SINGAPORE STANDARD

SS 554 : 2009

(ICS 13.040.20; 91.040.01)

CODE OF PRACTICE FOR

Indoor air quality for air-conditioned buildings

(Incorporating Erratum No. 1, November 2009)

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ASHRAE (Singapore Chapter)
Building and Construction Authority
CapitaLand Retail Limited
Institution of Engineers, Singapore
Method Engineering Pte Ltd
Micro Filtration Technology Pte Ltd
Ministry of Health
Ministry of Manpower
National Environment Agency
National University of Singapore
Temasek Polytechnic

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Foreword

This Singapore Standard Code of Practice was prepared by the Technical Committee on Building Maintenance and Management under the direction of the Building and Construction Standards Committee.

Indoor air quality (IAQ) refers to the quality of the air inside an air-conditioned environment. The quality of indoor air is determined mainly by the indoor thermal environmental conditions and the levels of indoor airborne contaminants. It is of concern because most people spend the majority of their time indoors.

The thermal environmental conditions have a great impact on the comfort and well-being of people. Many indoor air contaminants are known to cause asthma, allergic reactions and other respiratory problems. Many illnesses are aggravated by these air contaminants.

Good indoor air quality is an important component of a healthy indoor environment, which contributes to productivity, comfort, and a sense of health and well-being at the workplace. Poor indoor air quality causes sick building syndrome and building-related illness which affect the health and well-being of occupants, and contributes to productivity loss and absenteeism at work.

The purpose of this Code specifies indoor air quality that will be acceptable to the majority of building occupants, and which will minimise the risk of adverse health effects. The Code also provides information, advice and guidance on measures to improve the quality of air in air-conditioned environments.

This Code is intended to complement Singapore Standard 'Code of practice for air-conditioning and mechanical ventilation in buildings (SS 553)'.

This Code will be useful to building owners, management corporations, building occupants, and those responsible for designing, operating and maintaining the building environment, as well as others involved in servicing the ventilation and air-conditioning systems.

In preparing this Code, reference was made to the following publications:

1. ISO 16814 : 2008 Building environment design – Indoor air quality – Methods of expressing the quality of indoor air for human occupancy

2. NEA Guidelines for good indoor air quality in office premises (1996)

Permission has been sought from the following organisation / authors for the reproduction of:

1. Figures A.2 and A.4 from Dr Olli Seppanen and Dr William Fisk

2. Figures A.3 from Dr Pawel Wargocki

3. Table E.1 from the NAFA Guide to Air Filtration, 4th Edition 2007, Addendum 7.1 'A Brief Description of the ANSI/ASHRAE Standard 52.2 Test Method'

Acknowledgement is made for the use of information from the above organisation / authors.

This Code is expected to be used by MOM, WSH Council, BCA and NEA. Occupiers and employers are encouraged to use this Code of Practice to fulfil their general duties as specified in the Workplace Safety and Health Act.

Attention is drawn to the possibility that some of the elements of this Singapore Standard may be the subject of patent rights. SPRING Singapore shall not be held responsible for identifying any or all of such patent rights.

NOTE

1. *Singapore Standards are subject to periodic review to keep abreast of technological changes and new technical developments. The changes in Singapore Standards are documented through the issue of either amendments or revisions.*

2. *Compliance with a Singapore Standard does not exempt users from legal obligations.*

Code of practice for indoor air quality for air- conditioned buildings

1 Scope

The Code applies to all air-conditioned premises where air-conditioning is used intermittently or continuously, with the exception of residential premises, factory production areas, hospitals, polyclinics and laboratories.

It applies to all types of air-conditioning and air-distribution systems.

In setting indoor air quality (IAQ) standard, this Code considers environmental factors, which include thermal, physical, chemical and biological factors. The purpose of the standard is to specify indoor air quality that will be acceptable to building occupants and to minimise the potential of adverse health effects.

For the recommended minimum ventilation rates, the Code should be used in conjunction with the SS 553, which provides guidance for the design, construction, installation, testing, commissioning, operation and maintenance of air-conditioning and mechanical ventilation (ACMV) system.

NOTE 1 – Neither SS 553 nor this Code prescribes specific ventilation rate requirements for zones that contain smoking. ANSI/ASHRAE 62.1 may be referred to if smoking zones are present (see also 4.3.5).

NOTE 2 – Meeting the requirements of this Code might not achieve the acceptable indoor air quality for everyone in all air-conditioned buildings, due to one or more of the following reasons:

(a) The diversity of sources and contaminants in indoor air;
(b) Many other factors that may affect occupant perception and acceptance of indoor air quality, such as air temperature, humidity, noise, lighting and psychological stress;
(c) The wide range of susceptibility and preferences in the population;
(d) Outdoor air brought into the building may be unacceptable or may not be adequately cleaned.

2 Normative references

This Code incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed thereafter. For dated references, subsequent amendments to or revisions of any these publications apply to this Code only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ANSI/ASHRAE 55	Thermal environmental conditions for human occupancy
ANSI/ASHRAE 62.1	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE 129	Measuring air change effectiveness
ISO 7730	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
ISO 12569	Thermal performance of buildings – Determination of air change in buildings – Tracer gas dilution method
ISO 16000	Indoor air
	Part 1: General aspects of sampling strategy
	Part 2: Sampling strategy for formaldehyde

	Part 3: Determination of formaldehyde and other carbonyl compounds – Active sampling method
	Part 5: Sampling strategy for volatile organic compounds (VOCs)
	Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID
	Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions
	Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)
	Part 15: Sampling strategy for nitrogen dioxide (NO_2)
ISO 16017	Indoor, ambient & workplace air – Sampling and analysis of volatile organic compounds by sorbent tube / thermal desorption / capillary gas chromatography
ISO 16702	Workplace air quality – Determination of total organic isocyanate groups in air using 1-(2-methoxyphenyl) piperazine and liquid chromatography
ISO 16814	Building environment design – Indoor air quality – Methods of expressing the quality of indoor air for human occupancy
SS 553	Code of practice for air-conditioning and mechanical ventilation in buildings

3 Definitions

For the purpose of this Singapore Standard, the following definitions apply:

3.1 Acceptable IAQ

Air in an occupied space toward which a substantial majority (80 %) of occupants express no dissatisfaction and in which there are not likely to be known contaminants at concentrations leading to exposures that pose a significant health risk.

3.2 Acceptable perceived IAQ

Air in an occupied space toward which a substantial majority (80 %) of occupants express no dissatisfaction on the basis of odour and sensory irritation. Acceptable perceived IAQ is necessary but not sufficient to meet the acceptable IAQ.

3.3 Air change rate (air change per hour)

The air flow rate to a space expressed as volume per unit time divided by the volume of the space in consistent units.ac.h^{-1}.

3.4 Air change effectiveness

A measure of the relationship between the contaminant concentration in the exhaust air and the contaminant concentration in the breathing zone.

3.5 Air-conditioning

Process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness and distribution.

3.6 Air temperature

The dry-bulb temperature of the air surrounding the occupant.

3.7 Building-related illness

Any illness which occurs directly as a result of human exposure to a specific health hazard present in the building.

3.8 Competent person

A person who is qualified by training and experience, and has sufficient knowledge of IAQ, and is recognised by cognizant authorities to perform the work to be carried out.

3.9 Airborne contaminant(s)

An unwanted airborne constituent that may reduce acceptability of the indoor air quality.

3.10 Microbial contaminant(s)

Fungal, bacterial, or viral organisms, toxins they produce, or particles bearing such organisms or toxins that are airborne or deposited on indoor surfaces and that can cause disease, irritation, allergic reaction. Also referred to as biological contaminants or biocontaminants. These terms include substances such as insect and pet allergens.

3.11 Enclosure

An individual room, space or part thereof able of being isolated, either permanently or temporarily, from adjacent areas by means of doors or windows or other equivalent barriers.

3.12 Exhaust air

Air removed from an enclosure and discharged into the atmosphere.

3.13 Environmental tobacco smoke (ETS)

Mixture of aged and exhaled mainstream and sidestream smoke produced from the burning of tobacco substance.

3.14 Indoor air

Air inside a building, including air which is within a room and air which is removed from a room by mechanical means.

3.15 Infiltration air

Uncontrolled passage of air into a space through leakage paths in the building envelope.

3.16 Humidity, relative

The mass of water vapour in the air by volume divided by mass of water vapour by volume at saturation at the same temperature.

3.17 ACMV systems

Refers to the air-conditioning and mechanical ventilation system of the building.

3.18 Local exhaust

Extraction of objectionable or hazardous contaminants close to the source for safe discharge to the external atmosphere.

3.19 Occupied zone

The region normally occupied by persons within a space, generally considered to be between the floor and 1.8 m above the floor, and more than 0.6 m from the walls.

3.20 Odour

A quality of gases, liquids, or particles that stimulates the olfactory organ.

3.21 Outdoor air

Ambient air entering the system or opening from outdoors before any air treatment.

3.22 Outdoor air intake

Any opening through which outdoor air is admitted.

3.23 Predicted mean vote (PMV)

An index that predicts the mean value of the votes of a large group of persons on the 7-point thermal sensation scale (see ISO 7730), based on the heat balance of the human body.

3.24 Predicted percentage dissatisfied (PPD)

An index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cold or too warm (see ISO 7730).

3.25 Re-circulated air

Enclosure air that passes through a local air cleaning unit and returns to the same or other enclosures.

3.26 Sick building syndrome

An excess of work-related irritations of the skin and mucous membranes and other symptoms (including headache and fatigue) reported by occupants in modern office buildings.

3.27 Source

Indoor generation from persons, materials or processes (activities) from which indoor air contaminants are released. Can also be a route of entry of contaminants from outdoor air or soil.

3.28 Supply air

Air introduced into an enclosure by mechanical or natural means.

3.29 Suspended particulate matter

The mass of particles suspended in a unit volume of air when collected by a high volume air sampler.

3.30 Mechanical ventilation

Ventilation provided by mechanically powered equipment.

3.31 Natural ventilation

Ventilation through leakage paths (infiltration) and intentional openings (ventilation) in the building envelope or room enclosure which relies on pressure differences without the aid of powered air moving components.

3.32 Thermal comfort

Condition of mind derived from satisfaction with the thermal environment. Thermal comfort is the combined thermal effect of environmental parameters including air temperature, relative humidity, air movement, mean radiant temperature (fixed factors) and clothing and activity level of occupants (variable factors).

3.33 Ventilation

The process of supplying or removing air by natural or mechanical means to or from a space for the purpose of controlling air contaminant levels, humidity, odours or temperature within the space.

3.34 Ventilation rates

Airflow rate at which outdoor air enters a building or enclosed space.

4 Guidelines for achieving acceptable IAQ

4.1 General

IAQ may be expressed as the extent to which the quality of indoor air meets human requirements. Humans have two basic requirements for IAQ: the risk of any adverse health effects of breathing the air should be low and the air should be perceived as acceptable in relation to comfort.

NOTE – A range of factors not directly related to IAQ such as lighting, acoustics, social psychological factors should be taken into account if IAQ complaints persist.

4.2 Impact of IAQ on productivity and health

There is a close relationship between productivity and IAQ in a well managed workplace. It is generally assumed that healthy and comfortable employees would be more productive at work. The option of specifying IAQ that is better than the minimum standards specified in this Code (where there is evidence that this would enhance productivity) should be considered (see Annex A).

4.3 Design

IAQ in a building is the result of several factors, not just ventilation rate and ventilation characteristics. Consideration should also be given to all the following relevant elements (see 4.3.1 to 4.3.4) in the early stages of building design.

A building, including its ventilation or air-conditioning system, should be designed to provide acceptable IAQ under normal operating conditions.

4.3.1 Location of the building

4.3.1.1 Environment

The environment where a building is located can have a major impact on the IAQ of the building. Special consideration must be taken to minimise the impact.

4.3.1.2 Outdoor air quality

The quality of outdoor air introduced into the building should conform with the relevant USEPA or WHO ambient air quality standards adopted by NEA. Where this is not possible, appropriate air treatment should be considered. Outdoor air filters having a Minimum Efficiency Reporting Value (MERV) of 6 or higher rated in accordance with ASHRAE 52.2, should be installed to clean the outdoor air before introduction into the indoor environment.

Air intake locations should be carefully selected to optimise the quality of outdoor air for the purpose of ventilation.

All outdoor air introduced to the indoor environment through the ACMV system should be filtered (refer to Annex E). In the event of elevated ozone levels in outdoor air, appropriate air filtration technique to reduce the ozone may need to be considered.

4.3.2 Sources and control of indoor air contaminants

For sources and control of indoor air contaminants, please refer to Annex B.

4.3.3 Ventilation characteristics

The purpose of providing ventilation is to dilute indoor contaminants so that an acceptable indoor air quality can be maintained.

The recommended minimum ventilation rates can be found in SS 553.

In addition to ventilation rates, air classification and recirculation criteria should be followed for acceptable IAQ. It is also important to note that it is the occupant's breathing zone which is relevant when minimum outdoor air flow rates are considered. Information on the ventilation characteristics, with the objective of quantitatively measuring the ventilation performance (such as outdoor air change rate and air exchange effectiveness) when necessary, is given in Annex C.

4.3.4 Nature and use of the building

4.3.4.1 Flexibility

The design of the building and its various systems should be flexible to accommodate minor changes to building usage. It is recommended that the impact on IAQ be re-evaluated once the building use has been identified.

4.3.4.2 Type of building materials

The building materials and the integrity of the building architecture can contribute to the quality of indoor air. Additional care should be exercised in selecting building materials (see Annex D).

4.3.4.3 Building hygiene activities

A high degree of cleanliness should always be maintained in a building since poorly cleaned furnishings can have an adverse effect on IAQ. Removal of contaminants through regular and judicious cleaning activities can have a positive effect on the IAQ.

4.3.4.4 Air tightness and pressure differentials

The building envelope design should minimise the introduction of pollutants due to infiltration from outside the structure. Pressure differentials between various zones within the building should be controlled so as to minimise unwanted movement of contaminants between zones.

4.3.4.5 Air cleaning

To ensure acceptable IAQ, air cleaning should always be considered as an integral part of a good ACMV system.

4.3.4.5.1 Supply, re-circulated and mixed air filters

The double-stage air filtration consists of:

(a) Primary air filtration

Primary air filters having a Minimum Efficiency Reporting Value (MERV) rating of 6 or higher should be installed to protect the secondary air filters and ACMV system.

(b) Secondary air filtration

Secondary air filters having a MERV rating of 13 or higher should be installed to protect building occupants from airborne particulate matter (PM 2.5). If the outdoor air is to be supplied directly into the occupied space (e.g. pre-cooled outdoor air systems), a combination of MERV 6 and 13 (or higher) should be used.

See Annex E (Tables E.1 to E.3) for air filtration and air filter classification.

4.3.4.5.2 Differential pressure monitoring

Differential pressure monitoring equipment could be installed in the Air Handling Units (AHUs) to monitor the condition of air filters and to determine accurately when they should be replaced.

4.3.4.5.3 Other air cleaning techniques

Other air cleaning techniques for the improvement of indoor air quality could be considered where appropriate. The potential benefits should be weighed against any safety and health risks.

4.3.4.6 Use or occupancy type

Special consideration should be taken since contamination levels in a building are directly influenced by the type of activities that take place within the building. For instance, IAQ in office buildings is affected by the emissions from office furniture, office materials and equipment such as copiers and printers. Similarly IAQ in food establishments are affected by the humidity, fumes, odour generated by cooking, and environmental tobacco smoke (ETS) from smoking room infiltrating into other parts of the building.

4.3.4.7 Number of people

The number of people in a given area (occupant density) should be considered when designing the ventilation system. Variable occupancy should be given adequate consideration in determining ventilation rates and the capacity to vary them during the day in each zone of the building.

4.3.4.8 ACMV operation and maintenance considerations

When designing the ACMV system, consideration should be given to its operation and maintenance (see SS 553). There should be adequate and safe means of access to components that require maintenance on a regular basis.

4.3.5 Smoking and no-smoking areas

4.3.5.1 Separation

Smoking areas should be separated from no-smoking areas by solid walls, partitions and doors.

4.3.5.2 Sign

A conspicuous sign stating the area contains or may contain tobacco smoke should be posted outside every entrance to a smoking area.

4.3.5.3 Pressurisation

Smoking areas should be at a negative pressure with respect to any adjacent no-smoking areas.

4.3.5.4 Ventilation rate

Smoking areas shall have more ventilation and/or air cleaning than comparable no-smoking areas. Minimum ventilation rates for smoking zones cannot be specified.

4.3.5.5 Transfer air

Air from smoking areas should not be transferred or re-circulated to no-smoking areas by natural or mechanical ventilation.

4.3.5.6 Exhaust air

Exhaust air from a smoking area should be discharged such that the air is not re-circulated into any no-smoking area.

4.4 Construction

4.4.1 During construction phase, the following measures should be taken to minimise possible contamination to the indoor environment:

(a) Interior building materials (e.g. carpets, ceiling acoustic tiles etc) and ACMV components should be properly stored and protected against being contaminated;

(b) Fabrication and installation (e.g. welding, masonry, carpentry, painting etc) should be carried out in a manner that minimises the generation of airborne contaminants.

Appropriate measures should be taken to prevent dust and dirt from contaminating the internal surfaces of the ductwork.

4.4.2 Before a Temporary Occupation Permit (TOP) is issued:

(a) Air ducts should be cleaned (e.g. by source removal mechanical cleaning) to remove any contaminants trapped inside them. It should be left to the competent person to decide on the appropriate cleaning method;

(b) Air purging should be done to remove the volatile organic compounds and other contaminants to below acceptable limits (Table 1/Table 2);

(c) Interior surfaces should be clean and free of dust;

(d) Re-balancing of the supply air should be done.

4.5 Renovation work

Major renovation work should be undertaken in such a way that satisfactory indoor environment is secured.

For occupied buildings undergoing renovation, the following measures should be followed:

(a) Spaces to be renovated should be effectively isolated from the occupied zones;

(b) Materials and processes / activities that generate the lowest possible emissions should be selected;

(c) Interior building materials (e.g. carpets, ceiling acoustic tiles, etc) and ACMV components are properly stored and protected against contamination;

(d) Fabrication and installation (e.g. welding, masonry, carpentry, painting etc) should be carried out in a manner that minimises the generation of airborne contaminants;

(e) Air ducts should be cleaned to remove any contaminants trapped inside them where appropriate;

(f) Air purging should be done to remove the volatile organic compounds and other contaminants to below acceptable limits (Table 1 / Table 2);

(g) Re-balancing of the supply air should be done.

4.6 Commissioning, operation and maintenance

Before a new or retrofitted building is commissioned or put into service, it should be demonstrated that the ACMV system has been so designed, installed and capable of functioning to achieve acceptable IAQ. The entire ACMV system should be cleared of any construction debris and dirt, and cleaned before it is operated.

The buildings ventilation and air-conditioning components should be maintained in accordance with the guidelines given in Annex F.

4.7 IAQ management programme

An active IAQ management programme specific to the building should be developed to achieve long term IAQ goals (see Annex G).

5 Indoor air quality parameters and measurement

5.1 IAQ parameters

IAQ is influenced by thermal comfort parameters and airborne contaminants.

Factors that affect thermal comfort include air temperature, mean radiant temperature, relative humidity and air movement. Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) can be used as thermal comfort indices that integrate these parameters with clothing and activity for the evaluation of the dissatisfaction level of the occupants in the building (see ISO 7730 and ANSI/ASHRAE 55).

Airborne contaminants include a wide range of gases, vapours and particulates as well as biological organisms generated from building materials, human activities, office equipment, outdoor air and activities outside the building.

Common airborne contaminants and thermal comfort parameters required to be monitored for acceptable IAQ are presented in Table 1 as recommended IAQ parameters. Other contaminants that may exist in a particular indoor environment are presented in Table 2 as target contaminants triggered

by specific sources. These airborne contaminants if suspected to be present in the indoor environment should be included for monitoring.

The acceptable limits and methods of measurement are included in Tables 1 and 2 respectively.

5.2 Indoor air quality audit

In order to carry out an indoor air quality audit to develop an IAQ profile of a building, a four-step audit protocol is recommended as follows (see Figure 1).

IAQ audit for existing buildings is recommended once every three years in line with the risk assessment requirements under the Workplace Safety and Health (Risk Management) Regulations.

For new buildings and newly renovated premises, an audit should be conducted after fitting out works and before occupancy.

5.2.1 IAQ Audit Step 1 – Walk-through inspection

A walk-through inspection of the premises and the ACMV system should be conducted by a competent person to identify possible irregularities. A sample checklist for building inspection is provided in Annex I and the following should be obtained:

(a) Building plans showing the details of all the floors, and location of the cooling towers and outdoor air inlets to the building;

(b) ACMV system layout plans or schematics;

(c) ACMV system operating schedule and maintenance records**.**

5.2.2 IAQ Audit Step 2 – Conduct air sampling and obtain feedback from building occupants

5.2.2.1 Measurement of IAQ parameters should be made on an eight-hour basis as far as practicable. Where it is not practical to make eight-hour continuous measurement, a surrogate measurement (i.e. an intermittent strategy based on the average of half-hour measurements conducted at four time slots) is acceptable. When detection tubes are used, at least four random samples should be taken at each location over the exposure period. Alternatively, sampling strategies based on professional judgment by a competent person can be followed.

5.2.2.2 Feedback should be obtained from occupants on the conditions in the building and the operation of the ACMV system should be obtained by the competent person. A sample confidential questionnaire which can be administered to obtain information is provided in Annex J. Depending on the need, a customised questionnaire tailored to the needs of the situation could be used.

5.2.3 IAQ Audit Step 3 – Data analysis

The IAQ parameters measured should be analysed by comparing the various thermal comfort parameter values and airborne contaminant concentrations with the recommended acceptable limits in Tables 1 and 2. The analysis should include an investigation into the possible causes if the thermal comfort parameter values fall outside recommended ranges, or the airborne contaminant concentrations exceed the acceptable limits. The questionnaire responses solicited should be evaluated through statistical analysis.

5.2.4 IAQ Audit Step 4 – Building remedial action

Based on the findings of 5.2.1 to 5.2.3, building remedial measures should be formulated, implemented and evaluated so that good indoor air quality can be achieved and maintained.

Table 1 – Recommended IAQ parameters

Parameter	Acceptable limit (8 hours)	Unit	Measurement method / Analytical method
i. Thermal comfort parameters			
Operative temperature[1)]	24 to 26	°C	Air temperature – by hot wire, thermistor, thermometer sling or equivalent method. Globe temperature – by Globe thermometer.
Relative humidity	< 65 (for new buildings) < 70 (for existing buildings) (under peak and common part load conditions)	%	By thin film capacitor, hygrometer, thermometer sling or equivalent method.
Air movement	0.10 - 0.30	m/s	By hot wire method for linear air velocity or Kata thermometer for omni-directional air velocity method or equivalent.
ii. Chemical parameters			
Carbon dioxide	700 above outdoor	ppm	By real-time non-dispersive infra-red sensor or equivalent method.
Carbon monoxide	9	ppm	By real-time electrochemical sensor or equivalent method (NIOSH Manual of Analytical Methods 6604).
Formaldehyde	120 0.1	$\mu g/m^3$ ppm	By detection tubes, real-time electrochemical sensor or equivalent method for screening (ISO 16000-2). When formaldehyde concentration is higher than the limit, collect continuous air samples using dinitrophenylhydrazone (DNPH) cartridges and analyse by High Performance Liquid Chromatography (HPLC) using: NIOSH Manual of Analytical Methods 2016 or EPA Method 0100: Sampling for Formaldehyde and other Carbonyl Compounds. ISO 16000-3 or NIOSH Manual of Analytical Methods 2016.
Total volatile organic compounds (TVOC) that are photoionisable (10.6 eV)[2)]	3000	ppb	By real-time photoionisation detector or equivalent method.
iii. Respirable suspended particles (aerodynamic diameter less than 10 μm sampled with a particle size-selective device having a median cut point of 4 μm)	50	$\mu g/m^3$	By real-time optical scattering or piezoelectric monitors or equivalent method

NOTES –

[1)] Operative temperature is the average of the air temperature (weighted by the convective heat transfer coefficient) and the mean radiant temperature (weighted by the linearised radiant heat transfer coefficient for the occupant). For occupants engaged in near sedentary physical activity (with metabolic rates between 1 and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s, the relationship can be approximated with acceptable accuracy by:

$t_o = (t_a + t_r) / 2$

t_o = operative temperature

t_a = air temperature

t_r = mean radiant temperature (see also ISO 7726 'Ergonomics of the thermal environment - Instruments for measuring physical quantities')

Mean radiant temperature for a fully clothed subject: $t_r = t_g + 2.44 \times V^{0.5} (t_g - t_a)$

t_g is the globe temperature in ^0C

t_a is the air temperature in ^0C

V is the air speed in m/s

[2)] When TVOC > 3000 ppb or when smell is perceived or when ventilation rate is less than the recommended rate by SS 553 or recommendation by competent person, specific VOCs should be identified (e.g. endocrine disrupting chemicals, microbial VOC, etc.) by identifying the individual VOC species.

Table 1 – Recommended IAQ parameters (cont'd)

Parameter	Acceptable limit (8 hours)	Unit	Measurement method / Analytical method
iv. Biological parameters			
Total viable bacterial count	500	cfu/m^3	By Andersen single-stage impactor (N6), or equipment designed for airborne microbial sampling, flow rate at 28.3 L/min (1 ft^3/min) for 4 minutes or equal volume of air. Bacteria is cultured by Tryptone Soya Agar (TSA) media and incubated for 48 hours at 35 ^{0}C. When a single species dominating from the culture plate, speciation should be done (see Table 2). The samples on the culture plate should yield between 30 and 300 colonies for best results.
Total viable mould count	Up to 500 is acceptable, if the species present are primarily *Cladosporium*	cfu/m^3	By Andersen single-stage impactor (N6), or equivalent equipment designed for airborne microbial sampling, flow rate at 28.3 L/min (1 ft^3/min) for 4 minutes or equal volume of air. Mould is cultured by 2 % Malt Extract Agar (MEA) and incubated for 5 days at 25 ^{0}C. When a single species dominating from the culture plate, speciation should be done. The confirmation presence of 1 or more fungal species occurring as a significant percentage in indoor sample and not present in concurrent outdoor sample is an evidence of fungal growth. Air testing is used in some circumstances as part of an investigation to determine whether or not there is mould growth in a building, and is never a substitute for a building investigation. Surface sample should be taken from the growth area by tapes for microscopic identification.

NOTES –

Micro-organisms are ubiquitous in indoor environment and do not necessarily constitute a health hazard. The concentration at which contamination becomes a threat to health is unknown and may vary greatly with each individual. Culture-based methods are suitable for detection of culturable infection agents and allow species identification. However, it is widely agreed that only a small fraction (0.1 to 10 %) of the total microbial flora in an indoor environment is currently culturable (White DC, 1983). Total viable bacterial counts and total viable mould counts are a measure of the sanitary conditions of the premises and may not correlate with the presence of any specific pathogen.

If in the professional judgement of a competent person, investigation into target contaminants is necessary, then Table 2 is to be followed.

Table 2 – Target contaminants triggered by specific sources

Parameter	Acceptable limit	Unit	Measurement method / Analytical method
PM 2.5	35	$\mu g/m^3$	By real-time piezoelectric monitors or optical scattering or equivalent method
Ultra-fine particles	Not applicable	particles / cm^3	By a nuclei condensation counter or equivalent method. Note - This measurement may be helpful to trace the pollutant source, especially from emission processes.
Nitrogen dioxide	100	$\mu g/m^3$	By real-time chemiluminescence, diffusion tube passive samplers, chemical detector tubes or equivalent method. ISO 16000-15 / NIOSH Manual of Analytical Methods 6014.
Ozone	0.1	ppm	By real-time chemiluminescence, using potassium iodide in phosphate buffer as absorbing solution and analysed spectrophotometric, or chemical detector tubes or equivalent method.
Radon	150	Bq/m^3	By an electronic radon monitor equivalent method which complies with the device performance test described in the USEPA National Radon Proficiency Program Handbook (EPA, 402-R-95-013, Jul 1996).
Asbestos	0.01	fibre / cc	By phase contrast microscopy or equivalent method, followed by Scanning Electron Microscopy (SEM) or Transmission Electron Microscopy (TEM) for identification of fibre [5)] ISO 8672 / ISO14966 / NIOSH Manual of Analytical Methods 9000/9002.
Nicotine	Not detected		By gas chromatography -nitrogen phosphorus detector. Air collected by XAD-2 tube. NIOSH Manual of Analytical Methods 2544/2551.
Pathogenic bacteria	Presence of specific species		Collect air sample by Andersen single-stage impactor (N6), or equipment designed for airborne microbial sampling, flow rate at 28.3 L/min for 4 minutes or equal volume of air. Bacteria is cultured by Tryptone Soya Agar (TSA) media and incubated for 48 hours at 35 ^{0}C. Transfer the suspected colony to its selective media for detecting the presence of specific pathogens. Incubate in accordance to the specific requirement of the suspected pathogen. Sampling from outdoor, indoor complaint area and non-complaint area. Confirmation by API strips or Polymerase Chain Reaction (PCR).
Pathogenic mould	Presence of specific species		Collect dust using 3-piece 37 mm cassette, preloaded with 0.45 μm pore-size filters with flow rate at 3 to 4 litres/min for 8 hours. Confirmation by culture by Polymerase Chain Reaction (PCR). Sampling from outdoor, indoor complaint area and non-complaint areas.
Semi volatile and volatile organic compounds (VOC)	PEL of toxic substances	ppm	ISO 16000-5 (Table 1 Sampling Strategy for VOC) ISO 16000-12 ISO 16017 (Pumped Sampling) ISO 16702 (semi-VOC) NIOSH Manual of Analytical Methods 2549

NOTES -

1. The above contaminants may not be commonly found in a typical indoor space. These parameters should be monitored in a situation when a potential source is suspected.

2. When the complaint cannot be traced to IAQ problems, other factors such as ergonomic (e.g. lighting, noise) and work stressors covered in SS 514 `Code of Practice for `Office Ergonomics' may be explored.

3. Whilst indoor ozone concentration levels are generally within the permissible exposure level (PEL), it is important to ensure that they are not elevated at all times. Recent research findings suggest that elevated ozone levels in the indoor environment (e.g. ozone from outdoor air or ozone generating equipment) can trigger indoor chemistry involving ozone and VOC resulting in oxidation products that can be associated with poor perceived air quality, irritation and health impacts.

4. For background information on the airborne contaminants, mould remediation, prevention of mould in dwellings and clean up methods, refer to Annex H.

5. PCM is the accepted method for measuring the asbestos-in-air concentration. However, as the method does not allow for discrimination of fibres and may result in false results obtained from other fibres (e.g. fibre glass, gypsum, etc), it is therefore often used in conjunction with electron microscopy methods (such as Transmission Electron Microscope (TEM) or Scanning Electron Microscope (SEM)) when it is not certain whether other fibres are present.

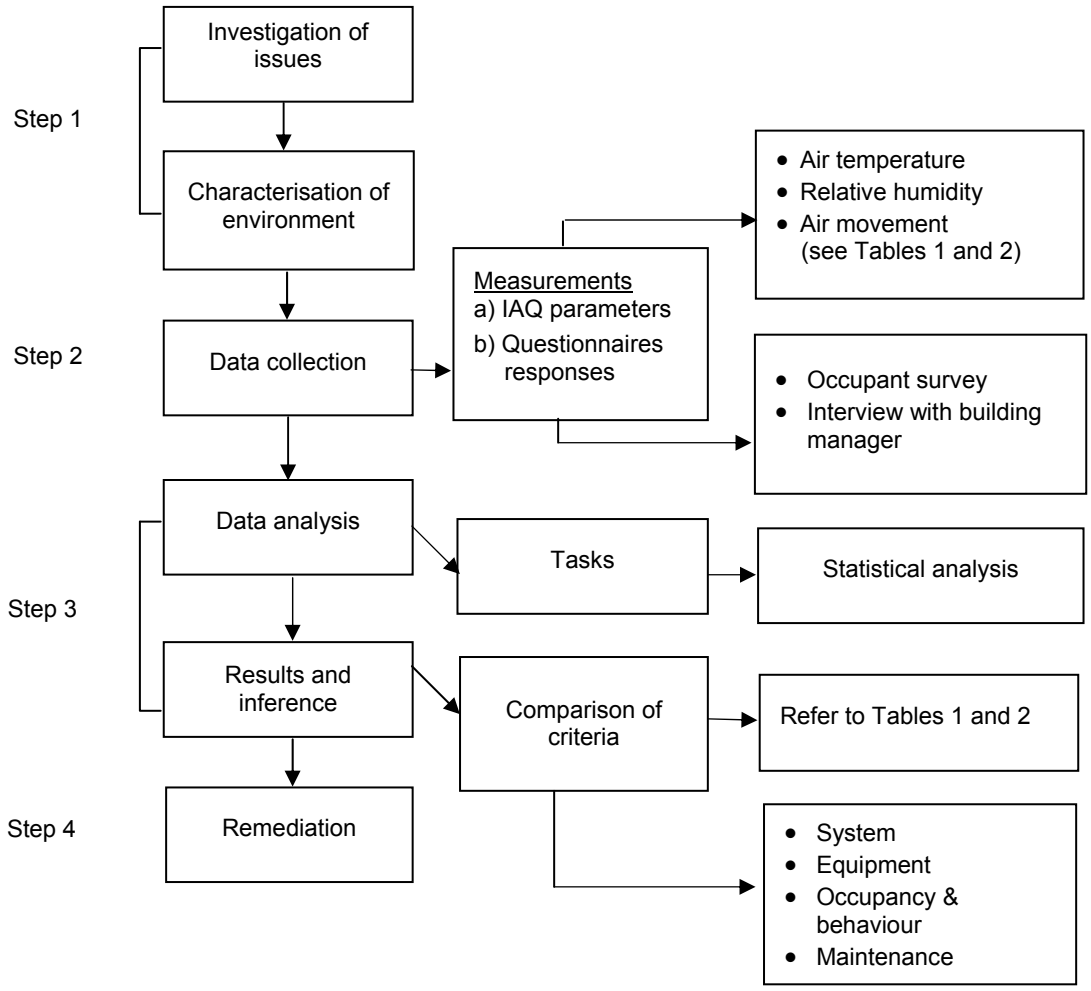

Figure 1 – Indoor air quality audit methodology

5.3 Measurement of indoor air quality

5.3.1 Number of sampling points

The sampling requirements are as follows:

(a) Indoor

For a multi-storey building, the percentage of floors to be sampled randomly is indicated in Table 3. For each floor selected, at least one sample should be taken from each separated area serviced by a separate air handling unit, fan coil unit or any air-conditioning or air distribution system. Samples should be collected from an area with the highest occupant density or area with any IAQ complaints.

(b) Outdoor

At least two samples should be taken at the entrance to the building or at the outdoor air intake location. Where there is a centralised intake for outdoor air, one sample should be taken. Also, when the target contaminant(s) could be influenced by outdoor condition, the outdoor air should be sampled daily.

Table 3 – Sampling requirements for indoor environment

Number of occupied floors in a building	Percentage of randomly selected floors to be sampled (%)*
< 5	80 % of floors*
5 - 10	70 % of floors*
11 - 20	60 % of floors*
21 - 30	12 floors or 50 % of floors*, whichever higher
31 - 40	15 floors or 40 % of floors*, whichever higher
41 - 50	16 floors or 35 % of floors*, whichever higher
> 50	18 floors or 30 % of floors*, whichever higher

NOTES –

* round up to whole number.

The recommended or required sample size will ensure with 90 % confidence that at least one floor from the 10 % floors with the highest IAQ levels is included or contained in the sample.

5.3.2 Sample position

The sampling point or sampling probe should be located between 75 and 120 cm from the floor at the centre of the room or an occupied zone, and as close as possible to the breathing zone of the building occupants.

6 Competency of IAQ personnel

Indoor air quality auditing and air sampling should be conducted by a competent person who has attended and met the requirements of an indoor air quality course conducted by a training provider recognised by cognizant authorities.

Samples that require laboratory analysis should be analysed by a laboratory accredited for procedures related to the analysis of indoor air quality parameters under the Singapore Laboratory Accreditation Scheme (SINGLAS) administered by the Singapore Accreditation Council (SAC).

The competent person should ensure that the instruments used are properly calibrated and records of calibration are maintained.

Annex A
(informative)

IAQ and work productivity and health

A.1 General

Whilst there have been a number of scientific publications on IAQ and work performance and health, these have not yet been incorporated into existing standards or codes. The link between exposure to indoor environment and productivity is still actively being researched, although the evidence of the effects of some exposures has been documented. This section provides a summary of the published scientific literature on this topic which is derived from a meta-analysis of the referenced works presented by Seppanen and Fisk (2005). A list of publications is included for further reference.

In interpreting the information, the following should be noted:

(a) The referenced works straddle a diversity of climates and very little work has been performed in tropical climates;

(b) Specific effects of different dimensions of IAQ (e.g. ventilation and temperature) for tropically acclimatised people cannot be derived from the agglomerated data.

A.2 Summary of meta-analysis of referenced work

Poor indoor environmental quality (IEQ) has been related to increases in sick building syndrome (SBS) symptoms, respiratory illnesses, sick leave, and losses in productivity. Calculations indicate that the cost of poor IEQ can be higher than energy costs, space conditioning and ventilation, and that many measures taken to improve IEQ will be highly cost-effective when considering the monetary savings resulting from improved health or productivity.

Whilst IEQ is more encompassing (including lighting, acoustics, etc), the findings highlighted in this Annex pertain to the IAQ parameters.

Initial models for quantifying the health and productivity benefits of better indoor environment are presented, based on an analysis of published works, to enable building professionals to make selections of building designs and operating practices that account for effects on health and productivity. These include quantitative relationships between ventilation rate and short-term sick leave, ventilation rate and work performance, perceived air quality (PAQ) and performance, temperature and performance, and temperature and SBS symptoms. These indicate that a relationship exists between SBS symptoms and work performance.

A.2.1 Ventilation rates and short term sick leave

Ventilation reduces the concentration of indoor-generated airborne contaminants. Inadequate ventilation increases the prevalence of some types of communicable respiratory diseases (Seppänen et al. 1999; Fisk, 2000; Wargocki et al. 2002a). A quantitative relationship between ventilation rate (air change per hour) and sick leave was estimated by combining published field data and a theoretical model of airborne transmission of respiratory infections shown in Figure A.1 (Fisk et al. 2003). Uncertainties in the model include:

(a) Limited empirical data available to calibrate and evaluate the model;

(b) Size, filtration rate, and deposition rate of infectious particles in typical buildings;

(c) Natural loss of viability of airborne infectious microorganisms has not been accounted due to a lack of information on the survival times of the airborne virus and bacteria that cause respiratory diseases.

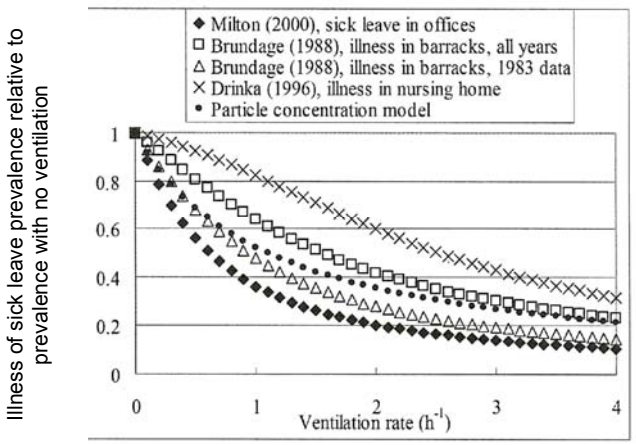

Figure A.1 – Predicted trends in illness of sick leave versus ventilation rate
(source : Fisk et. al. 2003)

A.2.2 Ventilation rates and performance

Ventilation affects productivity both indirectly and directly through its impact on short-term sick leave due to infectious diseases. This is evidenced from adjusted, normalised and weighted data from five relevant workplace studies (call centres where speed of work, i.e. time per call, was used as a measure of work performance) (Heschong group 2003, Federspiel et al. 2004, Tham 2004, Tham and Willem 2004, Wargocki et al. 2004); two studies in controlled laboratory environment (where the speed and/or accuracy of simulated office task performance) (Bako-Biro 2004, Wargocki et al. 2000a); and a study conducted in schools (using Swedish performance evaluation system with reaction times) (Myhrvold and Olesen 1997). The trend of increasing performance with increased ventilation rate is statistically significant up to approximately 16 L/s-person with 90 % confidence interval (CI) and up to 14 L/s-person with 95 % CI. In practice, the equipment and energy cost also limit the ventilation rates. Based on the estimated polynomial models, the performance at all ventilation rates relative to the performance at a reference ventilation rate of 6.5 L/s-person was calculated and plotted in Figure A.2.

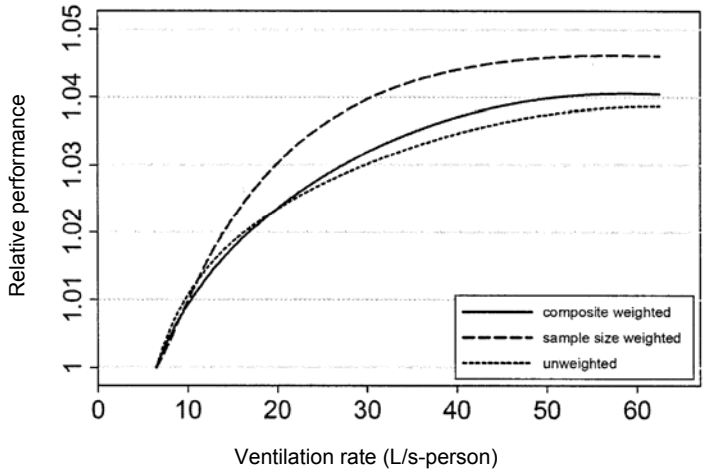

Figure A.2 – Relative performance in relation to the reference value at 6.5 L/s-person versus average ventilation rate (source: Seppanen, O.A. and Fisk, W.J. 2005)

A.2.3 PAQ and performance

Sensory evaluation is an integrated measure of air quality as sensed by human senses (olfactory and facial nerves). PAQ can be evaluated with trained or untrained olfactory panels. The trend has been towards untrained panel whose members evaluate the air quality as either acceptable or unacceptable for an eight-hour occupancy. The percentage of panel members finding the air quality unacceptable (dissatisfied with air quality) is used as an indicator of PAQ. This metric seems to be more sensitive than evaluation of air quality with reference scales.

Laboratory-based studies (Wargocki et al. 1999, 2000a, 2000b; Lagercrantz et al. 2000; Bako-Biro, 2004) indicate that performance (simulated office work including text typing, addition tasks, logical reasoning) deteriorated with percentage dissatisfied with the air quality upon entering the space (Figure A.3). However, it has not been established whether lower PAQ is causally related to performance or only an indicator of some other factors in the building which have a causal relation to performance. The PAQ is affected by several factors. It depends mainly on contaminant sources and ventilation rate, but also on temperature and humidity.

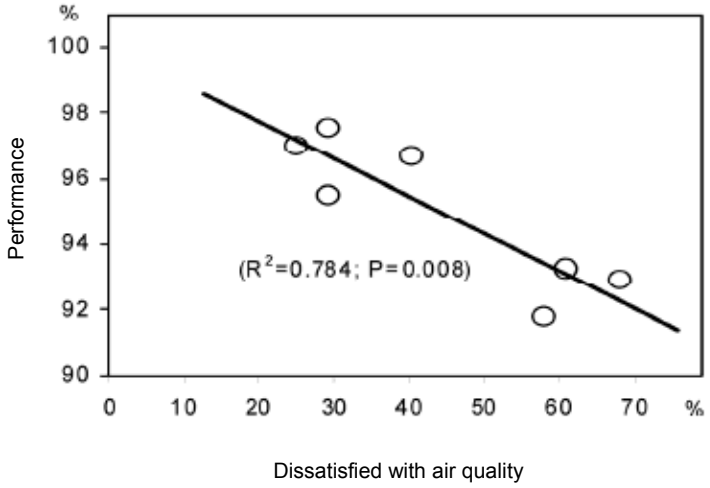

Figure A.3 – Relative performance in office work depending on the PAQ
(source: Wargocki et al. 2000b)

A.2.4 Temperature and performance

A review of 26 studies including local data shows that there is a relationship between air temperature and performance (see Figure A.4).

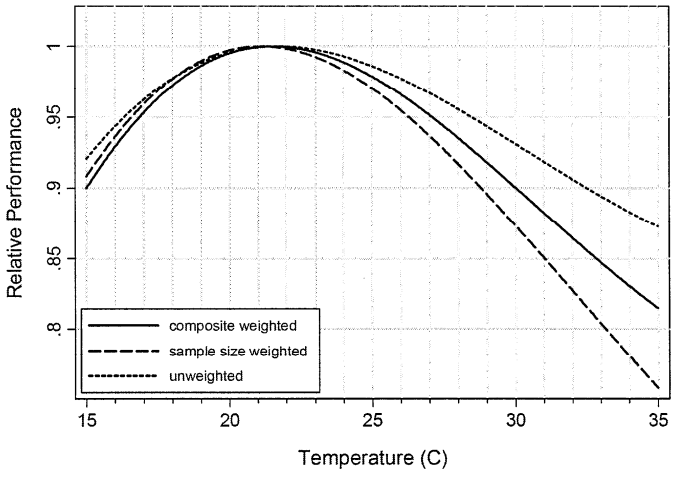

Figure A.4 – Relative performance versus temperature: maximum performance is set equal to 1
(source: Seppanen, O.A. and Fisk, W.J. 2005)

A.3 SBS symptoms and performance

Many studies have shown that SBS symptoms are linked to characteristics of buildings and indoor environments. Identified risk factors for SBS symptoms include air-conditioning (Seppänen and Fisk 2002), lower ventilation rate and higher carbon dioxide concentrations (Seppänen et al. 1999, Wargocki et al. 2002a), higher air temperature (Mendell 1993, Mendell et al. 2002), higher concentrations of some types of volatile organic compounds (Ten Brinke et al. 1998, Apte and Daisey 1999, Apte and Erdman 2002), excess dirt and moisture in HVAC systems (Mendell et al. 2003), and moisture problems in buildings (Park et al 2005).

From 24 studies which simultaneously reported the prevalence or intensity of SBS symptoms and a measure of work performance, the following were found:

(a) In field studies, objectively measured productivity was negatively associated with SBS symptoms in office environments (Niemelä et al. 2002, Niemela et al. 2004, Tham 2004, Tham and Willem 2004), and in school environments (Myhrvold et al. 1996, Myhrvold and Olesen 1997);

(b) In laboratory studies, objectively measured performance in tasks related to productivity in office work was negatively associated with reported SBS symptoms (Bako-Biro 2004, Lagercrantz et al. 2000, Nunes et al. 1993, Wargocki et al. 1999, Wargocki et al. 2000a).

Two studies using objective performance data suggest a relationship of SBS symptoms and performance. Niemela et al. (2004) suggest, based on data from a call center, that an average reduction of 7.4 % points in the prevalence of weekly central nervous symptoms correspond with a 1.1 % increase in productivity. Tham and Willem (2004) report a linear relationship between intensity of mean score of neurobehavioral symptoms and average talk time in a call center. The talk time improved (shortened) 5 % per 10 points change in intensity of symptoms. The intensity of symptoms was measured with an analog-visual scale from 0 to 100.

A.3.1 Temperature and SBS symptoms

Studies have reported a linkage between warmer temperatures and higher prevalence or higher intensity of SBS symptoms. Three studies reporting the intensity of symptoms were made in the field in non-problem buildings (Mendell et al. 2002, Tham 2004, Tham et al. 2003) and two were performed in the laboratory (Fang et al. 2004, Kaczmarczyk et al. 2002).

A.4 Summary

The above data suggest an influence of IAQ and related building conditions on employees' health and productivity. It is possible to estimate quantitatively how ventilation rates, temperatures, and PAQ are related to health and work performance outcomes. A relation between SBS symptoms and decreased productivity is strongly suggested by the available data. Reliable functions relating SBS symptoms to productivity or absence would be very valuable because there are many existing data relating building design and operation to SBS symptoms prevalence.

Annex B
(informative)

Sources and control of indoor air contaminants

B.1 Choice of methods of control

B.1.1 Available methods

There are various ways to reduce pollution in the indoor air. Ventilation is often regarded as convenient because it can be seen as addressing all contaminants of indoor origin at the same time. However, it is not always the best solution. The choice of one approach against another depends on a number of factors including the nature of the pollutant itself, its source characteristics, effect of the pollution on people, relative practicability and economics (initial costs and operating costs).

The following measures should be adopted to eliminate or reduce the exposure of occupants to airborne contaminants in buildings.

Source control (see B.1.2):

(a) Eliminate the source(s) of the contaminant(s);

(b) Substitute with sources that produce less harmful or less malodorous contaminants;

(c) Modify the source(s) to reduce emission rate of contaminant(s);

(d) Local pollutant management (see B.2);

(e) Segregate occupants from potential sources of contaminants;

(f) Improve local ventilation, e.g. by local exhaust (if source of contamination is local);

(g) Use of air cleaning to reduce local contaminants.

Ventilation (see Annex C):

(a) Improve air change effectiveness, for example by choice of system type – mixing vs displacement;

(b) Use appropriate air cleaning;

(c) Require personal protection.

These measures are not mutually exclusive and some combination will usually be necessary. Adequate ventilation will always be required regardless of the approach used.

B.1.2 Source control

B.1.2.1 Elimination

Elimination of a source means taking a source away altogether because it is not needed in the building. This could mean, for example, moving storage of source material or processes to another location or not allowing certain activities (e.g. smoking, using correction fluids) where they are not required. In some cases, even eating and drinking can represent a significant source and can be restricted, at least in time if not in space.

B.1.2.2 Substitution

If the source of contamination is necessarily present in the building in some form, then consideration can be given to using materials or equipment that emit at a lower rate. The following are examples of possible approaches:

(a) Low-emission materials should be selected for use in buildings, for the basic structure, furnishings, building services, and materials used in cleaning the building;

(b) All new buildings should be designed to minimise unacceptable odour, as far as reasonably practicable and economically viable;

(c) It is also important to reduce contamination sources within ventilation or air-conditioning systems, including the entrainment of outdoor pollution into air intake;

(d) Regular cleaning and maintenance of systems and furnishings are also very important factors in reducing odours.

B.1.2.3 Modification

Even if a source is inherently a high emitter, it is sometimes practicable to modify it to reduce emissions. For example, materials emission rates vary over time and with temperature and humidity. Positioning materials in buildings (and ventilating spaces at a high rate) in advance of occupancy can reduce emission rates when the building is later occupied.

B.2 Local pollutant management

B.2.1 Segregation

This involves separating the occupants from sources or contaminants. For example, in terms of the processes within an office, paper storage could be in a separate area from employees, or there could be a separate area for printers and photocopiers and designated smoking areas. Where such an approach is taken, special attention should be given to ventilation and air tightness where the contaminant sources are located. Additional ventilation measures are generally required in such areas.

B.2.2 Local exhaust

Local exhaust close to contaminant sources, e.g. a photocopier or an area where chemicals are used can reduce the need for total ventilation of the building. Air curtains can sometimes improve exhaust efficiency.

B.2.3 Local air cleaning

Local air cleaning (particle / gaseous filtration) can be used to clean contaminants generated in a localised area.

B.3 Dilution

B.3.1 Overall ventilation

Ventilation is the most common approach to reducing levels of contamination in buildings. The usual strategy is simply to introduce outdoor air (assumed to be fresh air) at a rate calculated to be necessary to dilute the contaminants in the building.

The methods are quite simple. Identify the contaminants that are present, determine their human effects and calculate what concentrations should be allowed. The sources in the building, the production rate, and the target concentration levels are then used to calculate the required outdoor air supply rate. Additional dilution may not be appropriate for some biological agents.

Where recirculated air is used, care should be taken that spaces served by common recirculation systems are of similar occupancies, unless the recirculated air is acceptably treated.

B.3.2 Air cleaning

Cleaning of the air delivered to a space reduces the contaminant concentration in the space. Re-circulation and ventilation airstreams may be cleaned separately and/or after they have been combined. Where there is a risk of exhaust air being re-entrained into the ventilation air, cleaning the exhaust air can also improve IAQ. Normally this should not arise because the locations of exhaust and intake openings should be located to avoid re-entrainment, although cleaning of the exhaust air may still be required if the outdoor environment around the exhaust would otherwise be adversely affected.

Air cleaners (‘filters’) are of two types: particulate air cleaners and gas phase air cleaners.

Different standards have differing recommendations about the minimum efficiencies of filters but they generally recommend two stages of filtration of outdoor air, i.e. pre-filter and main filter. For more details, see Annex E.

Annex C
(informative)

Exposure control – Ventilation

C.1 Ventilation rates

This annex summarises some of the key aspects from SS 553 pertaining to air classification, recirculation and ventilation rates. Air is classified in the range of Class 1 to Class 4 based on the relative contaminant concentration and the criteria that Class 1 Air is air with low contaminant concentrations and Class 4 Air is air with highly objectionable fumes or gases at concentrations high enough to be considered harmful. Air recirculation is limited depending on the class of air, and based on the general principle that a class of air with a higher contaminant concentration should not be re-circulated or transferred to a class with a lower contaminant concentration. For more information on air classification, refer to ASHRAE 62.1.

For comfort air-conditioning design purposes, the minimum quantity of outdoor air flow needed in the breathing zone of the occupied space(s) of any zone in a building, i.e. the breathing zone outdoor airflow, should be based on the floor area and determined according to the rates given in SS 553. The quantities of breathing zone outdoor air flow stated in SS 553 have taken into consideration the occupancy load given in the SCDF Code of Practice for Fire Precautions in Buildings, the requirement for diluting the odour caused by people and their activities and the requirement for diluting the contaminants caused by the interior furnishing.

C.2 Ventilation characteristics

An adequate air change is of fundamental importance for indoor air quality. Proper ventilation of buildings is necessary for the health and comfort of the occupants as well as to protect against damage. Modern buildings, e.g. office and residential, with tightly sealed windows can lead to insufficient ventilation which may in turn cause an increase in the concentration of contaminants emitted indoors. Manual ventilation by the occupants or the use of air-conditioning and mechanical ventilation systems is thus required. However, excessive ventilation can lead to discomfort and increased energy consumption.

Building regulations make provision for ventilation to control moisture and other contaminants. Measurements of the ventilation conditions allow confirmation of whether these requirements are met in practice. Knowledge of the ventilation conditions is important in order to be able to analyse the possible causes of poor IAQ. Thus, sampling and analysis of contaminants indoors should ideally be accompanied by ventilation measurements, making it possible to estimate the strengths of contaminant sources.

C.2.1 Methods employed

The methods employed involve the use of tracer gas techniques to determine air change rate (ISO 16000-8) and air exchange effectives.

C.2.1.1 Air change rate

This can be obtained by determining the local mean age of air (and its inverse the local effective air change rate) in buildings as an indicator of ventilation conditions in a building. The mean age of air in a building zone indicates the average time the air in a zone has been in the building accumulating contaminants and is closely connected to the time taken to exchange air within a zone. The concentration of a contaminant released from continuous indoor sources increases with the length of time the air has resided indoors. The lower the age of air in a space, the lower is the concentration. A detailed description of the procedures involved and the methods used can be found in ISO 16000-8 and ISO 12569.

C.2.1.2 Air change effectiveness

The age of air obtained using tracer gas techniques can be used to compute air change effectiveness in air-conditioned or mechanically ventilated buildings. It describes how well the ventilation air is utilised compared with ventilation achieved in an ideal “piston flow”. The definition of air change effectiveness is based on a comparison of the age of air in the occupied portion of the building to the age of air that would exist under conditions of perfect mixing of ventilation air. For a fully mixed system, the air change effectiveness is 1. The method to measure air change effectiveness in air-conditioned or mechanically ventilated buildings can be found in ANSI/ASHRAE Standard 129.

Annex D
(informative)

Source control - Emissions from building materials

D.1 Selection of building and furnishing materials

Building and furnishing materials may be sources of indoor air contaminants. To achieve IAQ objectives for chemical emissions, building designers should limit the use of high-emitting building and furnishing materials. Materials with 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 materials is used in an area.

Due to the limited choice of materials and information available at present, professionals in the building design industry should make use of product information available from other countries or carry out emission tests on the product where practicable.

In Europe, a number of labelling schemes have been introduced for control of VOC emissions from building materials. The following is a summary of these requirements for flooring products (see Table D.1) and paints and coating products (see Table D.2).

Table D.1 – European labelling schemes for low emission flooring products

Labelling schemes	Classification requirements
Danish voluntary labelling scheme http://www.byggeri.dti.dk.html or http://www.dsic.org/dsic.html	Requires evaluation of the VOC emission rates and odour and irritation thresholds of the flooring materials in an environmental chamber or cell, with results scaled to a 17 m^3 modelled room.
Finnish M1 label for finishing materials http://www.rts.fi/	Requires measurements of TVOC (< 200 μg m^{-2} h^{-1}), carcinogens (< 5 μg m^{-2} h^{-1}), formaldehyde (< 50 μg m^{-2} h^{-1}), ammonia (< 30 μg m^{-2} h^{-1}) and odour dissatisfaction (15 %) after 28 days of exposure in an environmental chamber.
GuT, Environmental Quality Mark for Carpets http://www.tfi.ac-net.de/d/gut.html	Regulates emissions of CFCs, pesticides, carcinogens (recognised, proven or suspected, e.g. benzene, butadiene, vinyl chloride, vinyl acetate and formaldehyde) which must not be detected in product; and limit emission of toluene (50 μg m^{-3}), styrene (5 μg m^{-3}), 4-vinylcyclohexene (2 μg m^{-3}), 4-phenylcyclohexene (20 μg m^{-3}), TVOC (300 μg m^{-3}), total aromatic hydrocarbons (150 μg m^{-3}), and odours, tested in a standard environmental chamber. Dyes or auxiliary substances must not contain heavy metals, such as lead, cadmium, mercury or chromium VI.
GEV EMICODE Labelling System for adhesives, primers and smoothing compounds http://www.emicode.com	The product is analysed for carcinogenic compounds after 24 hours of exposure in an environmental chamber. The substances are classified as recognised (C1), proven (C2) or suspected (C3) carcinogen according to European Directives or German legislation. The following carcinogenic compounds are currently restricted - C1: acrylamide, acrylonitrile, benzene, 1,4-dioxane; C2: acetaldehyde and formaldehyde; C3: vinyl acetate. EMICODE sets the following limits: C1 substances: < 2 μg m-3, C2 substances: < 10 μg m-3 and C3 substances: < 50 μg m-3. TVOC and the principal VOCs (above 20 μg m-3) are also quantified, after 10 days of exposure. The following three categories of product are used, based on TVOC emission rates. EC 1 / EC 2 / EC 3 Primers: < 100 / 100 - 300 / > 300 Levelling Compounds: < 200 / 200 - 600 / > 600 Flooring adhesives: < 500 / 500 - 1500 / > 1500
Swedish standard for floorings GBR/SP Trade standards GBR 1992	Requires measurement and declaration of TVOC emission rates after 4 and 26 weeks of exposure of the flooring materials in an emission cell, and the 10 principal individual VOCs.
Nordic Swan Ecolabelling programme http://www.interface.no/ecolabel/english/about/html	The scheme forbids the presence in the product of carcinogens, halogenated VOCs, organic tin compounds, phthalates, poly-brominated diphenyl ethers and also substances that are mutagenic or harmful to the human reproductive system. Heavy metals are also not allowed. Emission of formaldehyde from the finished product must be less than 0.13 mg m^{-3} in chamber air. The procedures used in the Danish and Finnish schemes also apply in Nordic Swan Ecolabelling programme. Both the environmental chamber and emission cell tests can be used.

Table D.1 – European labelling schemes for low emission flooring products (cont'd)

Labelling Schemes	Classification Requirements
German Blue Angel Ecolabelling Scheme RAL-UZ 38 RAL-UZ 76 RAL-UZ 430	This labelling scheme covers flooring materials, furniture and wall panels. Auxiliary materials such as adhesives and coating materials are also included in the scheme. The scheme provides labelling to cover the whole life cycle of the products. The scheme controls emissions of formaldehyde, TVOC, halogenated organic compounds, and toxic substances that are carcinogenic, mutagenic and teratogenic. Standard environmental chamber tests are required for certification of VOC emissions from the products. The following are the emission requirements for large surface products used in building. Formaldehyde: 1 day -, 28 days 62 μg m^{-3} TVOC (50-250 °C): 1 day -, 28 days 300 μg m^{-3} Total VOCs (>250 °C): 1 day -, 28 days 100 μg m^{-3} Toxic substances: 1 day < 1μg m^{-3}, 28 days 1 μg m^{-3}

Table D.2 – European labelling schemes for control of VOC emissions from coating

Labelling schemes	Requirements
Danish voluntary labelling scheme http://www.byggeri.dti.dk.html or http://www.dsic.org/dsic.html	See Table D.1 for requirements.
Finnish M1 label for finishing materials http://www.rts.fi/	See Table D.1 for requirements.
EU Ecolabel Scheme http://www.ecosite.co.uk B & Q and British Coating Federation Scheme	Provides criteria for paints, varnishes and cleaning products for indoor uses. The quantity of VOCs and volatile aromatic hydrocarbons (VAHs) are included in restrictions. The limits for Class I and Class II paints and varnishes are similar to those required by B & Q and the British Coatings Federation schemes. The 'Ecolabel' criteria limit the use of paints and varnishes that contain toxic, highly toxic, carcinogenic, mutagenic or teratogenic substances classified under the European Directives 79/831/EEC and 83/4367/EEC, and also substances that are mandated a warning label by Directives 88/379/EEC. The VOCs included in this restriction are benzene, methanol, acetonitrile, 1,1,1-trichloroethane, xylenes, toluene, turpentine, ethylbenzene, butanol, 2-ethoxyethylacetate and formaldehyde. Paint category 1 (for walls and ceiling): The VOC content must not be greater than 30 gL^{-1} (and in warm and dry climate ≤ 60 gL^{-1}). The VAHs must not be greater than 0.5 % of the product weight. Paint category 1 (for use on other surfaces): VOC content ≤ 250 gL^{-1}; and VAHs ≤ 5 % of the product weight.
German Federal Environment Agency, Blue Angel Scheme	This scheme requires that the paints and varnishes do not contain mutagenic or carcinogenic substances. The maximum allowed levels are: • VOC content 10 % by weight for water-soluble paints and 15 % by weight for oil based paints; • Toxic VOC content ≤ 0.5 % by weight for water-soluble paints and ≤ 5 % by weight for oil based paints. The product should not contain any heavy metals, such as lead, cadmium and chromium. Chamber tests of low emission paints that had qualified for the Blue Angel Label showed that, after 48 hours of paint application, the emission of the solvent VOCs was reduced to below the detection range of the analysis [12]. The scheme also has restrictions on the production and uses of dyes that contain more than 1 % 2-naphthylamine, 1 % 4-nitrodiphenyl and ≤ 1 % chlorinated solvents such as carbon tetrachloride, tetrachloroethanes and pentachloroethanes.
The Danish Technological Institute 'Paint favourable to IAQ'	The factors included for consideration are: IAQ and working environment; paint application characteristics; coating performance. Emission rates of VOCs and odour are the properties to be assessed as well as drying time, adhesion and paint weight application. Three categories of paints are provided. This classification scheme is supported by a Nordic group of industries and institutes. 'Amongst the very best paints' – paints that will produce a VOC concentration less than 5 μg m^{-3}, within 2-4 weeks after paint application. 'Acceptable' – paints that do not emit any substances that are carcinogenic or have a toxic effect or cause mucous membrane irritation to the eye or the respiratory system. 'Poor quality paints' – paints that do not meet the criteria for acceptable paints.

Annex E
(informative)

Air filter classification

Table E.1 – Minimum Efficiency Reporting Value (MERV) Parameters
(extracted from NAFA Guide to Air Filtration, 4th Edition, Addendum 7.1, Table 7.1.2)

ASHRAE 52.2 Minimum Efficiency Reporting Value (MERV)	Composite average particle size efficiency, % in size range, µm			Average *arrestance, % by ASHRAE 52.1
	0.3 to 1.0	1.0 to 3.0	3.0 to 10.0	
1	NA	NA	$E_3 < 20$	$A_{avg} < 65$
2	NA	NA	$E_3 < 20$	$65 \le A_{avg} < 70$
3	NA	NA	$E_3 < 20$	$70 \le A_{avg} < 75$
4	NA	NA	$E_3 < 20$	$75 \le A_{avg}$
5	NA	NA	$20 \le E_3 < 35$	NA
6	NA	NA	$35 \le E_3 < 50$	NA
7	NA	NA	$50 \le E_3 < 70$	NA
8	NA	NA	$70 \le E_3$	NA
9	NA	$E_2 < 50$	$85 \le E_3$	NA
10	NA	$50 \le E_2 < 65$	$85 \le E_3$	NA
11	NA	$65 \le E_2 < 80$	$85 \le E_3$	NA
12	NA	$80 \le E_2$	$90 \le E_3$	NA
13	$E_1 < 75$	$90 \le E_2$	$90 \le E_3$	NA
14	$75 \le E_1 < 85$	$90 \le E_2$	$90 \le E_3$	NA
15	$85 \le E_1 < 95$	$90 \le E_2$	$90 \le E_3$	NA
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	NA

* ASHRAE Test Dust for Arrestance (Gravimetric) comprising: 72 % standardised air cleaner test dust (fine dust), 23 % powdered carbon & 5 % of lint – mean diameter of 7.7 micron.

Table E.2 – Air filter classification according to ASHRAE 52.2 and possible applications

MERV	Possible applications
1	Remove coarse dusts that cause plugging to the cooling coil
2	
3	
4	
5	
6	
7	Pre-filter for MERV 13 or higher
8	
9	Medium Efficiency (Pre-filtration may not be necessary)
10	
11	
12	
13	Reduce indoor contaminants and provide better protection for AHU and cleaner ductwork
14	High removal rate against sub-micron particle size. Improve IAQ and provide good protection for cooling coil and reducing frequency or eliminating duct cleaning
15	
16	

Table E.3 – Air filter classification according to EN and possible applications

Filter classification according to EN 779 / EN 1822			Possible applications
Class	**Average synthetic dust weight arrestance, %**	**Average atmospheric dust spot efficiency 0.4 μm**	
G1	< 65	NA	Remove coarse dust that cause plugging to the cooling coil
G2	65 - 80	NA	
G3	80 - 90	NA	
G4	> 90	NA	Pre-filter for Class F7 or higher
F5	NA	40 – 60	Normal (Pre-filtration not recommended)
F6	NA	$60 \leq A_{avg} < 80$	
F7	NA	$80 \leq A_{avg} < 90$	Reduce indoor contamination, provide better protection to AHU, cleaner ductwork
F8	NA	$90 \leq A_{avg} < 95$	Better IAQ and protection to AHU and reducing frequency or eliminating duct cleaning.
F9	NA	$95 \leq A_{avg}$	
H10	NA	$A_{avg} > 95$	

Annex F
(informative)

Maintenance of ACMV systems

F.1 Inspection of ACMV systems

ACMV systems should be visually inspected for cleanliness. The recommended inspection schedule for major ACMV components is shown in Table F.1. More frequent cleanliness inspections may be necessary depending on the environmental and mechanical conditions as well as human factors.

Table F.1 – Recommended intervals for ACMV system cleanliness inspection

ACMV component	Inspection interval
Air Handling Unit	6 months
Supply air ducts	12 months
Return air ducts	12 months

The cleanliness inspection should be conducted in such a manner so as not to cause excessive disruption of settled dust, microbial amplification or other debris, which can have a negative impact on indoor environment.

The cleanliness inspection should include the AHU and representative portions of the ACMV system components and ductwork. The minimum percentage of systems and the portions that should be inspected in various situations are indicated in Table F.2.

Table F.2 – Recommended portions to inspect

Situation	System to inspect	Portion to inspect
During routine inspections	10 % of similar systems	• Outdoor air intake • AHU • Main ducts • 10 % of branch ducts
When problems are discovered during routine inspections	100 % of similar systems	• Outdoor air intake • AHU • Main ducts • 10 % of branch ducts
In response to complaints	100 % of the system(s) serving the affected area	• Outdoor air intake • AHU • Main ducts • Branch ducts

F.1.1 Internal surface condition testing for ACMV systems

Two internal surface condition tests can be used to indicate the potential for the system to release contaminants into the air:

(a) Deposit thickness test;

(b) Vacuum test.

The tests are recommended to be repeated at intervals not exceeding 12 months. The recommended location of test points and the minimum number of test points are shown in Table F.3.

Table F.3 – Recommended location of test points

Total linear length of air duct per system	Location of test point	Minimum number of test point
First 300 m	1 test point per 50 m	3 test points per system
> 300 m	1 test point per 100 m	

The average values should be calculated across all tests conducted on each system, and the results are used to determine whether it is necessary to clean the system.

F.1.2 Conditions requiring ACMV system cleaning

ACMV systems should be cleaned when a system cleanliness inspection indicates that the system is contaminated or the system performance is compromised due to contamination buildup. The conditions requiring ACMV system cleaning are stated in Table F.4.

Table F.4 – Recommended conditions requiring ACMV system cleaning

Condition	Definition
ACMV system contamination	• When significant accumulations of substances not intended to be present in the ACMV system (e.g. dust, dirt and debris) and microbial growth are visually observed. • When the ACMV system discharges visible particulate into the occupied space or a contribution of airborne particles from the ACMV system into the indoor ambient air.
Compromised performance	When ACMV system components suffer from restrictions, blockages, or contamination deposits that cause system performance inefficiencies, airflow degradation or other conditions that may significantly affect the design intent of the ACMV system.

ACMV systems should also be cleaned when internal surface condition testing results indicate that the levels of surface deposits are above the recommended surface deposit limits. The recommended surface deposit limits requiring ACMV system cleaning are specified in Table F.5.

Table F.5 – Recommended surface deposit limits requiring ACMV system cleaning

System type	Surface deposit limit	Test method
Extract	6 g/m²	Vacuum test
	180 μm	Deposit thickness test
Recirculation	1 g/m²	Vacuum test
	60 μm	Deposit thickness test
Supply	1 g/m²	Vacuum test
	60 μm	Deposit thickness test

Annex G
(informative)

IAQ management programme

G.1 Appoint an IAQ Manager

A person possessing the relevant experience in managing IAQ should be appointed and be responsible for establishing and managing the overall IAQ programme.

G.2 Develop an IAQ profile of the building

Review all available documents and/or records related to the design, construction, operation and maintenance of the building and the ACMV system. Conduct a walkthrough inspection (refer to sample checklist in Annex I) of the building and IAQ measurements in accordance with Clause 5.

G.3 Address existing and potential IAQ problems

Identify contaminant sources and adopt the appropriate control strategies as contained in Annex B.

G.4 Develop and implement plans for facilities operation and maintenance

Develop and implement plans for the operation, preventive maintenance and unscheduled maintenance of the ACMV system and housekeeping activities.

G.5 Develop and implement plans for specific activities

Develop and implement procedures for dealing with building renovation, addition and alteration, pest control and other activities that may have an impact on IAQ.

G.6 Educate facilities management (FM) personnel about IAQ management

Identify FM personnel whose functions and activities could affect the IAQ of the building and equip them with relevant IAQ knowledge.

G.7 Communicate with occupants about their role in maintaining acceptable IAQ

Inform building occupants about their activities that may impact IAQ and what they can do to maintain acceptable IAQ.

G.8 Establish procedures for responding to IAQ complaints

Establish clear procedures for recording and responding to IAQ complaints and inform FM personnel and building occupants of these procedures.

Annex H
(informative)

Information on indoor air contaminants and micro-biological agents including guidelines on mould remediation

H.1 Common sources of indoor air contaminant

Indoor air contaminant	Common sources
Carbon dioxide	- Exhaled air - Complete combustion
Carbon monoxide	- Incomplete combustion - Cooking fumes - Vehicular exhaust - Cigarette smoke
Respirable suspended particles / ultra-fine particles	- Incomplete combustion - Cooking fumes - Vehicular exhaust - Cigarette smoke - Internally generated dust (paper, carpet, curtains, fabric and furnishing materials)
Formaldehyde / Total volatile organic compound	- Wooden (plywood, particleboard) furniture - Organic cleaning compounds, disinfectants - Paints, lacquers - Adhesives, glues, sealants - Aerosol sprays (e.g. air freshener), insect repellents - Cosmetics, perfumes - Fabric materials in rugs and upholstery - Corrective fluid
Ozone	- Ozone generators or ionisers - Electrostatic precipitators - Photocopiers - Laser printers - Electric discharge
Mould	- Wet or moist carpets, drapes, upholstery - Water leakages (e.g. from chilled water pipes and pitted copper pipes, cracks in slabs) - Condensation surfaces (e.g. poorly insulated air ducts / water pipes, internal surface exposed to moist air, cooling coils and condensate drain pans, wall between conditioned and unconditioned zones) - High humidity environment - Over-watered indoor potted plants
Bacteria	- Building occupants - Stagnant water - Decomposed food - Insects, bugs, pets - Condensation surfaces (e.g. poorly insulated air ducts / water pipes, internal surface exposed to moist air, cooling coils and condensate drain pans, wall between conditioned and unconditioned zones

H.2 Microbiological agents in the indoor environment

H.2.1 Bacteria

The predominant bacteria in indoor air are generally Gram-positive species of *staphylococcus*, *Micrococcus* and *streptococcus* which emanate from the mouth, nose, nasopharynx and skin. Gram-negative bacteria may occasionally be abundant (e.g. *acinetobacter*, *aeromonas*, *flavobacterium*, *pseudomonas*) when there is an abundant source of water e.g. drain pan and saturated surfaces. The bacteria can also be found in bio-film growing on the wetted supply surface of coil fins. Therefore prompt and effective maintenance of such a system is crucial to prevent contamination

Legionella pneumophila may be present as a result of aqueous aerosols spreading from contaminated aerosol generating equipment e.g. water fountains, cooling towers, mist fans, shower heads, spas, jacuzzis, etc. The Environmental Public Health (Cooling Towers and Water Fountains) Regulations stipulate the frequency of the bacteriological test and the permissible limits for *legionella* bacteria.

H.2.2 Indoor mould

Moulds belong to the kingdom Fungi; unlike plants, they lack chlorophyll and survive by digesting plant materials, using plant and other organic materials for food.

Moulds produce tiny spores to reproduce and they can be easily spread through the air. Most moulds found indoors come from outdoor sources. It needs moisture to grow and becomes a problem only where there is high water activity, high humidity, or dampness. Common sources of indoor moisture that cause mould problems include flooding, roof and plumbing leaks, damp basements, pitting of water pipes (e.g. copper pipes) from ceiling or any moisture condensation on cold surfaces. Bathroom showers and steam from cooking may create mould problems if the space is not well-ventilated. Uncontrolled humidity can also be a source of moisture leading to mould growth, particularly in hot, humid climates like Singapore.

It is recommended to repair water leakages promptly, and dry out and clean or replace water-damaged materials within 24 hours. Materials that stay wet for more than 48 hours are likely to produce mould growth.

Allergic reactions, similar to common pollen or animal allergies, and irritation are the most common health effects for individuals sensitive to moulds. Flu-like symptoms and skin rash may occur. Mould may also aggravate asthma. Most symptoms are temporary and eliminated by correcting the mould problem.

There is a wide variability in how people are affected by mould exposure. People who may be affected more severely and quickly than others include infants, children, pregnant women, elderly, individuals with existing respiratory conditions such as asthma, environmental or other types of sensitivities and immuno-compromised individuals.

H.2.2.1 Common indoor moulds

The common indoor spores are *Cladosporium*, *Penicillium* and *Aspergillus*. Below is a brief description of these spores:

Cladosporium	*Cladosporium* is an outdoor mould and usually found in leafy plants. *Cladosporium cladosporioides* and *Cladosporium herbarum* are phylloplane species that occur in outdoor air at high level. In an indoor environment, *Cladosporium spp*. occur as secondary wall colonisers, appearing after the primary ones such as *Penicillium* and *Aspergillus spp.* *Cladosporium* is very common in wet building materials.
Penicillium	The species of *Penicillium* are commonly found outdoors and widespread indoors. Many *Penicillium* species cause damage to damp building materials, including the toxigenic species *Penicillium aurantiogriseum* which is commonly found in house dust.
Aspergillus	Species of *Aspergillus* are common in warmer climates. These species grow on a vast array of organic materials. *Aspergillus versicolor* is commonly present on building materials. *Aspergillus fumigatus* is pathogenic and one of the main causes of the invasive disease, aspergillosis.

H.2.2.2 Hidden moulds

Possible location of hidden moulds are walls behind furniture, porous thermal or acoustic liners inside ductwork, condensate drain pans inside AHU, and roof material above ceiling tiles. Other locations include dry walls covered with vinyl wallpaper, wood paneling and carpets, which serve as vapor barriers and trap moisture underneath their surfaces.

H.2.3 Mould remediation

H.2.3.1 Contamination assessment

An assessment should be conducted before commencement of any remediation work to determine the following:

(a) Size of the mould and/or moisture problem;

(b) Type of damaged materials.

H.2.3.2 Remediation plan

A remediation plan should be made to include:

(a) Steps to fix the water or moisture problem;

(b) Steps to carefully contain and remove mouldy building materials;

(c) Use of appropriate personal protective equipment (PPE) and containments.

H.2.3.3 Clean-up methods

The clean-up methods involve:

(a) Wet vacuuming hard surfaces or steam cleaning carpets and upholstered furniture;

(b) Damp-wiping and / or scrubbing with plain water and/or detergent solution;

(c) High Efficiency Particulate Air (HEPA) vacuuming after materials have been thoroughly dried;

(d) Discarding water-damaged materials by sealing them in plastic bags for disposal as normal waste.

H.2.3.4 Personal protective equipment (PPE)

Appropriate PPE should be used to prevent inhalation of mould and mould spores and to avoid contact with the skin and eyes during clean-up.

For small areas (below 3 m^2) of contamination, wear gloves, goggles and an N-95 respirator.

For larger areas of contamination, wear gloves, disposal overalls, shoe covers, and a full-face respirator with HEPA filters. Goggles should be worn if a half-face respirator is used.

H.2.3.5 Containment

Appropriate containments should be used to limit the release of mould into the indoor environment, and to minimise the exposure of remediation personnel and building occupants to mould.

For small areas (below 1 m^2) of contamination, no containment is required.

For contamination areas of up to 3 m^2, apply polyethylene sheeting from ceiling to floor to form an enclosure, and maintain a negative pressure with HEPA filtered exhaust.

For larger areas of contamination, apply double layers of polyethylene sheeting instead of a single layer.

H.2.4 Prevention of mould in dwellings

As part of routine building maintenance, buildings should be inspected for evidence of water-damaged areas and visible mould. Materials or areas damaged by water should be rectified early (within 48 hours) and building surfaces or furnishings dried to prevent mould growth. If any type of visible mould growth is found, the water / moisture source leading to it should be rectified and visible mould removed.

Annex I
(informative)

Sample checklist for building inspection

NOTE – A walk-through inspection should include the premises, its air-conditioning system and any other ventilation installations. The purpose of the inspection is to identify irregularities. The following checklist is provided as a guide and is not meant to be exhaustive. Where necessary, assistance should be sought from the building manager.

1 Human exposure and comfort levels

1.1 Is the indoor temperature regulated by thermostats? Where are they located? Have they been correctly positioned following building alterations? Are they set to the correct temperature? Are they calibrated regularly?

1.2 Is there discomfort due to radiant heat from warm window surfaces? Or other heat sources?

1.3 Does air reach all parts of the office or are there dead spaces (use a smoke detection tube to test)?

1.4 Does the occupant sit directly under the air diffuser?

1.5 Is the building still used for the purpose it was intended? Have partitions/walls been added or removed? Have occupancy levels changed?

1.6 Is there any twisted flexible duct?

2 Potential sources of contaminants

2.1 Is there any equipment which gives off gases or fumes? If so, is the equipment supplied with separate exhaust ventilation? Does the exhaust convey air to the exterior of the building or into corridors or into the air-conditioning system?

2.2 Are there furniture, furnishings, carpets, etc. that emit noticeable odours? Have detergents, pesticides or other chemicals been used in the building?

2.3 Are renovation works being undertaken in any part of the building? Are they done during working hours? Are the air-conditioning ducts properly sealed to prevent infiltration to other units?

2.4 Is there a kitchen or pantry where cooking is done? Is exhaust ventilation provided there?

2.5 Is the building adequately cleaned? Is regular dusting of office furniture, ledges, shelves, etc. carried out to help keep dust to a minimum? Are the carpets vacuum-cleaned regularly?

3 Ventilation and air-conditioning

3.1 How many supply air and extract air vents are there in each room or area? Is there at least one each in every room?

3.2 Are vents located in positions that will permit the best air circulation?

3.3 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow? Has dust collected around the air vents?

3.4 Is the air-conditioning system turned off any time during the day?

3.5 Is the system turned off after office hours? Are there still occupants in the building after office hours?

3.6 Where is the outdoor air intake duct located? Is it near the cooling tower in this building or near adjacent buildings? Is it near any kitchen exhaust? Is it at street level or near a car park? Is it blocked? Are heavy industries located nearby? Is there any construction work going on nearby? Does outdoor air enter the building?

3.7 Are filters being used? Are they adequate? Are they being bypassed? How often are they replaced?

3.8 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building? Are all the components of the air-conditioning system regularly inspected for leaks, breaches, etc.?

Annex J
(informative)

Sample confidential questionnaire for building occupants

Note - This short questionnaire is to be given to building occupants to help determine the existence of health problems that may be related to the office environment. Their answers are to remain confidential.

---

1. Personal information

1.1 Gender: Male / Female
1.2 Age:
1.3 No. of years you worked in this office:
1.4 Building type: office/shopping centre/school/others
1.5 Office level:

2. Environmental conditions

2.1 Age of the building:
2.2 Type of workstation: Enclosed room / Open concept
2.2 Floor carpeted: Yes/No
2.4 With wallpaper: Yes/No
2.5 Infiltration of cigarette smoke: Yes/No
2.6 Infiltration of vehicular exhaust: Yes/No
2.7 No. of people who share your workstation:
2.8 How is your area air-conditioned? Centralised unit / Fan coil unit
2.9 How is your workstation lighted? Fluorescent lighting / Non-fluorescent lighting
2.10 Please indicate if you work with or near the following equipment:
Photocopier : Yes/No
Server : Yes/No
Air cleaner : Yes/No
Others (Please specify:_____)
2.11 Do you have to put on extra clothing for comfort? Regularly / Sometimes / Never
2.12 Does the office air feel stuffy? Regularly / Sometimes / Never
2.13 Does the office air have an unpleasant odour? Regularly / Sometimes / Never
2.14 Visible mould : Yes/No
2.15 Dusty air vent : Yes/No

3 Nature of occupation

3.1 No. of hours spent per day at your main workstation with a computer:

3.2 Please rate how you find the stress in your working conditions:
Physical stress experience : Low / Moderate / High
Mental stress experience : Low / Moderate / High
Climate of cooperation at work : Low / Moderate / High

3.3 What is your job category? Managerial / Professional / Secretarial / Clerical / Others (if Others, specify: _____)

4 Health complaints

4.1 Please indicate your experience of the following symptoms at work during the past one month:

Stuffy nose : Daily / 2-3 times weekly / Less
Dry throat : Daily / 2-3 times weekly / Less
Cough : Daily / 2-3 times weekly / Less

Skin rash/itchiness	:	Daily / 2-3 times weekly / Less
Eye irritation	:	Daily / 2-3 times weekly / Less
Headache	:	Daily / 2-3 times weekly / Less
Lethargy	:	Daily / 2-3 times weekly / Less
Drowsiness	:	Daily / 2-3 times weekly / Less
Dizziness	:	Daily / 2-3 times weekly / Less
Nausea/vomiting	:	Daily / 2-3 times weekly / Less
Shortness of breath	:	Daily / 2-3 times weekly / Less

4.2 No. of days in the past one month that you had to take off work because of these complaints:

4.3 When do these complaints occur?
Mornings / Afternoons / No noticeable trend

4.4 When do you experience relief from these complaints?
After I leave my workstation / After I leave the building / Never

4.5 Please indicate if you have any of these medical conditions:

Asthma	:	Yes, on medication / Yes, not on medication / No
Allergy	:	Yes, on medication / Yes, not on medication / No
Sinus	:	Yes, on medication / Yes, not on medication / No
Migraine	:	Yes, on medication / Yes, not on medication / No

4.6 If female, are you currently pregnant? Yes / No / Not sure

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