Appendix to the Position Statement on Indoor Air Quality Assessment Levels

This appendix provides further information on the assessment levels listed in the Position Statement. It does not express an IAQM position, it presents other organisations' assessment levels, and it has been agreed by the IAQM's Indoor Air Quality sub-committee.

Good general discussions of indoor air quality and indoor and outdoor pollution sources can be found in the Building Research Establishment (BRE's) 2019 report, "*Ensuring good indoor air quality in buildings*"[i] and the Royal College of Paediatrics and Child Health and the Royal College of Physicians, 2020 report, "*The inside story: Health effects of indoor air quality on children and young people.*"[ii]

1. LEGISLATION

1.1 HSE COSHH Workplace Exposure Limits

Exposure to gases and (airborne) particulate matter in any place of work are covered by the COSHH regulations.[iii] There are Workplace Exposure Limits (WELs) which are Long-term exposure limits (LTELs) 8-hour time-weighted average concentrations (TWAs), and Short-term Exposure Limits (STELs), generally 15-minute average concentrations. WELs are expressed in mg/m^3 and have been provided for 426 substances including some UK Air Quality Objective[iv] (AQO) pollutants; they are set out in the Health and Safety Executive's guidance document EH40/2005.[v] Guidance is provided on converting the 8-hour WELs to other averaging times in EH40/2005 and in EH75/2.[vi]

WELs are generally based on Indicative Occupational Exposure Limit Values (IOELVs) which are health-based limits set under the Chemical Agents Directive (98/24/EC).[vii] IOELVs are listed in Directives which Member States are obliged to implement by introducing national occupational exposure limits for the substances listed. In most cases, this will mean that the UK limits will be identical, or very close to the IOELV.

WELs apply to employees in every workplace and to any person affected by the employees' work:

> Regulation 6(1) states that an employer *"… should carry out a suitable and sufficient assessment of the risks to the health of your employees and any other person who may be affected by your work, if they are exposed to substances hazardous to health".*

Table 1. Selection of WELs (AQO pollutants are *shown in italics*)

Substance	WEL	
	8-hour (mg/m^3)	15-minute (mg/m^3)
PM_{10} and $PM_{2.5}$	No equivalent – see total inhalable and respirable[viii] limits below	
$PM_{2.5}$	No equivalent – see total inhalable and respirable limits below	
Nitrogen dioxide	0.96	1.91
Ozone	-	0.4
Sulphur dioxide	1.3	2.7
Polycyclic aromatic hydrocarbons (PAH)	No equivalent for total PAH	
Benzene	3.25	-
1-3 butadiene / Buta-1,3-diene	2.2	-

Carbon monoxide	23	117
Lead	No equivalent – regulated separately (HSE Control of Lead at Work (CLAW) Regulations (2002)[ix])	
Total inhalable dust	10	-
Respirable dust (PM_4)	4	-
Toluene	191	384
Formaldehyde	2.5	2.5
Carbon dioxide	9,150	27,400

2. REGULATIONS

Building regulations are the main regulatory requirement for buildings in the UK. Guidelines for energy efficiency and ventilation are set down in the Approved Documents of the Building Regulations[x] and Standards in devolved Governments and assemblies. Section headings 2.1 to 2.3 are given in terms of the Approved Documents (England and Wales), Technical Handbook[xi, xii] (in Scotland), and Technical Booklets[xiii, xiv, xv] (in Northern Ireland).

Components of these relevant to indoor air include protection from moisture and radon, and energy efficiency, which includes air-tightness. Ventilation requirements are primarily based on control of moisture and only specify indoor air standards for a few substances.

2.1 Approved Documents F1: Means of Ventilation, Appendix A: Performance-Based Ventilation

Approved Document F1 outlines ventilation performance criteria for a range of buildings, dwellings and non-dwellings, and Appendix A specifies the performance criteria in terms of concentrations of pollutant to be achieved. These are shown in Table 2.

Table 2. Approved Document F1 performance criteria

Pollutant	Dwelling		Non-dwelling	
	Long-term average	1 hr average	Long-term average	1 hr average
Nitrogen dioxide	40µg/m^3	288µg/m^3	40µg/m^3	288µg/m^3
Carbon monoxide	10mg/m^3	30mg/m^3	10mg/m^3 35mg/m^3 (Occupational Exposure)	30mg/m^3 N/A
TVOC	300µg/m^3		300µg/m^3	N/A
Ozone			100µg/m^3	N/A

Note: N/A: not applicable

2.2 Building Regulations Approved Documents C: Site Preparation and Resistance to Contaminants and Moisture

This document outlines the site preparation and methods for to avoid ingress of contaminants from the soil into the building, including methane, VOCs and radon. No specific concentrations are set for methane or VOCs. An action level of 200Bq/m^3 has been set for Radon which is a long-term average concentration, typically monitored over a period of at least 3 months.

2.3 Approved Document D: Toxic Substances D1 Cavity Insulation

This document sets out criteria for insulating materials and their insulation to avoid exposure to excessive formaldehyde fumes; there are no concentration levels specified.

3. GUIDELINES

3.1 Building Bulletin 101 Guidance on Ventilation, Thermal Comfort and Indoor Air Quality in Schools

The 2018 Building Bulletin 101[xvi] (BB101) was published by the government's Education and Skills Funding Agency (ESFA). It has the status of an "extra document" providing additional guidance to Approved Document F (in England and Wales) the Non-Domestic Technical Handbook (in Scotland), and Technical Booklet K (in Northern Ireland). BB101 notes:

> "… that following the guidance in an AD, Technical Handbook or Technical Booklet does not guarantee compliance with Building Regulations, but there is a legal presumption of compliance."

The (statutory) guidance on indoor air quality refers to HSE EH40 and to the Approved Document F1, Appendix A, and sets limits on carbon dioxide concentrations that are shown in Table 3. It also references WHO and UK AQO guidance as "…beyond the ESFA recommended design standards".

This document states "*Where external air pollutants exceed the levels in National Air Quality Standards, consideration will need to be given to means of reducing pollutant levels in the indoor air*". The guidance is aligned with the latest health and safety standards and industry practice.

Table 3. BB101 assessment levels for carbon dioxide

Condition	Ventilation	CO_2 concentration (ppm)
Daily average concentration, when the number of room occupants is equal to, or less than the design occupancy	Where mechanical ventilation is used, or hybrid systems operating in mechanical mode in general teaching and learning spaces	**1,000**
Maximum concentration for more than 20 consecutive minutes each day when the number of room occupants is equal to, or less than the design occupancy		**1,500**
Daily average, during the occupied period, when the number of room occupants is equal to, or less than the design occupancy	General teaching and learning spaces where natural ventilation is used or when hybrid systems are operating in natural mode	**1,500**
Maximum concentration for more than 20 consecutive minutes each day when the number of room occupants is equal to, or less than the design occupancy		**2,000**
New building for the majority of the occupied time during the year - this is the criterion for a category II building (800 ppm above the outside carbon dioxide level, taken as 400ppm)		**1,200**
Refurbished building for the majority of the occupied time during the year - this is the criterion for a category III building (1,350ppm above outside air level)		**1,750**

3.2 WHO Guidelines

In 2010 the WHO published guidance[xvii] for the protection of public health from risks associated with a number of pollutants commonly found in indoor air (benzene, carbon monoxide, formaldehyde,

naphthalene, nitrogen dioxide, PAH, radon, trichloroethylene and tetrachloroethylene). The pollutants selected were identified as all having potential indoor sources, were known as being hazardous to health and often occurring in concentrations of specific health concern. The guidelines were prepared to provide a scientific basis for legally binding standards for use by public health professionals and specialists and authorities involved in the design and use of buildings and building materials. They are based on a comprehensive review and evaluation of accumulated scientific evidence by a multidisciplinary group of experts who studied the toxic properties and associated health effects of the selected pollutants.

Table 2. Selection of WHO Guideline Values (substances that appear in Table 1 of EH40/2005)

Substance	Guideline concentration
Benzene	No safe level of exposure can be recommended Unit risk of leukaemia per 1µg/m^3 air concentration is 6×10^{-6} The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17µg/m^3, respectively
Carbon monoxide	100mg/m^3 (15-minute mean)
	35mg/m^3 (1-hour)
	10mg/m^3 (8-hours)
	7mg/m^3 (24-hours)
Formaldehyde	100µg/m^3 (30-minute mean)
Nitrogen dioxide	200µg/m^3 (1-hour mean)
	40µg/m^3 (annual mean)
PAH	B[a]P is taken as a marker of the PAH mixture No threshold can be determined and all indoor exposures are considered relevant to health Unit risk for lung cancer for PAH mixtures is estimated to be 8.7×10^{-5} per ng/m^3 of B[a]P The corresponding concentrations for lifetime exposure to B[a]P producing excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are approximately 1.2, 0.12 and 0.012ng/m^3, respectively

3.3 PHE Guidelines

In PHE Guideline published in 2019[xviii], were developed in recognition that there are no UK indoor air quality guidelines for specific volatile organic compounds (VOC). PHE noted that guidance existed (e.g. HM Government (2010) Building Regulation Part F) for Total Volatile Organic Compounds (TVOC) but stated that assessing TVOC revealed little about the nature of individual compounds, their concentrations and potential, specific toxicity to humans. They undertook a comprehensive literature review to propose guidelines for individual VOCs in the UK, starting with the WHO guidelines but extending to health-based guidelines from other countries and organisations. They considered the most recent scientific evidence regarding substance toxicity and the presence of VOCs in new building materials. The VOCs they selected were acetaldehyde, α-pinene, benzene, d-limonene, formaldehyde, naphthalene, styrene, tetrachloroethylene, toluene, trichloroethylene and xylene (mixtures).

Table 3. Selection of PHE Guideline Values (substances that appear in Table 1)

Substance	Limit value concentration
Benzene	No safe level of exposure can be recommended
Formaldehyde	100µg/m^3 (30-minute mean)
	10µg/m^3 (1 year)
Toluene	15,000µg/m^3 (8-hours)
	2,300µg/m^3 (24-hour mean)

3.4 Domestic Indoor Air Quality - NICE Guidance

In January 2020 the National Institute for Health and Care Excellence (NICE) published guideline NG149[xix] setting out the importance of good air quality in people's homes and how to achieve it. The guidance avoids setting out assessment criteria or limit values.

The guideline includes recommendations on:

- Prioritising indoor air quality in local strategy or plans;
- Housing assessment referrals;
- Raising awareness of poor indoor air quality in the home and advice for the general public;
- Advice for people with pre-existing health conditions and pregnant woman;
- Using standards to improve indoor air quality;
- Ensuring architects and designers take account of indoor air quality;
- Ensuring builders, contractors and developers comply with building standards; and,
- Ensuring rental properties comply with regulations.

Recommendation 1.6 requests that regulators and building control teams should *"Update existing standards, for example building regulations, or develop new ones for indoor air quality. Base them on current safe limits set for pollutants in residential developments. See, for example, World Health Organization guidelines on selected pollutants (2010) and dampness and mould (2009), and the Public Health England indoor air quality guidelines for selected VOCs (2019)".*

4. VOLUNTARY ASSESSMENT AND CERTIFICATION SCHEMES

4.1 Building Research Establishment Environmental Assessment Method (BREEAM):

BREEAM is a sustainability assessment method that can be used for master-planning projects, infrastructure and buildings. As part of BREEAM, the assessment criterion "BREEAM Hea 02 Indoor Air Quality" sets out a post-completion, pre-occupancy building air quality test for formaldehyde and TVOCs. BREEAM guidance indicates that the post-construction pre-occupancy concentrations should not exceed the following thresholds:

- Formaldehyde: 100µg/m^3 over 30 minutes; and,
- TVOC: 300µg/m^3 over 8 hours.

4.2 Leadership in Energy and Environmental Design (LEED)

LEED[xx] is a set of rating systems for building certification run by the non-profit US Green Building Council. It can be used for all building types and all building phases including new construction, interior fit outs, operations and maintenance and core and shell.

Several LEED credits address measuring and monitoring indoor air quality. For new construction, there is the Indoor air quality assessment credit in the LEED v4 Building Design and Construction (BD + C) rating system; To gain a "credit" towards the rating system the applicant can demonstrating ventilation performance or monitor air quality post-construction, pre-occupation. Table 4 shows the LEED v4 (BD + C) maximum concentration levels and the required testing methods.

Table 4. Limit values for a new building, during occupancy (indoor air quality assessment credit)

Contaminant			Maximum concentration	ASTM and U.S. EPA methods	ISO method
Particulates	**PM10** (for all buildings)		50µg/m^3 Healthcare only: 20µg/m^3	EPA Compendium Method IP-10	ISO 7708
	PM2.5 (for buildings in EPA nonattainment areas for PM2.5, or local equivalent)		15µg/m^3		
Ozone (for buildings in EPA nonattainment areas for Ozone, or local equivalent)			0.075 ppm	ASTM D5149 - 02	ISO 13964
Carbon monoxide (CO)			9 ppm; no more than 2 ppm above outdoor levels	EPA Compendium Method IP-3	ISO 4224
Total volatile organic compounds (TVOCs)			500 µg/m^3 Healthcare only: 200µg/m^3	EPA TO-1, TO-17, or EPA Compendium Method IP-1	ISO 16000-6
Formaldehyde			27 ppb Healthcare only: 16.3 ppb	ASTM D5197, EPA TO-11, or EPA Compendium Method IP-6	ISO 16000-3
Target volatile organic compounds*	1	Acetaldehyde	140 µg/m^3		
	2	Benzene	3 µg/m^3	ASTM D5197; EPA TO-1, TO-17, or EPA Compendium Method IP-1	ISO 16000-3, ISO 16000-6
	3	Carbon disulfide	800 µg/m^3		
	4	Carbon tetrachloride	40 µg/m^3		
	5	Chlorobenzene	1000 µg/m^3		
	6	Chloroform	300 µg/m^3		
	7	Dichlorobenzene (1,4-)	800 µg/m^3		
	8	Dichloroethylene (1,1)	70 µg/m^3		
	9	Dimethylformamide (N,N-)	80 µg/m^3		
	10	Dioxane (1,4-)	3000 µg/m^3		
	11	Epichlorohydrin	3 µg/m^3		
	12	Ethylbenzene	2000 µg/m^3		
	13	Ethylene glycol	400 µg/m^3		
	14	Ethylene glycol monoethyl ether	70 µg/m^3		
	15	Ethylene glycol monoethyl ether acetate	300 µg/m^3		

	16	Ethylene glycol monomethyl ether	60 µg/m^3		
	17	Ethylene glycol monomethyl ether acetate	90 µg/m^3		
	19	Hexane (n-)	7000 µg/m^3		
	20	Isophorone	2000 µg/m^3		
	21	Isopropanol	7000 µg/m^3		
	22	Methyl chloroform	1000 µg/m^3		
	23	Methylene chloride	400 µg/m^3		
	24	Methyl *t*-butyl ether	8000 µg/m^3		
	25	Naphthalene	9 µg/m^3		
	26	Phenol	200 µg/m^3		
	27	Propylene glycol monomethyl ether	7000 µg/m^3		
	28	Styrene	900 µg/m^3		
	29	Tetrachloroethylene (Perchloroethylene)	35 µg/m^3		
	30	Toluene	300 µg/m^3		
	31	Trichloroethylene	600 µg/m^3		
	32	Vinyl acetate	200 µg/m^3		
	33-35	Xylenes, technical mixture (m-, o-, p- xylene combined	700 µg/m^3		

ppb = parts per billion; ppm = parts per million; µg/cm = micrograms per cubic meter

*The target volatile organic compounds are from CDPH Standard Method v1.1, Table 4-1. The Maximum concentration limits for these target compounds are the full CREL adopted by Cal/EPA OEHHA in effect on June 2014
http://oehha.ca.gov/air/allrels.html

4.3 WELL V2 Air Quality Standards (WELL)

WELL is another US-based building rating system[xxi] that focuses on the impacts of buildings on human health and wellness. The A01 Fundamental Air Quality feature requires projects to provide acceptable air quality levels as determined by public health authorities and has three requirements:

- Part 1 Meet Thresholds for Particulate Matter
- Part 2 Meet Thresholds for Organic Gases
- Part 3 Meet Thresholds for Inorganic Gases
- Part 4 Meet Radon Threshold

The A01 thresholds are shown in Table 5 and Table 6. The A05 Enhanced Air Quality Feature has enhanced thresholds for particulate matter, organic gases and inorganic gases.

Table 5. WELL v2.1 pollutant thresholds for Fundamental Air Quality (all spaces except commercial kitchens)

Pollutant name	WELL v2.1 Fundamental Air Quality Threshold (reference averaging time for the assessment level*)		
Level of certification	Platinum	Gold (if outdoor annual mean $PM_{2.5}$ > 35µg/m^3)	Silver (if outdoor annual $PM_{2.5}$ > 35µg/m^3)
$PM_{2.5}$	15µg/m^3	25µg/m^3	$PM_{2.5}$ equal to 30% of the 24- or 48-hour average

	(annual mean, averaged over 3 years)		of outdoor levels on the day(s) of performance testing.
PM_{10}	50µg/m^3 (annual mean)	50µg/m^3	PM_{10} equal to 30% of the 24- or 48-hour average of outdoor levels on the day(s) of performance testing.
Formaldehyde	27ppb 8-hour mean	-	-
VOCs	See Table 6 below	-	-
Carbon monoxide	9ppm (8-hour mean)	-	-
Ozone	51ppb (8-hour mean)	-	-
Radon	150Bq/m^3 90 days or more	-	-

Note: *The reference averaging time is that of the standard from which the thresholds have been derived. It may be different from the sampling time used to demonstrate compliance with the thresholds.

Table 6. Current prescribed specific thresholds for organic gases required to meet WELL v2.1 for Fundamental Air Quality (long-term average concentrations)

Organic gas compound name	Allowable concentration (µg/m^3)
Benzene	30
Carbon disulfide	400
Carbon tetrachloride	20
Chlorobenzene	500
Chloroform	150
Dichlorobenzene (1,4-)	400
Dichloroethylene (1,1)	35
Ethylbenzene	1,000
Hexane (n-)	3,500
Isopropyl alcohol	3500
Methyl chloroform	500
Methylene chloride	200
Methyl tert-butyl ether	4,000
Styrene	450
Tetrachloroethene	17.5
Toluene	150
Trichloroethylene	300
Vinyl acetate	100
Xylene (m, o, p combined)	350

[i] Building Research Establishment (2019) – Ensuring good indoor air quality in buildings
[ii] Royal College of Paediatrics and Child Health and the Royal College of Physicians (2020) The inside story: Health effects of indoor air quality on children and young people
[iii] The Control of Substances Hazardous to Health Regulations 2002, UK Statutory Instruments 2002, No. 2677
[iv] Defra, National air quality objectives for the protection of human health https://uk-air.defra.gov.uk/assets/documents/National_air_quality_objectives.pdf

[v] Health and Safety Executive EH40/2005 Workplace Exposure Limits (Fourth Edition 2020)
[vi] Occupational exposure limits for hyperbaric conditions: Hazard assessment document Environmental Hygiene Guidance Note EH75/2 HSE Books 2000
[vii] Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)
[viii] BS EN 481:1993 *Workplace atmospheres – Size fraction definitions for measurement of airborne particles*
[ix] The Control of Lead at Work Regulations 2002, UK Statutory Instruments 2002, No. 2676
[x] Ministry of Housing, Communities and Local Government, Approved Documents www.gov.uk/government/collections/approved-documents
[xi] Scottish Government, Building standards technical handbook 2019: domestic
[xii] Scottish Government, Building standards technical handbook 2019: non-domestic
[xiii] Department of Finance and Personnel, Building Regulations (Northern Ireland) 2012, Guidance, Technical Booklet K, Ventilation, October 2012
[xiv] Department of Finance and Personnel, Building Regulations (Northern Ireland) 2012, Guidance, Technical Booklet C - Site preparation and resistance to contaminants and moisture, October 2012
[xv] Department of Finance and Personnel, Building Regulations (Northern Ireland) 2012, Guidance, Technical Booklet B - Materials and workmanship, July 2013
[xvi] HM Government Education and Skills Funding Agency (2018) – Building Bulletin (BB) 101: Guidelines on ventilation, thermal comfort and indoor air quality in schools (Version 1)
[xvii] World Health Organisation (2010) – WHO guidelines for indoor air quality: selected pollutants
[xviii] Public Health England (2019) – Indoor Air Quality Guidelines for Selected Volatile Organic Compounds (VOCs) in the UK
[xix] Public Health England NICE (2020) NG149 – Indoor air quality at home.
[xx] US Green Building Council, Leadership in Energy and Environmental Design, www.usgbc.org/leed
[xxi] International WELL V2 Building Institute Air Quality Standards, v2.wellcertified.com