***A close up of a building

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Indoor air quality guidance

Revision 01 – Sept 2024

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**Document Revision**

This document will be revised regularly, the below table should be used to track revisions:

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1. Introduction

People in the UK spend an estimated 90% of their time inside enclosed spaces – in homes, schools, offices and other building environments. During this time, exposure to air pollutants can lead to a variety of health and wellbeing outcomes.

The World Health Organization (WHO) identifies several long-term illnesses linked to poor air quality such as asthma, lung cancer, heart disease, Alzheimer’s disease and other inflammatory conditions. Less serious symptoms include headaches, dizziness, fatigue, eye and nose irritation. Public Health England estimates the annual death toll in the UK from air pollution at between 24,000 and 36,000 with associated healthcare costs between £8bn and £20bn.

Poor air quality can impact productivity, stress, cognitive function, absenteeism and turnover. The UK Green Building Council report “health wellbeing and productivity in offices” highlights that better indoor air quality (IAQ) can lead to productivity improvements of 8-11%.

While ambient outdoor air is often better quality, however indoor air quality can be diminished if external air quality parameters are poor. Pollutants will enter a building through natural ventilation methods, operable doors and windows, and by mechanical ventilation systems such as ventilation or air conditioning. But there are also pollutants created and present inside buildings.

Improving IAQ therefore requires a combination of adequate design solutions, effective ventilation eliminating sources of air pollution and behaviour change of building occupants.

There is no legislation in place for IAQ thresholds, monitoring and measurement currently. However there are several industry guidelines, standards and building accreditations that focus on air quality and have been drawn upon for the purposes of this report.

1. Air pollutants

There are various pollutants that are found indoors that can have a negative impact on our health. Acceptable thresholds have been obtained from Based on the WHO Air Quality Guidelines. The values are the recommended short-term (24-hour) air quality thresholds unless otherwise stated.

For buildings located in more polluted regions, the recommended thresholds set out below should be amended accordingly. The World Health Organization’s Global Urban Ambient Air Pollution Database may be consulted to view outdoor air quality levels, available at <https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database>

* 1. Particulate matter: PM10 & PM2.5

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| Particulate Matter | |
| Description: | Solids and liquids present in the air in the form of particles of various sizes. |
| Common sources: | Activities such as cooking and cleaning; exhalation; shedding of dust from people and processes; from fixtures and fittings such as carpets and furniture. |
| Acceptable thresholds: | * PM2.5 - ≤ 15 µg/m3 * PM10 - ≤ 45 µg/m3 |

Particulate matter (PM) is a generic term used to describe a complex mixture of solid and liquid particles of varying size, shape and composition. It is recognised by the WHO as one of the air pollutants that is most damaging to health because it can penetrate via the lungs deep into the bloodstream and organs. Particulates are categorised by size, which influences how they impact the human body.

PM10 refers to particles that are less than 10 micrometres (also called ‘microns’) in diameter. This measure is shown by the symbol µm and is equal to 0.001mm. This size of particle is known as ‘coarse PM’.

The smaller the particles of PM, the more harmful they are to humans because they are more easily transferred through our airways into other parts of the body. The size of fine particulate matter is PM2.5 or below.

* 1. Carbon Monoxide

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| Carbon Monoxide | |
| Description: | Gas |
| Common sources: | Combustion, especially gas appliances (cookers & gas boilers) |
| Acceptable thresholds: | ≤ 4 mg/m3 |

Carbon monoxide (CO) is a tasteless, odourless gas formed as a product of combustion, notably in motor vehicle engines, and heating and cooking appliances. It is toxic at relatively low levels because of problems with poorly vented heating equipment. It can also combine with other pollutants to form ground-level ozone.

* 1. Carbon Dioxide

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| Carbon Dioxide | |
| Description: | Gas |
| Common sources: | Naturally present in the air and caused by respiration; can build up in poorly-ventilated spaces. |
| Acceptable thresholds: | ≤ 800 ppm |

Carbon dioxide (CO2) is produced by respiration and by combustion of carbon-based fuels. Carbon dioxide in buildings is typically influenced primarily by human exhalation. It therefore provides an excellent measurement of the adequacy of ventilation, which serves to dilute its concentration by introducing outdoor air. Some difficult-to-measure, internally generated contaminants will be diluted and removed when ventilation levels are adequate to remove exhaled carbon dioxide.

It cannot sensibly be described as a ‘contaminant’ until it reaches very high levels, usually only seen in an occupational context. CO2 is typically measured at around 420 ppm in UK cities. People may be able to detect CO2 levels >750ppm

* 1. Volatile Organic Compounds

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| Volatile Organic Compounds | |
| Description: | Include a range of chemicals found in the air indoors. |
| Common sources: | Cleaning products; aerosol sprays; paints, carpets, scented candles; glues, resins, cigarettes, printers, photocopiers. |
| Acceptable thresholds: | ≤ 500 µg/m3  (threshold of total volatile organic compounds (TVOCs). An alternative method is to measure individual VOCs – benzene, formaldehyde, toluene). |

Volatile organic compounds (VOCs) include benzene (classified by the EPA as a known human carcinogen), formaldehyde, toluene, and other chemical compounds, which at high concentrations can lead to irritation of the nose and pharynx, and have been associated with leukaemia, childhood asthma and other respiratory disorders.

* 1. Ozone

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| Ozone | |
| Description: | Gas |
| Common sources: | Pollution emitted from cars, power plants, boilers. Also produced when other pollutants are exposed to sunlight |
| Acceptable thresholds: | ≤ 100 µg/m3  (over an 8-hour period) |

Ozone (O3) is a gas that can form and react under the action of (ultraviolet) light and that is present in two layers of the atmosphere. In the upper atmosphere, ozone forms a layer that shields the Earth from ultraviolet rays. However, at ground level, ozone is considered a major air pollutant.

Ground-level ozone is formed from other pollutants and can react with other substances, in both cases under the action of (ultraviolet) light. Concentrations are often low in busy urban centres and higher in suburban and adjacent rural areas.

Ozone is relatively difficult to measure accurately. It may be necessary to use more accurate and specific measurement techniques, use local publicly available air measurements or use other pollutants as a proxy measure for combustion-related pollution (e.g. PM, TVOC, CO).

* 1. Nitrogen Dioxide

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| Nitrogen Dioxide | |
| Description: | Gas |
| Common sources: | Combustion processes including power generation, industrial processes and domestic heating but notably from transport |
| Acceptable thresholds: | ≤ 25 µg/m3 |

Nitrogen dioxide (NO2) is a gas that is produced along with nitric oxide (NO) by combustion processes. Together these two gases are often referred to as “oxides of nitrogen (NOx)”.

The Department for Environment, Food & Rural Affairs (DEFRA) estimates that 80% of NOx emissions in areas where the UK is exceeding NO2 limits are due to transport, with the largest source being emissions from diesel light duty vehicles (cars and vans).

* 1. Mould

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| Mould | |
| Description: | Mould spores transferred by air currents |
| Common sources: | Caused by damp conditions, poor ventilation and accumulation of dirt |

Mould often grows on cooling coils in heating, ventilation and air conditioning (HVAC) systems due to moisture condensation and can be introduced into the building's indoor air. It can also occur on or within wall assemblies due to water damage or improper detailing in humid locations, for example kitchens and bathrooms.

To prevent mould growing indoors, humidity levels should be kept between 30% and 60%. Devices like air conditioners and dehumidifiers will help to achieve that goal. Mould spores can trigger asthma, headaches, allergies and other respiratory system disorders. They are especially dangerous for people with chronic lung illnesses.

1. Achieving good IAQ
   1. Ventilation

Ventilation is the removal of stale indoor air from a building and its replacement with fresh air of reasonable quality. To ensure a well-ventilated workplace you should provide general ventilation that removes stale, contaminated, or hot and humid air so that the employees do not suffer any ill-health effects. When removing or reducing indoor pollution sources is not possible, ventilation (mechanical or natural) can reduce their effect by replacing polluted indoor air with clean outdoor air. Therefore, good ventilation is a critical pre-requisite for good IAQ.

The Workplace (Health, Safety and Welfare) Regulations 1992 (WHSW), regulation 6 requires that every enclosed workplace is ventilated by a sufficient quantity of fresh or purified air. The Guidance for regulation 6 states that the fresh air supply rate to the workplace should not normally fall below 5 to 8 litres per second, per occupant.

* + 1. General ventilation

General ventilation or 'dilution' ventilation is a term used to define the flow of air into and

out of a working area, for example an office space, so that any contaminants are diluted by

adding some fresh air.

Ventilation may be achieved naturally (e.g. opening windows, trickle vents etc.), through

mechanical ventilation systems, or by a combination of the two. Mechanical ventilation will usually give finer control of ventilation rates and most importantly, supply air ventilation will give the opportunity to filter outdoor air to a greater or lesser degree, thus helping to provide cleaner air to breath for the occupants.

***Natural ventilation***which relies on wind pressure and temperature differences to move fresh air through a building and is usually not fully controllable; and

***'Forced' or mechanical***ventilation which uses mechanical supply and/or extraction to

provide fresh air and is controllable.

* + 1. Effective ventilation

Ventilation effectiveness is a measure of how well a ventilation system works in terms of delivering the supply air to the occupants of a building. Ventilation effectiveness is dependent on the ventilation system design, its installation and way in which occupants use the space.

A complimentary strategy for achieving good indoor air quality is to reduce the release of water vapour and/or pollutants into the indoor air, i.e. source control.

The fresh air' which is brought into the workplace should be free of contaminants such as engine exhaust emissions, or discharges from oil or gas fired flues or extract outlets. If you expect the inlet air to be heavily contaminated with particulates (eg heavy traffic, smoke etc) then it should be filtered. Air to be recirculated should be adequately filtered to remove particulates and should have fresh air added to it before being reintroduced into the workplace. When providing fresh air for the employees, ensure that there are no uncomfortable draughts from the movement of air.

To predict the effectiveness of ventilation, reference should be made to ventilation rates, most pertinently in terms of litres per second per person, or air changes per hour. The downsides to high rates of ventilation are the potential energy costs required to heat and/or cool outdoor air, the possibility of noise pollution if windows are the only form of ventilation available, and the risk of introducing outdoor air pollution.

* + 1. Air recirculation

Air recirculation can be used to conserve energy. The recirculation air returning to the workspace can be provided by mechanical ventilation such as air conditioning units. This will include heating or cooling the air, filtering it and, in some cases, adjusting the humidity to provide the most comfortable working conditions.

This method is however unlikely to remove all contaminants. Therefore, there should always have a provision of adequate supply of air into the system at a sufficient rate to replace lost air. In this manner contaminants can be diluted using the correct fresh air supply rate.

* + 1. Assessing ventilation effectiveness

Assessment of the effectiveness of the ventilation in the workplace should start with information on:

* Size and layout of the area; The larger the area the greater affinity to:
  + Have more air dilution
  + Tend to have been designed with ventilation rates consideration
  + Takes longer for IAQ to deteriorate.
* The likely source of pollution,
* Evidence of draughts and thermal conditions
* Assess how fresh air is supplied in the workplace either through natural ventilation or mechanical ventilation.
* List areas in the workplace and how they are ventilated, including changing rooms and areas used for breaks, such as canteens.
* Establish how many people occupy the area and whether the number is constant or fluctuates and what their views on ventilation provided.
* Decide what types of activities are undertaken in these areas.
* Establish smoking habits of occupants.
* Activities incurring higher rate of exertion/respiration is likely to lead to increased level of CO2.

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|  | If you cannot tell easily how and area is ventilated, it may be because it is poorly ventilated. |

Once this data is collated, an assessment can be made on whether the ventilation systems in use provide sufficient fresh air. A recommended fresh air supply rate of 8 litres per second per person should provide a clean and hygienic workplace in open plan offices. Higher fresh air supply rates of up to 36 litres per second per person may be required for heavily contaminated buildings.

It is important to strike a balance between the benefits of ventilation against issues such as:

* The energy required to heat (and/or cool/humidify/de-humidify) the outdoor air before it enters the building
* Causing discomfort to occupants with air that is too cold or too warm
* The risk of introducing more pollution into the building
* The possible increase of noise in the building caused by additional mechanical ventilation or through open windows.

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|  | If there are work processes generating hazardous air contaminants, then you will be required to undertake a risk assessment under the COSHH Regulations. You may then need to prevent or adequately control such exposure. Ventilation requirements for the emitted hazardous substances will need to be adopted as per the findings of the COSHH assessment. |

Various techniques can be used to assess the effectiveness of building ventilation systems ranging from the simple smoke test to the more complex measurement of tracer gas.

Examples include:

* Using smoke tubes to visualise the pattern of air movement in a workplace.
* measuring air velocities either in the work area, in ductwork or at grilles to determine air flow rates.
* using tracers to follow air movement through a building or to determine the air exchange rates by plotting the decay rate of a tracer gas (see HSE publication Measurement of air change rales in factories and offices).

Mechanical ventilation with heat recovery (MVHR) - MVHR systems can reduce energy consumption while maintaining the required ventilation to remove internally generated heat, moisture and pollutants. They are key to maintaining good indoor air quality and as such should be equipped with the highest appropriate quality of filtration and installed so that they can be easily maintained and kept clean. It is possible to carry out an outside air quality assessment near the building to determine the level of filtration required.

* 1. Eliminating sources of pollution

Removing or reducing sources of pollution is the most effective way of improving indoor air quality. The following strategies should be considered.

Combustion is a major source of air pollution, from space heating, cooking and nearby transportation. Opting for non-combustion or low-emission combustion products is an important consideration. Additionally, designing spaces so combustion equipment and other polluters (e.g. printers) are separate from regularly occupied spaces.

Various sources within buildings can emit harmful pollutants including cleaning products, insulation, paints, coatings, adhesives, furniture and furnishings, composite wood products and flooring. Applying a ‘green’ buying policy consider the ingredients and impact of these products and improve indoor air quality. These materials are increasingly tested and certified for their pollutant capability so buyers can make more informed decisions.

Keep room surfaces and hidden surfaces in air ducts in HVAC equipment clean (see the BESA publication TR19 for best practice guidance on ductwork cleaning). Regular cleaning of ductwork and filters should also be considered a key part of air quality improvement. In general, maintenance should be prioritised, and indoor air quality made one of its key objectives.

Implementing a smoke free environment or radius around buildings protects building users from second-hand smoke and prevents smoke entering the buildings through entrances, windows and air intakes.

* 1. Air filtration

Filters - these can play a crucial role in removing many major pollutants from air as it enters a building via ventilation and air conditioning systems. There are recognised standards in place for application of filters, as well as ratings for low energy filters.

The global technical standard ISO 16890:2016 includes three efficiency classes for filters:

* ePM1 (best-performing);
* ePM2.5 (intermediate); and
* ePM10, the lowest efficiency ('e' stands for filtration efficiency).

Most standard mechanical ventilation with heat recovery (MVHR) system filters are designed to protect the unit itself, rather than to improve indoor air quality. It is recommended that you check if your MVHR system can accept high-grade filters such as those mentioned above.

The higher the filter class the more effective is the filtration to stop small particles such as pollen or fungus spores. A filtration system must however be properly maintained according to manufacturer's recommendations, which gives us certainty, that it operates as designed.

In areas with high levels of outdoor pollution, filtering the incoming air is vital. But this means that ventilation and air conditioning (HVAC) equipment must be powerful enough to accommodate this approach.

Natural ventilation strategies can improve indoor air quality if outdoor air quality is acceptable – building users in buildings with operable windows can improve indoor air quality by supplying outdoor air. For this method to be effective, a system for monitoring local outdoor parameters is necessary. In areas with poor outdoor air quality this strategy may worsen indoor air quality. The World Health Organization’s Global Urban Ambient Air Pollution Database can be utilised to monitor outdoor air quality levels, available at <https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database>

* 1. Measuring and monitoring air quality

Indoor air quality can vary, even on an hourly and daily basis. Therefore, real-time continuous monitoring is recommended with regular recalibration and updating of policies. This allows deviations in air quality metrics to be addressed efficiently and building users exposure to pollutants to be minimised.

Selecting the right monitors that measure a range of pollutants is necessary, as well as ensuring they are positioned correctly to ensure accurate measurements. There are

many factors which affect air movement (and the pollutants in it) around a space, such as position of the room in a building, height of a space or type of ventilation system. Positioning monitors correctly ensures that you have a clear understanding of indoor air quality - and can spot where there may be problems.

Today’s monitoring technology can measure a wide range of contaminants. However, unless your building has local issues, that you are aware of, it may be best to concentrate on a smaller range of easier-to-measure pollutants at the outset:

* PM10 & PM2.5
* Carbon monoxide
* Carbon dioxide
* VOCs
* Nitrogen dioxide

In addition to monitoring, educating building users, particularly Building Services and Facilities Management teams on the risks associated with air pollution and actions to reduce these risks will further enhance indoor air quality.

# Bibliography

BESA (2021). *Guide to good practice for Indoor Air Quality for Health and Wellbeing H&W002*

BESA. (2021). *Summary of Practical Measures for building services operation VG002 Version 6.*

BESA. (2022). *Buildings as Safe Havens. A Practical Guide H&WB003*

BS (2023). *40102-1: Health and well-being and indoor environmental quality in buildings*

CIBSE. (2021). *CIBSE COVID-019 Ventilation Guidance V5.*

Electric, B. &. (2021). *A beginner's guide to indoor air quality.*

HSE. (2000). *General Ventilation in the workplace: Guidance for employers HSG202.*

WELL. (n.d.). *WELL Building Standard Guide.*

WHO. (2021). *WHO global air quality guidelines.*

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