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

AMENDMENT NO. 1

September 2021

1. Pages 5 and 6, Table of contents

a) *Add* "Annex K Mitigating risk of aerosol-mediated transmission of infection diseases" after Annex J.

b) *Add* "Table K.1 – Risk factors and enhanced measures" after Table H.5.

2. Page 14, 4.1 a) General

Replace 4.1 a) with:

a) The risk of any adverse health effects of breathing or contacting the air should be low. Indoor air contaminants (which are known to cause asthma, allergic reactions or other health issues such as respiratory diseases) should be managed by adopting good practices aimed at controlling the contaminant source, providing adequate ventilation and effective air cleaning. Table 1 and Table 2 provide the limits of contaminants that may be commonly found in indoor environment. Achieving these limits reduces the risk of contaminants of unknown identity or with unknown health limits. Annex K addresses the risk of indoor airborne transmission of infectious disease in the midst of a pandemic.

3. Page 14, 4.2 Impact of IAQ on productivity and health

Replace 4.2 with:

4.2 There is a close relationship between IAQ, health and productivity.

Good IAQ leads to a healthy indoor environment, which contributes to comfort, health and a sense of well-being. It is generally assumed that healthy and comfortable occupants are more productive.

On the other hand, occupants who are exposed to airborne contaminants or infectious pathogens may suffer from poor health and well-being, leading to reduced productivity.

The option of achieving 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. Page 16, 5.1.4.5.2 Air filters

Replace 5.1.4.5.2 with:

5.1.4.5.2 SS 553 specifies the minimum filter class requirements.

In the event of poor outdoor air quality (such as during periods of haze) or presence of indoor source of fine particles, the use of fine dust filters of at least a rating of minimum efficiency reporting value, MERV14 (ASHRAE Standard 52.2:2012), F8 (EN 779:2012) or ePM1 70 – 80 % (ISO 16890-1:2016), to treat outdoor and return air is required. Such filters are also required to mitigate aerosol-mediated transmission of infectious pathogens by preventing the build-up of pathogens in recirculated air.

Such filters, installed in preparation for these situations, offer additional benefits of further maintenance of general indoor air quality and keeping the ACMV system clean. Where installation of MERV14, F8 or ePM1 70 – 80 % filters is not feasible to treat return air (e.g. split-unit air conditioning systems, fan coil units, etc.), other measures (e.g. use of portable air cleaners, opening of windows/doors etc.) may be considered (refer to Annex K).

Gas-phase filters can be used in conjunction with the particulate filter to control gaseous pollutant. For such purposes the fan motor needs to be sized accordingly such that the required air flow rate can be maintained.

5. Page 16, 5.1.4.5.4 Other air cleaning techniques

Replace 5.1.4.5.4 with:

5.1.4.5.4 Other air cleaning techniques for the improvement of indoor air quality can be considered, especially for areas with high contamination risk and poor ventilation. For cleaning particulate matters, the efficiency should be at least equivalent to MERV14, F8 or ePM1 70 – 80 %. The potential benefits should be weighed against any safety and health risks.

6. Page 18, 5.3 Renovation work

Replace the first line of 5.3 with:

Renovation work should be undertaken in a way that minimises contamination to the indoor environment.

7. Page 19, 5.5.2.5 Develop and implement plans for facilities operation and maintenance

Replace 5.5.2.5 with:

5.5.2.5 Develop and implement plans for the operation, preventive maintenance, and unscheduled maintenance of the ACMV system and housekeeping activities. The plan should also consider risks that may affect facilities operation, e.g. risk of diseases that can potentially be transmitted by aerosols within the building (refer to Annex K).

8. Page 20, new clause 5.5.3 Operation of ACMV systems

Replace 5.5.3 as follows:

5.5.3 Operation of ACMV systems

To ensure ventilation is provided as intended to occupied spaces, physical checks on ACMV system should be done at regular intervals. This is to identify any irregularities in the ACMV operations that may unknowingly be introduced (e.g. during servicing or cleaning), so that rectification works can be done in a timely manner.

5.5.4 Maintenance of ACMV systems

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

9. Page 22, Table 1 – Recommended IAQ parameters

Add the following statement for air movement below < 0.30:

(Poorer air flow areas with less than 0.10 m/s air movement need further evaluation for virus removal efficacy)

10. Page 34, B.1.1 Available methods

Replace the first paragraph of B.1.1 with:

There are various ways to reduce pollution in the indoor air. Increasing 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 only solution. The choice of one approach over another depends on a number of factors including the nature of the pollutant itself, its source characteristics, effects of the pollution on people, relative practicability and economics (initial costs and operating costs).

11. Page 35, B.3.1 Ventilation

Replace first paragraph of B.3.1 with:

Ventilation is the most common approach to reducing airborne contaminant levels in buildings. Relying solely on ventilation as a contaminant control strategy can be energy-intensive and unsustainable. Sole reliance on ventilation should only be considered if source elimination, substitution or mitigation is not possible.

12. Page 36, B.3.2 Air cleaning

Replace second paragraph of B.3.2 with:

Air cleaners ('filters') that are commonly used in ACMV systems are of two types: particulate air cleaners and gas phase air cleaners. Particulate air cleaners remove particulate matters including aerosols, while gas phase air cleaners remove gaseous contaminants. Annex E provides more details on air cleaners.

13. Page 62, new Annex K

Add the following new Annex K after Annex J.

Annex K
(informative)

Mitigating risk of aerosol-mediated transmission of infectious diseases

K.1 Scope

Building and facilities managers play a critical role in managing the risk of infectious disease transmission in the community, including transmission mediated by aerosols (including bioaerosols). Restricted ventilation in indoor spaces may create an environment with increased risk of aerosol-mediated transmission of infectious diseases, especially where occupant density is high (e.g. meeting rooms), or where the crowd is dynamic with different occupants at different time periods. For premises owners and operators, ensuring good ventilation in indoor spaces augments other risk reduction measures, such as implementing safe distancing measures and carrying out regular disinfection of high-touch points within the building.

This annex aims to help building and facilities managers better manage the risk of aerosol-mediated transmission of diseases in indoor spaces, by providing a guide for risk assessment and mitigation.

K.2 Risk assessment and mitigation

K.2.1 Considerations

Building and facilities managers should conduct an assessment to evaluate the risk of aerosol transmission of diseases within the building. Such assessment should be updated regularly whenever new knowledge emerges.

The assessment should take into consideration the following situations:

a) No or limited outdoor air supply – Enclosed air-conditioned premises with no mechanical ventilation (e.g. installed with split-unit air-conditioning systems), or with weak mechanical ventilation/air filtration (e.g. fitted with FCUs) are considered to be of higher risk as they have no or limited outdoor air supply and inadequate filtration for small particles.

b) Prolonged time spent in a crowded facility – Crowded spaces or those with prolonged occupancy (e.g. childcare, tuition and enrichment centres) are of higher risk, as the risk of exposure increases with the number of people and time spent in the space.

c) Presence of infected persons – Areas with a potential source of disease introduction (e.g. clinics and their waiting areas) are of higher risk as infected persons may be present.

d) Potential bioaerosol-generating activities – Spaces with bioaerosol-generating activities (e.g. swabbing, dental procedures, singing, heavy breathing) are of higher risk, as bioaerosols that potentially contain pathogens may be generated.

e) Activities with close proximity between persons and removal of masks – Spaces with activities involving removal of masks (e.g. in F&B outlets, in gyms) are of higher risk as more bioaerosols can be released, while unmasked people will be less protected against these aerosols.

K.2.2 Planning and communication

A comprehensive plan should be created for safe management of indoor spaces, including developing communication plans to garner support from occupants, increasing ventilation, and ensuring supply of critical items such as filters. Managers should tailor the measures to each space, maximising ventilation while taking factors such as the type of ventilation system in the indoor space, the area of the indoor space, occupants' thermal comfort, and relative humidity into consideration. Indoor relative humidity should be closely monitored and maintained as closely as practicable according to Table 1.

K.2.3 Recommended measures

K.2.3.1 Air-conditioned premises with mechanical ventilation provision (e.g. centralised air-conditioning system)

The following procedures for air-conditioned premises with mechanical ventilation provision should be carried out:

a) Ensure that ventilation systems are in good working order. The recommendations are as follows:

   i) Check ACMV systems to ensure adequate ventilation in all occupied spaces, based on at least the minimum outdoor air supply rates specified in SS 553 or ANSI/ASHRAE Standard 62.1-2019, "Ventilation for acceptable indoor air quality". Sensors and systems for monitoring outdoor air supply rate should be used.

ii) Check air handling unit (AHUs) / fan coil units (FCUs) / primary/pre-cool air handling unit (PAUs) / fresh air fan (FAFs) / exhaust air fan (EAFs) daily to ensure continuous operation, especially in occupied spaces.
iii) Check all supply air diffusers and exhaust grilles to ensure that air distribution is balanced to ensure outdoor air provision to all intended spaces and the air flow is in the correct direction. If transfer or recirculation of air is necessary, the airflow direction in occupied spaces should be from clean to less-clean areas.
iv) Maintain ACMV systems regularly. This includes inspecting and cleaning supply fans and exhaust fans to ensure optimal operation, checking of air ducts and dampers to ensure no air leakages or blockages, and checking filter seals to avoid air bypass. Recommended maintenance frequencies are specified in Annex H. Toilet and kitchen exhaust fans and systems should also be inspected and cleaned regularly to ensure optimal operation and avoid build-up of contaminants. The recommendations are as follows:
   - Air filters should be changed when the filter pressure drop reached the allowable limit of AHU fan static or at the manufacturer's recommended final pressure drop, whichever comes first. Changing of filters should be done during non-operational periods, with the ACMV system turned off. Used filters should be properly disposed of in sealed bags.
   - Maintenance staff should wear the appropriate personal protective equipment (PPE), comprising at least N95 masks, eye protection, and gloves, especially when changing filters. Soiled PPE should be removed after completion of work at a safe area to avoid contamination to general areas.
   - Where practicable, the performance of installed air filters should be verified through in situ testing.
v) Check other systems to ensure there is no undesired air leakage into occupied spaces, including water seals in the sanitary system, cracks in pipes and ducts, and wall gaps. Rectify faults detected.

b) Maximise ventilation for indoor air dilution. The recommendations are as follows:

i) Maximise outdoor air intake and supply by setting AHUs/FCUs/PAUs/FAFs/EAFs to maximum speed and capacity with all air dampers (e.g. volume control dampers) opened fully. Increase outdoor air supply rate to at least 10 L/s/person if the system can accommodate this [53]. Maximising outdoor air intake is important if the ACMV system is not equipped with at least MERV14, F8 or ePM1 70 – 80 % filters, or the air in indoor space is not disinfected with a safe and effective cleaning system.
ii) Deactivate demand control systems, such as those with CO_2 sensors, to avoid automatic reduction of outdoor air supply.
iii) Open all air dampers and do not block air ducts to ensure optimal provision of outdoor air to all occupied spaces.
iv) Operate exhaust fans (e.g. in toilets, kitchens) at full capacity to expel air from indoor spaces. Keep windows and other openings (e.g. back door) around exhaust fans closed to avoid short-circuiting of air flow.
v) Install additional supply and/or exhaust fans if the existing system does not deliver sufficient outdoor air.
vi) If the system does not allow for increasing the ventilation up to the recommended minimum per person requirement, reduce the maximum room occupancy.
vii) If the indoor air quality is worsened by increasing ventilation (e.g. rise in PM2.5 levels), the efficient filters and air cleaning strategies in the AHU described in K.2.3.1 d) i) should be used. This would be in lieu of, or in addition to increasing ventilation. If these are not practicable, use portable air cleaners [see K.2.3.2 c) i) – iv)] as an interim measure. Managers may also monitor PM2.5 levels to assess infiltration of outdoor air contaminants via the outdoor air supply.

c) Purge indoor air before occupancy. The recommendations are as follows:

i) Perform air purging at least once a day and for at least two hours before each occupancy. Increase purging frequency for spaces with high disease transmission risk, such as

spaces where bioaerosol-generating procedures are performed on people (e.g. nasopharyngeal swab taking and dental procedures), where COVID-19 patients may be present, or where masks must be removed (see K.2.4).

ii) Extend operation of ACMV systems for buildings without air purging systems, with outdoor air intake for at least 2 h before and after each occupancy.

d) Treat recirculated air. The recommendations are as follows:

i) Use at least MERV14, F8 or ePM1 70 – 80 % filters in AHUs to treat recirculated air. Filters should be properly installed (e.g. without any gaps in between) and maintained according to manufacturers' recommendation.

ii) Use air-cleaning technologies such as ultraviolet germicidal irradiation (UVGI) in upper rooms, in AHU rooms or AHUs to augment MERV14 filters. The UV intensity or irradiance should be high enough to deliver the germicidal dosage required to inactivate the targeted biological agent. It should be noted that many UVGI systems installed in AHUs are intended for disinfection of cooling coils to improve their performance, and may not be effective at cleaning moving supply air. It is essential to ensure the efficacy and safety of all air-cleaning devices under the operating conditions.

iii) Switch off rotatory heat changers or heat recovery wheels to reduce risk of carry-over leakage from exhaust air.

e) Increase ventilation in premises with limited ventilation and air filtration provision. The recommendations are as follows:

i) Open operable windows and doors as frequently as possible [54], unless outdoor/outside air quality is poor. Air-conditioning should be reduced or turned off when doors and/or windows are opened.

ii) Position fans at windows to blow air outwards and increase air exchange.

iii) Add dedicated outdoor air supply and/or exhaust. To avoid mould growth due to condensation caused by introduction of excessive humid outdoor air, outdoor air may be treated by a dedicated outdoor air processing system. The outdoor air system can be designed such that at least MERV14, F8 or ePM1 70 – 80 % filters can be fitted when necessary. The filter will be useful during times when windows cannot be opened due to poor outdoor air quality.

iv) Use portable air cleaners (with a cleaning efficiency equivalent to HEPA i.e. at least 99.97 % @ 0.3 microns) for localised air cleaning as an interim measure, where there is a high risk of disease transmission (see K.2). If the unit of clean air delivery rate (CADR) is in cubic metres per hour, the total CADR of the air purifier(s) should be at least five times the room volume in cubic metres.

K.2.3.2 Enclosed air-conditioned premises without mechanical ventilation provision (e.g. split-unit air-conditioners or FCUs without fresh air supply)

The following procedures for enclosed air-conditioned premises without mechanical ventilation provision should be carried out:

a) Increase ventilation and enhance air exchange. The recommendations are as follows:

i) Open operable windows and doors as frequently as possible [54], unless outdoor air quality is poor. Air-conditioning should be reduced or turned off when doors and/or windows are opened.

ii) Add dedicated outdoor air supply and/or exhaust. To avoid mould growth due to condensation caused by introduction of excessive humid outdoor air, outdoor air may be treated by a dedicated outdoor air processing system. The outdoor air system can be designed such that at least MERV14, F8 or ePM1 70 – 80 % filters can be fitted when necessary. The filter will be useful during times when windows cannot be opened due to poor outdoor air quality.

iii) Operate exhaust fans (e.g. toilet, kitchen) at full capacity to expel air form the indoor space. Keep windows or other openings (e.g. back door) around exhaust fans closed to avoid short-circuiting of air flow.

b) Install window-mounted exhaust fans to enhance ventilation. The recommendations are as follows:

i) The fan system should at least provide the minimum outdoor air supply rates specified in SS 553.
ii) Air supply and exhaust system can be aligned to provide uni-directional airflow in a poorly ventilated space.

c) Use air cleaners for localised air cleaning as an interim measure in enclosed spaces with high risk of disease transmission. The recommendations are as follows:

i) Portable air cleaners should be equipped with high-efficiency air filters such as HEPA filters, which are effective at removing virus aerosols.
ii) The CADR for smoke or equivalent of a portable air purifier should be used to determine the size and number of portable air cleaner devices needed in a space. If the unit of CADR is in m^3/h, the total CADR of the air purifier(s) should be at least five times the room volume in cubic metres. Where ventilation is very limited, consider increasing the total CADR of the air purifier(s) to at least 7.2 times the room volume in cubic metres specified in AHAM AC-1-2020 “Method for Measuring Performance of Portable Household Electric Room Air Cleaners”.
iii) If present, the portable air cleaner’s ozone generation function should be turned off to avoid exposure to excessive ozone levels and by-products, which may be hazardous to health.
iv) Localised air cleaning does not replace the need for adequate ventilation to prevent bioaerosol accumulation. Regular surface cleaning and disinfection should also continue according to guidance issued by the authority, as portable air cleaners do not remove surface contamination.
v) Effective air-disinfecting technologies such as ultraviolet germicidal irradiation (UVGI) in upper rooms or AHU rooms may be used. It is essential to ensure safety for occupants and maintenance staff.

d) Check other systems to ensure there is no undesired air leakage into occupied spaces, including water seals in the sanitary system, cracks in pipes and ducts, and wall gaps. Rectify faults detected.

K.2.4 Enhanced measures to mitigate increased airborne disease transmission risks

Building and facility managers should implement enhanced measures for spaces with high disease transmission risk (see Table K.1). The general strategies to manage the risk of aerosol-mediated transmission of infectious diseases are source control, improved ventilation, and enhanced air cleaning.

Table K.1 – Risk factors and enhanced measures

Risk factors	Enhanced measures
No or limited outdoor air supply	<u>For air-conditioned premises with mechanical ventilation provision (e.g. centralised air-conditioning system)</u> 1. Install additional supply and/or exhaust fans if the existing system does not deliver sufficient outdoor air. 2. If the system does not allow for increasing the ventilation up to the recommended minimum per person requirement, reduce the maximum room occupancy.

	For enclosed air-conditioned premises without mechanical ventilation provision (e.g. split-unit air-conditioners or FCUs without fresh air supply) Adopt the recommended measures in K.2.3.2.
Prolonged time spent in a crowded facility	1. Ensure that the occupancy in the facility is managed such that the outdoor air supply rates in SS 553 can be met. If possible, the ventilation rate should at least be 10 L/s/person of outdoor air. 2. Increase the purging frequency (e.g. before every session) to keep aerosol levels low. 3. Enclosed air-conditioned premises with no or weak mechanical ventilation are not ideal for occupancy over prolonged periods. Use localised air cleaning devices in the interim while measures to improve ventilation is being implemented. The recommendations are as follows: a) Use portable air cleaners equipped with high-efficiency air filters such as HEPA filters, which are effective at removing virus aerosols. Recommendations for sizing are described in K2.3.1 e) iv). If present, any function that generates ozone should be turned off to avoid exposure to excessive ozone levels and by-products, which may be hazardous to health. b) Where ceiling height allows, upper-room ultraviolet germicidal irradiation (UVGI) may be considered. As viral disinfection efficacy and safety are greatly dependent on the system and how it is installed, professional services should be used to ensure safety and effectiveness. 4. Regular surface cleaning and disinfection should continue, as portable air cleaners do not remove surface contamination.
Presence of infected person/ Increased bioaerosol generation	1. Shift high-risk bio-aerosol generating events/activities to an outdoor area with good natural ventilation where possible. 2. If outdoor area is unavailable, maximise provision of outdoor air to indoor spaces above standard levels. The recommendations are as follows: a) Set all fans in the ACMV system (e.g. AHUs, FCUs, PAUs, FAFs and EAFs) to operate at maximum speed with all air dampers along the air supply (e.g. volume control dampers) opened fully. b) Provide sufficient outdoor air or reduce the room occupancy such that the ventilation rate is at least 10 L/s/person of outdoor air [53]. 3. Close recirculation air dampers from affected space, and ensure air does not flow from the affected space to other areas.

	4. Increase the purging frequency (e.g. before every session) to keep aerosol levels low. 5. Enclosed air-conditioned premises with no or weak mechanical ventilation are not ideal for such high-risk bio-aerosol generating events/activities. Use localised air cleaning devices in the interim while measures to improve ventilation is being implemented. The recommendations are as follows: a) Use portable air cleaners equipped with high-efficiency air filters such as HEPA filters, which are effective at removing virus aerosols. Recommendations for sizing are described in K2.3.1 e) iv). If present, any function that generates ozone should be turned off to avoid exposure to excessive ozone levels and by-products, which may be hazardous to health. b) Where ceiling height allows, upper-room ultraviolet germicidal irradiation (UVGI) may be considered. As viral disinfection efficacy and safety are dependent on the system and how it is installed, professional services should be used to ensure safety and effectiveness. 6. Regular surface cleaning and disinfection should continue, as portable air cleaners do not remove surface contamination.
Removal of masks	1. Maximise provision of outdoor air to indoor spaces above standard levels. The recommendations are as follows: a) Set all fans in the ACMV system (e.g. AHUs, FCUs, PAUs, FAFs and EAFs) to operate at maximum speed with all air dampers along the air supply (e.g. volume control dampers) opened fully. b) Provide sufficient outdoor air or reduce the room occupancy such that the ventilation rate is at least 10 L/s/person of outdoor air [53]. 2. Enclosed air-conditioned premises with no or weak mechanical ventilation are not ideal for such spaces where masks can be removed. Use localised air cleaning devices in the interim while measures to improve ventilation is being implemented. The recommendations are as follows: a) Use portable air cleaners equipped with high-efficiency air filters such as HEPA filters, which are effective at removing virus aerosols. Recommendations for sizing are described in K2.3.1 e) iv). If present, any function that generates ozone should be turned off to avoid exposure to excessive ozone levels and by-products, which may be hazardous to health. b) Where ceiling height allows, upper-room ultraviolet germicidal irradiation (UVGI) may be considered. As viral disinfection efficacy and safety are dependent on the system and how it is installed, professional services

	should be used to ensure safety and effectiveness. 3. Regular surface cleaning and disinfection should continue, as portable air cleaners do not remove surface contamination.

K.2.5 Assessment of ventilation adequacy and use of CO_2 levels as a surrogate

To assess the adequacy of ventilation in a space, ventilation rates should be measured to ensure that outdoor air supply meets the minimum requirements set out in SS 553. In view of the COVID-19 risk, managers should strive to achieve the higher rate of at least 10L/s/person recommended by WHO if the ventilation system can accommodate this.

Measurement of ventilation rates is not always possible or feasible (e.g. in air-conditioned spaces without mechanical ventilation or in naturally ventilated spaces), and ventilation rates may vary widely across spaces in an ACMV-equipped building. It is therefore recommended to use CO_2 levels as a surrogate measure to quickly assess ventilation adequacy. Managers may use CO_2 readings to identify problematic spaces with underventilation and/or overcrowding, so that prompt action can be taken to improve the situation.

To quickly assess ventilation adequacy, CO_2 levels over a period of at least 5 min per sampling location should be carried out at occupied areas. According to Table 1, high CO_2 levels, more than 700 ppm in excess of outdoor level, indicate poor ventilation or overcrowding. In view of the COVID-19 situation, it is recommended that CO_2 levels should not exceed an average of 800 ppm over the measurement period [55,56].

Sampling should be conducted at multiple locations within the space, including locations with poorer air flow, to better identify areas where interventions are needed to enhance ventilation. In spaces with a dynamic crowd, managers should implement constant monitoring by installing a CO_2 sensor at the occupied zone with a visible display.

It should be noted that while high CO_2 levels indicate poor ventilation and/or overcrowding, there is no simple correlation between CO_2 levels and risk of exposure to virus. Good ventilation and existing measures (masks, safe distancing, cleaning) are still needed even if CO_2 levels are within the recommended limits.

14. Page 69, Addition of Bibliography

Add the following publications after No. 52.

53. Roadmap to improve and ensure good indoor ventilation in the context of COVID-19, World Health, 1 March 2021, https://www.who.int/publications/i/item/9789240021280

54. Heating, ventilation and air-conditioning systems in the context of COVID-19: first update, European Centre for Disease Prevention and Control, 11 November 2020, https://www.ecdc.europa.eu/en/publications-data/heating-ventilation-air-conditioning-systemscovid-19

55. Ventilation in Buildings, Centers for Disease Control and Prevention, 2 June 2021, https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html

56. How to operate HVAC and other building service systems to prevent the spread of the coronavirus (SARS-CoV-2) disease (COVID-19) in workplaces, REHVA COVID 19 Guidance version 4.1, 15 April 2021, https://www.rehva.eu/activities/covid-19-guidance/rehva-covid-19-guidance

NOTE – Hyperlinks are valid at the time of publication.