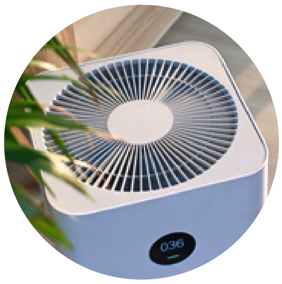
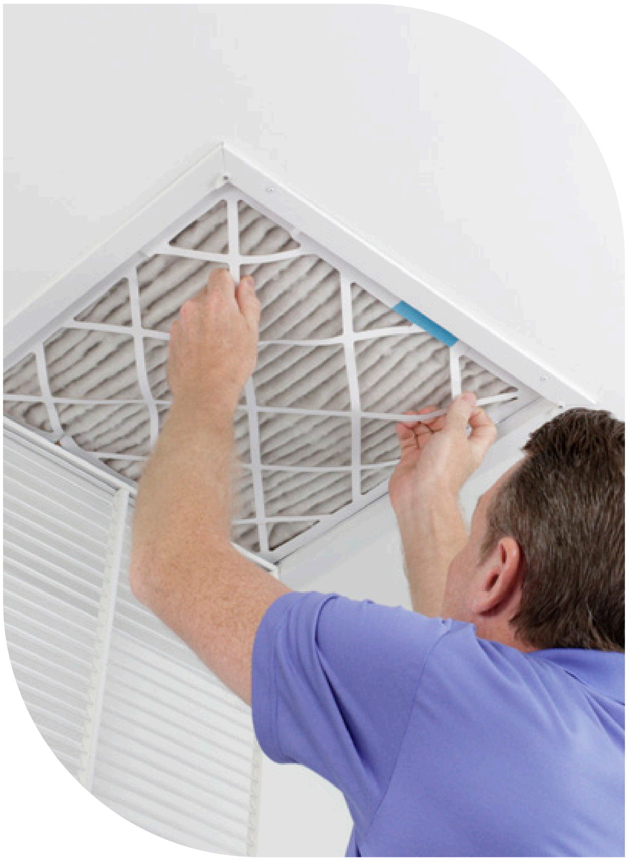
An tÚdarás Sláinte agus Sábháilteachta
Health and Safety Authority

Code of Practice for Indoor Air Quality





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Foreword

The Health and Safety Authority, with the consent of Mr. Neale Richmond, Minister of State for Business, Employment and Retail, and following public consultation, publishes this *Code of Practice for Indoor Air Quality,* in accordance with Section 60 of the Safety, Health and Welfare at Work Act 2005 (No. 10 of 2005).

This Code of Practice provides practical guidance as to the observance of the provisions of the Safety, Health and Welfare at Work (General Application) Regulations 2007 (S.I. No. 299 of 2007), as amended by S.I 255 of 2023. This Code of Practice comes into operation on 26th May 2023. Notice of the publication of this Code of Practice was published in *Iris Oifigiúil* on 6th June 2023.

With regard to the use of codes of practice in criminal proceedings, Section 61 of the Safety, Health and Welfare at Work Act 2005 provides as follows:

- 61. (1) Where in proceedings for an offence under this Act relating to an alleged contravention of any requirement or prohibition imposed by or under a relevant statutory provision being a provision for which a code of practice had been published or approved by the Authority under Section 60 at the time of the alleged contravention, subsection (2) shall have effect with respect to that code of practice in relation to those proceedings.
- (2) (a) Where a code of practice referred to in subsection (1) appears to the court to give practical guidance as to the observance of the requirement or prohibition alleged to have been contravened, the code of practice shall be admissible in evidence.

  (b) Where it is proved that any act or omission of the defendant alleged to constitute the contravention- (i) is a failure to observe a code of practice referred to in subsection (1), or (ii) is a compliance with that code of practice, then such failure or compliance is admissible in evidence.
- (3) A document bearing the seal of the Authority and purporting to be a code of practice or part of a code of practice published or approved of by the Authority under this section shall be admissible as evidence in any proceedings under this Act.

Marie Dalton

Marie Dalton
Secretary to the Board

Section 1

1.0 Introduction

Workers spend a significant amount of time indoors, and the quality of air within indoor work environments has a direct impact on the health, well-being and productivity of those workers.

Contributing factors to poor indoor air quality (IAQ) include poor external air quality, inadequate or poor ventilation, and exposure to a range of chemicals, biological agents and other contaminants in the workplace air. Poor IAQ can cause a variety of both short-term and long-term health problems.

As was evident during the coronavirus disease 2019 (COVID-19) pandemic, sufficient ventilation and air filtration was an important factor in reducing the risk of aerosol transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19.

This Code of Practice provides a practical risk assessment approach to help employers make a reasonable determination of IAQ in their workplace. It includes parameters for carbon dioxide (CO_2), air changes per hour, temperature, humidity, ventilation rates, and other contaminants in order to enable baseline assessments. This Code of Practice addresses risk assessment competency in terms of workplace complexity and provides advice on investigating IAQ complaints. It also provides information on IAQ, ventilation, air filtration and CO_2 monitors.

This Code of Practice differentiates between the requirements under the Safety, Health and Welfare at Work (General Application) Regulations 2007 (S.I. No. 299 of 2007) and those of other legislation and codes of practice. Requirements in other health and safety legislation related to chemical agents, biological agents, and other substances (such as asbestos) influence IAQ, so it is important that employers deal with these substances and agents holistically, rather than in isolation, when addressing IAQ.

1.1 Scope of this Code of Practice

This Code of Practice is relevant to all places of work. Employers should use this Code to develop policies, conduct risk assessments and implement control measures to address IAQ and ventilation in the workplace. Any standards or sector-specific advice on IAQ and ventilation should be utilised in conjunction with this Code of Practice in order to ensure that best practice IAQ techniques are applied.

This Code of Practice aims to provide practical guidance on managing IAQ in the workplace (specifically to employers and employees) on:

- improving IAQ;
- improving ventilation in workplaces;
- establishing a set of acceptable values for specific chemical and physical parameters; and
- describing mechanisms to identify, evaluate and control IAQ issues.

This Code of Practice provides assistance on meeting the requirements of the Safety, Health and Welfare at Work (General Application) Regulations 2007 (S.I. No. 299 of 2007), as amended by S.I. No. 255 of 2023.

In line with Section 2(6) of the Safety, Health and Welfare at Work Act 2005 (also referred to as the 2005 Act), all employer duties for which this Code of Practice provides guidance should be carried out as far as is reasonably practicable.

This Code of Practice should be consulted in the planning and design of new work environments and in the refurbishment or upgrading of existing work environments.

This Code of Practice does not apply to the use of hazardous substances or exposure to those substances regulated under the **Safety, Health and Welfare at Work (Chemical Agent) Regulations 2001 as amended** and the **Safety, Health and Welfare at Work (Carcinogens) Regulations 2001 as amended.** Employers must complete separate chemical risk assessments under each of these two groups of regulations.

Some substances with occupational exposure limit values listed in the ***2021 Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations (2001-2021) and the Safety, Health and Welfare at Work (Carcinogens) Regulations (2001-2019)*** may be relevant for the purposes of assessing IAQ.

This Code of Practice does not apply to the Safety, Health and Welfare at Work (Biological Agents) Regulations 2013 and 2020 (S.I. No. 572 of 2013 as amended by S.I. No. 539 of 2020) or its associated code of practice. Employers must complete separate biological agent risk assessments under these Regulations.

However, compliance with the above legislation addressing chemical and biological agents in the workplace will significantly support the objectives of this Code of Practice.

Finally, this Code of Practice excludes practical advice on local exhaust ventilation (LEV). Separate guidance on LEV is available at https://www.hsa.ie/eng/publications_and_forms/publications.

1.2 Definitions

Air changes per hour (ACH) is a measure of ventilation that estimates how many times the air in a room/space is replaced with fresh, clean air per hour.

Air conditioning controls the air temperature and/or humidity and recirculates the air. Alone, it does not provide fresh air or ventilation.

CE marked means products sold in the EEA have been assessed to meet high safety, health, and environmental protection requirements.

HVAC means 'heating, ventilation and air conditioning' and is often a descriptor used to refer to a dedicated system that is used to control the condition of air being mechanically moved in a building or internal space.

Local exhaust ventilation (LEV) is an engineering system designed to capture contaminants (such as dust, mist, fumes, vapour or gas) in the workplace at their source and transport them to a safe emission point or to a filter/scrubber. It is not part of general ventilation.

Occupational exposure limit value (OELV) is defined as the limit of the time-weighted average of the concentration of a chemical agent in the air within the breathing zone of a worker in relation to a specified reference period (either 8 hours or 15 minutes).

PM_{10} refers to particulate matter (PM) where the particles have a diameter equal to or less than 10 micrometres.

$PM_{2.5}$ refers to particulate matter (PM) where the particles have a diameter equal to or less than 2.5 micrometres.

Ventilation refers to the movement of outdoor air into a building, and the circulation of that air within the building or room while removing stale air to improve the air quality.

1.3 Relevant legislation

Safety, Health and Welfare at Work Act 2005

Employers have duties under the **Safety, Health and Welfare at Work Act 2005 (No. 10 of 2005)** to provide a safe place of work. The principle of risk assessment is enshrined in **Section 19** of the Act. The 2005 Act outlines the principles of prevention: a hierarchy of control measures (elimination and substitution, engineering controls, administrative controls, and personal protective equipment) to mitigate identified risks.

In the context of IAQ, **Section 8** of the 2005 Act requires employers to ensure that the workplace, articles, plant and machinery are designed, provided and maintained in a condition that is safe and without risk to health. The employer should also ensure, as far as is reasonably practicable, the safety and the prevention of risk to health at work of employees relating to the use of any article, substance, ionising or other radiation, or any other physical agent.

Section 8 requires the provision and maintenance of facilities and arrangement for the welfare of employees and requires employers to provide the information, instruction, training and supervision necessary to ensure, as far as is reasonably practicable, the safety, health, and welfare at work of employees.

Section 19 of the 2005 Act places a duty on those also in control of places of work (as defined in **Section 15** of the 2005 Act). They may also have to carry out a written risk assessment to the extent that their duties may apply to persons other than their own employees.

Section 15 of the 2005 Act states that this person shall ensure, by virtue of any contract, tenancy, etc., that the place of work, and any article or substance provided for use in the place of work, are safe and without risk to health as far as is reasonably practicable.

Employers also have a duty to co-operate under **Section 21** where a place of work is shared.

Employers must co-operate in complying with and implementing the relevant health and safety statutory provisions and co-ordinate their actions in matters relating to the protection from and prevention of risks to safety, health and welfare at work for their respective employees.

Safety, Health and Welfare at Work (General Application) Regulations 2007 (as amended)

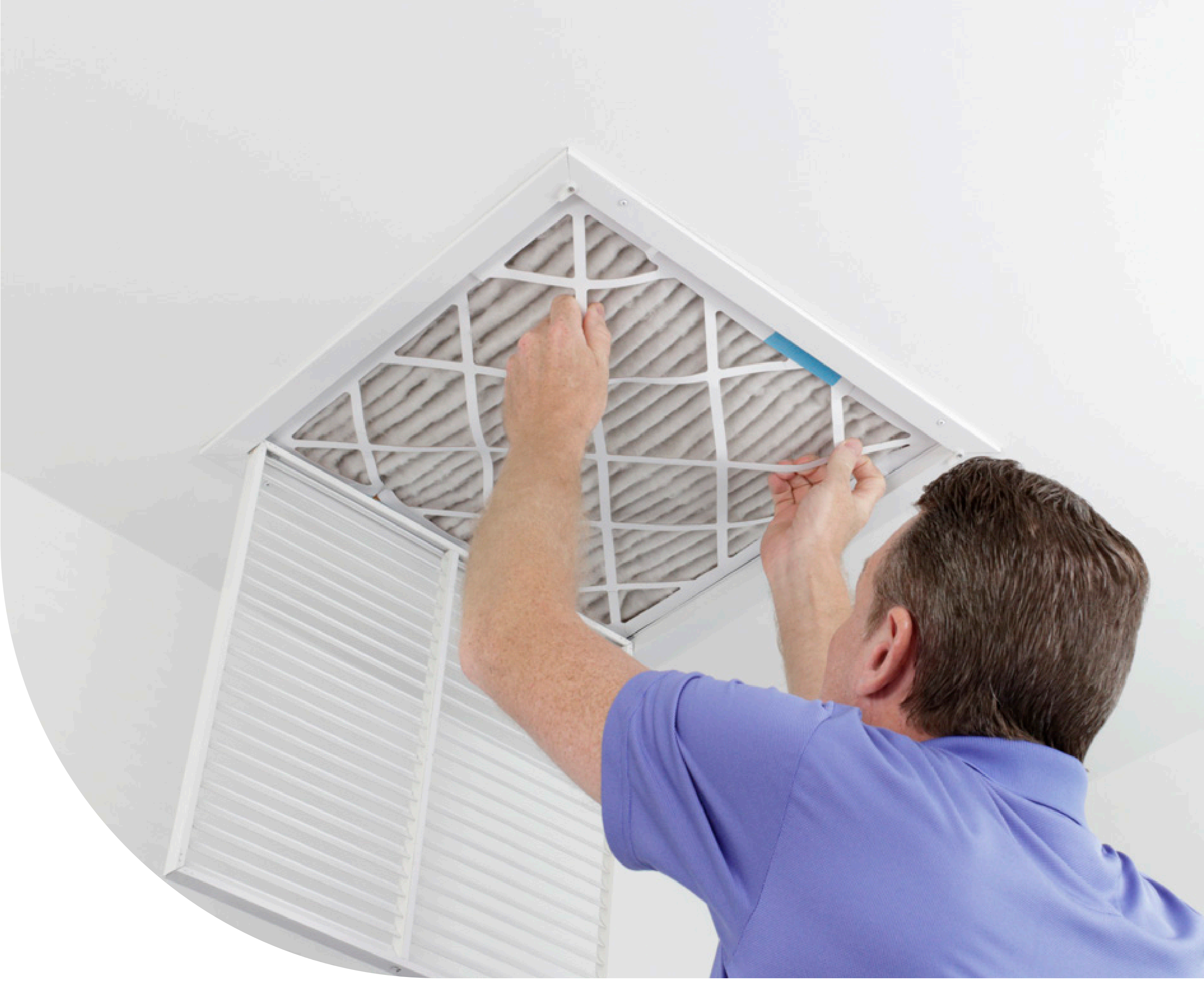
Regulation 6 of the **Safety, Health and Welfare at Work (General Application) Regulations 2007 (S.I. No. 299 of 2007) (as amended)** requires employers to make sure sufficient fresh air is provided in enclosed places of work. Employers must give consideration to the working methods used and the physical demands placed on the employees.

Where present, mechanical ventilation systems (such as heating, ventilation and air conditioning (HVAC) systems) must be maintained in good working order - for example, as part of a plant preventive maintenance system - and operate in such a way that employees are not exposed to draughts which cause discomfort. Mechanical ventilation systems must also be cleaned regularly to avoid contamination. **Regulation 6** also states that any deposits or dirt likely to create an immediate danger to the safety and health of employees by polluting the atmosphere must be removed immediately and without delay.

Regulation 18 deals with general welfare requirements which impact IAQ. An employer must ensure that every place of work is kept in a clean state and that accumulations of dirt refuse, trade refuse, and waste are removed by a suitable method as frequently as necessary in order to maintain an appropriate level of safety and health. The floor of every workroom must be cleaned by a suitable method as frequently as necessary in order to maintain an appropriate level of safety and health.

1.4 References to legislation and standards

As legislation is reviewed regularly, where this Code of Practice makes reference to legislation, the status of this legislation should be checked on the Attorney General's website at www.irishstatutebook.ie. Where reference is made to a particular standard, the status of such standards can also be checked on the National Standards Authority of Ireland's website at www.nsai.ie.



Section 2

2.0 Indoor air quality in enclosed places of work

Indoor air quality (IAQ) is an important component of a healthy workplace, as many people now spend a considerable amount of their time indoors. IAQ can affect job satisfaction, worker productivity, comfort and health.

IAQ comprises the indoor environment, including the composition of the air and comfort factors such as temperature and relative humidity. IAQ depends on a range of internal and external factors. 'Good' IAQ may be considered as air with no known contaminants present at harmful concentrations. In order to enable good IAQ, there should be:

- provision of sufficient fresh air supply rates to dilute and remove contaminants;
- effective ventilation;
- low external pollutant/contaminant concentrations; and
- low pollutant/contaminant emission rates from internal sources.

It is important that when making improvements to an area such as ventilation, other environmental comfort factors are not compromised. For example, it would not be acceptable to open doors and windows to achieve adequate ventilation if this would result in a breach of recommended minimum working temperatures.

Table 1 provides a list of IAQ issues and contaminants including their potential sources.

Table 1: Workplace IAQ issues and potential sources

IAQ issues/contaminants	Potential sources
Inadequate ventilation (insufficient outside air, insufficient airflow, inadequate circulation)	Energy-saving and maintenance measures, incorrect system design or operation, overcrowding, occupants tampering with the heating, ventilation and air conditioning (HVAC) system, broken HVAC equipment, poor office layout, an unbalanced system, windows that are sealed shut, blocked vents, etc.
Temperature and humidity extremes	Incorrect placement of thermostats, poor humidity control, a system that is not designed to cope with climate extremes, inadequate heating/ cooling, etc.
Combustion contaminants such as carbon monoxide, nitrogen dioxide, polycyclic aromatic hydrocarbons, and particulate matter (PM_{10} and $PM_{2.5}$)	Can come from a mix of indoor and outdoor sources such as malfunctioning boilers, stoves, generators, gas or kerosene heaters, and vehicle exhaust emissions. There are numerous non-combustion sources of $PM_{2.5}$, such as nebulisers and vapes (these are direct particle emissions), as well as chemical reactions occurring in the air such as particulate matter originating from atmospheric reactions between sulphur and nitrogen oxides, and ammonia and organic compounds (this is called secondary particle formation).
Volatile organic compounds (VOCs)	VOCs are potentially present in paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, essential oil diffusers, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry-cleaned clothing, building materials and furnishings.
Ozone (O_3)	O_3 can come from outdoor sources, photocopying, and air-purifying and disinfecting devices.
Asbestos	Asbestos-containing materials in buildings constructed pre-2000 will release fibres if they deteriorate or are disturbed during renovation or maintenance activities.
Biological micro-organisms (bacteria, viruses or mould) and biological allergens	Person-to-person infection; wet or damp materials; poorly maintained HVAC systems, cooling towers, humidifiers, cooling coils or drain pans; damp duct insulation/filters; condensation; bird droppings; rodents; dust mites on carpeting or upholstery; pollen; etc.
Heavy metals (such as lead, cadmium and mercury)	Outdoor sources, fuel-consumption products, incense burning, smoking, and building materials.
Particles and fibres	Particles and fibres in the workplace can result through the deterioration of materials, construction and renovation activities, and cleaning activities (such as vacuuming and housekeeping).

Radon	Radon is a radioactive gas that is formed naturally in the ground by the radioactive decay of uranium, which is present in igneous rocks and soils. Radon can enter the workplace from the ground through small cracks in floors and through gaps around pipes or cables. Workplaces in some parts of Ireland are more likely to have a radon problem; these parts of the country are called High Radon Areas (HRAs).
Environmental tobacco smoke (ETS), e-cigarettes and vaping	ETS used to be a significant indoor air pollutant. Under the Public Health (Tobacco) Act, 2002, smoking has been banned in the general workplace (with some exceptions) since 2004, and this has had a significant positive impact on IAQ and public health. In terms of vaping, as with use of any product or substance in the workplace, employers should complete a risk assessment and develop a written policy on the use or otherwise of these devices in the workplace. However, employers should ensure that the designation of any outdoor smoking/vaping areas at the workplace does not affect IAQ due to inappropriate location with the potential for contaminants to enter the indoor working environment.

2.1 Impact of external air pollution on IAQ

It is important that employers are aware of the potential impact of external air pollution on their workplace's IAQ.

Outdoor air can be polluted with a complex mixture of both man-made and natural sources of pollution. This mixture includes primary pollutants like nitrogen oxides (NOx) and primary particles, which come directly from their sources, such as fuel combustion in different sectors (including the transport, energy, industrial and agricultural sectors) and from households.

The ambient air quality pollutants of most concern are NO_2, particulate matter (PM) (such as PM_{10} and $PM_{2.5}$), O_3 and PAHs.

Secondary pollutants like O_3 and secondary particles are formed through chemical and physical transformations in the atmosphere. For example, ground-level O_3 is created by chemical reactions between NOx and VOCs. This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight.

External air pollution can be a major risk to health. Both $PM_{2.5}$ and PM_{10} are capable of penetrating deep into the lungs, but $PM_{2.5}$ can even enter the bloodstream, resulting primarily in cardiovascular and respiratory impacts, but also affecting other organs.

NO_2, sulphur dioxide and O_3 can irritate the lungs, increasing the symptoms of those already suffering from lung diseases.

Atmospheric contaminants from external sources may impair indoor air quality following ingress into the workplace by the following means:

- **natural ventilation**, such as through open windows and doors;
- **infiltration**, a process by which outdoor air enters through openings, joints and cracks in walls, floors, and ceilings, and around windows and doors; and
- **mechanical**, such as through outdoor air intakes associated with the HVAC system, or through outdoor-vented fans that intermittently remove air from a single room, such as a bathroom or kitchen.

Air quality standards are set out in European Union (EU) and Irish legislation. The Environmental Protection Agency (EPA) and the local authorities are the relevant responsible bodies nationally for environmental air quality legislation.

The EPA monitors various air pollutants in Ireland in order to ensure that Ireland meets legislated standards. Under the Air Pollution Act, 1987, Local Authorities must take whatever measures they consider necessary to prevent or limit air pollution in their area. Depending on the type and size of the industrial process, either Local Authorities or the EPA regulate emissions from industry.

Complaints regarding environmental air pollution can be made directly to the relevant local authority or the EPA.

2.2 Health effects associated with poor indoor air quality

Poor IAQ can cause a variety of short- and long-term health problems. The health effects from poor IAQ can be wide-ranging and may include:

- Headache
- Dizziness
- Nausea
- Fatigue
- Difficulty concentrating
- Sinus problems
- Congestion
- Irritation of the mucus membranes of the eyes, nose, and/or throat, causing coughing and/or sneezing
- Respiratory illnesses such as COVID-19 or legionnaires' disease
- Cancer from long-term exposure to radon, asbestos, etc.

Factors other than indoor pollutants - such as poorly managed temperature, low or high relative humidity, poor ergonomic or lighting conditions, noise, overcrowding, and work-related stress - may also give rise to short-term symptoms and complaints.

For example, relative indoor humidity should be kept between 40% and 70%. If the relative indoor humidity is low, this can result in dry skin followed by itchiness. If the relative indoor humidity is extremely low (under 20%), contact with the dry air might cause the bronchial mucous to dry up, which can lead to or exacerbate other health problems in the respiratory system, such as asthma or allergies.

Conversely, the combination of high relative indoor humidity and maintaining a comfortable room temperature will cause problems such as increased growth of mould and bacteria that can lead to respiratory problems, particularly in sensitive individuals. Therefore, it is important to note that some workers are more susceptible to poor IAQ - for example, workers with asthma or other respiratory conditions, or workers who are immunocompromised.

In terms of respiratory illnesses, COVID-19 is an infectious disease caused by the SARS-CoV-2 virus. The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. These particles range from larger respiratory droplets to smaller aerosols. Legionnaires' disease is a form of pneumonia caused by *Legionella* bacteria. Legionnaires' disease is caught through breathing in air containing the *Legionella* bacteria in an aerosol that may not be visible.

Sick building syndrome (SBS) is an imprecise term used to describe those buildings in which there is a prevalence of a range of symptoms causing discomfort and a sense of being unwell, rather than a distinct illness. SBS complaints can be localised in a particular zone or room within a building. These symptoms usually disappear when the person leaves the building. SBS is a complex phenomenon, and although a number of potential contributory factors have been suggested, much of the evidence is circumstantial, and no single underlying cause has been found.

Section 3

3.0 Assessment and control of indoor air quality

Under Section 19 of the Safety, Health and Welfare at Work Act 2005, employers must carry out a risk assessment in order to determine the IAQ in their workplace.

A risk assessment is a systematic written process that should achieve the following:

- identification of the hazards in the workplace(s) under the control of the employer;
- assessment of the risks presented by these hazards; and
- implementation of control measures to reduce the risk of these hazards causing harm.

This approach can be applied to assessing and controlling indoor air quality (IAQ) in the workplace. The risk assessment process to identify, assess and implement control measures that will improve IAQ in the workplace is set out in **Tables 3 and 4**.

Consultation with and involvement of employees, along with any safety representatives, should be undertaken during the risk assessment process.

3.1 Competence and IAQ risk assessment

Prior to carrying out a risk assessment, it is important to ensure that this will be done by a competent person depending on the specific circumstances and type of workplace.

According to the Safety, Health and Welfare at Work Act 2005, an individual is deemed to be a competent person if that person possesses sufficient training, experience and knowledge appropriate to the nature of the work to be undertaken. Therefore, anyone involved in assessing IAQ must have the competency to do so.

The level of technical competency required will depend on the complexity of the workplace (see Table 2). For example, simple workplaces may only need to utilise in-house support. A simple workplace could be a small office or shop with no mechanical ventilation.

For intermediate-type workplaces, such as a welding facility with canteen and offices, a combination of in-house support and external expertise (for example, a local exhaust or mechanical ventilation engineer) may be required. However, workplaces such as food production, healthcare, and large industrial facilities with multiple or complex mechanical ventilation systems in place would normally require expert technical advice (such as from a ventilation engineer). It may also be necessary to obtain specialist expertise (such as an occupational hygienist, environmental scientist or aerosol scientist) depending on the nature of the known or suspected indoor air contaminants.

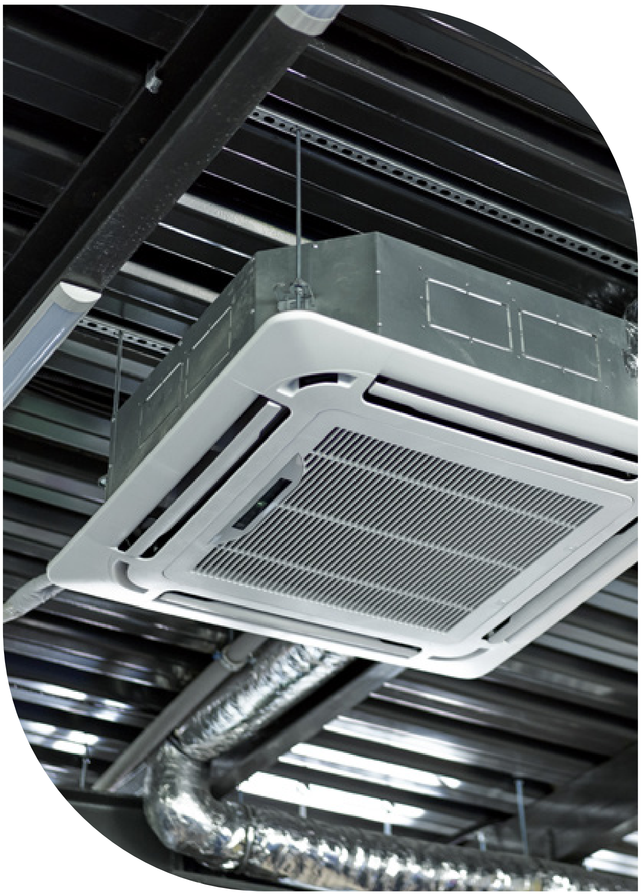


Table 2: IAQ requirements depending on complexity of the workplace

Level of complexity	IAQ competency requirements
Simple	For the assessment of relatively simple rooms or buildings, the following may be all that are necessary: • The absence of any obvious contaminants or uncontrolled hazards • The presence of natural ventilation from a clean source (such as an open window) • Consultation with employees • Some local heating or cooling arrangements • Documentation of arrangements
Intermediate	For settings that are more complex, additional information will be required: • Identification of any contaminants or uncontrolled hazards • The source and content of natural ventilation • Information on performance of mechanical ventilation • Consultation with employees • Some local heating or cooling arrangements • A readily available specification setting out the required performance of the natural or mechanical ventilation system • Documentation of IAQ arrangements
Complex	Dealing with a complex workplace would incorporate aspects similar to those of simple and intermediate workplaces. For the most complex settings, it is important that, where possible, a detailed written specification setting out the required performance of the natural or mechanical ventilation is available. This is to ensure that the employer's objectives are met. These objectives must be clearly defined. They do not just relate to IAQ from a worker protection perspective but may also relate to good manufacturing practice (GMP), food safety, infection prevention and general indoor environmental quality. In general, for complex settings, competencies from the fields of aerosol science, exposure science, ventilation engineering and/or computer modelling are often required. This is in addition to the specialist competencies of GMP, infection prevention and control, and Hazard Analysis and Critical Control Point. The IAQ specification and requirements for this level of complexity are outside the scope of this Code of Practice. Further guidance is provided in Section 5: Further information and resources.

3.2 Identification of IAQ issues

An initial review of the indoor environment of the workplace should be carried out. This can be achieved through a visual inspection, consultation, and gathering appropriate information and data. Where mechanical ventilation systems are present, it is important to obtain the specification, manual, and any relevant performance data. Carbon dioxide (CO_2) or IAQ monitors and a means for measuring temperature and relative humidity may also be important to support the initial assessment.

Table 3 provides information to assist with this review process.

Table 3: Initial assessment of the indoor environment

Key area	What to look for (non-exhaustive)
Room or site layouts	**Identify the following:** • Areas/rooms where there is no natural or mechanical ventilation • Areas/rooms that use mechanical ventilation if the system recirculates air and has no outdoor air supply in place • How canteens, toilets and changing areas are currently ventilated (that is, by natural means, mechanical means, or a combination of both)
Temperature and relative humidity	**Is there any data available on typical internal temperature and relative humidity levels?** For most people, an acceptable temperature for office work lies within the range of **18-23 °C**. The Safety, Health and Welfare at Work (General Application) Regulations 2007 state that the legal lower limit to observe for sedentary office work is **17.5 °C**; this minimum temperature should, as far as is reasonably practicable, be achieved and maintained at every workstation after the first hour of work. For other sedentary work, at every workstation where a substantial proportion of the work is done sitting and does not involve serious physical effort, **a minimum temperature of 16 °C** must, as far as is reasonably practicable, be achieved and maintained after the first hour of work. The law also requires that means be available to enable persons at work to measure the temperature in any workplace inside a building. Optimum relative humidity levels should be kept between **40% and 70%**.

Data from CO_2 monitors	**If available, what is the average CO_2 reading (from an appropriate CO_2 / IAQ monitor) for relevant areas?** • In most occupied spaces, a CO_2 concentration consistently below **1,000 parts per million** is likely to indicate that an indoor space is adequately ventilated. The amount of CO_2 in the air is measured in parts per million (ppm). Indoor measurements and comparisons with outdoor air concentrations of CO_2 (approximately 400-480ppm) are often used as an indicator of ventilation indoors. People exhale CO_2, so if there is a build-up of CO_2 in an area, it can indicate that ventilation needs to be improved. CO_2 or IAQ monitors can be used to check for poorly ventilated areas where people work and are a useful proxy to estimate airflow rates. For example, indoor CO_2 concentrations below 1000ppm normally correspond to recommended ventilation rates of 10 litres per second (L/s) per person in offices. A consistent CO_2 value below 1000ppm is likely to indicate that an indoor space is adequately ventilated. However, the recommended threshold of 1000ppm should not be misinterpreted as an acceptable limit before some form of action is required; even if indoor CO_2 concentrations are consistently below 1000ppm, every effort must be made to reduce CO_2 levels as far as is practicable, taking into account outdoor CO_2 concentrations. It is important that when making improvements in an area such as ventilation, other environmental comfort factors are not compromised. For example, it would not be acceptable to open doors and windows to achieve adequate CO_2 concentrations if this would result in non-compliance with recommended minimum working temperatures. • A CO_2 concentration consistently higher than 1400ppm indicates poor ventilation. CO_2 levels consistently higher than 1400ppm in an occupied room indicate poor ventilation, and action should be taken well before this upper threshold is reached. Remember that CO_2 measurements are only a general indication of ventilation adequacy. See Section 4.1: Carbon dioxide monitors for detailed information.

Mechanical ventilation system (if present)	**Identify the following:**
	• Are there mechanical ventilation performance reports available?
	• Is the mechanical ventilation system being regularly maintained, cleaned and repaired as per the manufacturer's instructions (or, at a minimum, every 24 months) by a trained and competent person? (Grilles, vents, fans, filters and ductwork all need to be included.)
	• Can physical features in the workplace which might affect ventilation be moved immediately?
	  - Is there large furniture or machinery in use which might impede cross-ventilation airflow?
	  - Are items blocking vents?
	  - Have trickle vents been covered over due to draughts?
	• Are filters part of your existing system? Where filters are used as part of a central ventilation system, are these the most efficient filters for the system (for example, a Minimum Efficiency Rating Value (MERV) of 13-16, or an International Organization for Standardization (ISO) ISO 16890-1:2016, ePM1 rating of 60-90%)?
	• If filters are not part of your existing system, can they be installed? Not all systems can be retrofitted. Expert advice may be needed in order to ensure that mechanical fans can cope with increased pressure drop.
	• Check if the ventilation systems are recirculating poor-quality air to other poorly ventilated areas of the workplace, where workers are working.
	• Can the system be optimised to maximise air changes or fresh air intake? The amount of fresh air should be maximised. **Four to six air changes per hour** for an office space is normally recommended.
	• Ventilation rates of **10 L/s per person** in offices normally corresponds to indoor CO_2 concentrations below 1000ppm. Recommended ventilation rates can vary (in other words, they can be higher or lower) for different settings.
	• If air recirculation systems are being used, can air filtration be increased to the highest degree possible without significantly diminishing design airflow or the amount of fresh air provided? High efficiency particulate air (HEPA) filtration or the highest efficiency filter possible according to the heating, ventilation and air conditioning (HVAC) manufacturer's specifications should be considered (for example, a MERV of 13-16, or an (ISO) ISO 16890-1:2016ePM1 rating of 60-90%) where air is recirculated.
	• If unsure about any of the above, contact the manufacturer or your service ventilation engineer. See Section 4.0 for further information on ventilation.

Products, materials, equipment, and water systems present	**Identify the following:** • **Building materials, floor coverings and furnishings** (insulation, fabrics, carpets, and flooring). Many of these can release gases such as volatile organic compounds (VOCs) that were trapped in the materials as a result of their composition or their manufacturing process. Newly furnished or carpeted rooms are likely to have poorer air quality if ventilation rates are not increased to address these types of emissions. • **Equipment, tools and machines present.** Photocopiers and printers can release ozone, and sealants or adhesives used for minor repairs can off-gas.
Processes involving/using chemicals	**Identify the following:** • **Processes that involve or use chemicals (manufacturing, maintenance, or cleaning)**. There must be specific chemical risk assessments carried out for each of these activities and control measures must be in place to reduce the exposure of the workers themselves and any others in the vicinity or nearby. • **Any process-generated substances present (dust due to sweeping, construction dust, welding fumes)**. There must be specific risk assessments carried out for each of these activities and control measures must be in place to reduce the exposure of the workers themselves and any others in the vicinity or nearby. See further Health and Safety Authority guidance: *Your steps to chemical safety: A guide for small business*.
External air quality	**Identify the following:** • The intake source (and quality) of the external air being used for ventilation. Is there available data on external air that may affect the workplace IAQ? Readings between 1 and 6 on the EPA Air Quality Index (for ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide, $PM_{2.5}$, and PM_{10}) indicate good to fair external air quality, while readings between 7 and 10 indicate poor external air quality. Unless the workplace is very close to a monitoring station, data from the Air Quality Index should be considered indicative only. • Are there any adjacent industrial processes or activities that could be affecting IAQ? Odours, fumes, dust or vapours from adjoining buildings or activities can affect IAQ. These can vary depending on the nature of the business and resulting emissions.

Occupancy levels	**Identify the following:** • Quantify normal occupancy levels in relevant workspaces. In offices, a minimum of 4.65 square metres of floor space should be allowed for every person employed in any room, including the area occupied by the office desk and chair but excluding filing cabinets and other office furniture. At least 11.3 cubic metres should be provided for each person at work in a room (other than an office) at any one time. When calculating the volume, no space more than 4.3 metres from the floor should be taken into account.
Level of activity within the enclosed place of work	**Identify the following**: • Normal work activities in each relevant workspace. • Type and frequency of maintenance, repair and cleaning activities.
Consulting with employees and safety representatives	**Identify the following:** • Areas that feel stuffy or smell bad. • Any complaints or health issues reported.
Radon	**Identify the following:** • Are occupied work areas at ground and basement level located in a High Radon Area (HRA)? Visit www.radon.ie and check the radon risk map for workplaces in Ireland.
Asbestos	**Identify the following:** • Is there an asbestos survey and register available (for buildings constructed pre-2000)? A **management asbestos survey and register** will form part of an employer's asbestos management plan (AMP) and enable asbestos-containing materials (ACMs) to be managed correctly during normal occupation and use of the premises. For further details on identifying and managing ACMs, refer to the Health and Safety Authority's publication ***Asbestos-containing Materials (ACMs) in Workplaces: Practical Guidelines on ACM Management and Abatement*** at www.hsa.ie.

Biological agents	**Identify the following:** • Presence of mould or potential for airborne legionella. This can be related to condensation, ventilation or construction of the building. For a simple kitchen area, check if there is appropriate ventilation extraction for cooking activities. Specialist advice is likely to be needed for more complex problems. See advice on moulds: https://www.hsa.ie/eng/topics/biological_agents/specific_biological_agents_diseases/moulds/. In terms of HVAC systems, humidifiers etc., see further information on control of legionella at https://www.hsa.ie/eng/topics/biological_agents/specific_biological_agents_diseases/legionellosis/ • Occupational exposure to biological agents. Occupational exposure to biological agents via airborne transmission can result from carrying out work activities that involve a deliberate intention to work with biological agents or can occur incidentally from specific work activities involving direct exposure to biological agents. A biological agents risk assessment as per the Safety, Health and Welfare at Work (Biological Agents) Regulations 2013 and 2020 and associated Code of Practice is required.
Other considerations	In addition to the above, where public health authorities have identified an issue that may affect IAQ (such as infectious diseases, air quality issues involving airborne asbestos because of a fire, etc.), specific public health advice is likely to be issued and should be followed. Please see Section 3.4 for additional information on enhanced control measures.

3.3 Assessment and implementation of control measures for IAQ

The information and data collected based on Table 3 will now assist with making a general assessment of the existing IAQ conditions within the workplace using Table 4. This will allow completion of a written IAQ action plan to address any IAQ issues in the short, medium and long term.

Table 4: Assessment and implementation of controls to improve IAQ

	Outcome from initial review (Table 3) - non exhaustive	Further action/control measures to be implemented
Natural ventilation (no mechanical ventilation present)	All occupied areas have good natural ventilation, and CO_2 concentrations are consistently **below 1000ppm.** There are no unresolved IAQ complaints from employees.	**No further action needed,** but CO_2 levels should be monitored.
	Occupied areas are identified with little or no natural ventilation, or an air conditioning system is present (recirculates unfiltered air only). CO_2 readings are **above 1000ppm but below 1400ppm.** Employees may have also reported symptoms or made an IAQ complaint.	**Take action** to increase the amount of fresh air in the room, such as by opening windows for longer periods or installing vents to reduce CO_2 concentrations to below 1000ppm. Consider installing an air cleaning unit with HEPA filtration to prevent airborne contaminants from being recirculated if elevated levels persist and consider installing mechanical ventilation in the medium to longer term. Note: air filtration systems will not reduce CO_2 concentrations; see Section 4.2 on air filtration systems.
	An occupied area with poor natural ventilation and CO_2 concentrations consistently above 1400ppm is identified. Employees will most likely have reported symptoms or made a complaint about the IAQ.	**Take immediate action** to increase levels of fresh air, such as by opening windows for longer periods, installing vents, etc. If high CO_2 concentrations persist, occupancy levels may need to be reviewed and installation of a mechanical ventilation system should be considered in the short to medium term. As an interim measure, an air filtration system should be installed to address any risks from other airborne contaminants. Note: air filtration systems will not reduce CO_2 concentrations; see Section 4.2 on air filtration systems.
	Natural ventilation is present, but employees complain of symptoms, odours, etc. CO_2 levels are below 1000ppm, and temperature and humidity levels are within acceptable parameters.	**Carry out an investigation** to determine the cause of the IAQ complaints. Specialist expertise may be required in order to identify the source(s). See Section 3.6: Investigation of IAQ complaints.

Ventilation (mechanical)	The mechanical ventilation system (MVS) is being maintained, cleaned and serviced and **is working effectively** (that is, at the correct ventilation rate for the occupied areas and providing the appropriate number of air changes per hour). No IAQ complaints have been received from employees.	**No further action needed.** Ensure that the MVS is serviced by a competent person and kept in effective working order. See Section 3.5: Information, training, instruction and supervision. It is recommended that the MVS is inspected, serviced and certified at least every 24 months (or more frequently based on supplier specification) in order to ensure optimal performance.
	An assessment of the MVS by a competent person has identified issues with the MVS, such as poor performance, incorrect operation, noise, damage or deterioration, incorrect ventilation rates or air changes per hour, incorrect filters or overdue filter replacement, faulty controls, or intermittent airflow.	**Take action** to ensure that the MVS is repaired, cleaned, and/or optimised by a competent person in order to ensure that it is working correctly and providing appropriate filtration, ventilation rates and air changes per hour. It is recommended that the MVS is inspected, serviced and certified at least every 24 months (or more frequently based on supplier specification) in order to ensure optimal performance.
Temperature and relative humidity	All temperature and relative humidity levels are within range.	**No further action needed but** keep under review.
	No data is available for temperature and relative humidity.	**Take action.** A means to obtain temperature measurements should be put in place. Humidity levels should also be monitored, especially if IAQ complaints are received.
	Temperature and relative humidity are out of range.	**Take action.** Investigate the reason for the out-of-range temperature and relative humidity levels and take appropriate remedial measures.

External air quality	No external air quality issues are identified.	**No further action needed but** keep under review.
	External air quality is identified as poor.	**Take action.** Address this through suitable ventilation management until external air quality improves.
	Workplace air quality is being impacted by poor environmental air quality (for example, odour or industrial process from another nearby location).	**Take action.** Follow the environmental complaint resolution advice on the EPA's website to resolve the issue. This may involve making direct contact with the other company or person, or with the Local Authority or the EPA, depending on the source and type of workplace causing the air quality issue.
	There are complaints of environmental tobacco smoke entering the workplace.	**Take action.** If the source is another workplace, a complaint can be made to the local Health Service Executive Environmental Health Officer or Health and Safety Authority Contact Centre.
	External building works are planned, such as the use of a paint coating to seal a flat roof.	**Take action.** Any external works that may affect indoor air quality need to be planned correctly, fully risk assessed and appropriately managed in order to mitigate cross-contamination of the indoor environment.
Exposure to chemicals or process-generated substances	Work activities are identified which involve the use of hazardous chemical substances and/or process-generated substances.	**Take action.** Any work activities involving the use of hazardous substances must have a specific chemical agent risk assessment completed. The application of specific ventilation and at-source capture techniques, such as local exhaust ventilation, may be required for some activities.
	No significant use of or exposure to hazardous substances is identified, except for the use of routine cleaning products.	**Take action.** A specific chemical risk assessment for any cleaning activities should be carried out.
	The potential for contracted third parties to use hazardous substances during renovations or maintenance activities is identified.	**Take action.** Ensure that all contracted third parties have completed relevant site-specific and task-specific chemical and/or dust risk assessments and that their method statements have fully addressed mitigation and control of potential impacts on IAQ. For further information on chemical risk assessments, see https://www.hsa.ie/eng/your_industry/chemicals/

Radon	The workplace is located in a High Radon Area (HRA) according to the EPA radon risk map.	**Take action.** For further details on radon, testing and remedial options, see www.radon.ie.
	The workplace is not located in a HRA according to the EPA radon risk map.	**No further action needed** but it is recommended to carry out a radon test of the ground and basement areas of the workplace; see www.radon.ie.
Asbestos (for buildings constructed pre-2000)	An asbestos survey and register is available. A recent check on the condition of the asbestos-containing materials (ACMs) was carried out by a competent person in accordance with the asbestos management plan (AMP).	**No further action needed** but a further condition check should be scheduled in accordance with the AMP. A competent specialist contractor should remove ACMs prior to any refurbishment, maintenance or demolition activities.
	An asbestos survey and register is available, but no condition check of ACMs has been completed.	**Take action.** Arrange to have a condition check of the ACMs carried out by a competent person and update the asbestos register. Implement an AMP.
	No asbestos survey is available.	**Take action.** A competent person should carry out an asbestos management survey. The survey and register should be maintained.
	All ACMs have been removed.	**No further action needed.** For further information, see the Health and Safety Authority's publication ***Asbestos-containing Materials (ACMs) in Workplaces: Practical Guidelines on ACM Management and Abatement*** at www.hsa.ie.
Exposure to biological agents	Work activities are identified which involve a deliberate intention to work with biological agents (for example, laboratory work). Work activities are identified which occur incidentally from specific work activities involving direct exposure to a biological agent (such as working directly with an infected patient, handling infected waste, etc.).	**Take action.** A biological agents risk assessment is required, as per the Safety, Health and Welfare at Work (Biological Agents) Regulations 2013 and 2020 and associated Code of Practice.
	No risk assessment for Legionella under Section 19 of the 2005 Act has been completed and there are systems e.g., HVAC, potentially at risk.	**Take action:** Carry out suitable risk assessment for legionella.
	No use of or exposure to biological agents is identified or relevant risk assessments and implementation of controls are in place.	**No further action needed.**

Short-term, medium-term and longer-term actions to improve IAQ, with responsibility assigned and resources allocated, should be documented following the risk assessment process. The control measures that are in place to protect employees should be monitored in order to ensure that they are working. It is recommended that the arrangements in place for maintaining good IAQ should be reviewed at least annually in conjunction with the review of the workplace Safety Statement.

It will also be important to carry out a reassessment if there are any significant modifications made to the workplace which may affect ventilation.

3.4 Enhanced IAQ control measures

An employer should review existing IAQ control measures if circumstances change and necessitate improvements to deal with significant IAQ issues, such as a workplace outbreak or increased levels of airborne infections in the community. Enhanced IAQ control measures may include:

- increasing ventilation rates and air changes per hour to enhance dilution and fresh air intake;
- if relying on natural ventilation alone, airing rooms between uses or regularly throughout the day (such as by opening windows and doors to maximise ventilation);
- maintaining carbon dioxide (CO_2) concentrations below 1000ppm, as far as is practicable;
- increasing or introducing appropriate air filtration systems;
- disabling unfiltered recirculating air (such as air conditioning units);
- keeping toilet, restroom or changing room extractor fans functional and running;
- extending the hours that the mechanical ventilation system (MVS) runs (for example, running it at the lowest setting when the workplace is unoccupied, or at least for extended periods before and after the use or occupancy of a room, such as activating it two hours before the building is occupied and two hours after the building has emptied) in order to ensure that occupied areas are well ventilated before occupancy each day;
- ensuring that demand-controlled mechanical ventilation systems are set to only circulate air when a certain threshold is passed (usually the amount of CO_2 build-up in the room or a set ambient room temperature) and disabling this (if possible). If it is not possible to bypass this system, then setting the threshold to the lowest possible setting (such as 400ppm or less of CO_2) so that the system remains ventilating at a nominal speed; and
- communicating enhanced control measures to all employees in order to ensure that the enhanced measures are implemented and maintained for the required intervention period.

In addition to enhanced ventilation management, any additional public health measures for infectious diseases as set out by the public health authorities must be followed. For example, CO_2 measurements alone may not be a reliable proxy of the risk of airborne exposure to a virus, so adherence to other public health measures is critical.
Enhanced measures may also be required if there is an external event such as a significant local fire. This may involve increased filtration of intake air or increased use of air filtration systems until the external air quality reverts to normal.

3.5 Information, training, instruction and supervision

The results of the risk assessment must be made available to all employees and any others likely to be affected.

All the control measures must be communicated so that employees and others (such as safety representatives) know how to implement these measures in order to maintain good IAQ. Training and instruction are necessary in relation to the correct operation of ventilation systems.

Training is also required for any servicing, cleaning or maintenance of ventilation systems or air purification systems. This is the responsibility of the service provider unless in-house technical competence is available. The employer should keep records of training and maintenance.

Supervision is required in order to ensure that the control measures are being used correctly; for example, that staff keep windows opened or that staff do not adjust ventilation settings unnecessarily.

3.6 Investigation of IAQ complaints

In addition to an employer's IAQ policy and risk assessments, a complaints procedure to promptly investigate any IAQ concerns from employees should be established. An employer's existing complaints procedure for addressing health and safety concerns should be sufficient to address common IAQ complaints.

A complaints procedure should include a process for receiving an IAQ complaint and recording the nature of the complaint, when the issue occurred and any reported signs and symptoms from employees. The procedure should set out the approach to investigating an IAQ concern. One of the first steps in this procedure should be to try to identify the source of the issue, which may be obvious (such as new equipment, a busier car park, etc.). The procedure and any concerns raised must be documented and followed up in an appropriate manner, with solutions clearly communicated to employees and, if appropriate, safety representatives.

However, for cases that are more complex, and depending on the initial investigation and IAQ issues involved, it may be necessary to obtain specialist expertise, such as from an occupational hygienist, environmental scientist and/or aerosol scientist. Only some cases require air sampling and analysis as part of an investigation, and this must be done in conformance with recognised measurement, analytical and reporting standards advised by the specialist carrying out the work.

There are many substances with occupational exposure limit values (OELVs) available in the *2021 Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations (2001-2021) and the Safety, Health and Welfare at Work (Carcinogens) Regulations (2001-2019)* that are relevant to IAQ.

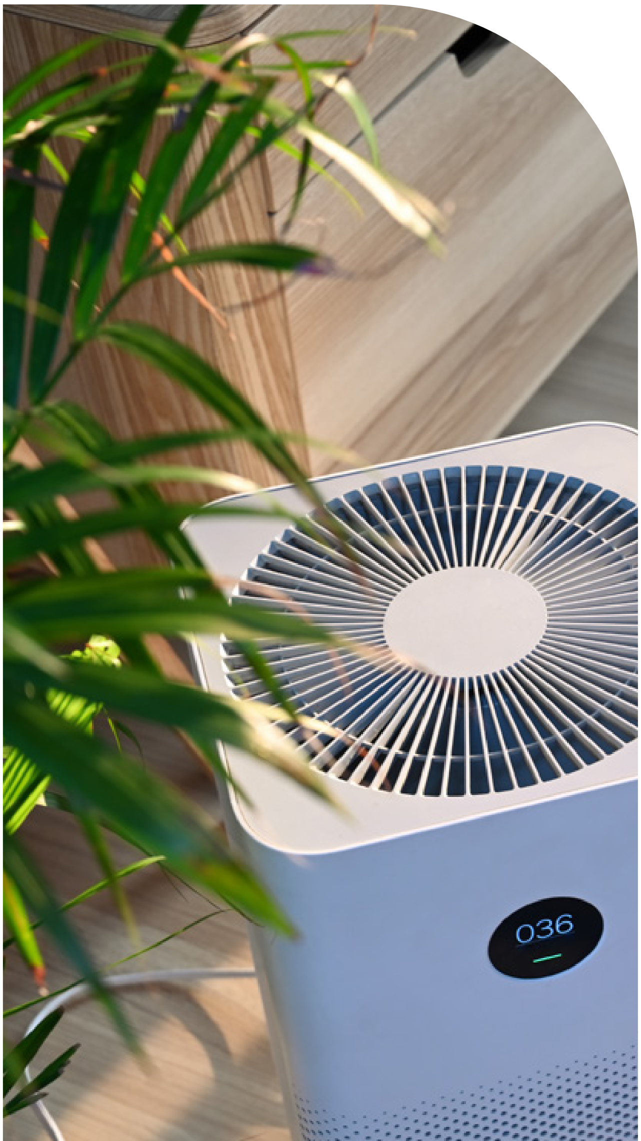
However, the OELVs concern occupational exposures where employees are explicitly working with the substances generally over an 8-hour period, so applying a reduction factor for IAQ purposes is appropriate. The factor applied would vary depending on the population, the contaminant and reference period. Combined and sequential exposure to several contaminants as well as interactions between contaminants also have to be considered. Expert occupational health or hygiene advice should be sought.

Other standards for pollutants are useful when assessing IAQ or investigating IAQ complaints, such as:

- those regulated under the Air Quality Standards Regulations 2011 (S.I. No. 180 of 2011),
- the World Health Organization's annually updated *WHO global air quality guidelines*, or
- the database developed by the International Society of Indoor Air Quality and Climate accessible at www.ieqguidelines.org.

Air sampling and analysis reports should conform to accepted best practice, such as the Health and Safety Authority's guidance on occupational hygiene report writing.

IAQ investigations can present challenges. For example, it is not possible to draw any health-related conclusions about an odour merely by perceiving it. Even if a human perceives a smell as being very strong, the source of the odour may not reach the analytical detection limit for that specific substance.



Section 4

4.0 Ventilation

Ventilation refers to the movement of outdoor air into a building and the circulation of that air within the building (or room) while removing stale air in order to improve the air quality.

Ventilation is a critical method of removing contaminants from buildings and is essential to ensuring good indoor air quality (IAQ) as well as thermal comfort.

Thermal comfort
The level of acceptable thermal comfort may differ across individuals and may be subjective; it is the condition of mind that expresses satisfaction with the thermal environment. The main factors that influence thermal comfort are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed, and relative humidity. Thermal comfort can be assessed by subjective evaluation; for example, calculation for predicted percentage of dissatisfied (PPD) using the method set out in ISO 7730:2005.

Buildings can be ventilated in three different ways; they can:

- be naturally ventilated with outside air;
- be fully closed, with no user-controlled openings, and ventilated mechanically; or
- use a combination of the two approaches.

Natural ventilation uses the natural driving forces of wind (wind effect) and temperature differences within the building (the 'stack effect', or hot air rising) to drive airflow through the building on a daily or even hourly basis.

The outside environment influences natural ventilation performance.

Mechanical ventilation uses fans, ducts and control systems to drive the ventilation process, and is generally independent of the outside environment in typical weather conditions.

The quantity of ventilation required depends on a number of factors, including the fresh air required for the number of people expected to be in the space; what they will be doing; how they are expected to dress; the types of local heat sources, such as lighting, small appliances and computers; any sources of pollutants in the space, such as copiers; and sources of humidity, such as catering equipment.

It is important to ensure that air intakes are not located in contaminated areas or near where contaminated discharged air is exhausted. Likewise, it is important to ensure that discharge exhaust air is kept away from doors, windows and other air inlets.

There is no 'one-size-fits-all' approach when it comes to ventilation. It is critical that competent advice is sought prior to modifying or installing a ventilation system.

A detailed description of ventilation types and components is provided in **Table 5**.

Table 5: Ventilation systems and components

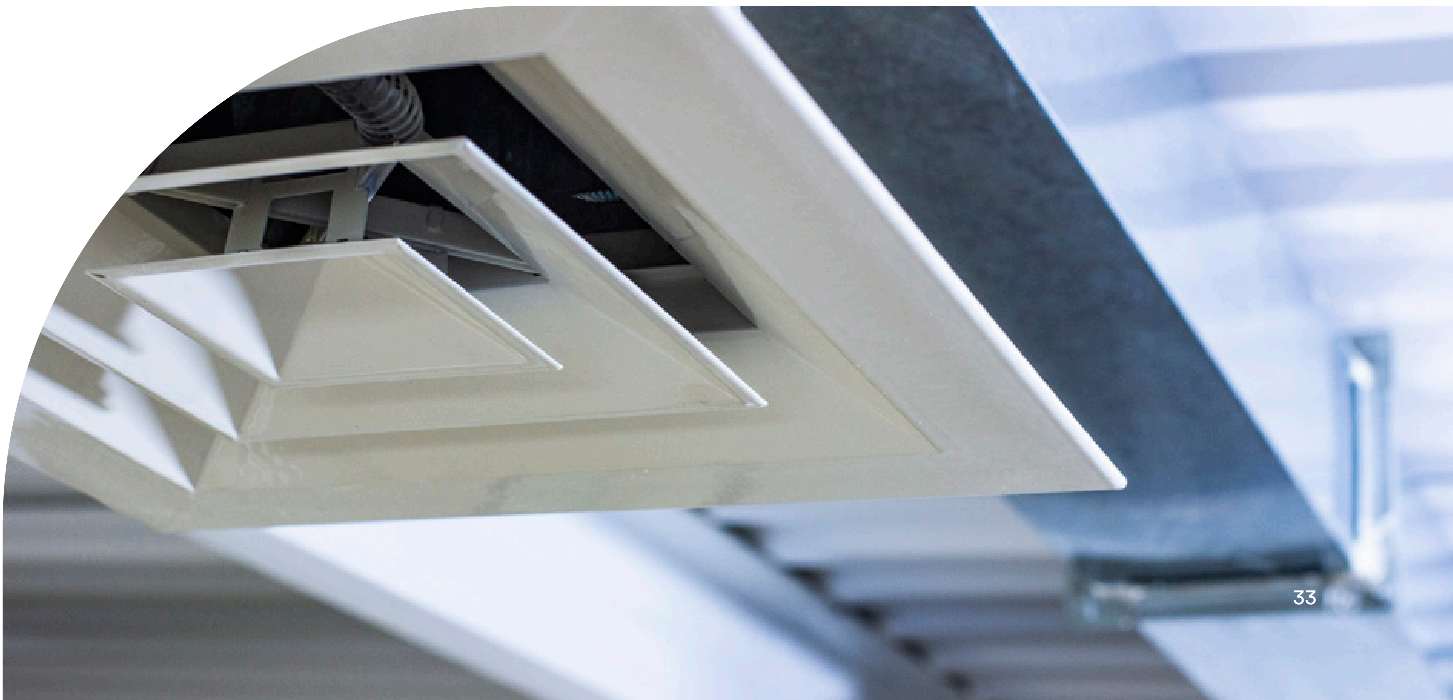
Type of ventilation or component	Description	Considerations (if appropriate)
Natural ventilation	**Natural ventilation** is the way that outside air is brought into a building via passive flow, without using fans or other mechanical means. This includes airflow through openings in the building, such as: • partial or complete window openings; • partial or complete external door openings; • roof turrets; • trickle vents (small slots or openings in window or building envelope components that allow small amounts of ventilation (trickle ventilation) through a window and/or door when it is closed); • other vents; and • unplanned openings (that is, **infiltration:** the process by which outdoor air flows into the building through openings, joints and cracks in walls, floors and ceilings, and around windows and doors).	Natural ventilation usually relies on individual behaviour to open windows and vents, which can present issues with winter thermal comfort, uncontrolled energy use, noise, pollution intrusion, and security. Automatic controls are especially useful, as they can feature smart technology that is able to recognise weather patterns and fire alarms, thus opening or closing windows or vents as necessary. Where there are issues with outside air, consideration must be given to air filtration or air cleaning systems.
Mechanical ventilation	**Mechanical ventilation** employs mechanical or powered means (such as fans) to transfer air into and/or out of an area. In smaller indoor spaces, these may be in the room; for example, outdoor-vented fans, which intermittently remove air from toilets or kitchens. Larger buildings may employ a network of inlet grilles, ducts and fans (air distribution equipment) to bring outside air into rooms and/or another set of fans, ducts and grilles, and to extract the stale air. If a mechanical ventilation system only recirculates air and has no outdoor air supply, the area is likely to be poorly ventilated. Air conditioning is not mechanical ventilation.	Consideration must be given to the source of outside air. Depending on the source of outside air, the air may need to be filtered or cleaned before it enters the building. Where present, mechanical ventilation systems must be maintained in good working order as part of a plant maintenance system and must operate in such a way that employees are not exposed to draughts which cause discomfort. Mechanical ventilation systems must also be cleaned regularly in order to avoid contamination. These arrangements must be documented, and records kept.

Supply ventilation	**Supply ventilation** works by pressurising the building and forcing external air inside via a fan. Air will then escape via cracks in the building, through doors and windows, or through purpose-built ducts and vents.	Depending on the source of outside air, it may need to be filtered or cleaned before it enters the building. For the system to provide adequate outside air, it is essential that external grilles are kept free from blockages. Incoming air can be provided via diffusers in the ceiling, the wall or the floor. If not correctly installed, these can cause excessive moisture in colder temperatures.
Exhaust ventilation	**Exhaust ventilation** systems operate by depressurising the building, reducing the inside air pressure so it is below the outdoor air pressure. The stale air is sucked out via the exhaust mechanism and through a ducting system outside. It is then replaced by fresh air from a different source (usually another air vent).	These systems are most commonly found within toilets, kitchens, or utility rooms in order to prevent a build-up of steam and humidity. It is most effective to position exhaust ventilation systems in localised spaces near to where steam builds up, although larger rooms may require additional systems. Extract grilles or exhausts must be positioned to prevent extracted air from re-entering the building.
	Spot ventilation involves having local exhaust fans (the same as those used in the bathrooms or kitchens) that remove the moisture and inside air pollution at their source and, as a result, improve the usefulness of the ventilation system.	
	Supply and extract ventilation has one series of ducts and inlet grilles delivering outside air into a space, while another set of ducts extracts stale air from the space and exhausts it to the outside.	There are a number of different systems that use this method. The grilles that deliver the incoming air can be located in diffusers in the ceiling, the wall or the floor. For the system to provide adequate outside air, it is essential that these grilles are kept free from blockages. Depending on the source of outside air, it may need to be filtered or cleaned before it enters the building.

Balanced ventilation	**Balanced ventilation** designs can be implemented that neither pressurise nor depressurise the building. They supply and extract the same level of air by positioning at least two fans and two duct systems in the most effective positions around the room.	
Mixed-mode ventilation	**Mixed-mode ventilation** is a hybrid approach. The requirement for sufficient fresh air in enclosed places of work is achieved through a combination of natural and mechanical ventilation. Mechanical ventilation may rely on natural ventilation to maximise the supply of fresh air. Mechanical ventilation may be the primary means of delivering outside air into the room year-round. Openable (whether manual or automatic) windows provide the additional benefit of allowing more outside air into the building in order to help cooling during the summer or to purge the room, for example from a smell caused by a spillage.	Recirculation of untreated air should be avoided.
Heating, ventilation and air conditioning (HVAC) systems	**HVAC systems** are a combination of both mechanical ventilation and air conditioning. Air conditioning heats or cools the air or controls humidity, and only recirculates the air.	Recirculation of untreated air should be avoided. Air conditioning alone does not provide fresh air or ventilation.
Mechanical ventilation with heat recovery (MVHR)	**MVHR** is a controlled method of ventilation that minimises waste energy by using a heat exchanger. It transfers heat from the warm exhaust air to the cold supply air, thus reducing the cost of heating ventilated incoming air. If the air temperature inside the building is colder than the outside air, the exhaust air absorbs the heat from the warmer fresh air and cools the fresh air down, thus reducing the cost of cooling.	There are airtightness requirements for buildings where MVHR systems are used. MVHR, heat recovery ventilation and comfort ventilation are different names for the same thing.

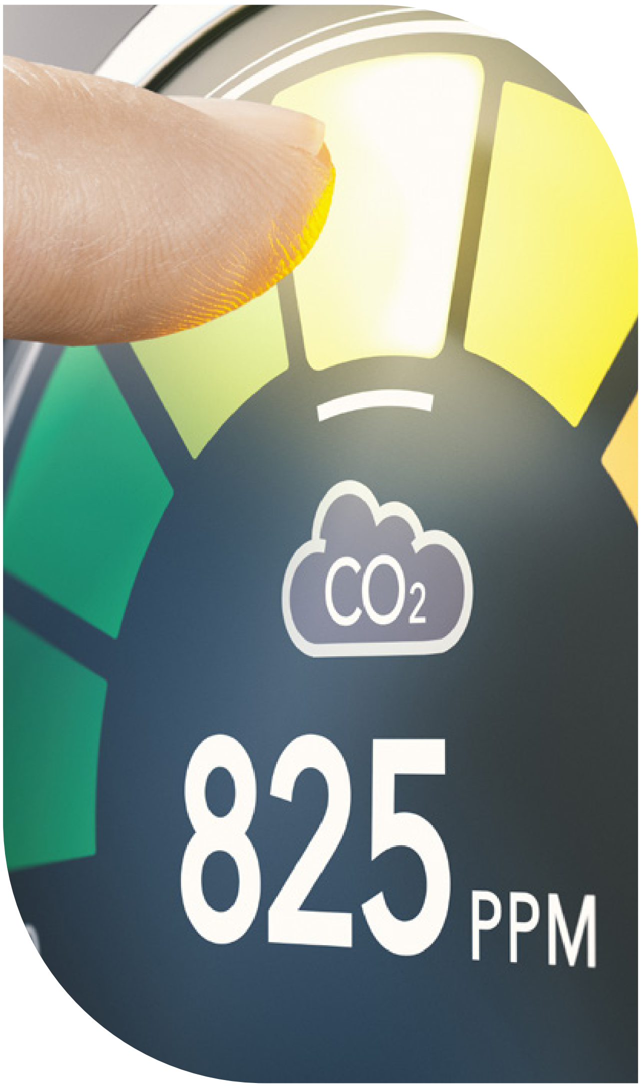
Air circulation	**Air circulation in the** ventilation system is not only for introducing fresh clean air into a space. The pattern of air circulation and the airflow direction within the space are equally important.	If airflow paths and circulation are not good, the air is not well mixed and there can be zones inside a room with higher concentrations of contaminants. This can happen if intake and extract grilles are too close together at roof level. In high-ceilinged rooms where air intake and extraction are both at high levels on opposite sides of the room, stratification can occur resulting in very clean air only being present at high levels (above breathing zones). Avoid directing airflow onto individuals or across groups of individuals.
Directional airflow	**Directional airflow** is a protective ventilation concept where air movement flows in a clean-to-less-clean direction. Directional airflow can be achieved within a particular space or between two adjacent spaces. This can be done passively, through intentional placement of supply and exhaust HVAC grilles, or by the intentional creation of pressure differentials between adjacent spaces through specification of offset exhaust and supply airflow rates. Directional airflow can also be achieved actively, through the use of fans exhausting through open windows, strategic placement of ductwork attached to portable high efficiency particulate air (HEPA) filtration units, or dedicated exhaust systems (installed or portable) that generate a desired airflow by exhausting air out of windows, doorways, or through temporary ducts.	Directional airflows must be carefully evaluated. Directional airflow effectiveness can be tested using visual tracer techniques that use 'smoke tubes' or hand-held 'fog generators.' Other tools (such as electronic monitors or visual aids to monitor pressure differences) can be used when directional airflow is established between two adjacent spaces. In order to reduce the potential for directing airflow from infectious towards non-infectious space occupants, it is important that the 'clean' and 'less-clean' space determinations be established using infection control risk assessment considerations.

Fans	**Fans** alone are not ventilation systems. Ceiling-mounted, desk and portable fans do not provide fresh air and can mask poor ventilation issues.	Fans can be difficult to keep clean and could increase the duration of particle suspension by creating air currents in confined spaces. Fans merely recirculate air in a room if there is no source of fresh air. Therefore, a fresh air supply should be provided when using a fan. When used, fans should be directed to exhaust directly to the exterior environment (in other words, through an open window) in order to minimise the potential spread of contaminants. Fans should ideally only be used where there is a single occupant in a room.
Filters	**Filters** in ventilation systems have a variety of functions: • keeping the ventilation system clean in order to protect the mechanics of the ventilation system; • collecting and filtering external pollutants; and • collecting and filtering internal pollutants. In order for your ventilation system to work correctly and effectively and to maintain good IAQ and energy efficiency, the correct filters must be used as per the manufacturer's specifications, and air filters should be properly sized and within the recommended service life span.	It is important that the filters are changed regularly and are checked frequently. If the premises is located near a busy road or other source of pollution, it may be necessary to change the filters more often. Consideration should be given to installing the most efficient filter for the system (for example, a HEPA filter, or a filter with a Minimum Efficiency Rating Value (MERV) of 13-16 or an ISO 16890-1:2016 ePM1 rating of 60-90%); not all systems will be able to cope with a HEPA filter without significantly diminishing design airflow or the amount of fresh air provided. This will be determined by the ventilation system manufacturer's specifications.



In addition to health and safety regulations, ventilation arrangements or planned changes to ventilation also need to consider the regulatory requirements under building and food legislation along with other consequences such as comfort, cost, energy use, noise and security. These considerations can all be documented in the risk assessment.

A combination of natural ventilation, mechanical ventilation and air conditioning can work very well. Natural ventilation can be used when it is feasible or desirable, thereby reducing the energy costs of the mechanical ventilation and air conditioning. The HVAC system can be used when and where it is necessary.



4.1 Carbon dioxide monitors

Carbon dioxide (CO2) measurements form the basis of building ventilation standards in many countries.

Indoor measurements and comparisons with outdoor air CO2 concentrations (approximately 400-480 parts per million (ppm)) are often used as an indicator of ventilation indoors. CO2 monitors can be used to check for poorly ventilated areas where people work. People exhale CO2, so if there is a build-up of CO2 in an area, it can indicate that the ventilation needs improving.

CO2 monitors can assist with the initial risk assessment of workplace areas that are usually occupied and poorly ventilated. Monitoring is also likely to be beneficial in raising a person's awareness of ventilation requirements and is used to inform individual behaviour in improving ventilation.

The amount of CO2 in the air is measured in ppm. A consistent CO2 value below 1000ppm is likely to indicate that an indoor space is adequately ventilated. CO2 levels consistently higher than 1400ppm in an occupied room indicate poor ventilation, and action should be taken well before this upper threshold is reached.

CO_2 monitors should:

- be CE marked;
- be based on non-dispersive infrared (NDIR) technology, as NDIR CO_2 monitors are the most appropriate portable devices to use in the workplace ('equivalent CO_2' sensors or monitors that estimate concentrations based on measurements of other indoor pollutants are not recommended);
- have a measurement range up to at least 2000ppm;
- be used in accordance with the manufacturer's instructions (it is important to follow the manufacturer's instructions to understand how to use your monitor correctly); and
- be calibrated (it is important to follow the manufacturer's instructions to understand how to calibrate the monitor).

Like any other indoor air pollutant, some precautions need to be observed when taking and interpreting measurements of indoor CO_2 concentrations.

The following are some key points in relation to measuring CO_2 concentrations indoors:

- Human exhaled breath contains high concentrations of CO_2 (approximately 40000ppm), and CO_2 measurements should therefore be made at least 0.5 metres away from people (a monitor should not be placed on an employee's desk, for example).
- Similarly, as outdoor air contains approximately 400-480ppm of CO_2, indoor measurements should not be made near windows or ventilation grilles. If practical, CO_2 monitors should be placed in the centre of the room at head height (1.5 metres). Keep them away from windows, doors, air supply openings and heaters.
- Try out several locations to find the most representative position for the monitor in the space. In larger spaces, more than one sampling location will usually be required.
- Single or 'snapshot' readings can be misleading. Measurements should be taken over a minimum of one hour in order to allow the readings to reach a steady state and to collect a representative sample of data. Short-term or spot measurements are unreliable and should not be used to assess ventilation performance.
- Take several measurements throughout the day, when the room is occupied, in order to represent changes in activities, the number of people using the room, and ventilation rates.
- As weather changes you may need to repeat monitoring due to differences in ventilation, such as from opening windows and doors. Measurements taken over several days or weeks can enable occupants to become familiar with the impact of certain activities, occupancy levels and outdoor weather conditions on ventilation. Such detailed investigations could be used to inform a strategy for improving ventilation.
- Record CO_2 readings, the number of occupants and the type of ventilation being used at the time.
- It is recommended to check the CO_2 readings (that is, the sensor response) weekly by measuring the CO_2 concentration outdoors, where recorded values should be approximately 400-480ppm.
- Portable CO_2 monitors capable of working from both battery and mains electricity can facilitate measurements in a wider range of locations and allow the user to periodically check the response of the sensor outdoors in fresh air.
- If the ventilation is controlled by the occupant (for example, by opening windows in naturally ventilated rooms), CO_2 sensors may provide a useful visual or audible alert to occupants to warn against poor ventilation. They could be used as 'traffic-light-style' indicators of indoor air quality. REHVA, the Federation of European Heating, Ventilation and Air Conditioning Associates, recommends setting CO_2 sensors to 'warn' if CO_2 concentrations rise to between 800ppm and 1000ppm, and to 'alarm' when concentrations approach or exceed 1000ppm.

CO_2 monitors will only be effective in certain workspaces. They are of limited use in:

- work areas used by few people (such as areas with not many people in them or large offices with one or two occupants);
- large workspaces (including large, open spaces with higher ceilings, such as production halls or warehouses), where you cannot be sure that the air is fully mixed and CO_2 monitors may be less representative;
- work areas where there are other CO_2 sources in addition to people, such as fuel combustion (fires and stoves), cooking, baking, brewing, or dispensing carbonated drinks; and
- work areas that rely on air cleaning units, which remove contaminants (such as SARS-CoV-2) from the air but do not remove CO_2.

Measurement of carbon dioxide levels are a useful indicator of ventilation but should not be used as a sole indicator of good IAQ. They should be used in conjunction with other indicators of good IAQ, as described in this code of practice.

4.2 Air cleaning and filtration units and other systems

Local air cleaning or air purification systems remove certain pollutants from the indoor air. Local air cleaning is not a substitute for good ventilation. It may be beneficial in reducing risks in some spaces, particularly where it is not possible to increase ventilation using natural or mechanical means, as set out Section 4.

Priority should be given to making improvements in other ways to any areas identified as poorly ventilated before using an air cleaning device.

These devices are usually stand-alone and can be deployed in any space or installed in a manner similar to a local air conditioning unit. While these devices can increase airflow, their effectiveness will depend on the volume of the room or area, the flow rate through the device and the location of the device. Two smaller devices at different locations may be more effective than one large device.

Therefore, it is important that if considering an air cleaning device as an option, the device should be of a suitable specification for the relevant area. The introduction and use of air cleaning devices in the workplace should be done as part of an overall assessment of the existing ventilation systems in place to show that their use is necessary. There are also drawbacks to using these devices (such as additional physical or chemical-related hazards), and these impacts need to be risk assessed before using air cleaning devices. In addition, operators need to be trained to use them correctly. They should not be placed beside windows or barriers.

Air cleaning devices that are based on filtration with a HEPA filter are likely to be the most effective. All filter units should be regularly maintained, and filters changed according to the schedule specified by the manufacturer.

When comparing devices, check that the performance ratings (such as the Clean Air Delivery Rate (CADR)) are comparable. The CADR is the volume of clean air that a specific model of air purifier is capable of producing every hour. It is important to select a unit that is capable of dealing with the needs of the space it is to serve. One metric included in air cleaning unit specifications is the unit's ability to deliver either airflow in cubic metres per hour or the air change rate in air changes per hour (ACH). This metric is normally included in the air cleaning unit's performance data sheet.

In general, the higher the CADR number, the more particles the air cleaner can remove and the larger the room the device can reasonably be expected to clean. In order to compare various units, you can calculate the air change rate of cleaning equivalent to the air cleaner's CADR using the following formula:

ACH (cleaner) = CADR ÷ volume of air in the room

Depending on the room volume and number of occupants, you may need more than one air cleaning unit. When calculating the room's air volume, be sure to exclude the volume taken up by built-in furniture items.

Remember that air cleaners are intended to be used as a support to natural ventilation, and this should be taken into account when selecting your unit. It should be selected to bridge the ventilation gap in the short term until permanent ventilation solutions are put in place.

Where noise is a potential issue with air filtration units, running the device at less than full power can reduce noise. However, additional devices may then be required.

Ultraviolet germicidal irradiation (UVGI) is the use of ultraviolet (UV) energy to kill viral, bacterial and fungal organisms. UVGI fixtures produce ultraviolet-C energy, which has shorter wavelengths than more penetrating ultraviolet-A and ultraviolet-B rays and poses less of a risk to human health.

UVGI units are typically installed near a room ceiling (upper-room UVGI) or inside the HVAC system of a building. Fixtures must be installed in a way that prevents direct UV exposures to people in the room. The airflow rate is crucial for in-duct UVGI, because if the airflow past the device is too fast, the air will not be disinfected. The specification and installation of these systems is a specialist job.

Other devices, such as ozone-generating devices and air disinfection devices, may present additional physical or chemical-related hazards in the workplace, and their use should be fully justified by an appropriate risk assessment. They tend to be best suited to more specialist settings and applications (such as healthcare sterilisation) and require competent advice from qualified personnel prior to their installation. It is not recommended to use these devices in occupied spaces. Contamination builds up when they are not in use.

Where any of these systems have been introduced, emergency plans must be reviewed and updated if required. In addition, a documented cleaning, servicing and maintenance regime is required (such as filter changes). All these activities must be risk assessed and training carried out.

4.3 Other IAQ considerations

Ventilation or filtration to improve IAQ cannot be looked at in isolation. A holistic, multifaceted approach is required. There are multiple legislative, economic and environmental aspects to consider.

A well-designed building begins with consideration of building orientation and intelligent façade design in order to minimise heating and cooling loads. The location of the building also plays a role in the choice of ventilation; for example, buildings near motorways usually require additional air cleaning. Choice of construction materials (to favour those with low volatile organic compound emissions) and arrangements for natural ventilation (such as openable windows), mechanical ventilation (location of intakes), air filtration, good air circulation (high ceilings), and the relative location of intakes and extracts in rooms are far more cost-effective if implemented at the design stage. Computer modelling can be useful for complex designs or specialist facilities.

Designing out risks is part of initial building design, but it can also be incorporated into retrofit and refurbishment projects.

All the fixtures and fittings that are present in the workplace can play a role in IAQ. The paint on the walls, the flooring, the furniture and many other items could be sources of chemicals known as volatile organic compounds (VOCs). These are released from plastics, adhesives and sealants. Wood composite products can have formaldehyde and VOC emissions, and water-based paints can have added biocides.

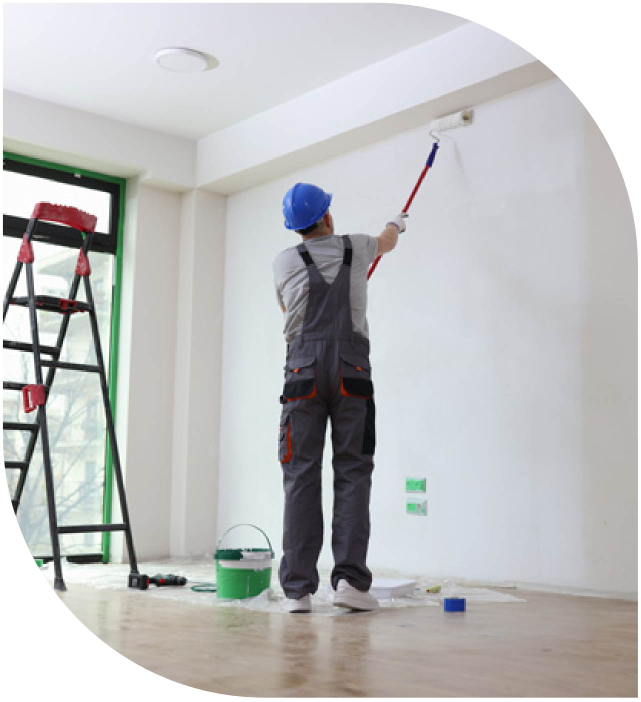
When painting a room, the room should be ventilated and left to dry and off-gas. The Safety Data Sheets for the paint must be consulted and a risk assessment completed. The risk assessment should take account of the risk to the painter and the room occupants. A similar approach can be taken for new furniture and fittings with increased heating and ventilation of the room or building for a period of time after initial installation and before occupation.

Look out for labels such as “low VOC” or “no added formaldehyde” on products. Check if the products have been independently tested to back up these claims. The use of no-emission or as low as possible emission equipment and products helps improve IAQ.

Regular cleaning can help improve IAQ when it is done correctly. Sweeping and dusting can re-suspend dirt and dust, but vacuuming can reduce this when suitable filters are installed to prevent release of these particles back into the air.

Environmentally friendly cleaning products are often purchased due to their perceived health benefits. People assume that there is no risk, as they are environmentally friendly products. However, labelling can be confusing. ‘Natural ingredients’ can still cause allergic contact dermatitis as well as respiratory irritation. The form of the cleaner also plays a role in its safety; for example, a cream cleaner probably releases fewer airborne contaminants than a spray.

The safety data sheets for cleaning chemicals must be consulted and a risk assessment completed. Ideally, cleaning products must have adequate cleaning performance and be both environmentally friendly and healthy for the user.



4.4 Energy efficiency and IAQ

European Union (EU) directives on the energy performance of buildings and energy efficiency (Directive 2010/31/EU, Directive 2012/27/EU and Directive (EU) 2018/844) specifically reference the issue of a healthy indoor climate, including indoor air quality.

Energy performance upgrades of existing buildings should contribute to achieving a healthy indoor environment.

Section 5

Further information and resources on indoor air quality

Building Engineering Services Association (BESA):
www.thebesa.com

Chartered Institution of Building Services Engineers (CIBSE) Ireland:
www.cibseireland.org/about

European Centre for Disease Prevention and Control (ECDC):
www.ecdc.europa.eu/en

Department of Education
www.gov.ie/en/publication/ad236-guidance-on-ventilation-in-schools/

Department of Housing, Local Government and Heritage
Building Regulations 2019 - Technical Guidance Document F - ventilation

Engineers Ireland:
www.engineersireland.ie/about-us

Expert Group on the Role of Ventilation in Reducing Transmission of COVID-19:
www.gov.ie/en/publication/aa43c-expert-group-on-the-role-of-ventilation-in-reducing-transmission-of-covid-19/

Health and Safety Authority:
www.hsa.ie/eng/topics/ventilation

Health Protection Surveillance Centre
www.hpsc.ie (building and facilities guidance)

HSE Environmental Health Service
www.hse.ie/eng/services/list/1/environ/

International Organisation for Standardisation (ISO)
www.iso.org

- ISO 16890-1:2016 *Air filters for general ventilation - Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePMAir filters for general ventilation - Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM).*
- ISO 7730:2005 - Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.

National Standards Authority of Ireland:
www.nsai.ie

EN 16798-1:2019 - *Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.*

REHVA, the Federation of European Heating, Ventilation and Air Conditioning Associates
www.rehva.eu

World Health Organisation:
www.who.int

An tÚdarás Sláinte agus Sábháilteachta
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