of EPA Emission Test Methods*, Title 40, Office of Air Quality Planning and Standards (refer to: https://www.epa.gov/sites/production/files/2016-07/documents/highlights2013.pdf).

It is good practice to ventilate newly decorated or newly furnished areas before occupation. The time required for 'airing' will vary according to the rate of emissions from the material and may be shorter or longer than the 48 hour purge recommended after completion of construction work (*Section 4.2.1* above). Purges may sometimes be completed in shorter time by increasing ventilation rates to much higher levels than those required for normal occupation purposes.

While indoor planting may improve the aesthetic value of indoor environment, this may cause sensitisation and trouble to allergic persons. It is not recommended to have strongly smelling (flowering) indoor plants inside the building as they may cause symptoms in persons with asthma, or hay fever in both allergic and non-allergic persons.

4.2.3 Selection of Office Equipment

When choosing and installing equipment such as photographic processing equipment and gas appliances, equipment having specific pollution controls such as built-in gas filters, or complying with appropriate emission standards, should be given priority. The USEPA recommended the following criteria as part of a proposed preventive approach to indoor air pollution:

- require testing data on emissions rates from manufacturers or suppliers of office machinery;
- require manufacturers to provide testing reports describing emission factors for five major VOCs emitted and for any compounds known to be toxic or irritating at concentrations of 5 mg/m^3 or less; information on chamber testing conditions, and on the procedures for storing and handling the product;
- require information on ozone emission rates for office equipment;
- reject office machinery that increases VOC concentrations by 500 $\mu g/m^3$ or more in occupied space; and
- reject office machinery that increases ozone concentrations by more than 19.6 $\mu g/m^3$ (0.01 ppmv) in occupied space.

4.3 Building Uses and Layout

Good planning of building uses and internal layout may help prevent many unnecessary IAQ problems. In mixed-use buildings, of which there are many in Hong Kong, areas where pollutants are actively emitted, e.g. a printing shop using chemical reagents, or a food preparation area, should be sited well away from areas susceptible to pollution, e.g. child care centre or conference room. Similarly, activities such as heavy duty photocopying should be enclosed in area away from densely occupied office space to reduce the impact of dust and ozone on the occupants. The partitioning of the layout may affect the effectiveness of air distribution resulting in stagnant zones with poor air quality.

4.4 Mechanical Ventilation and Air Conditioning (MVAC) System

Adequate and properly designed ventilation systems are the most effective strategies for achieving the IAQ objectives. These strategies are discussed in the following sections.

4.4.1 Design of MVAC System

A building is normally provided with a mechanical ventilation system to introduce and disperse fresh air. Under the Building (Planning) Regulations (Cap. 123F), offices, rooms for habitation, kitchens and toilets are provided with natural ventilation through openable doors and windows. In Hong Kong, most of the offices and public buildings are fitted with MVAC systems. For these buildings, the factors which determine the adequacy and quality of the air supplied by the MVAC system are:

- quality of outdoor air
- fresh air intake

- air filters and cleaners
- siting of ventilation equipment
- recirculation
- insulation
- air distribution systems
- variable air volume system controls
- ventilation controls
- humid climatic conditions
- ventilation of pollution-emitting activities
- ventilation rates

This list is not exhaustive. Building managers and designers should make reference to relevant ASHRAE standards for a comprehensive list of factors to be taken into consideration and detailed guidance.

4.4.1.1 Outdoor air quality

Outdoor air quality should be assessed for compliance with the acceptable objectives specified in Table 3-1 of this GN. If the outdoor air does not meet the prescribed objective, this may result in unacceptable IAQ. Special air cleaners can sometimes reduce the concentration of the air pollutants to acceptable levels: filters with permanganate oxidisers and activated charcoal in the filter remove gases, while carbon impregnated filters reduce VOCs (see *Section 4.4.1.3* below). However, in general, unacceptable outdoor air quality is something which cannot be easily remedied at building level given the difficulty of extracting gaseous pollutants. For these reasons, this GN recommends only that outdoor air quality should be assessed. Apart from those with fresh air intakes situated in locations where there are long periods of poor outdoor air quality, it is generally not encouraged to bring the outdoor air quality to objective by provision of air treatment, e.g. by cleaning with gas filters if pollutant concentrations exceed the minimum levels in Table 3-1.

Controls could be equipped in the MVAC system to temporarily reduce fresh air supply rates below design minimum levels during occupied periods while outdoor air contaminant concentrations exceed the Air Quality Objectives and the MVAC system's filtration capacity to remove these contaminants.

4.4.1.2 Fresh air intakes

Fresh air intake should be placed where the air is likely to be cleanest, taking into account any sources of contaminants close to or upwind of the intake. The latter may include the exhaust outlet from the building or adjacent buildings, traffic, car parks, unloading bays, rubbish chutes, kitchens, and toilets. Intakes should not be located below ground level or close to cooling towers.

Intake openings should locate away from potential pollution sources. They should also be protected from rain entrainment, and covered by a screen to prevent the entry of birds, rodents, and extraneous articles. Care should also be taken to ensure that debris (e.g. bird droppings) does not accumulate at the intake. Apart from interrupting air flow, such debris could become a source of microbiological contamination.

4.4.1.3 Air filters and cleaners

To improve IAQ and protect MVAC equipment, outdoor air—and recirculated indoor air—needs to be filtered to remove dust, bacteria, pollens, insects, soot and dirt particles before it enters the MVAC system. Air cleaning devices, dependent on their compatibility with the general MVAC system, can be incorporated into the system as in-duct devices, or be stand-alone devices. Air cleaning devices usually work by drawing contaminated air through a cleaning mechanism and returning the cleaned air into the indoor environment. In-duct devices clean the air as it passes through the general air distribution system, while the stand-alone models produce a recirculation of the room air. Many different types of air cleaners based on various principles are available. The most commonly used types are:

- particulate filters
- electrostatic precipitators
- gas filters

Like MVAC systems, air cleaners also require regular maintenance and cleaning. Failure to do so may result in the air cleaner either impeding the performance of the general MVAC system, or acting itself as a pollution source releasing collected contaminants from the saturated media.

(a) Particulate filters

Particulate filters are the most commonly used air cleaning devices in modern buildings. Filters are classified according to their efficiencies and types to suit different applications. There are various standards of measurement of filter efficiency and ASHRAE[18] has established procedures for characterising filter cleaning performance in terms of arrestance, dust spot efficiency and minimum efficiency reporting value.

Building designers should select one or a combination of filters depending on the physical characteristics and levels of the dust to be controlled, the capacity of the system to overcome the associated pressure drop across the filter, and the degree of indoor air cleanliness required. Design and supervision of installation of the MVAC system should be conducted by qualified Building Services Engineer; while installation and maintenance of the system should be performed by a Registered Specialist Contractor (sub-register of Ventilation Works Category) under the Buildings Ordinance (Cap. 123).

Building managers should ensure that filters are cleaned or replaced on a regular basis according to the manufacturer's instructions. All filters must be either replaced or cleaned when a maximum pressure drop is reached. To prolong service life, high efficiency filter should be used in conjunction with medium efficiency pre-filters. This prevents premature clogging of the high efficiency filter and frequent replacement which would be uneconomical.

The most effective filters for capturing small particles are High Efficiency Particulate Air (HEPA) filters which have a collection efficiency of at least 99.97% when tested with dioctyl phthalate (DOP) aerosol of diameter at 0.3 mm. HEPA filters have a high resistance to air flow and therefore cannot be installed in the air distribution ductwork of the average MVAC system. There are also stand-alone air cleaning devices employing filters including HEPA filters. These devices work by recirculating the room air through the filter media. Their performance depends on filter efficiencies, air recirculation rates, and air mixing factors. These devices are increasingly used in areas where significant extra dust loads are generated or for sensitive usage, such as hospitals.

(b) Electrostatic precipitators

Electrostatic precipitators are the most common type of electronic air cleaners. Dust particles are electronically charged by one set of electrodes and then collected by another set of electrodes with the opposite charge. The absence of any filtering media means that this type of cleaner has minimal effect on air flow and can be installed in air distribution systems without having to modify the system significantly. Stand-alone electronic precipitators with their own air circulation mechanisms are also common. Electrostatic precipitators offer relatively high efficiencies of up to 95% dust spot values. However the efficiency rate may be substantially reduced if air is very moist or if the collecting plates inside the precipitator become clogged with dust. The latter is a particular problem when buildings are not regularly cleaned and maintained.

[18] ASHRAE Standard 52.2-2017.

Some models of electrostatic precipitators can generate potentially significant amounts of ozone and should be avoided.

(c) Gas filters

Gas filters are designed to remove contaminating gases from the air, through adsorption. Solid sorbents, including activated carbons, molecular sieves, silica gel and activated alumina, are used to remove the various contaminant gases by different adsorbing characterisitics. Activated carbons can adsorb most of the common VOCs in indoor air. Other reactive gases such as formaldehyde can be removed by oxidation using activated alumina impregnated with potassium permanganate. Gas filters can be installed either in-duct or as independent devices. They are commercially available in a range of filter bed designs. Despite the potential usefulness of gas filters, there are currently no widely accepted performance standards. There are also considerable difficulties in determining the breakthrough time of these gas filters in real life usage situations. Gas filters should therefore only be used with good technical support and maintenance.

4.4.1.4 Siting of ventilation equipment

Access should be provided to the internal surfaces of ductwork, air handling units, and other parts of the air circuit to facilitate inspection and cleaning near those areas with high moisture content e.g. cooling coils and humidifiers (if applicable). Trays and sumps for collecting condensate and other water should be accessible for inspection and cleaning.

It is important to ensure that there is adequate plant room space and ceiling space to allow access to the MVAC systems. Where the use of ceiling mounted fan coil unit is deemed necessary, due consideration should be given to the design, installation, and siting of the units to ensure good filtration and accessibility of maintenance.

Water cooling towers of MVAC systems, should be sited so that their exhaust air is not likely to be entrained into any occupied areas, fresh air intakes and building openings. They should also be positioned to avoid drawing contaminated air, such as air from kitchen exhaust, toilet exhaust, car park exhaust, food processing exhaust and laboratory exhaust, into their cooling towers. Cooling towers should be provided with a water treatment system, preferably an automatic dosing system, to prevent microbial growth, corrosion and scaling. Drift eliminators should be installed to minimise the discharge of water aerosols.

4.4.1.5 Recirculation

Recirculated air is extracted from a space and reused as supply air, usually by passing it through an air cleaning and conditioning system. It is important to ensure, e.g. by not siting return air plenums in or near rooms where there are pollution-emitting activities, and by having an adequate filter system, that recirculated air does not contain contaminants of significant level and that it is adequately diluted with fresh air.

4.4.1.6 Insulation

Cold surfaces in building interiors can cause condensation, which in turn can promote microbial growth and damage furnishing materials. Unlined cooling supply ductwork (except ducts within the air- conditioned area) and cold water pipes should therefore be insulated with durable insulating material.

4.4.1.7 Air distribution systems

Air distribution systems determine the supply air rates and fresh air delivery rates. A critical concern in maintaining IAQ is the ability to measure these rates, so that the system can be rebalanced if necessary. Air volume control dampers should be placed at suitable positions to ensure the effectiveness of evenly distributing the air to the areas. The air distribution system should be designed to facilitate measuring and rebalancing by providing access at key points (e.g. the fresh air intake, supply air duct and return air duct) or by incorporating air flow monitoring stations and balancing stations. The design documents should specify the points at which rates can be tested and balanced as well as instructions for testing and rebalancing. See ASHRAE Standard 111-2008 (RA 2017) for detailed guidance.

To help conserve energy while achieving good IAQ, demand controlled ventilation can be considered. A sensor device such as a carbon dioxide sensor can be used for fresh air supply, and the supply air volume can be adjusted using a variable speed drive ventilation fan.

4.4.1.8 Constant Air Volume (CAV) and Variable Air Volume (VAV) system controls

Most MVAC systems in office and public buildings are either constant volume or variable air volume systems. Constant air volume (CAV) air conditioning systems supply a constant volume of air and vary the temperature as required for the thermal comfort. Variable air volume (VAV) systems supply air at a constant temperature but varying airflow. A potential risk with some VAV systems is that when airflow is reduced, the outdoor air supply is also reduced. For these systems, air flow at the air handler should be monitored and, if necessary, a pressure or other device should be installed to ensure that enough fresh air is taken in.

VAV terminals, which modulate the amount of conditioned air supply to the space, should have minimum position stops to ensure that adequate amounts of outside air is supplied to each space at all times to avoid overcooling. Some VAV systems would need to be provided with means of reheating the supply air, e.g. electric duct or VAV terminal heaters. Building managers should ensure that power supply to these reheat devices are not turned off. In addition, the correct functioning of the VAV control system and control devices, such as VAV boxes, thermostats and compressed air circuitry, should be ensured through proper maintenance and regular inspection.

4.4.1.9 Ventilation controls

If ventilation is on and the cooling system is off, it may be necessary to have dehumidifiers operating to prevent excessive humidity.

To ensure thermal comfort, thermostats for MVAC systems should be sensibly located, for example if there is a wide range of temperature, there should be a thermostat in each temperature zone. Thermostats should be located in occupied areas, away from draughts, direct sunlight and equipment which gives off heat.

4.4.1.10 Humid climatic conditions

Hong Kong being an area with humid climate, air conditioning systems should ensure that relative humidity is low compared to the outdoor relative humidity to minimise the problem of microbial growth. ASHRAE Standard 62.1-2016 recommends maintaining the relative humidity of occupied space at 65% or less. Another problem in humid climates is the infiltration of moist outside air which then condenses on interior surfaces. This risk can be minimised by pressurisation. In most buildings the amount of air entering through the fresh air intake should exceed the amount of air exhausted from the building. If the proportions are reversed, i.e. more air is exhausted than is introduced, the indoor pressure will drop drawing fresh air into the building through doors or other leakage sites. The positive pressure created inside could also prevent pollutants from outdoors infiltrate into the building. Building managers should therefore ensure that the supply of fresh air is always equal to or greater than the rate of air exhausted from the building in order to maintain a net positive or neutral average pressure relative to ambient air pressure.

4.4.1.11 Ventilation of pollution-emitting activities

Most buildings use general dilution or ‘supply air’ MVAC systems for areas where there is no active emission of toxic pollutants. These general dilution systems control indoor air by diluting the indoor air with both "fresh" outdoor air and filtered recycled air. The level of dilution depends on the rate of introduction, and total supply, of fresh air. To some extent, the dilution of pollutants can be increased by increasing the fresh air rate. Building managers should bear in mind, however, that increasing supply rates will increase the energy requirement[19].

Special purpose rooms, such as photographic darkrooms, kitchens, toilets, garages and car parks, incineration or other fuel-burning sites, where known toxic or irritating pollutants are emitted, should always be ventilated by local exhaust ventilation, or a combination of supply air and exhaust ventilation. Local exhaust ventilation can remove a large amount of pollutant with a minimal amount of conditioned room air, thus representing high efficiency and low energy costs. The design of local exhaust ventilation is a highly specialised area requiring both ventilation engineering and occupational hygiene expertise.

For pollution sources that are spread over a large area, e.g. VOC emissions from carpet, a local exhaust via MVAC system cannot effectively control the level of pollution, such local exhaust can only control a point source that is stationary. For areas which may temporarily be subject to high levels of pollution, for example during major renovation work or after an accidental spill of a toxic liquid, temporary exhaust systems should be set up where possible. The extraction hood should be positioned close to the pollution source.

For locations where fuel burning appliances are used, it is necessary to provide enough make-up air to supply oxygen for combustion to achieve proper air balance within the space.

4.4.1.12 Ventilation rates

A MVAC system supplies fresh air to the occupied space, and exhausts or allows room air to escape thus expelling bioeffluents and other air contaminants from the building. In the absence of active emission sources such as gas cooking, vehicle exhaust, spray painting, etc., the rate of outdoor air supply should comply with the latest edition of ASHRAE Standard 62.1—*Ventilation for Acceptable Indoor Air Quality* and all current Government regulations. While these outdoor air rates would provide acceptable IAQ under most circumstances, they are not meant to offer complete protection against long-term effects such as the carcinogenic risk of some VOCs.

4.4.2 Operation and Maintenance of MVAC System

In order to ensure proper operation and maintenance of the MVAC systems, it is important that the tasks are carried out by properly trained personnel. Staff involved in operation and maintenance should be trained to understand, operate and maintain the system correctly according to the designer/manufacturer's instructions. An Operation and Maintenance Manual should be prepared by the installation contractor, who should be a Registered Specialist Contractor (sub-register of Ventilation Works Category) under the Buildings Ordinance (Cap. 123).

4.4.2.1 Operation

MVAC systems of specific area should be switched on whenever and as long as it is occupied. It is also a good practice to switch the system on before the occupants return to an area, to minimise the effects of accumulated pollutants over unoccupied periods. For buildings or areas which are particularly vulnerable to condensation and mould growth, e.g. libraries and computer rooms, the dehumidification system may need to remain in operation during extended unoccupied periods.

Occupants themselves can have an important influence on the effectiveness of the MVAC system and should be shown how to operate thermostat and ventilation controls responsibly. Operators should ensure that the outside air controls and dampers are functioning properly.

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[19] Electrical and Mechanical Services Department (2015). *Code of Practice for Energy Efficiency of Building Services* Installation.

Overall, the MVAC system design should cater to the usage of the places it serves (e.g. the MVAC system requirements can be different between offices and restaurants) and the number of occupants the area is designed to accommodate.

4.4.2.2 Maintenance

A comprehensive maintenance regime is vital to ensure that the MVAC system performs as well as it is designed to. This will involve cleaning and inspecting the various components, verifying pressure relationships, adjusting and replacing equipment as necessary. The maintenance service personnel should follow the maintenance manual, manufacturers' recommendation and to make appropriate adjustment in maintenance requirements and frequencies (e.g. Table 8.2 of ASHRAE Standard 62.1-2016 could be referred as a reference), so as to suit operational needs, site conditions, maintenance standard and IAQ requirement. As a general guide:

Monthly services should be carried out on:

- fresh air intakes
- air filters
- air grilles/diffusers
- cooling coils
- all trays and sumps
- condensate drains and water traps
- water cooling towers
- water treatment system of the cooling towers
- MVAC equipment room

Three monthly services should be carried out on:

- fresh air dampers
- automatic controls

Annual services should be carried out on:

- accessible parts of the ductwork
- fans
- fan coil units and terminal units
- supply and return air plenum systems
- refrigerant leakage
- oil leakage

4.4.2.3 Checklist and documentation

Compiling a maintenance checklist can reduce the risk of items being overlooked and save time in the long run. The checklist should identify each routine maintenance activity, the frequency at which it should be performed (based on manufacturers' recommendations wherever possible), and where to find the instructions for carrying out each task. In addition, the frequency of routine maintenance should depend on the extent of equipment usage and the environment of the buildings.

The results of regular inspections, the name of the person making the inspection and the person's company, and the date of the inspection, and similar details of any cleaning/maintenance carried out should be recorded. These records should be kept for future reference. Details of any modifications such as rebalancing or recommissioning of the system, changes to operating procedures, changes in use of space, renovation or retrofits affecting system operations, should be attached to MVAC system design documents. These documents should be kept in an accessible location for the lifetime of the MVAC system.

4.4.2.4 Duct cleaning

Duct cleaning is a delicate process which sometimes involves the use of powerful chemicals to loosen particles. Air duct cleaning can be minimised through the use of high efficiency filters, regular maintenance of filters and other components of the MVAC system, checking air flow rates, and good housekeeping. Should duct work cleaning be deemed necessary, e.g. in the case if ductwork is water damaged or shows signs of biological growth, if debris in ductwork is restricting airflow or dust coming out of supply diffusers, the following principles should be observed:

- cleaning should be scheduled outside occupied hours and carried out by experienced workers
- the air handling unit should be switched off at all times
- negative air pressure should be maintained in the duct area, e.g. with vacuum equipment to prevent particles dispersing into the indoor air
- vacuum equipment should have an outdoor collection unit, or be fitted with a HEPA filter to prevent leakage of fine particulate matter into indoor air
- duct cleaning with high (6,000 cfm or more) volume airflow should be supplemented by gentle brushing to remove loosened particles
- access holes should be carefully sealed on completion and their position noted on mechanical installation plans
- water-damaged or contaminated porous materials should be removed and replaced to prevent microbial growth
- the causes of contamination should be removed to prevent the problem recurring

An industry standard has been developed by the US National Air Duct Cleaners Association (NADCA) using a vacuum test to measure the results of duct cleaning. The standard specifies the maximum surface debris loading of 1 mg/100 cm^2 on non-porous system components after completion of a duct cleaning job[20].

4.5 Renovation Works

Major renovation works should be undertaken outside normal operating hours if practicable to reduce the impact on the occupants. If this is not possible, the renovated area should be effectively isolated (e.g. by temporary partitions or plastic sheeting) and under negative pressure so that cross contamination of the occupied areas by dust and other nuisance/toxic substances is minimised. If necessary, supply air to the renovated and occupied zones should be separated. Use of toxic substances such as solvent based paint should be scheduled outside normal working hours. The air return registers for the works area should be blocked to minimise the spread of dust and other contaminants to adjacent areas. Temporary exhaust ventilation may need to be installed in the works areas to control dust and reduce the level of contaminants. Air filters of the MVAC system where renovation works take place should be inspected and changed more frequently than usual to allow for the higher dust load.

If the isolation of a renovated area affects the airflow, e.g. by erection of partitions, the air conditioning system should be rebalanced when the work is complete.

See also recommendations on Building Design and Construction (*Section 4.2* above).

4.6 Pest Control

Pesticides contain chemicals that can have serious effects on human health, and misapplication of pesticides is a frequent cause of IAQ complaints. The need to use pesticides in non-commercial buildings should be minimised, as far as possible, by caulking and plastering cracks and crevices, improving sanitation and waste management, and physical measures to keep pests at bay.

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[20] National Air Duct Cleaners Association (NADCA) (1992). *Mechanical Cleaning of Non-Porous Air Conveyance System Components (Standard 1992-01*) Washington, D.C.

When it is necessary to use pesticides, managers should follow the Code of Practice published by the Hong Kong Pest Management Association. Pesticide spraying should be carried out outside normal operating hours, and preferably during the weekends for offices. Occupants in areas to be sprayed should be notified in advance to avoid any unnecessary exposure. Pesticides should be applied in targeted locations, with minimum treatment of exposed surfaces. General periodic spraying should be kept to a minimum and may not be necessary. The building manager or other person who organises the pest control activities should have information on the chemical identities and the potential health hazards of all pesticide products used. This information is usually available from suppliers of pesticides in the form of Material Safety Data Sheets (MSDSs).

Building managers should consider using temporary exhaust systems, or running air handling units on 100% fresh air during pesticide application. After application, the ventilation system should be switched on at least 24 hours before occupants return to purge contaminated air. Again, temporarily increasing the fresh air intake to 100% would also reduce the level of contaminants.

4.7 Prevention and Control of Indoor Moulds

To limit mould growth in an indoor environment, it is important to control moisture and limiting dust accumulation. Elimination of moisture intrusion, leaks, and removal of mouldy items, as well as regular or weekly vacuuming using cleaners with HEPA filtration or central vacuum systems with adequate filtration will help reducing mould growth.

Good building design and proper housekeeping can help prevent and control dust accumulation, dampness and water problems. Mould-resistant and easily cleaned building and fitting out materials (e.g. non-porous flooring and wall covering materials), wherever possible, should be used to avoid dust accumulation. MVAC system should be properly designed to efficiently filter the outdoor air pollutants including dust, prevent condensation, and be accessible for regular inspection, cleaning and maintenance. Besides, building management should develop and implement a mould prevention and control plan. This should include a checklist for routine inspection, regular servicing and maintenance and remediation plans for water and mould incidents.

When there is visible mould or mouldy/musty odour, an investigation is needed to determine the location, extent of the damage, and identify the source of the water/moisture problem before working out the cleanup procedures. Hidden areas (e.g. behind wallpapers, under carpet and walls behind furniture) and the components of the ventilation system (e.g. filters, insulation and coils/fins) should also be checked for any moulds or water damage. The problem should be fixed as soon as possible to avoid causing health effects to the occupants and limit further damage to the building. After the cleanup, the facility manager or building management staff should inspect the sites to ensure mould problem has been fixed.

Following are the general tips for mould prevention and control. For more details, please refer to *A Guide on Prevention and Control of Indoor Mould* [21]:

<u>*Minimise dampness and water condensation/leakage/flood*</u>

- Maintain the relative humidity at <70% through MVAC system and use of dehumidifier.
- Close all openings at building envelope and shut off the fresh air/exhaust air outlets to avoid infiltration/ingress of hot humid air including water condensation in the air-conditioning space, in particular, when switching off the air conditioners/chillers and/or ventilation system.
- Avoid condensation on walls, ceiling and floors.
- Prevent leaks and floods, e.g. plumbing leaks, floods from washrooms, seepage from water dispensers and kitchen drains.

[21] Published by the Environmental Protection Department, The Government of the Hong Kong Special Administrative Region.

- Avoid placing water dispensers in areas with carpets.
- Dry water damaged areas and materials within 24 to 48 hours.

Prevent and control dust accumulation
- Use mould-resistant and easy-to-clean materials (e.g. non-porous material).
- Vacuum regularly using cleaners with HEPA filter or central vacuum system with adequate filters.
- Clean air diffusers and exhaust grilles regularly.
- Inspect and clean air ducts regularly.

Clean up mould
- Remove and clean visible moulds once they are found.
- Remove mouldy materials immediately if moulds cannot be cleaned.
- If mouldy odour is detected, take action to locate the mould growth.

Implement mould prevention and control plan
- Set up checklist for routine inspection, regular servicing and maintenance schedules, and remediation plans for water and mould incidents.
- Routine inspection at areas susceptible to dampness and water problems, leaks or maintenance failures.
- Assign facility manager or building management staff to perform mould-related inspections.

4.8 Housekeeping and Cleaning

Housekeeping is important in preventing IAQ problems as it keeps dust levels down and removes dirt which could otherwise become sources of contamination, including mould growth. The cleaning schedule should be arranged with reference to occupancy patterns and activity levels. Daily cleaning of surfaces and vacuuming of floors is advisable for areas with high traffic or which are in constant use during the day. These include most office areas and public places.

When chemical based cleaning agents are used, MSDSs on the cleaning agents should be available to the building manager and other occupants. Generally, cleaning agents emitting vapours with strong odours should be avoided, or only used after normal occupied hours. Building managers should make sure that smells from cleaning products have disappeared before air handling systems switch to their ‘unoccupied’ cycles. Cleaning products should be safely stored.

5. OVERALL INDOOR AIR QUALITY MANAGEMENT STRATEGY

5.1 Basic Principles

IAQ is the result of the interplay of many different and often very complex factors unique to each building. It is not a subject which is susceptible to prescriptive policies. Actions which may improve air quality in one building may not work for other buildings. In order to prevent and deal with IAQ problems, it is therefore necessary to create a management strategy **specific to the building**.

The second principle for an effective management strategy is that it should be **comprehensive**, encompassing the various mechanical, environmental, chemical and human activities which affect the indoor air environment.

The third principle is that it should be an **active** programme, i.e. actively developed to keep up-to-date with changes in, e.g. building use, condition, or modification of the ventilation system, and actively implemented in day-to-day management, maintenance, cleaning and other activities.

5.2 The 7-Step IAQ Management Programme

The following seven steps provide a model of the areas to be covered and the different stages of implementation. The detailed scope and implementation of the IAQ management programme will vary for individual buildings according to the size and type of building and the division of responsibilities, e.g. for the ventilation system, within the building.

Step 1: Allocation of responsibility. Organisations with responsibility for the buildings and/or air conditioning systems should assign overall responsibility for developing and implementing the programme to a person, usually the building manager, with sufficient authority and resources, and with a detailed knowledge of the building.

Step 2: Preparation. The appointed IAQ manager should:

- study this GN and related IAQ literature to reach a basic understanding of factors which affect IAQ
- be aware of new and existing legislative requirements, e.g. affecting MVAC systems
- discuss with building owners the desired IAQ outcome (from the options set out in Table 3-2)
- use IAQ-related information from the building project team regarding ventilation design, building materials used in construction, etc., and information about the operation and usage of the building, to identify potential problem areas
- identify staff and contractors whose activities affect IAQ (a pollutant and source inventory form is provided in Appendix D)
- assign responsibilities for administering the programme to staff within the building management team, while retaining overall supervisory control
- provide appropriate staff training and access to this GN and relevant IAQ objectives and manuals for designated IAQ staff
- place no smoking signs in a prominent position to remind the public that the premises are statutory no smoking areas and maintain such signs in good order[22]

[22] Section 3(3) of the Smoking (Public Health) Ordinance empowers the manager of a no smoking area to enforce the relevant law to ensure no person shall smoke in the premises he manages. If the manager finds anyone smoking in a no smoking area, the manager may request the smoker to extinguish the lighted cigarette, cigar, or pipe. If the smoker is not cooperative and continues to smoke, the manager may request the smoker to leave the no smoking area, or request the smoker to provide his name, address, and documentary proof of identity. If the smoker refuses to cease smoking or refuses to leave the no smoking area, or refuses to provide his name, address or documentary proof of identity despite the manager's request, the manager may call for police assistance if necessary.

Step 3: Review of work contracts and procedures. The IAQ manager should institute or revise as necessary:

- standard procedures for building and equipment cleaning, maintenance, and renovation work
- scheduling of cleaning, maintenance, renovation work and other activities that produce dust or other air contaminants
- specifications for cleaning products, construction materials, furnishings, etc. to be used in the building
- terms of contracts with pest control companies and other parties whose activities may affect building air quality

To promote good IAQ, the IAQ manager should check whether all new or revised procedures are observed, e.g. through periodic inspections and oversight of contractors.

Step 4: Review of occupation contracts. The IAQ manager also needs to define tenants' responsibilities for IAQ and, where appropriate, insert them in occupation leases. The IAQ manager should consider requiring tenants to:

- inform management of alterations (e.g. partition relocation) and redecoration plans
- inform management of dates and duration of any decoration or alteration work
- ensure furnishings and office equipment are placed where they will not obstruct ventilation
- inform management of changes in occupation density
- assist in any IAQ investigation

Step 5: Communication. The IAQ manager should develop, document and communicate policy for (see *Section 6* for detailed advice):

- notifying of activities generating smells and indoor air pollutants
- reporting any spills, leaks or strong smells
- receiving and responding to indoor air complaints

Step 6: Investigation of complaints. The IAQ manager should develop and document procedures for (see *Section 7* for detailed advice):

- conducting an initial walkthrough investigation
- gathering information
- communicating on the progress of an investigation and conducting interviews as part of an investigation
- making more detailed assessments and environmental monitoring
- engaging outside professionals
- testing hypotheses about the causes of an IAQ problem
- taking and evaluating mitigation actions

Step 7: Record keeping. The IAQ manager should:

- keep up-to-date records of IAQ complaints and follow-up action
- obtain MSDSs for materials used and stored in the building

6. COMMUNICATION

IAQ problems can often be prevented or more easily resolved if occupants, building management and any other parties involved communicate effectively. On the other hand, poor communication between occupants and management, for example, lack of information on simple preventive measures, delays in responding to complaints, and absence of feedback can make a simple IAQ problem very disruptive and difficult to handle, especially if there is misunderstanding of the causes of a problem or false perceptions of the health risks involved.

Good communication strategies should begin as early as the design stage of the building, and continue through the operational stage with the development of effective communication between building management and building tenants. Guidelines on consultation in connection with an IAQ investigation is given in *Section 7*.

6.1 Consultation on Design Criteria

The building owner/developer, the architect, the building designer, the building services engineer and, if possible, a representative of prospective tenants, should meet at critical stages of the design and construction process to discuss issues related to the future IAQ in the building. The building owner/developer should specifically consult the other parties on:

- expected use of the building
- for office buildings, the expected IAQ objective (from the options listed in Table 3-2)
- ventilation requirements including special circumstances e.g. car parks
- flexibility of the ventilation systems to cater for any future modification of building use
- expected occupancy rates
- any forthcoming legislation which may impact on the IAQ
- selection of building materials with respect to emission rates of air pollutants
- impacts of some building uses on others in mixed-use buildings e.g. cooking odours from kitchens may upset the adjacent office staff

Any potential IAQ problems that are identified should be factored into building design and planning. These considerations should be documented by the building project management in the form of an IAQ design protocol and passed onto the building facilities manager on completion of the project.

6.2 Communication with Tenants and Contract Workers

Building occupants can strongly influence IAQ, for better or worse. The building manager is responsible for communicating recommendations to promote good IAQ to users and visitors of the building such as contractors, cleaning staff and tenants. The best means of communication will depend on particular circumstances but could include:

- setting up a building management/tenant IAQ committee;
- awareness-raising strategies; and
- incorporation of notification and other requirements in occupation leases and work contracts.

6.2.1 Notification of Pollution-emitting Activities

IAQ problems often arise when people are unaware of restrictions on the use of chemicals and their responsibility to warn other occupants about certain activities, or when occupants are not informed in advance about activities generating air contaminants. For example one group of occupants may complain about a chemical odour, unaware that a neighbouring office is having a new carpet laid. Both the restriction on activities in which pollutants are emitted, and the responsibility for warning should be clearly communicated by the building manager to all tenants and occupants, and contractors in a building. These conditions can be put into the lease agreements and contracts. Activities that may need to be covered include:

- renovation
- pest control
- cooking
- modification to internal partitions
- adjustment of a central air-conditioning system shared by multiple tenants
- use of chemical based agents
- major changes in building use

Tenants should have established easy-to-use channels of communication for such activities. The building manager should act as coordinator, receiving and disseminating information about such activities through individual correspondence and/or public notices.

6.2.2 Other Requirements

Good housekeeping and regular cleaning, careful control of the use and storage of chemicals, and responsible operation of thermostats and ventilation controls, can strongly influence IAQ. It is for managers to consider how to ensure that tenants and other occupants may carry out their responsibilities in these areas, whether through encouragement or by including provisions in building leases. Similarly, managers should consider how to ensure compliance among tenants and other occupiers, such as visitors and customers, with IAQ related rules laid down by the building management.

6.2.3 Promoting Awareness of Indoor Air Quality

In most cases, education and awareness-raising will promote a more intelligent and cooperative response from tenants than contractual obligations. In devising an appropriate awareness-raising strategy in the IAQ management programme, building managers should remember that the objective of achieving good IAQ is to promote tenants' comfort and well-being, and encourage tenants to regard the subject as a shared interest.

Information about IAQ can be spread through inserts on IAQ-related topics in newsletters or bulletins circulated to tenants. Items of interest might include, for example, information on emission standards for different models of office equipment on the market, simple ways of improving the working environment, or advice on how to select environmentally friendly products. The object of such communication is twofold: to encourage behaviour which will promote good IAQ, and to foster mutual trust between the building management and the tenants to help in resolving IAQ complaints when they arise.

Management staff should encourage occupants, through newsletters or health and safety committees, and cleaning staff to report accidents or spills, leaks in the building shell, faults in the ventilation system, or other factors which may create an IAQ problem, as soon as possible.

Contractors who carry out renovation work or other tasks in building should be encouraged to minimise the impact on the air quality of occupied premises. Building managers should specifically discuss with the contractors the use of less hazardous substances, and, as far as possible, restriction of pollutant-producing activities to areas away from building occupants and to periods when the building is empty.

6.3 Making a Complaint

The building manager should have an established procedure for handling IAQ complaints in his IAQ management programme. Building occupants should be made aware of the procedure for making IAQ complaints. Building tenants should make staff aware of internal procedures, for example, who to refer complaints to within the office or organisation (this might typically be a supervisor, health and safety representative, or company doctor). Building management should issue a standard form to anyone seeking to make a complaint. Occupants should be given details of where to obtain and submit a complaint form. After-hours emergency contacts for building management staff should also be available to building tenants. For various reasons, such as for the fear of being victimised by employers or neighbours, some complainants may wish to remain anonymous. Building managers should make provision for this in their complaints procedures. Records of all complaints and subsequent responses should be kept for a period until there is no longer any possibility of litigation.

6.4 Responding to Complaints

6.4.1 Emergencies

The following problems should be treated as emergencies:

- acute or sudden onset of headaches, nausea and complaints of combustion smells. This could be caused by carbon monoxide poisoning. Open windows and evacuate the occupants of the buildings immediately.
- flooded carpet. If wet carpet is not lifted and thoroughly dried within a short period (24 to 48 hours), it is likely to grow mould which could cause serious indoor air problems. Carpet which cannot be dried should be discarded. Dried carpeting should be treated with disinfectant.

The management programme should provide an action plan for dealing with emergencies. This should include information on how to contact internal and external technical staff who can take immediate remedial action.

6.4.2 Non-urgent Complaints

Complaints which do not fall into the above categories such as the following require a response but not immediate action:

- a group of occupants share common symptoms of headaches, eye irritation and respiratory complaints that they attribute to poor IAQ.
- occupants complain of odours and discomfort immediately after new furnishings are installed.

A protocol for responding to this type of non-urgent complaints is an essential part of a good IAQ management programme. The plan should ensure that all IAQ complaints are taken seriously and responded to promptly. This will help to prevent the problem escalating, enable good relations to be maintained within the building and show that IAQ is taken seriously by building management.

If possible, an initial response should be given on the same day the complaint is made. The initial response need be no more than speaking directly, either in person or by phone, to the complainant, acknowledging the complaint and seeking further details if required. If possible, the complainant should also be given a rough idea of how the building management will approach the problem.

The initial response should be followed up with a more substantive response as soon as possible. Communication should be maintained on a regular basis with the complainant during the course of the investigation. Written or verbal communications should:

- confirm the type of complaint received
- state management policy on responding to complaints
- describe what has been done to date, e.g. data collection
- what further investigation and action are planned to correct the problem

- contact numbers for management staff who can provide further information or to whom the complainant should direct any further information he/she may have about the problem

6.4.3 Communication with Other Building Occupants

It is important to maintain tenants' cooperation and trust in the investigatory process in order to solve IAQ problems quickly. For this reason, management should maintain open lines of communication and avoid secretiveness. Factual information about an investigation which is not confidential should be made available to occupants if requested. If the problem seems to be widespread or potentially serious, other tenants should be alerted, preferably through a building management/tenant committee in the first instance. Tenants should be told:

- area of the building which has been subject to complaints
- progress of the investigation
- any factors which have been eliminated from the investigation
- likely length of the investigation
- action taken to improve IAQ and how long before the effects of such action are likely to be seen
- action that remains to be taken
- who to contact for further information

Management should carefully consider the potential effects of information about IAQ investigations on building occupants and always seek to ensure that tenants are provided with information that is accurate, timely and presented in a way that will minimise the risk of a panic response. Building occupants should always be told the timing, scope and purpose of any forthcoming investigation of their area. This can be done by posting or distributing a notice.

6.4.4 Confidentiality

Many IAQ complaints are confidential or sensitive. Some may be driven by other agenda such as poor industrial relations. Staff who handle complaints should be given clear instructions on how to deal with such complaints and observe the following basic rules:

- act and be seen to act in a professional and impartial manner at all times;
- do not participate in discussions on matters not related to the building environment;
- handle any personal medical information which may be produced in the course of an investigation, in accordance with the legal requirements on medical confidentiality (Personal Data (Privacy) Ordinance); and
- assure the individuals involved that their privacy will be respected.

7. INVESTIGATION

The task of investigating an IAQ problem is like that of a detective investigating a crime. In both cases it involves collecting information, setting and testing hypothesis, gradually eliminating possible causes, collecting more information and so on until the suspect—or the most likely source of air contamination—has been identified. The investigating team then seeks to remove or reduce the alleged source through mitigation measures. The re-investigation should be conducted if mitigation of that source does not help to resolve the IAQ problem.

The IAQ investigator, usually staff of the building management or an external person with relevant expertise, should be aware that many complaints or symptoms attributed to poor IAQ may in fact be due to other causes such as poor lighting conditions (glare, flicker or absence of natural light), noise, work stress, ergonomic problems, unrelated personal medical conditions, or psychosomatic factors. In other cases, symptoms may be due to a combination of factors, some of which are related to IAQ, for example, the odours of VOCs coupled with excessive stress may make an individual feel more irritable.

The approach and tools needed for an IAQ investigation will vary according to the nature of the complaint, building use, and the investigator's experience of IAQ problems. Investigators with more experience, or who are familiar with the building being investigated, may be able to skip a few steps. However, the general strategies and assessment tools set out below are relevant to most cases. They should be incorporated into the master IAQ management programme together with standard methods for environmental monitoring, and standard information gathering procedures.

7.1 Gathering Background Information

The first task on receiving a complaint is to collect relevant background information. This can be done by building management staff. Depending on the nature of the complaint, they should obtain:

- further details of the complaint such as whether it is continuous or intermittent, or whether other occupants experience the same symptoms
- details of the design of the MVAC system with as-installed plans
- information on chemical agents used in the area of complaint
- normal work activities and occupancy density of the area
- maintenance schedule of the MVAC system
- records of previous complaints in the same area
- any unusual activities in or near the area around the same time of the complaint, e.g. renovation works

This information will help to eliminate some possible causes and provide directions for further investigations.

7.2 Initial Walkthrough Inspection

The initial walkthrough inspection should provide enough information to enable the investigator to form a hypothesis about the cause of complaint, perhaps attempt to correct the problem, and make a plan for a more detailed assessment. The inspection is usually performed by members of the building management staff who are familiar with the building facilities or an external IAQ professional. To gain a better feel for how the space is used, the investigator may wish to be accompanied by a regular occupant of the area being investigated.

In the course of the walkthrough, the investigator should establish from the occupants and/or his own observations on:
- building layout and floor plan
- general thermal environment of the inspected area e.g. temperature, humidity and the

presence of draughts
- types of activities undertaken
- other parameters of the physical environment e.g. lighting, noise, vibration
- general housekeeping and cleaning programme
- use of any chemical agents including cleaning agents, pesticides, and glues
- signs of water condensation and water damages
- visible signs or musty odour of mould growth
- staining and discoloration of ceiling tiles, walls or carpets
- any particular odours
- any renovation works
- distribution of supply vents and return air grilles
- any obstructions to the air distribution e.g. covering supply air vents to reduce draughts
- any non-IAQ related problems affecting the complainant such as noise, poor illumination or vibrations

The investigator should also inspect:

- the cleanliness of the air handling plant rooms
- the conditions of air filters
- the general sanitation of the cooling towers and their locations
- the on-site MVAC system maintenance records

It is not usually necessary to take environmental measurements on an initial walkthrough inspection. However, the investigator may wish to make a rough test of, for example, the temperature, humidity, air flow, the presence of a specific chemical, or other parameters thought to be related to the complaint. Air temperature and humidity can be measured using a simple sling psychrometer, air current can be tested by a smoke tube, and presence of a specific chemical can be tested by a detector tube.

7.3 Communication with Appropriate People

Information from the relevant personnel may need to be gathered at different stages of the investigation. The people who may need to be consulted are:

- original complainant(s) for more details about the problem
- other occupants in the building, who may or may not have a similar complaint, for verification and for determining the exact location of the problem
- MVAC system maintenance contractor for details of defects and repairs
- contractors or other workers in the building for information of works and substances used
- medical practitioners for advice on the possible causes of symptoms related to the complaints (The information in personal medical records is confidential, and should only be gathered after obtaining the written consent of the patient)

The information can be gathered through personal interviews, telecommunication or correspondence, as appropriate. More reliable and clearer information regarding occupants' complaints and symptoms is often obtained by personal interviews. A questionnaire survey, such as the example given in Appendix D may be used for this purpose. Building occupants including the complainant can be interviewed during the initial walkthrough inspection or on a separate occasion. However, if circumstances indicate that the potential interviewee may be reluctant to talk openly about the complaint, the investigator should arrange a private interview on another occasion.

7.4 Review of Initial Findings

The first information gathering and walkthrough inspection should enable an investigator to identify:

- exact nature of the complaint
- number of occupants affected
- any changes in the building system parameters, e.g. temperature, operation of air conditioning, which match the timing and location of complaints
- possible deficiencies in the performance of the MVAC system
- any occupant interference with the ventilation system, e.g. improper thermostat setting, partial sealing up of air grilles/diffusers, opening of windows, etc.
- any obvious causes of air pollution
- other factors which may cause discomfort such as overcrowding, noise, poor lighting or vibration

The smells observed by the complainant are often good indicators of the source of the problem (see Table 7-1).

Table 7-1: Odours as Problem Indicators in Indoor Environment

Description	Problem
Auto exhaust, diesel fumes	Carbon monoxide
Body odour	Overcrowding, low ventilation rate (high carbon dioxide levels)
Musty smell	Microbial material, wet surfaces
Chemical smell	Formaldehyde, pesticides, other chemicals
Solvent smell	VOCs
Wet cement, dusty, chalky smell	Particulates, humidification system
Sewage gas odour	Water traps dry in floor drains in washrooms or basement

Symptoms may also provide a clue to the cause of the problem (see Table 7-2), although it is often difficult to prove a direct causal relationship especially where a combination of factors are involved.

Table 7-2: Symptom Patterns as Problem Indicators in Indoor Environment

Description	Possible problem
Thermal discomfort	• MVAC system • Extreme weather conditions which exceed design capacity of MVAC equipment • Drafts or stagnant areas • Excessive radiant heat gain or loss
Headache, lethargy, nausea, drowsiness, dizziness	• If onset is acute or severe, carbon monoxide (see *Section 6.4.1 'Emergencies')* • Other pollutant emissions • Poor ventilation
Congestion; swelling, itching or irritation of eyes, nose or throat; dry throat; possibly accompanied by non-specific symptoms (e.g. headache, fatigue, nausea)	• If only few occupants affected, may be allergic reaction caused by: a) poor sanitation, water damage, contaminated MVAC system b) outdoor allergens (e.g. pollen) c) irritating chemicals such as formaldehyde or those found in some solvents
Cough, shortness of breath, fever, chills and/or fatigue after returning to the building	• Hypersensitivity pneumonitis or humidifier fever caused by gross microbial contamination due to sanitation problems, water damage, or contaminated MVAC system
Discomfort and/or health complaints that cannot be readily ascribed to air contaminants or thermal conditions	• Poor lighting, noise, vibrations • Ergonomic or job-related stress

Where information provides a strong indication of the potential cause of the problem, simple remedial measures can be instituted immediately. If these measures do not solve the problem, or if the initial findings are inconclusive, a detailed assessment should be carried out. It is generally more cost effective to undertake a detailed assessment than to waste time and resources on mitigation measures based on inadequate information.

7.5 Detailed Assessment and Environmental Monitoring

Professional scientific and mechanical expertise may be needed for some stages of the assessment process, for example in analysing air samples, or examining the MVAC system. If such expertise is not available in-house, external assistance should be sought.

7.5.1 Pollutant Pathways

If the affected areas are confined to one or a few areas, it may be possible to find the source of the IAQ problem by analysing the air flows and openings by which an airborne pollutant can spread. This involves easy-to-use equipment and could be done by a member of the building staff. The investigator should, by making a detailed inspection of the site, and studying architectural and mechanical drawings, and a sketch plan of the complaint area, establish potential pollutant pathways between the complaint area and the outdoors or other possible sources of pollution. These may include doors, openable windows, stairways, lift shafts, duct work, and cracks in building fabric.

The next step is to find out whether differences in air pressure and the consequent pattern of airflow would allow pollutants to travel down the pathways identified. The direction of air flow can be roughly worked out by observing dust patterns on door frames or tested using a chemical smoke tube. Differences in pressure can be measured with a manometer.

Once the investigator has developed a hypothesis concerning a likely route or pathway, he can test it by releasing a chemical smoke at the entrance to the suspected pathway and asking an assistant to identify the smell in the complaint area. Tracer gases, in conjunction with monitoring equipment, can also be used for this purpose. If a pollutant pathway is discovered, the IAQ problem can usually be solved simply by blocking the pathway or altering the pressure relationship between different spaces.

7.5.2 Assessing Ventilation and Thermal Environment

The preliminary investigations should indicate what, if any, aspects of the ventilation system should be subject to detailed assessment. For example, if a potential cause is:

- uneven air distribution, the investigator should measure total air flow at various MVAC supply outlets;
- inadequate supply of fresh air, the assessor should take a direct measurement by using an anemometer to measure the amount of fresh air supplied, or use tracer gases or other techniques to measure the total fresh air rate;
- dirt or microbial growth in the MVAC system, the assessor should make a detailed inspection of the sanitary conditions of all accessible components of the MVAC system; and
- physical comfort, and spatial or temporal variations in temperature and/or humidity, the assessor should measure the non-directional average air movement.

Appendix D provides a MVAC checklist of items to be covered. The form can be used to record the results of the detailed inspection.

7.5.3 Sampling for Air Contaminants or Indicators

If the complaint cannot be attributed to any of the above causes, and if there is a suspected chemical cause of complaint, it may be necessary to test concentrations of individual pollutants. Unless there is a strong indication, such as a known source of a certain pollutant in a nearby building, of the identity of the suspected chemical contaminant, it is advisable to begin with the relatively simple and inexpensive tests for compounds (carbon dioxide and carbon monoxide) associated with building problems. These can help the investigator define the affected area and find out more about the cause of the problem. A carbon dioxide reading of over 1,000 ppmv is a good indicator of under-ventilation, while a carbon monoxide reading of over 5 ppmv indicates unexhausted combustion products or vehicle exhaust entrainment.

Testing for other chemical contaminants is an expensive and not necessarily very effective investigative tool. To maximise the benefits, it is important to use recognised standard testing methods, adopt an appropriate sampling strategy, and interpret the results in light of other information collected in the course of the investigation.

Assessment methods. The general environmental monitoring and testing methods for the common pollutants found in air are given in *Section 3.5* of this GN and *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019).* The testing or the analysis of results may require sophisticated equipment and professional scientific expertise.

Sampling strategy. To find out the maximum levels of exposure which occupants experience, samples or readings should be taken in the worst case conditions, i.e. as near to potential source of pollution as possible, and in the morning for pollutants arising from building materials, furnishings or microbial growth in ventilation systems, or towards end of working day for pollutants generated by occupants' activities, e.g. photocopying. For comparison, air samples should also be taken:

- outdoors
- for a problem which appears to be intermittent, from the complaint area at times when no problems are experienced
- for a problem confined to specific areas, from indoor locations where no complaints have been made
- (for consideration) from different ventilation zones, e.g. perimeter and interior areas

Interpretation of results. The results of any detailed assessment may be interpreted in light of the IAQ objectives set out in *Section 3*. Investigators should take into account:

- concentration levels of contaminants in the complaint area compared with those in samples taken from the outdoor air and other indoor areas. A significant variation in concentrations suggests that those chemicals may be causing or contributing to an IAQ problem
- variation in individual susceptibility to certain chemicals

7.5.4 Asbestos Investigations

It is a legal requirement under the Air Pollution Control Ordinance (Cap. 311) that a Registered Asbestos Consultant and a Registered Asbestos Laboratory should carry out asbestos investigations. The investigation itself should conform to the Environmental Protection Department's Codes of Practice (see Appendix C).

7.6 Concluding an Investigation

It is not unusual for an IAQ investigation to conclude without identifying any IAQ related causes. As mentioned above, IAQ investigations involve a process of information gathering and hypothesis testing which may have to be repeated several times. Difficult investigations may take weeks or months, and even then it may not be possible to draw firm conclusions. There obviously comes a point when it is no longer sensible to pursue the investigation further. When that point is reached largely depends on the seriousness of the complaint, the number of occupants affected, and the resources available. Complaints alleging serious health effects should be investigated until all potential IAQ-related causes are eliminated. Complaints about occasional unknown odours which have no apparent health effects, on the other hand, do not need to be investigated exhaustively. The reasons for closing a complaint investigation should be documented as a part of the IAQ management programme and communicated tactfully to the complainant.

8. MITIGATION

There are numerous solutions to IAQ problems. Some involve expensive modification of existing building layout or installations, while others require simple administrative measures. There are also situations where a combination of different strategies is needed to resolve the problem.

8.1 Selecting a Mitigation Strategy

Mitigation measures can generally be divided into four categories:

- Source control
- Ventilation
- Air cleaning
- Administration measures

The most effective measure or combination of measures for solving a particular problem will vary from building to building. Similar problems in different buildings may require radically different solutions and it is therefore impossible to prescribe the best course of action in each case. The parties involving in solving IAQ problems should formulate specific mitigation measures for their particular buildings themselves, using the guidelines in this GN as a general reference.

When selecting an appropriate strategy or strategies, the key factors to be considered are:

- whether a temporary or permanent solution is required, i.e. whether it involves a temporary or permanent problem
- which, of the strategies available, will be the most effective in the particular circumstances
- practicality
- installation and maintenance costs
- durability
- energy efficiency
- any problems, e.g. noise, which a proposed solution may create

An IAQ investigation may reveal that the problem causing the complaint is unrelated to IAQ factors. It may turn out to be the result of other building-related factors, for example noise from computer printers, or reflected glares from visual display units. These problems need to be resolved by mitigation measures, such as installation of acoustic booths or rearrangement of office furniture, which are outside the scope of this GN.

8.1.1 Source Control

Source control should always be considered as the first option. It is the most direct and usually the most effective way of improving IAQ. In some cases it may be the only available effective option. Some examples of effective source control are:

(a) Total elimination of the pollutant source

Examples: removal of friable asbestos insulation
discarding a ceiling tile contaminated with mould

(b) Substituting a source with a lower emission rate or emitting a less hazardous pollutant

Examples: using a water based/polyurethane paint to replace an organic solvent based paint
using a cleaning agent with a lower but adequate chemical strength

(c) Sealing the source or blocking the pollutant pathway

Examples: sealing the surfaces of some furniture items to cut formaldehyde emission
ensuring offices close to car parks and loading docks are under positive pressure

(d) Relocating the source away from occupied spaces

Examples: relocating photocopiers away from the general working area

(e) Minimizing source factors conducive to mould growth

Examples: controlling relative humidity; minimizing water condensation, leakage and flood
preventing and controlling dust accumulation

The best choice of source control—whether total elimination, relocation of polluting activities, etc.—will depend on the practicality and cost of implementation in particular circumstances.

8.1.2 Ventilation

The installation of new ventilation systems or modification to existing systems is an important means of pollutant control. If, for example, levels of carbon dioxide or other pollutants are unusually high (typical office levels of carbon dioxide are in the range 600–800 ppmv), the ventilation system may not be functioning properly. The effectiveness of existing ventilation systems can be improved by:

- adjusting and rebalancing the ventilation system to the level appropriate to the occupancy levels, and sources of heat and pollutants
- increasing the outside air supply
- removing obstructions from the return plenum
- controlling pressure relationships between areas with pollutant sources and other areas
- introducing (temporary or permanent) local exhaust ventilation for activities emitting highly toxic or highly concentrated pollutants such as cooking on gas appliances, photographic processing and soldering
- changing the positioning of supply and return diffusers, or alternatively adjusting their settings, to obtain a better relationship between source and distribution of air
- upgrading the air distribution system, e.g. by increasing fan capacity in the supply or return system

Investigators must ensure that any modification of the ventilation system is carried out in accordance with the "Energy Efficiency Requirements of Air Conditioning Installations" in the *Code of Practice for Energy Efficiency of Building Services Installation*[23] and other relevant codes. Ventilation systems will only deliver their designed function if they are serviced and maintained regularly (see *Section 4.4.2* for good maintenance practice). A poorly serviced system will not only give the building occupants a sense of false safety, but may also add to the problem of IAQ as the system itself can be a source of dust and other pollutants, including biological contaminants.

8.1.3 Air Cleaning

Another option is to upgrade air filtering systems to clean the air more thoroughly. Installation of particulate filters (*Section 4.4.1.3(a)*) with high dust spot efficiency (85% or higher) and electrostatic precipitators (*Section 4.4.1.3(b)*) can mitigate problems caused by particulate pollution or fungal spores. Gas filters (*Section 4.4.1.3(c)*) can, in addition, reduce levels of common VOCs, ozone,

[23] Published by the Electrical and Mechanical Services Department, The Government of the Hong Kong Special Administrative Region.

hydrogen sulphide and reactive gases such as formaldehyde in the air. As with ventilation systems, the performance of air cleaners will depend on regular cleaning and maintenance. Professional advice should be sought to select the device most appropriate to the problem and compatible with existing MVAC equipment.

8.1.4 Administrative Action

Some IAQ problems can be solved simply by taking administrative action such as:

- rescheduling activities such as renovation works or pest control to outside normal working hours
- limiting the period an individual can spend operating equipment that may produce pollutants
- relocating more susceptible individuals from the area where they experience symptoms
- adjusting the indoor temperature and relative humidity, where practicable and appropriate, to minimise water condensation on wall surfaces to prevent mould growth

Even if the problem cannot be solved by administrative measures, these administrative measures may provide some interim relief while a longer term solution is found. The advantage of this approach is that measures can be implemented immediately and at minimal cost. Managers should monitor compliance with any administrative measures to ensure they have the desired effect.

8.2 Evaluating Mitigation Measures

The success or otherwise of any mitigation strategy can only be judged by the effect of the strategy on the level of complaints and on the concentrations of pollutants. Unfortunately neither of these is a very reliable guide and managers should exercise caution in drawing conclusions.

The level of complaints may be affected by subjective judgements, e.g. about the way in which the problem has been handled, as well as changes in comfort levels and health symptoms resulting from effective mitigation measures. Occupants may, for example, continue making complaints if they are not satisfied with the way the problem has been addressed, or, conversely desist from making complaints if they know that firm action has been taken even though the problem is not solved. Complaints which continue for a long time may indicate that the mitigation strategy was unsuccessful, or, if complaints continue at a reduced level, the existence of more than one IAQ problem.

The effect of mitigation measures on concentration levels of specific pollutants can be tested scientifically but not necessarily very accurately. Test conditions, time of day, location, etc., should replicate as closely as possible the “worst case” conditions in which the original sample was taken. Even so, normal fluctuations in concentrations of air pollutants may make it difficult to make any meaningful before and after comparisons. The other risk is that the pollutant measured may not be causing the problem.

If, after implementing successive mitigation measures, there is still a significant problem it may be advisable to seek external assistance.

9. PROFESSIONAL ASSISTANCE

Achieving good IAQ is often simple common sense once the background and the principles are understood. The majority of IAQ issues can be handled by the building occupants and/or building management staff with basic knowledge of the MVAC system, or, if detailed inspection or adjustment of the MVAC system is involved, by external MVAC contractors.

In any of the following situations, it may be advisable to engage external professional assistance in investigating complaints or mitigating identified problems:

- a number of different or complicated IAQ and non-IAQ related factors are involved
- in-house investigation and mitigation strategies have failed
- environmental monitoring using specialised equipment and training is needed
- a susceptible population, e.g. children, are affected
- delays in solving the problem could have serious health consequences
- there is a lack of information on the alleged pollutants
- relationships between the occupants and the building management have become strained

The type of professional assistance required will depend on the nature of the complaint. As IAQ is a multidisciplinary subject, professionals with diverse backgrounds and experience will be needed to solve different types of problem. For example, suspected microbiological infection may require a professional with a background in microbiology and environmental pollution. Faults in the performance of the MVAC system may require a ventilation engineer. Chemical pollutants may require an environmental scientist or occupational hygienist with a background in chemistry.

When an external professional is needed, the building manager or other responsible personnel should approach more than one firm of suitably qualified consultants, brief them on the nature of the complaint and obtain a proposal from each for evaluation. Proposals should be evaluated according to the following criteria:

- academic and professional qualifications
- experience of IAQ issues, and any experience of handling similar problems to the one under investigation
- knowledge of relevant codes and legislation
- company reputation
- composition of assistant staff, if any
- cost
- proposed scope of professional service
- proposed methodology and assessment tools
- proposed timetable
- internal resources needed to support the external consultant

It may be useful to seek references from other organisations who have used the potential candidates before.

9.1 Professionals with Relevant Expertise

9.1.1 Environmental, Health and Safety Consultants & Environmental Monitoring Laboratories

A number of environmental health and safety professionals are available in Hong Kong to investigate and advise on IAQ matters. They have a duty to provide scientifically sound information and advice to their clients, to perform investigations or analyses according to established protocols and standards, and to report their findings accurately. For laboratory analysis, the Hong Kong Accreditation Service (HKAS) of the Innovation and Technology Commission (ITC) publishes an annual directory of the lists of laboratories accredited under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) and their services as well as overseas accreditation schemes that have established mutual recognition agreements with HOKLAS. The use of overseas laboratories with proper equipment set up and quality control procedures and with mutual recognition agreement (MRA) with HKAS could be an alternative provided that the samples are properly preserved and packed during the transportation

9.1.2 Ventilation Consultants and Contractors, and Registered Professional Engineers

Ventilation consultants can advise the building/system owners on the relationship between ventilation and IAQ. Registered Professional Engineers in building services or mechanical disciplines are experienced professionals with responsibility for design, supervision of installation, inspection, witnessing commissioning tests and certification of ventilation systems. Registered Specialist Contractors (sub-register of Ventilation Works Category), in accordance with Buildings Ordinance (Cap. 123), are eligible for installation, alteration, extension, testing, commission, repair and maintenance of ventilation systems. Engineers and contractors should ensure that they perform their responsibilities in accordance with the most up-to-date standards and legal requirements.

9.2 CIBs for Indoor Air Quality Certification

To participate in the IAQ Certification Scheme for Offices and Public Places, owners/management of the buildings should engage a CIB accredited by the Hong Kong Inspection Body Accreditation Scheme (HKIAS) operated by Hong Kong Accreditation Service or by an accreditation body who is a recognised partner of Hong Kong Accreditation Service under mutual recognition arrangement sfor IAQ measurement and issuing of certificates where IAQ objectives are complied.

Details on how to participate in the IAQ Certification Scheme and other certification requirements are set out in *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)*. The Guide is available at the IAQ Information Centre or at http://www.iaq.gov.hk.

APPENDIX A: LOCAL REGULATIONS / GUIDANCE ON INDOOR AIR QUALITY

I. Laws of Hong Kong

1. Air Pollution Control (Dust and Grit Emission) Regulations, Cap. 311B
2. Air Pollution Control (Furnaces, Ovens and Chimneys) (Installation and Alteration) Regulations, Cap. 311A
3. Air Pollution Control (Smoke) Regulations, Cap. 311C
4. Air Pollution Control (Specified Processes) (Specification of Required Particulars and Information) Order 1993, Cap. 311G
5. Air Pollution Control (Specified Processes) (Specification of Required Particulars and Information) Order 1994, Cap. 311N
6. Air Pollution Control (Specified Processes) Regulations, Cap. 311F
7. Air Pollution Control Ordinance, Cap. 311
8. Building (Planning) Regulations, Cap. 123F
9. Building (Ventilating Systems) Regulations, Cap. 123J
10. Occupational Safety and Health Ordinance, Cap. 509
11. Places of Public Entertainment Ordinance, Cap. 172
12. Public Health and Municipal Services Ordinance, Cap. 132
13. Smoking (Public Health) Ordinance, Cap. 371
14. Ventilation of Scheduled Premises Regulation, Cap. 132CE

The above legislation is available for view at http://www.elegislation.gov.hk

II. Local Guidance Notes/Codes of Practice

A. Environmental Protection Department

1. A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019), January 2019
   http://www.iaq.gov.hk

2. A Guide on Prevention and Control of Indoor Mould, 01/2019
   http://www.iaq.gov.hk

3. A Guide to the Air Pollution Control (Furnaces, Ovens and Chimneys) (Installation and Alteration) Regulations, 1999
   http://www.epd.gov.hk/epd/sites/default/files/epd/gn_pdf/GN2014P008-2017_e_txt.pdf

4. Control of Oil Fume and Cooking Odour from Restaurants and Food Business
   https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/guide_ref/files/pamphlet_oilfume_eng.pdf

5. Practice Note for Professional Persons—on Handling of Asbestos Containing Materials in Buildings, ProPECC PN2/97, July 1997
   http://www.epd.gov.hk/epd/sites/default/files/epd/english/resources_pub/publications/files/pn97_2.pdf

6. Practice Note for Professional Persons—Control of Radon Concentration in New Buildings, ProPECC PN 1/99, 1999
   http://www.epd.gov.hk/epd/sites/default/files/epd/english/resources_pub/publications/files/pn99_1.pdf

7. Hong Kong Planning Standards and Guidelines—Chapter 9 on Environment
   http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/index.html

8. Practice Note for Managing Air Quality in Air-conditioned Public Transport Facilities—Buses (ProPECC PN1/03), November 2003
http://www.epd.gov.hk/epd/sites/default/files/epd/english/resources_pub/publications/files/pn03_1.pdf

9. Practice Note for Managing Air Quality in Air-conditioned Public Transport Facilities—Railways (ProPECC PN2/03), November 2003
http://www.epd.gov.hk/epd/sites/default/files/epd/english/resources_pub/publications/files/pn03_2.pdf

10. Practice Note for Managing Air Quality in Air-conditioned Public Transport Facilities—Ferries (ProPECC PN1/15), October 2015
http://www.epd.gov.hk/epd/sites/default/files/epd/english/resources_pub/publications/files/pn15_1.pdf

B. Labour Department

1. Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace, 2002
http://www.labour.gov.hk/eng/public/oh/AirImpure.pdf

2. A Simple Guide to Health Risk Assessment, Office Environment Series OE 4/2004—Ventilation, November 2004
http://www.labour.gov.hk/eng/public/oh/Ventil_Eng_2004.pdf

3. Air Impurities in the Workplace, 2009
http://www.labour.gov.hk/eng/public/oh/impurities.pdf

4. Guidance Notes on Ventilation and Maintenance of Ventilation Systems, 2005
http://www.labour.gov.hk/eng/public/oh/OHB5a.pdf

C. Food and Environmental Hygiene Department

1. A Guide to Application for Restaurant Licenses, 2016 Edition
http://www.fehd.gov.hk/english/howtoseries/forms/new/A_Guide_to_Restaurant.PDF

D. Electrical and Mechanical Services Department

1. Code of Practice for the Prevention of Legionnaires' Disease, 2016
https://www.emsd.gov.hk/filemanager/en/content_645/COP-PLD_2016.pdf

2. Code of Practice for Energy Efficiency of Building Services Installation, 2015
http://www.beeo.emsd.gov.hk/en/pee/BEC_2015.pdf

E. Architectural Services Department

1. General specification for air-conditioning, refrigeration, ventilation and central monitoring & control system installation in government buildings of the Hong Kong Special Administrative Region, 2017 Edition
https://www.archsd.gov.hk/media/279793/acgs2017.pdf

F. Miscellaneous

1. HK-BEAM, BEAM Plus Interiors—Commercial, Retail and Institutional Version 1.0
https://www.beamsociety.org.hk/files/download/download-20131128124721.pdf

2. HK-BEAM, BEAM Plus for New Buildings Version 1.2
https://www.beamsociety.org.hk/files/download/download-20130724174420.pdf

3. HK-BEAM, BEAM Plus for Existing Buildings Version 2.0 Comprehensive Scheme
https://www.beamsociety.org.hk/files/download/download-20160324075326.pdf

4. HK-BEAM 4/04 for New Buildings
https://www.beamsociety.org.hk/files/download/download-20120314044753.pdf

5. HK-BEAM 5/04 for Existing Buildings
https://www.beamsociety.org.hk/files/download/download-20120314044807.pdf

6. HK-BEAM 1/96R, An Environmental Assessment for New Office Designs
https://www.beamsociety.org.hk/files/download/download-20120607204631.pdf

7. HK-BEAM 2/96R, An Environmental Assessment for Existing Office Buildings
https://www.beamsociety.org.hk/files/download/download-20120607204700.pdf

8. HK-BEAM 3/99 An Environmental Assessment for New Residential Buildings
https://www.beamsociety.org.hk/files/download/download-20120607204522.pdf

9. Guide to the Management of Indoor Air Quality for Hotels in Hong Kong, Hong Kong Polytechnic University
http://www.bse.polyu.edu.hk/research/BEP/hotels14000/acrobat/iaq_guide.pdf

10. Hong Kong Pest Management Association—Code of Practice
http://www.hkpma.org.hk/file/Eng_Code_of_Practice_for_Pest_Control_Companies_1.pdf

APPENDIX B: GUIDELINES ON OPTIMUM INDOOR AIR TEMPERATURE, RELATIVE HUMIDITYAND AIR MOVEMENT

1. OBJECTIVE

The guidelines are to assist relevant professionals and building managements to determine optimum temperature, relative humidity and air movement settings of the mechanical ventilation and air conditioning (MVAC) system for occupants in air-conditioned offices and public places.

2. INTRODUCTION

2.1 Air temperature, relative humidity and air movement inside an air-conditioned office or public place are the key factors if a comfortable environment is to be provided for its occupants. Apart from thermal comfort, energy saving and prevention of growth of mould and fungi are also relevant when determining the optimum temperature, relative humidity and air movement settings. The relevant considerations for these three factors are set out in sections 3, 4 and 5 below, respectively.

3. THERMAL COMFORT

3.1 Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and it can be varied from one individual to another. As thermal comfort is a subjective perception, it is not possible to have a single comfort level that can satisfy all people in a space. The primary factors including metabolic rate, clothing insulation, air temperature, mean radiant temperature, air movement and relative humidity should be addressed when defining conditions for thermal comfort.

3.2 Temperature has the most direct effect on thermal comfort while the relative humidity relates to thermal comfort by affecting the human body's ability to lose body heat through perspiration. In addition, clothing of the occupants and air movement in the air-conditioned space are also important factors. For example, it is often possible to provide at a higher indoor temperature the same thermal comfort level that may be experienced at lower temperatures through the wearing of suitable light clothing and increasing air flow by fan in summer time.

3.3 To determine the indoor temperature, relative humidity and air movement required for thermal comfort, all relevant factors mentioned in paragraph 3.1 above have to be duly addressed in designing and operating the air-conditioning system of the concerned space by making reference to international guidelines such as the *ASHRAE Standard 55-2017 and BS, EN 15251:2007*.

3.4 The user may observe some typical comfort zones shown in the standards such as Fig. 5.3.1 of *ASHRAE Standard 55-2017* and Table A.2 of *BSEN 15251:2007*, for reference. Based on different usages of premises and all relevant factors for thermal comfort, air temperature from 20°C to 26°C (20°C to 23°C in winter time and 24°C to 26°C in summer time), relative humidity from 40% to 70% and air movement not exceeding 0.2m/s[1] are optimum ranges for most occupants in air-conditioned offices and public places.

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[1] It is acceptable to use elevated air speed to increase the upper temperature limit for the comfort zone in certain circumstances as described in ASHARE 55-2017 Section 5.3.3.

4. ENERGY CONSERVATION

4.1 Air conditioning accounts for a very significant amount of the total electricity consumption of commercial buildings in Hong Kong. Optimizing the indoor air temperature, relative humidity and air movement can help save significantly the energy consumed in running the air conditioning system. In addition, as electricity generation is the major emission source of air pollutants and greenhouse gas in Hong Kong, reducing the consumption of electricity by setting indoor air temperature appropriately can also help combat the air pollution and global warming.

4.2 To save energy, indoor air temperature should not be set unnecessarily low during summer. The Government has set an example by encouraging their offices to maintain indoor temperature at 25.5°C. In addition, the Government launched the Energy Saving Charter on Indoor Temperature in June 2012 and June 2013 under which developers and property management companies pledged to maintain an average indoor temperature of the common areas in shopping malls, shops and office buildings between 24ºC – 26ºC in summer. In winter time, operation of the space heating facility is not encouraged for the sake of conserving energy unless for very cold weather conditions.

4.3 The energy saving measures recommended by the Energy Efficiency Office of the Electrical and Mechanical Services Department (e.g., those presented in their *Energy Saving Tips for Offices*) and other professional institutions should also be considered. Many of these measures, for example, dress light to minimise the use of air conditioner and use fans to increase air circulation, etc., will also be useful in reducing the cooling demands of the premises.

5. PREVENTION ON MICROBIAL GROWTHS

5.1 Microbial pollution involves hundreds of species of bacteria and fungi that grow indoors when sufficient moisture is available. Exposure to microbial contaminants is associated with respiratory symptoms, allergies, asthma and immunological reactions. Among others, moulds and fungi are of great concerns as the Hong Kong climate condition of high temperature and relative humidity is particularly favourable to their growth.

5.2 The most common cause of excessive mould and fungal growth indoors is water condensation. Proper control of indoor air temperature and maintenance of suitable relative humidity (recommended to be not exceeding 70%) are effective means to avoid water condensation on cold surfaces indoors. The criteria for preventing mould and fungal growth should also be taken into consideration while achieving other objectives of indoor air quality as promulgated by the Environmental Protection Department.

5.3 In 2009, the WHO has published its guidelines for indoor air quality on dampness and mould. Reference to the guidelines should also be made to prevent the persistence of dampness and microbial growth.

6. MEASUREMENT & MONITORING

6.1 To ascertain the indoor air temperature, relative humidity and air movement are within the optimum range, they should be monitored on a regular or even continuous basis.

6.2 Air temperature, relative humidity and air movement can be measured by several methods ranging from a simple thermometer for temperature, a wet and dry bulb thermometer for relative humidity and anemometer for measurement of air movement to sophisticated electronic instruments. Suitable type of instrument should be deployed with due regard to the purpose of the measurement. Electronic instruments for continuous measurement with data logger should be used when it is to measure the average air temperature and relative humidity over a period of time, or to investigate the fluctuation of the air temperature and relative humidity over time.

6.3 For details on the choice of measurement instruments and sampling locations, reference should be made to the international guidelines such as the *ASHRAE Standard 55-2017*.

7. ENQUIRIES

For any enquiries related to these guidelines, please contact:
Environmental Protection Department
33/F., Revenue Tower, 5 Gloucester Road, Wan Chai, Hong Kong
Tel: 2594 6251
Fax: 2827 8040

8. REFERENCES

- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (2017). *ASHRAE Standard 55-2017—Thermal Environmental Conditions for Human Occupancy*.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (2017). *ASHRAE Handbook – Fundamentals 2017*, Chapter 9.
- British Standard (2007). *BS_EN 15251:2007—Indoor environmental input parameters for design and assessment of energy performance of buildings—addressing indoor air quality, thermal environment, lighting and acoustics*.
- The Chartered Institution of Building Services Engineers, *CIBSE Guide A: Environmental Design*.
- Electrical and Mechanical Services Department (2011), Energy Efficiency Office, *Energy Saving Tips for Office*.
- Environment Bureau and Electrical and Mechanical Services Department (2017). *Energy Savings for All*.
- International Organization for Standardization (2005). *ISO 7730:2005—Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria*.
- World Health Organization (2009). *WHO Guidelines for Indoor air Quality—Dampness and Mould*.

APPENDIX C: ASBESTOS

1. BACKGROUND

Asbestos is a collective term referring to a group of naturally occurring hydrated silicate minerals crystallised in the form of long, strong and flexible fibres which can be separated into bundles of fibrils. The high tensile strength, durability and resistance to heat and corrosion has given asbestos wide applications in building materials for many years in the past and a large tonnage of these materials are found in existing buildings.

However, asbestos has been confirmed as a human carcinogen. The hazard of asbestos fibre also applies to the indoor environment as asbestos-containing material (ACM) is a candidate of building material commonly found indoors. ACM is hazardous when it is damaged or in poor physical conditions such that the asbestos fibre could be emitted into the air. The health hazard of ACM lies in its friability (the ease of crumbling when dry). The more friable the ACM is, the more susceptible it is to damage and the more likely it is to release asbestos fibre to the environment.

Asbestos is commonly found in building materials and building installations applied before mid-1980s. Those would be found indoors are asbestos spray, asbestos-textured paints, ceiling tiles, pipe lagging, vinyl floor tiles, flexible joints in air handling units, insulation boards and arc chutes in electrical switch boxes and brake lining in lift brake drums.

2. OFFICE/PUBLIC PLACE

Though the use of asbestos has been banned since April 2014, it may still be likely to find ACM in older offices or public places which were built before mid-1980s.

The hot water pipe asbestos lagging in washrooms and kitchens are those friable ACM most commonly found in publicly accessible locations in offices/public places in these days. "Asbestos spray", usually in the function of acoustical treatment, may also still exist in a few locations. These asbestos sprays can usually be found on ceiling and structural beams and occasionally on walls. It has a rough texture and usually coloured to match the interior of the buildings. Asbestos spray crumbles easily when impacted (such as scratching and poking) by a hard material.

Non-friable ACM also exists in area accessible to the general public. The most common ones are vinyl asbestos floor tiles, their underlying adhesive layers and ceiling cement boards.

There are also some other ACMs found in the indoor environment that are confined to areas inaccessible to the general public. Examples are pipe insulation or flexible joints in mechanical plant room/heating facilities, cement pipes inside the service ducts, air duct gaskets, asbestos plaster in the ceiling void and arc chutes in electrical switch boxes.

3. MANAGEMENT OF ACMs

Under normal circumstances, there is no urgent need to remove ACMs from a building if the concerned materials are in good and undisturbed condition. It is, however, a good practice for the owner to commission a registered asbestos consultant to prepare an Asbestos Management Plan for the effective management of these ACMs. This plan should cover the proper management of the existing ACMs and suspect materials before their ultimate removal and disposal. It should be updated once every two years by a registered asbestos consultant, and should be available to and understood by the building management and workers.

The preparation of this plan, other than those ACMs exempted under the Air Pollution Control Ordinance (Cap. 311), starts off with an asbestos investigation to be carried out by a Registered Asbestos Consultant and a Registered Asbestos Laboratory registered under the Air Pollution Control Ordinance (Cap. 311). The asbestos investigation involves a thorough visual inspection to all accessible areas of the premises by the Registered Asbestos Consultant and where a material is suspected to contain asbestos, have bulk samples collected by the Registered Asbestos Laboratory for analysis. An Asbestos Investigation Report should then be compiled. If ACM is located, the Registered Asbestos Consultant shall then compile an Asbestos Management Plan together with an Asbestos Investigation Report to the owner of buildings outlining the strategies on asbestos abatement basing on the findings in the asbestos investigation.

4. ASBESTOS ABATEMENT WORK

If the ACM is found in poor condition or damaged or measurements show the ambient asbestos concentration would be higher than 0.01 fibre per millilitre, asbestos abatement work should be done as soon as possible. Asbestos abatement work involves a Registered Asbestos Contractor who should employ under them, a Registered Asbestos Supervisor whose responsibility is to give continuous supervision on the implementation of the Asbestos Abatement Plan prepared by the Registered Asbestos Consultant. The owner is also required to submit to the Environmental Protection Department the Asbestos Management or Asbestos Abatement Plan together with the Asbestos Investigation Report and a written notice not less than 28 days of the date on which the asbestos abatement work is to be commenced.

5. LEGISLATION AND CODES OF PRACTICE

The following are the main legislation, codes of practice and guides regulating asbestos—

Legislation

(1) Air Pollution Control Ordinance (Cap. 311)

(2) Factories and Industrial Undertakings (Asbestos) Regulation, under the Factories and Industrial Undertakings Ordinance (Cap. 59)

(3) Waste Disposal Ordinance (Cap. 354)

The above legislation is available for view at http://www.elegislation.gov.hk

Codes of Practice/Guides

Although the codes of practices and guides have no legally binding force, they will form the criteria for judging compliance to the relevant legislation.

Environmental Protection Department

(1) Code of Practice on Asbestos Control—Preparation of Asbestos Investigation Report, Asbestos Management Plan and Asbestos Abatement Plan

(2) Code of Practice on Asbestos Control—Asbestos Work Using Full Containment or Mini Containment Method

(3) Code of Practice on Asbestos Control—Safe Handling of Low Risk Asbestos-containing Material

(4) Code of Practice on Asbestos Control—Asbestos Work Using Glove Bag Method

(5) Code of Practice on the Handling, Transportation and Disposal of Asbestos Wastes

The above is available for view at
http://www.epd.gov.hk/epd/english/environmentinhk/air/asbestos/asbestos.html

Labour Department

(1) Code of Practice: Safety and Health at Work with Asbestos (Second Edition)

(2) Health Hazards of Asbestos

(3) Guide to Occupational Diseases Prescribed for Compensation Purposes

The above is available for view at http://www.labour.gov.hk/

6. FORM OF CONTRACT

Should the owner of a building require the service of asbestos related work, he should include in his contract the following items as a minimum:

For Maintenance or Servicing:

- Use asbestos free materials as the replacement which shall be carried out by a Registered Asbestos Contractor in accordance with the relevant requirements under the Air Pollution Control Ordinance (Cap. 311).

For Asbestos Investigation:

- A Registered Asbestos Consultant to conduct a detailed visual investigation to ascertain the presence of ACM in the building or otherwise, and supervise a Registered Asbestos Laboratory to collect bulk samples of suspected ACM for confirmation.
- If ACM is present, the Registered Asbestos Consultant should prepare an Asbestos Investigation Report and an Asbestos Management Plan according to Environmental Protection Department's Code of Practice.

For Asbestos Abatement:

- Submission of an Asbestos Investigation Report and an Asbestos Abatement Plan to Environmental Protection Department not less than 28 days before commencement of the asbestos abatement work in accordance with section 69 of the Air Pollution Control Ordinance (Cap. 311).
- Submission of a written notification to Environmental Protection Department 28 days before the commencement of the asbestos abatement work, according to section 73 of the Air Pollution Control Ordinance (Cap. 311).
- A Registered Asbestos Contractor to carry out the abatement work or implement the Asbestos Abatement Plan and a Registered Asbestos Supervisor to provide continuous supervision on the required asbestos abatement works.
- The Registered Asbestos Contractor should also organise the disposal of ACM waste by a licensed chemical waste collector.
- A Registered Asbestos Consultant to provide supervision on the carrying out of the abatement work.
- A Registered Asbestos Laboratory to carry out sampling and air monitoring according to the Asbestos Abatement Plan.

7. CONTACT

The following departments can be contacted for information regarding the control of asbestos in Hong Kong:

Advice on asbestos control
Environmental Protection Department
Asbestos Management & Control Sections
28/F, Southorn Centre, 130 Hennessy Road, Wan Chai, Hong Kong
Telephone no.: 2755 3554

Advice on disposal of asbestos wastes
Environmental Protection Department
Chemical Waste and WEEE (Licensing and Control Support) Section
25/F., Southorn Centre, 130 Hennessy Road, Wan Chai, Hong Kong
Telephone no.: 2835 1063

Advice on occupational safety and health for asbestos work employees
Labour Department
Occupational Hygiene Division
15/F, Harbour Building, 38 Pier Road, Hong Kong
Telephone no.: 2852 4041

APPENDIX D: SUGGESTED FORMS

page no

POLLUTANT AND SOURCE INVENTORY

Building Name:__________________________Address: _____________________________________

Completed by:___________________________Date: ____

1. **Outdoor sources:**

- ☐ Garbage dumpsites
- ☐ Heavy motor vehicle traffic
- ☐ Electricity generators
- ☐ Power plants
- ☐ Construction activities
- ☐ Industrial stacks
- ☐ Other: ________________________

2. **Maintenance Activities:**

Activity	Checked	Needs Attention	Location	Comments
Use of Materials with VOC (e.g. paint, caulk, adhesives)				
Stored supplies with VOC				
Use of Pesticides				
Welding				

3. **Housekeeping Activities**:

Activity	Checked	Needs Attention	Location	Comments
Cleaning Materials				
Cleaning Procedures				
Stored Cleaning Supplies				
Trash Storage				

4. **Special Use/Mixed Use Areas**:

	Existence (Y/N)	If Yes (state location)	Communication with test office		
			Dedicated Ventilation Systems	Dedicated Exhaust Fan	Doorway
Laboratories					
Printshops					
Graphics arts facilities					
Kitchen/pantry					
Loading dock					
Parking garage					

5. **Accidental Events:**

Damage		Yes/No	Location	When
Fire	Recent			
	Current			
Water	Recent			
	Current			
Chemical Spillage	Recent			
	Current			

6. **Renovation activities that induce emissions of VOC, odour and dust:**

Activity	Checked	Location	When	Comments
Painting				
New carpet				
Re-roofing				
New furniture				
Partition replacement or interior wall movements				
New air duct				
Renovation of air duct				
New floor (wooden)				

7. **Furnishings and Equipment:**

	Checked	Needs Attention	Location	Comments
Furnishings				
Office Equipment				
Others				

MVAC CHECKLIST

Building Name:__________________________Address: ____________________________________

Completed by:___________________________Date: _______________________________________

Central Air Handling and Distribution System

1. Air Handler Number

2. Air Handler Location ___________________ , Room No. __________

3. System Type
   - ☐ Single Duct, Constant Volume, Single Zone
   - ☐ Single Duct, Variable Air Volume
   - ☐ Single Duct, Variable Air Volume, Reheat
   - ☐ Single Duct, Variable Air Volume, Fan Powered, Constant Fan
   - ☐ Single Duct, Variable Air Volume, Fan Powered, Intermittent Fan
   - ☐ Single Duct, Variable Air Volume, Dual Conduit
   - ☐ Single Duct, Variable Air Volume Interior, Fan Powered Variable Air Volume Perimeter
   - ☐ Dual Duct, Variable Air Volume, Single Fan
   - ☐ Dual Duct, Variable Air Volume, Dual Fan
   - ☐ Multizone, Constant Volume
   - ☐ Other

Other System Information: The following information can sometimes be determined from the mechanical equipment specifications but must be verified by inspection and discussion with the building operator.

4. Number of thermostatically-controlled zones served by the air handler ___________________

5. Return air fan ☐ Yes ☐ No

6. Variable supply air temperature set point (for VAV system only):
   - ☐ YES, the system is VAV and the supply air temperature is varied by the control system in response to conditions
   - ☐ NO, the system is VAV and does not have a variable supply air temperature set point

Fresh Air Intake

7. Intake Strategy: ____Conditioned Positive
   ____ Unconditioned Positive
   ____ Unconditioned Suction

8. Intake Control Strategy: ____100% Fresh Air Intake
   ____ Fixed Minimum Fresh Air Intake
   ____ Economist Cycle

Air Handling Specification

9. Air Handler No. ________________________
10. Design Supply Airflow Rate Capacity______________________m^3/s or cfm
11. Design Minimum Fresh Air Intake Rate_________________m^3/s or cfm
12. Space served by Air Handler _____________________
13. Return Fan Capacity_______________________m^3/s or cfm

Maintenance & Inspection

14. Adequate access for maintenance? ______________________
15. Ducts and coils clean? _______________________________
16. Controls operating properly? ___________________________
17. Drain pans clean? Any visible mould growth? ___________________
18. **Inspection & Cleaning Schedule**

	Inspection	**Cleaning**	**Frequency**
Air Handler Inspection			
Drain Pans			
Heating & Cooling Coils			
Air Cleaners			
Air Distribution Ductwork			
Cooling Towers			
Fan Coil Units			
Terminal Units			

19. **Filters**

Location	Type/Rating	Size	Date last Changed	Condition

20. **Supply Airflow Rate (Airflow Rate at Filters)**

Anemometer Readings, m/s

21. **Local Ventilation Performance**

	Airflow Rate	Supply Air Temperature
Diffuser No. 1		
Diffuser No. 2		
Diffuser No.		
Diffuser No.		
Diffuser No.		

QUESTIONNAIRE SURVEY FOR BUILDING OCCUPANTS

Personal Information

Male / Female Age: _______

How many years have you worked in this building? _______

Your employment status? Employer / Employee

What is your job nature? Managerial / Professional / Technical / Secretarial or clerical / Receptionist / Messenger / Others ______________

1. Workplace building type: ☐ Commercial ☐ Industrial & office

2. Your building is located in which district? ______________

3. What floor is your office located on?________Floor

4. No. of hours per week spent in workplace: _______

5. Do you have your own workstation at your office? _______

6. No. of people working on same floor: _______

7. Type of air conditioning system installed in your office? Central A/C / Window Unit / None

8. Is there any Air Cleaning device installed in your office? Yes / No / Don't know

   If yes, which type? ___________________________

   Do you feel any improvement? Yes / No / Don't know

9. How many hours per day do you work with a computer? _______

10. Have you ever observed to have the following whilst working at this office?

	No	**Yes (but not diagnosed by doctor)**	**Diagnosis made by a doctor, and during times working at this office**	
			Yes	**No**
Asthma	☐	☐	☐	☐
Hay fever/allergy to pollen	☐	☐	☐	☐
Bronchitis	☐	☐	☐	☐
Dermatitis	☐	☐	☐	☐
Episodes of unexplained flu	☐	☐	☐	☐
Allergy to dust mites	☐	☐	☐	☐
Allergy to moulds	☐	☐	☐	☐

11. Do you eat at your office? ________

12. Does your office have a pantry?________If yes, where? _______________

13. Do you have a window near your workstation?________Can you open it? ________

14. Do you have carpet at your workstation? ________

15. Has there been any recent renovation within 3 metres of your workstation?

☐ Painting ☐ Carpeting ☐ Partitioning

16. Are there any particular problems with the air quality of your office?

☐ Dust ☐ Stuffiness ☐ Mould ☐ Lighting

☐ Odours:_________________________ ☐ Others: _________________________

17. In your office, how would you rate the:

	V. Good	**Good**	**Fair**	**Poor**	**V. Poor**
Air quality:	☐	☐	☐	☐	☐
Comfort factor:	☐	☐	☐	☐	☐
Cleanliness:	☐	☐	☐	☐	☐

18. During the last four weeks you were at work, how often have you experienced each of the following symptoms while working in this building? And what happened to these symptoms when you were away from work?

Symptom	Frequency of occurrence	Got Better (1)	Stayed the same (2)	Got Worse (3)
Dry, itchy or watery eyes	____ days/week			
Runny nose (Rhinitis)	____ days/week			
Stuffy nose	____ days/week			
Sinus Congestion	____ days/week			
Sore or dry throat	____ days/week			
Cough	____ days/week			
Wheezing/asthmatic attack during exercise	____ days/week			
Shortness of breath/difficulty in breathing	____ days/week			
Sneezing	____ days/week			
Sputum/phlegm	____ days/week			
Dizziness	____ days/week			
Headaches	____ days/week			
Dry or itchy skin	____ days/week			
Redness, heat of skin	____ days/week			
Nausea	____ days/week			
Unusual tiredness, fatigue or drowsiness	____ days/week			
Difficulty in remembering or concentrating	____ days/week			
Stomach pain	____ days/week			
Muscle pain	____ days/week			
Diarrhoea	____ days/week			
Documented fever	____ days/week			

19. How many bouts of cold/flu did you get in the last 30 days? ________

20. How many days in total did you suffer from it?_______days

21. How many days of sick leave have you taken in the last 30 days? _______

APPENDIX E: USEFUL REFERENCESAND WEBSITES

References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (2009). *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning*. ASHRAE, Atlanta

US Environmental Protection Agency. *Controlling Pollutants and Sources: Indoor Air Quality Design tools for Schools.* (refer to: https://www.epa.gov/iaq-schools/controlling-pollutants-and-sources-indoor-air-quality-design-tools-schools)

Useful Websites

Air Conditioning Contractors of America (ACCA), US
http://www.acca.org/

Air-Conditioning, Heating and Refrigeration Institute (AHRI), US
http://www.ahrinet.org/Home

Air Infiltration and Ventilation Centre (AIVC) , UK
http://www.aivc.org/

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE),US
http://www.ashrae.org/

Building Research Establishment, UK
http://www.bre.co.uk/

Canada Mortgage and Housing Corporation (CMHC), Canada
http://www.cmhc-schl.gc.ca/

Carpet and Rug Institute, US
https://carpet-rug.org/

The Chartered Institution of Building Services Engineers, UK
http://www.cibse.org/

Nordic Swan Ecolabel
http://www.nordic-ecolabel.org/

The Electric Power Research Institute (EPRI), US
http://www.epri.com/

Office of Energy Efficiency and Renewable Energy, US
https://www.energy.gov/eere/office-energy-efficiency-renewable-energy

Environmental Protection Agency (EPA), US
http://www.epa.gov/iaq/

Federal Trade Commission (FTC), US
http://www.ftc.gov/

The Global Ecolabelling Network
https://globalecolabelling.net/

Hong Kong Council on Smoking and Health (COSH)
https://www.smokefree.hk/

Indoor Air Quality Association (IAQA), US
http://www.iaqa.org/

Indoor Air Quality Information Centre, Hong Kong
http://www.iaq.gov.hk/

The International Agency for Research on Cancer (IARC)
http://www.iarc.fr/

International Energy Agency
http://www.iea.org/

International Society of Indoor Air Quality and Climate (ISIAQ)
https://www.isiaq.org/

National Air Duct Cleaners Association (NADCA), US
https://nadca.com/

National Institute of Occupational Safety and Health (NIOSH), US
https://www.cdc.gov/niosh/

National Institute of Standards and Technology (NIST), US
https://www.nist.gov/

World Health Organization (WHO)
https://www.who.int/