5 Air

5.1 General

*COMMENTARY ON **5.1***

Radon and formaldehyde are not measured as part of the overall evaluation matrix. Information about them is given in Annex D.

5.1.1 For some measurements, the quality of outdoor air and the level of contaminants introduced via mechanical or natural ventilation can affect the indoor conditions; therefore, both outdoor and indoor measurements should be monitored and recorded for certain air quality pollutants.

5.1.2 The monitoring should take place as close as is reasonably practicable to the indoor location being monitored for naturally ventilated systems, or as close as is reasonably practicable to the intake position for a mechanically ventilated system.

NOTE This might be at a safe location directly outside the area under assessment for natural ventilation, or in the vicinity of supply air intake for mechanical ventilation.

5.1.3 Air quality values should be measured indoors and/or outdoors as detailed in 5.2 to 5.7.

5.1.4 Indoor monitoring of air quality should reflect how occupants use the building, based on the occupants and/or visitors survey.

5.1.5 The criteria in Table 3 should be used for checking validity when aggregating data and calculating statistical parameters.

Table 3 — *Data sampling and aggregation parameters*

Parameter	Required proportion of valid data
One-hour values	75% (i.e. 45 minutes)
Eight-hour values	75% of values (i.e. 6 hours)
Maximum daily eight-hour mean	75% of the hourly running eight-hour averages (i.e. 18 eight-hour averages per day)
24-hour values	75% of the hourly averages (i.e. at least 18 hour values)
Annual mean	90% (1) of the one-hour values or (if not available) 24-hour values over the year.

NOTE See EU Directive 2008/50/EC [2] for further information.

5.2 Particulate matter

*COMMENTARY ON **5.2***

Particulate matter (PM) is a generic term used to describe a complex mixture of solid and liquid particles of varying size, shape and composition. Some particles are emitted directly (primary PM); others are formed in the atmosphere through complex chemical reactions (secondary PM). The composition of PM varies greatly and depends on many factors, such as geographical location, emission sources and weather.

The main sources of primary PM emissions are the combustion of fuels (by vehicles, industry and domestic properties) and other physical processes such as tyre and brake wear. Sources of secondary PM include ammonia from agriculture such as manure or fertilisers. Natural sources include wind-blown soil and dust, sea spray particles and fires involving burning vegetation.

PM is often classified according to aerodynamic size and referred to as:

a) coarse particles (PM_{10}; particles that are less than 10 microns (μm) in diameter); and

b) fine particles ($PM_{2.5}$; particles that are less than 2.5 µm in diameter).

The size of particles and the duration of exposure are key determinants of potential adverse health effects. Particles larger than 10 µm are mainly deposited in the nose or throat, whereas particles smaller than 10 µm pose the greatest risk because they can be drawn deeper into the lung. The strongest evidence for effects on health is associated with fine particles ($PM_{2.5}$).

There is an extensive body of evidence that long-term exposure to PM increases mortality and morbidity from cardiovascular and respiratory diseases. Outdoor air pollution, particularly PM, has also been classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans (a Group 1 carcinogen) and causing lung cancer. There is some experimental evidence, however, that ultrafine particles can also pass through the lungs into the bloodstream.

For further information, see www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

5.2.1 Particulate matter (PM_{10} and $PM_{2.5}$) should be measured and recorded indoors for each room, zone or area forming part of the assessment, and outdoors. The height that the measurement should be taken at should be determined in relation to the activity being undertaken within the space.

5.2.2 The level of particulate matter should be assessed in accordance with the values given in Table 4 and Table 5.

Table 4 — *$PM_{2.5}$*

Level	Description	Value µg/m³ – annual running mean	Value µg/m³ – 24 h running mean
0	High	>5	>15
2	Acceptable	3–5	≤15[A)]
4	Low	<3	N/A

NOTE The information in this table is based on the WHO Air Quality Guidelines 2021 [3].

[A)] The recommended short-term (24-hour) AQG level and interim targets for $PM_{2.5}$ and PM_{10} are defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

Table 5 — *PM_{10}*

Level	Description	Value µg/m³ – annual running mean	Value µg/m³ – 24 h running mean
0	High	>15	>45
2	Acceptable	8–15	≤45[A)]
4	Low	<8	N/A

NOTE The information in this table is based on the WHO Air Quality Guidelines 2021 [3].

[A)] The recommended short-term (24-hour) AQG level and interim targets for $PM_{2.5}$ and PM_{10} are defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

5.3 Carbon monoxide

*COMMENTARY ON **5.3***

Carbon monoxide (CO) is a colourless, tasteless, odourless, non-irritating gas produced during incomplete combustion of fuels due to there being insufficient oxygen present. Complete combustion occurs when sufficient oxygen is present and leads to the production of carbon dioxide. Most combustion processes (natural or man-made) produce some carbon monoxide.

When inhaled, carbon monoxide enters the blood through the lungs and attaches to the body's oxygen carrier, haemoglobin. This reduces the amount of oxygen that can be carried round the body. A brief exposure to small amounts of carbon monoxide can cause headaches, flushing, nausea, dizziness, vertigo, muscle pain or personality changes. Exposure to higher amounts can cause movement problems, weakness, confusion, lung and heart problems, loss of consciousness and death.

Exposure to small amounts of carbon monoxide for a long time can lead to flu-like symptoms with tiredness, headaches, nausea, dizziness, personality changes, memory problems, loss of vision and dementia. It can be hard to tell the difference between the effects of being exposed to carbon monoxide at low levels for a long time and other common illnesses. See the PHE document for further information [4].

5.3.1 Carbon monoxide levels should be measured and recorded indoors for each room, zone or area forming part of the assessment. The height(s) that the measurement is to be taken at should be determined in relation to the range of activities likely to be undertaken within the space.

5.3.2 The level of carbon monoxide should be assessed in accordance with the values given in Table 6.

Table 6 — *Carbon monoxide (CO)*

Level	Description	Value ppm (mg/m³)			
		15 min average	1 h average	8 h average	24 h average
0	High	>85.8 (>100)	>30 (>35)	>8.6 (>10)	>3.4 (>4.0)
2	Acceptable	30–85.8 (35–100)	8.6–30 (10–35)	3.4–8.6 (4.0–10)	2–3.4[A)] (2.3–4.0)
4	Low	<30 (<35)	<8.6 (<10)	<3.4 (<4.0)	<2 (<2.3)

NOTE The information in this table is based on the WHO guidelines for indoor air quality [5].

[A)] The recommended 24-hour AQG levels are defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

5.4 Total volatile organic compounds

*COMMENTARY ON **5.4***

Total volatile organic compounds (TVOCs) are a very large group of organic compounds, which differ widely in their chemical composition but can display similar behaviour in the atmosphere. TVOCs are emitted to air as combustion products, as vapour arising from petrol, solvents, air fresheners, cleaning products, perfumes and numerous other sources, often when products are used at work or in the home. The diversity of products and processes which emit TVOCs is wide-ranging, covering not only industrial processes (22% of emissions), but also household products (18%), agriculture (14%), domestic burning and transport (5% each).

Other sources of TVOCs include furnishings, carpets and upholstery, products for cleaning and polishing, air fresheners and personal care products (for example, fragrances, deodorants and hair styling products).

For further information and guidance, see the DEFRA publication on clean air [6].

Health effects from VOCs can include:

a) eye, nose and throat irritation;

b) headaches, loss of coordination and nausea; and

c) damage to liver, kidney and central nervous system.

5.4.1 TVOCs should be measured at a representative task height and recorded indoors for each room, zone or area forming part of the assessment. The height that the measurement is to be taken at should be determined in relation to the activity being undertaken within the space.

5.4.2 The level of TVOCs should be assessed in accordance with the values given in Table 7.

Table 7 — *Total volatile organic compounds*

Level	Description	Value ppb (µg/m³ – 8 h average)
0	Very high	≥250 (≥1 000)
1	High	125–<250 (500–<1 000)
2	Acceptable	75–<125 (300–<500)
3	Low	25–<75 (100–<300)
4	Very low	<25 (<100)

NOTE The information in this table is based on Approved Document F [7] and BREEAM Guidelines [8].

If readings are high/very high, then further investigation should be carried out into those individual VOCs found to be present at such levels. High/very high TVOC levels, or levels changing over time, should alert the user to carry out further investigation into potential sources.

NOTE For measurement of individual VOCs, refer to the PHE IAQ guidelines for selected VOCs [2].

5.5 Nitrogen dioxide

*COMMENTARY ON **5.5***

Nitrogen dioxide (NO_2) 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 NO_2 limits are due to transport, with the largest source being emissions from diesel light duty vehicles (cars and vans). Other sources include power generation, industrial processes and domestic heating.

The Committee on the Medical Effects of Air Pollutants (COMEAP) has established that short-term exposure to NO_2, particularly at high concentrations, is a respiratory irritant that can cause inflammation of the airways leading to, for example, cough, production of mucus and shortness of breath. Studies have shown associations of NO_2 in outdoor air with reduced lung development and respiratory infections in early childhood and effects on lung function in adulthood.

Epidemiological studies have also shown associations of outdoor NO_2 with adverse effects on health, including reduced life expectancy. It has been unclear whether these effects are caused by NO_2 itself, or by other pollutants emitted at the same time by sources such as road traffic.

For further information, see www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

5.5.1 Nitrogen dioxide should be measured and recorded indoors for each room, zone or area forming part of the assessment, and outdoors. The height that the measurement is to be taken at should be determined in relation to the activity being undertaken within the space.

5.5.2 The level of nitrogen dioxide should be assessed in accordance with the values given in Table 8.

Table 8 — *Nitrogen dioxide*

Level	Description	Value ppm (µg/m³) – 1 h average	Value ppm (µg/m³) – 24 h average
0	High	>104.5 (>200)	>13.1 (>25)
2	Acceptable	13.1–104.5 (25–200)	5.2–13.1[A)] (10–25)
4	Low	<13.1 (<25)	<5.2 (<10)

NOTE The information in this table is based on the DEFRA Update on Implementation of the Daily Air Quality Index (April 2013) [10] and the WHO Air Quality Guidelines 2021 [3].

A) The recommended 24-hour AQG levels are defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

5.6 Ozone

*COMMENTARY ON **5.6***

Ozone (O_3) 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, particularly on sunny days in summer. However, ozone can be transported through air over long distances and across borders.

Short-term exposure to ozone peaks can temporarily affect the lungs, the respiratory tract and the eyes. It can also increase susceptibility to inhaled allergens. Long-term exposure to relatively low concentrations of ozone can reduce lung function.

5.6.1 Ozone should be measured and recorded indoors for each room, zone or area forming part of the assessment, and outdoors. The height that the measurement is to be taken at should be determined in relation to the activity being undertaken within the space.

5.6.2 The level of ozone should be assessed in accordance with the values given in Table 9.

NOTE O_3 is relatively difficult to measure accurately at the low levels of interest. If problems are indicated, it might be necessary to measure using more accurate and specific measurement techniques such as laboratory grade (A) instrumentation, wet chemistry, etc. In some localities, it might be possible to refer to publicly gathered outdoor air measurements. It might suffice to use PM, TVOC and CO as proxy measures or early-warning indicators for outdoor, combustion-related pollution.

Table 9 — *Ozone*

Level	Description	Value ppm (µg/m³ – 8 h average)
0	Very high	>50.1 (>100)
1	High	>30–50.1 (>60–100)
2	Acceptable	20–30 (40–60)
3	Low	10–<20 (20–<40)
4	Very low	<10 (<20)

NOTE The information in this table is based on the WHO Global Air Quality Guidelines 2021 [3].

5.7 Carbon dioxide

*COMMENTARY ON **5.7***

Carbon dioxide (CO_2) is produced by respiration and by combustion of carbon-based fuels.

Carbon dioxide in buildings is typically primarily influenced 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.

Carbon dioxide (CO_2) level is the concentration of carbon dioxide in a gaseous mixture. Depending on the CO_2 concentration inhaled and exposure duration, toxicological symptoms in humans range from headaches [in the order of 3% (30 000 ppm) for 1 h], increased respiratory and heart rate, dizziness, muscle twitching, confusion, unconsciousness, coma and death [in the order of >15% (150 000 ppm) for 1 min]. See HSE publication [11] for further information.

5.7.1 Carbon dioxide should be measured and recorded indoors for each room, zone or area forming part of the assessment. The height that the measurement is to be taken at should be determined in relation to activity being undertaken within the space.

NOTE Carbon dioxide is measured as a proxy for ventilation, rather than a pollutant, so there is no associated averaging period. Due to uncertainties of sources of CO_2 and limitations of measurement techniques, broad levels of CO_2 are given in Table 10.

5.7.2 The level of carbon dioxide should be assessed in accordance with the values given in Table 10.

Table 10 — *Carbon dioxide*

Level	Description	Value (ppm)
0	Very high	≥1 800
1	High	1 000–<1 800
2	Acceptable	800–<1 000
3	Low	550–<800
4	Very low	<550

NOTE The information in this table is based on BS EN 16798-1 (assuming an external value of 415 ppm).

