UK Health Security Agency

Indoor Air Quality in the home and impacts on health

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Yorkshire and Humber Homes and Health Webinar Series 2022:
Webinar 5: Health Protection In Our Home – 24/1/2022

Overview

❑ *What is indoor air quality?*

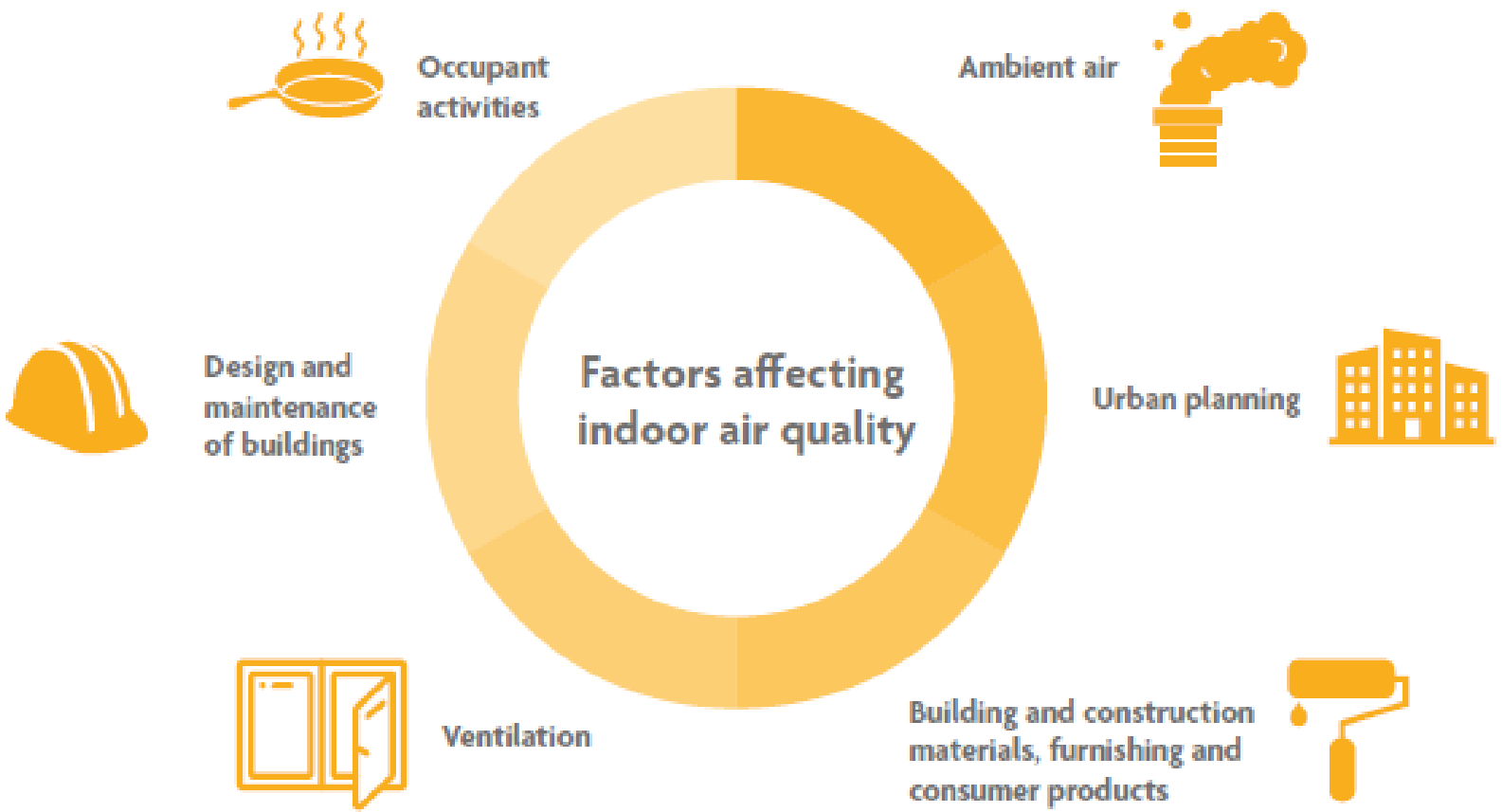
- Factors affecting indoor air
- Sources of indoor air pollutants
- People who may be particularly vulnerable

❑ *Why do we care about indoor air?*

- Health effects
- PHE (2019) indoor air quality guidelines for selected VOCs

❑ *Interventions*

- NICE (2020) IAQ guidelines at home
- Source control
- Ventilation / air purification



▲ Figure 1. Factors affecting indoor air quality.

Dimitroulopoulou, S (2021) Indoor Air Quality and Health. Environmental Scientist, 42-49; https://www.the-ies.org/sites/default/files/journals/improving-indoor-air-quality.pdf

Sources of IA pollutants

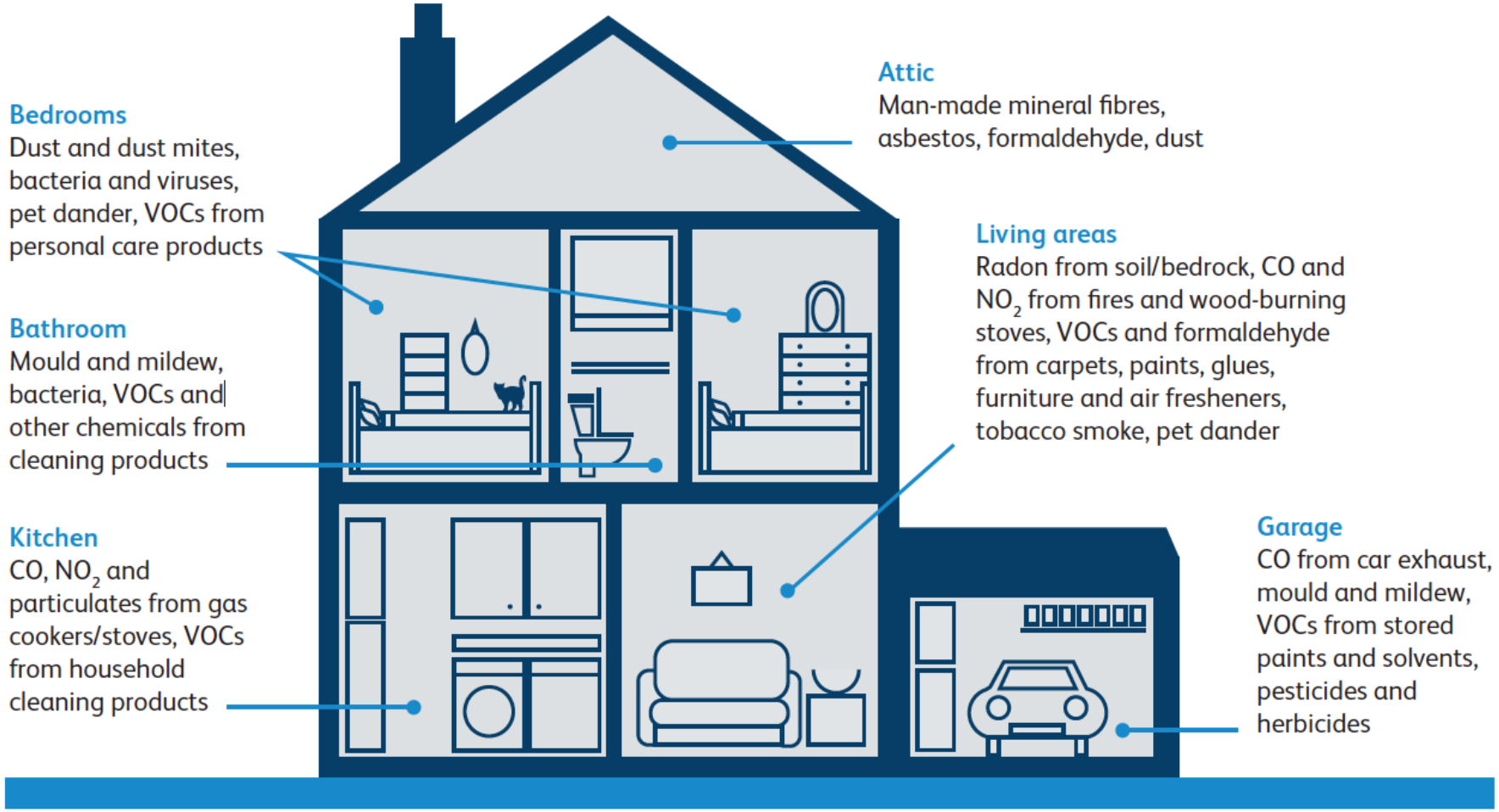


Fig 3. Sources and types of indoor pollution encountered in homes. VOCs = volatile organic compounds. Please note that these lists are not exhaustive and that the actual pollutants present, and their amounts, will vary from household to household.

RCP (2016); RCPCH / RCP (2020)

NICE IAQ guidelines at home (2020)

Box 1

People who may be particularly vulnerable and
factors that increase the risk of ill health due to exposure to poor indoor air quality

People who may be vulnerable

People who may be particularly vulnerable to ill health as a result of exposure to poor indoor air quality include:

- people with a pre-existing health condition such as asthma, allergies, chronic obstructive pulmonary disease (COPD) and cardiovascular disease
- pregnant women and their unborn babies
- pre-school children
- older people
- people who live in poor-quality housing
- people exposed to tobacco smoke in their homes
- people who live in poverty.

Housing conditions

Housing conditions that put people at increased risk of exposure to poor indoor air quality include:

- location (external factors such as high levels of outdoor air pollution, or where noise or security risks mean residents do not open windows)
- physical infrastructure (such as small room size, inadequate ventilation and the building's layout and orientation)
- standard of housing (for example, with damp and mould or physical disrepair including flood damage or with unflued or poorly maintained fuel-burning appliances)
- overcrowding.

There are a number of activities that might contribute to poor indoor air quality (see section 1.4).

Exposure to indoor air pollution across socio-economic groups in high-income countries: A review of the literature and a modelling methodology

Ferguson L, Taylor J, Davies M, Shrubsole C, Phil Symonds, Dimitroulopoulou S (2020)

Environment International 143 (2020) 105748

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journal homepage: www.elsevier.com/locate/envint

Exposure to indoor air pollution across socio-economic groups in high-income countries: A scoping review of the literature and a modelling methodology

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ABSTRACT

Disparities in outdoor air pollution exposure between individuals of differing socio-economic status is a growing area of research, widely explored in the environmental health literature. However, in developed countries, around 80% of time is spent indoors, meaning *indoor* air pollution may be a better proxy for personal exposure. Building characteristics - such as build quality, volume and ventilation - and occupant behaviour, mean indoor air pollution may also vary across socio-economic groups, leading to health inequalities. Much of the existing literature has focused on inequalities in exposure to outdoor air pollution, and there is thus a lack of an evidence base reviewing data for *indoor* environments. In this study, a scoping review of the literature on indoor air pollution exposures across different socio-economic groups is performed, examining evidence from both monitoring and modelling studies in the developed world. The literature was reviewed, identifying different indoor pollutants, definitions for socio-economic status and pre- and post- housing interventions. Based on the review, the study proposes a modelling methodology for evaluating the effects of environmental policies on different socio-economic populations. Using a sample size calculation, obstacles in obtaining sufficiently large samples of monitored data are demonstrated. A modelling framework for the rapid quantification of daily home exposure is then outlined as a proof of concept. While significant additional research is required to examine inequalities in indoor exposures, modelling approaches may provide opportunities to quantify exposure disparities due to housing and behaviours across populations of different socio-economic status.

1. Introduction

The presence of harmful substances such as gases, particulates or biological molecules in the Earth's atmosphere is known as *air pollution* (Loomis et al., 2013). Human exposure to air pollution has serious implications for health: Short term exposure may exacerbate asthma and be responsible for hospital admissions (Zheng et al., 2015), whilst long term exposure to ambient air pollution is repeatedly associated with a higher incidence of cardiovascular and respiratory diseases (Pope et al., 2011; Atkinson et al., 2016; COMEAP, 2018a), birth defects (Padula et al., 2013) and neuro-degenerative disorders (Moulton and Yang, 2012). The Committee on the Medical Effects of Air Pollution (COMEAP) have estimated that ambient air pollution is responsible for between 28,000 and 36,000 deaths each year in the UK (COMEAP, 2018b). While there is a significant body of international research highlighting evidence of the association of areas of low socio-economic status (SES) with high levels of outdoor air pollution (Clark et al., 2014; Milojevic et al., 2017; Pinault et al., 2016; Fairburn et al., 2019), there is little on equivalent exposures to indoor air pollution, despite populations in developed countries spending the majority of their time indoors. The indoor environment is overlooked in the environmental health discourse, despite the considerable health risks that can arise (Bernstein et al., 2008). Thus, understanding variations in population exposure to air pollution across socio-economic groups, in both indoor and outdoor environments, is critical in reducing existing and future health inequalities.

Environmental health equity is the equal distribution of environmental risks across populations, whereby disadvantaged sub-groups are

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- *Households of low socio-economic status experienced higher levels of indoor PM, NO_2, VOCs and ETS.*
- *Higher radon concentrations were found in homes with a greater material wealth.*
- *Inequalities in exposures may arise via;*
  - ***Poor quality housing;***
  - ***A lack of education regarding the harm of indoor second-hand smoke;***
  - ***Location near congested roads;***
  - ***Higher occupant density resulting in greater re-suspension of particles;***
  - ***Radon in homes is principally explained by geological variables.***
- *A holistic approach to improve indoor air quality (IAQ) is required by transforming existing cities through sustainable building design, clean household fuels and reduced dependency on cars.*

Indoor air – Health effects

- ***NICE guidelines for IAQ at home (2020)***

NO_2, VOCs, PM, PAHs (polycyclic aromatic hydrocarbons, naphthalene, benzo[a]pyrene) and biological agents (mould and pet dander)

are “sometimes associated with respiratory, cardiovascular and neurological systems”.

- ***WHO - Development of a tool to assess cumulative risks from exposure to indoor air pollutants in schools (WHO, 2021)***
  - respiratory system;
  - nervous system;
  - cardiovascular system
  - carcinogenicity
  - respiratory irritation

https://www.euro.who.int/__data/assets/pdf_file/0020/410780/Indoor-air-pollutants-public-children-first-consulation-report.pdf

RCPCH and RCP (2020)

- **Effects of indoor air quality on children and young people's health**
- **Research project**
- Produced an evidence-based report on the impact of indoor air pollution

Birth and infancy

- Respiratory problems – wheeze, rhinitis, atopic asthma, respiratory infections
- Low birthweight and pre-term birth

Pre-school

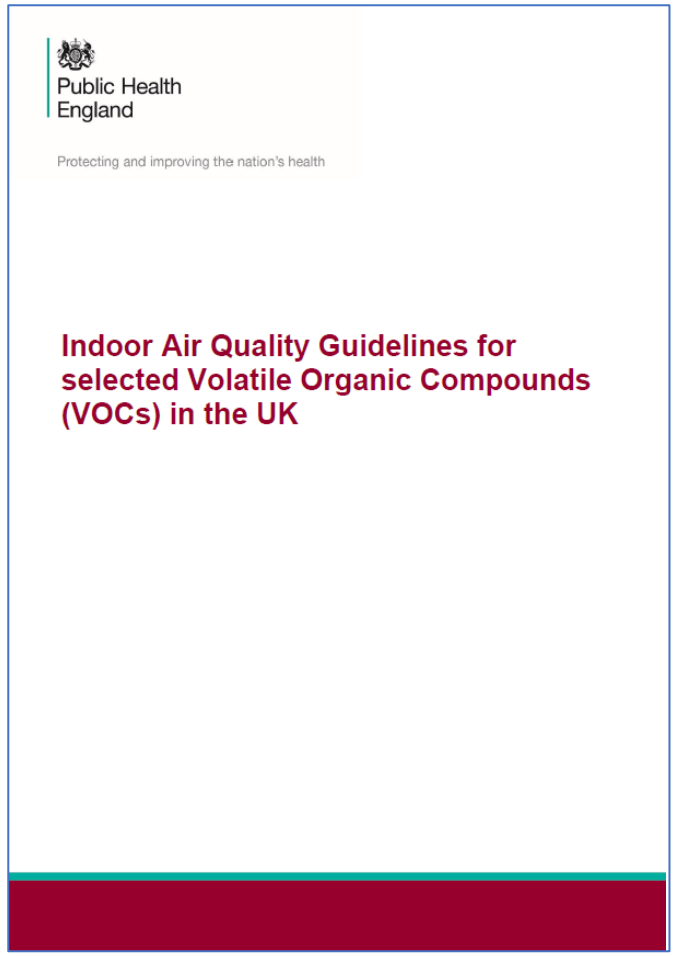
- Respiratory problems – wheeze, allergies, asthma, risk of respiratory diseases and pneumonia
- Eczema and atopic dermatitis
- Greater hyperactivity, impulsivity and inattention

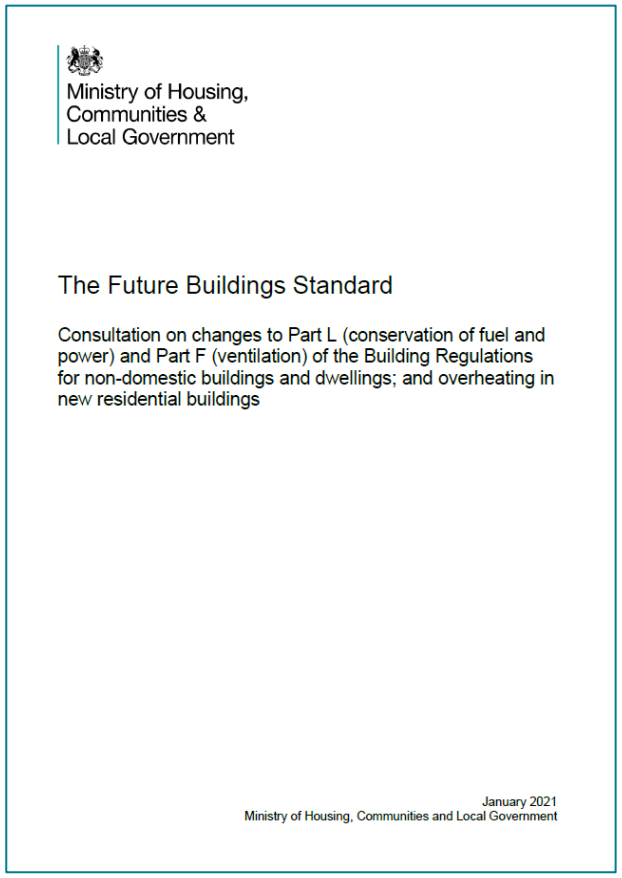
School age

- Respiratory problems – wheeze, rhinitis, asthma, throat irritation, nasal congestion, dry cough
- Eczema, dermatitis, conjunctivitis, skin and eye irritation
- Reduced cognitive performance, difficulty sleeping

RCPCH (2020) https://www.rcpch.ac.uk/sites/default/files/2020-01/the-inside-story-report_january-2020.pdf

PHE indoor air quality guidelines for selected VOCs





https://www.gov.uk/government/publications/air-quality-uk-guidelines-for-volatile-organic-compounds-in-indoor-spaces

Included in the Revised Building Regulations (ADF) and the Future Homes and Building Standards

PHE indoor air quality guidelines for selected VOCs (1)

VOCs	Limit Values in µg.m^{-3}		Source Document	Reasoning for choice	Potential Health impacts
	Short Term	Long Term			
Acetaldehyde (75-07-0)	1,420 (1h)	280 (1day)	Health Canada (2018)[a]	Most recent appraisal of evidence	Irritation of the eyes, skin, and respiratory tract following acute exposure.[3] Long-term animal studies have reported carcinogenicity and inflammation and injury to tissues of the upper respiratory tract (Health Canada, 2018)
α-Pinene (80-56-8)	45,000 (30min)	4500 (1 day)	EPHECT (Trantallidi et al., 2015)	Critical Exposure limit (CEL) inhalation exposure to key and emerging indoor air pollutants emitted during household use of selected consumer products	With the exception of its irritative (skin, eyes) and sensitizing properties, it is a chemical with fairly low acute toxicity.[4] Ozone initiated reactions with terpenes produce gaseous and aerosol phase products, causing sensory irritation of upper airways and airflow limitation.
Benzene (71-43-2)	No safe level of exposure can be recommended. The unit risk of leukaemia per 1µg.m^{-3} air concentration is 6×10^{-6}. The concentrations of airborne benzene associated with an excess lifetime cancer risk of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17µg.m^{-3}, respectively.		World Health Organisation (2010)	The risk estimates are based on human health risk. However, it is noted that the current Defra national air quality objectives for benzene for England and Wales is an annual mean of 5µg.m^{-3}, based on the European (EU) ambient air quality directive 2008/50/EC (EU, 2008), (Defra, 2010).	The International Agency for Research on Cancer has classified benzene as carcinogenic to humans (Group 1). Benzene causes acute myeloid leukaemia in adults. Positive associations have been observed for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children and cancer of the lung. (IARC, 2018a).
D-Limonene (5989-27-5)	90,000 (30min)	9000 (1 day)	EPHECT (Trantallidi et al., 2015)	Critical Exposure limit (CEL) inhalation exposure to key and emerging indoor air pollutants emitted during household use of selected consumer products	As for α-Pinene above
Formaldehyde (50-00-0)	100 (30min)	10 (1yr)	World Health Organisation (2010). ATSDR MRL (1999)	World Health Organisation guidelines valid for short term exposure. ATSDR value of 10 µg/m^3 suggested as the long-term health-based guideline value which accounts for the potential for child susceptibility.	Sensory irritation of the eyes, nose and throat, together with exposure-dependent discomfort, lachrymation, sneezing, coughing, nausea and dyspnoea. Human carcinogen -long-term exposure linked to nasal cancer.[1]
Naphthalene (91-20-3)	-	3.0[a] (1yr)	Agency for Toxic Substances & disease Registry (2005), USA	Value also selected by the Flemish Government (2018) There is no proposed guideline for short term exposure due to the lack of scientific evidence.	Haemolytic anaemia in humans at high doses. Respiratory tract lesions including carcinogenicity reported in long-term animal studies. [1,3]

PHE indoor air quality guidelines for selected VOCs

VOCs	Limit Values in µg.m^{-3}		Source Document	Reasoning for choice	Potential Health impacts
	Short Term	Long Term			
Styrene (100-42-5)	-	850 (1y)^	Health Canada (2018)	Most recent appraisal of evidence	Sensory irritation of the eyes, nose and throat. High concentrations- headache, nausea, vomiting, weakness, tiredness, dizziness, mild irritation to skin. Long-term exposure has been reported to cause neurological effects in humans including changes in hearing, balance, colour vision and psychological performance.
Tetrachloroethylene (127-18-4)	-	40 (1day)	US EPA (2012) and Health Canada (2018)	Most recent appraisals of evidence	Effects in the kidney indicative of early renal disease and neurotoxicity (visual and autonomic disturbances)[1,3] Evidence of carcinogenicity in animals. Limited evidence for carcinogenicity in humans (positive associations have been observed for bladder cancer)
Toluene (108-88-3)	15,000 (8h)	2,300 (1 day average)	Health Canada (2018)	Most recent appraisal of evidence, specifically the dose response relationship.	Eye, nose and throat irritation, headaches, dizziness and feelings of intoxication following short-term exposure. Neurological effects including reduced scores in tests of short-term memory, attention and concentration following long-term exposure[2]
Trichloroethylene (71-01-06)	-	0.2* (1yr)	US EPA (2011)	This value is based on human data for kidney cancer, which has also been adjusted for other cancers.	The International Agency for Research on Cancer has classified trichloroethylene as carcinogenic to humans (Group 1). Trichloroethylene causes cancer of the kidney. A positive association observed for non-Hodgkin lymphoma and liver cancer. It is assumed that trichloroethylene is genotoxic (IARC, 2018b)
Xylenes-mixture (1330-20-7)	-	100 (1y)^	Health Canada (2018)	Most recently derived and most precautionary value.	Irritation to the nose, throat and lungs. Severe inhalation exposure can cause dizziness, headache, confusion, heart problems, liver and kidney damage and coma[2]

*No safe level of exposure can be recommended. The concentrations shown are associated with an excess lifetime risk of 1/1,000,000 and are applicable to both long and short-term exposures.

+We are aware of new data that indicates that effects may occur at lower doses; however, this new data has not yet been evaluated by an authoritative body.

^ Health Canada uses screening values for some species - Indoor Air Reference Levels (IARL). These are used to assess possible risk. They are associated with acceptable levels of risk after long-term exposure (over several months or years) for each specific VOC. Due to uncertainties in derivation; these have simply been labelled as annual. In these cases, no separate short-term exposure limit has been stated.

Main References

[1]World Health Organisation. WHO Guidelines for selected pollutants.

[2]Public Health England. Chemical hazards compendium.

[3]United States Environment Protection Agency. Iris Assessments.

[4]Sarigiaannis et al., 2011

PHE Statement (2019): Indoor Air quality guidelines for selected VOCs in the UK, https://www.gov.uk/government/publications/air-quality-uk-guidelines-for-volatile-organic-compounds-in-indoor-spaces

Shrubsole C, Dimitroulopoulou S, Foxall AK, Gadeberg B, Doutsi A (2019). IAQ guidelines for selected volatile organic compounds (VOCs) in the UK. Building and Environment, Vol 165, https://doi.org/10.1016/j.buildenv.2019.106382

Interventions

Improving indoor air quality

NICE National Institute for Health and Care Excellence

Actions for local authorities

Checking people's homes and giving advice

Use inspections and home visits to identify poor indoor air quality.

Staff who visit people's homes should:

- know about sources of indoor air pollutants and their effects on health
- give advice on avoiding activities that increase pollutants and improving ventilation (see below)
- know who can provide help with repairs and necessary improvements
- give advice on requesting a housing assessment if poor indoor air quality is suspected.

Advise private and social tenants to contact their landlord if:

- ventilation is inadequate
- repairs are needed to prevent water from entering the home
- improvements are needed to heating or insulation to prevent condensation.

Advise tenants to contact their local authority if no action is taken to improve ventilation or carry out repairs.

Advice on reducing damp and condensation

- Use background ventilation (trickle vents or whole-house mechanical ventilation)
- Use extractor fans and open windows (if possible and safe)
- Avoid moisture-producing activities (such as air-drying clothes) or, if unavoidable, improve ventilation
- Repair sources of water damage and remove residual moisture

Advice on increasing ventilation

Use extractor fans in bathrooms and kitchens, or open windows (if possible and safe) when:

- using cookers, especially gas cookers
- using open solid-fuel fires or free-standing gas heaters
- using candles
- using cleaning products, household sprays or aerosols and paints
- having a bath or shower
- air-drying clothes

Other advice

- Do not use unflued paraffin heaters
- Follow product instructions if using, for example, paint, glue and solvents
- Choose low-emission materials if replacing furniture or flooring
- Ensure adequate ventilation when installing a new cooker, especially for gas cookers
- Do not use gas cookers to heat a room
- Avoid smoking in the home

Actions for healthcare professionals

Advice for people with breathing or heart problems

- Explain that indoor air pollutants can trigger or exacerbate asthma, other respiratory conditions and cardiovascular conditions
- If repeated or worsening cough or wheezing, ask about housing conditions and help request a housing assessment if concerned
- If household sprays or aerosols trigger asthma, advise avoiding them or using non-spray products

Advice for people allergic to house dust mites

Advise on how to reduce exposure to to house dust mites, including:

- avoiding second-hand mattresses if possible
- using allergen barriers such as mattress and pillow covers
- washing bedding regularly

Advice for pregnant women and babies under 12 months

- Advise on the increased risks from poor indoor air quality
- Explain the risks of tobacco smoke
- Ask about housing conditions and help request a housing assessment if concerned
- Advise on reducing use of household sprays and aerosols
- Advise on avoiding or reducing use of open solid-fuel fires or candles
- Advise on avoiding smoking in the home or around the woman and baby

Actions for architects, designers, builders and developers

These recommendations apply both to building new homes and renovating or refurbishing existing homes.

Building materials and products

- Architects and designers should consider specifying materials and products that emit low levels of formaldehyde and volatile organic compounds (VOCs)
- Builders and developers should use materials as specified or substitute with products of the same or lower emission levels
- Builders and developers should ensure materials and products comply with building regulations, design specifications and the manufacturer's guidance

Designing heating and ventilation systems

- Adopt a whole-building approach to heating and ventilation, balancing indoor air quality with standards for energy use
- Use heating systems that minimise exposure to particulate matter
- Ensure there is permanent, effective ventilation
- Include provision for removing indoor air pollutants in designs, for example, windows that open and extractor fans that extract to outside
- Design ventilation to reduce exposure to outdoor air pollution, for example, with windows that face away from busy roads

Installing heating and ventilation systems

- Ensure heating and ventilation is installed and commissioned in accordance with the manufacturer's instructions and meets building regulation requirements
- When installing heating and ventilation systems, ensure they are easily accessible for regular maintenance
- Ensure any variations to the heating and ventilation specification comply with design specifications and building regulations

This is a summary of the recommendations on advice and information for the general population, healthcare professionals, architects and designers, and builders, contractors and developers in NICE's guideline on indoor air quality at home. See the original guidance at www.nice.org.uk/guidance/NG149

Published: January 2020

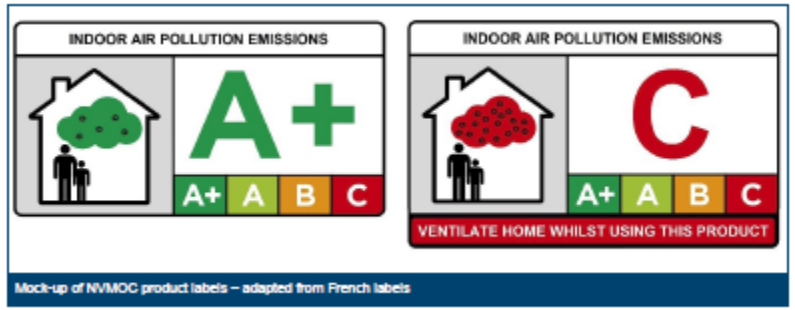
DEFRA Clean Air Strategy 2019

6. Action to reduce emissions at home

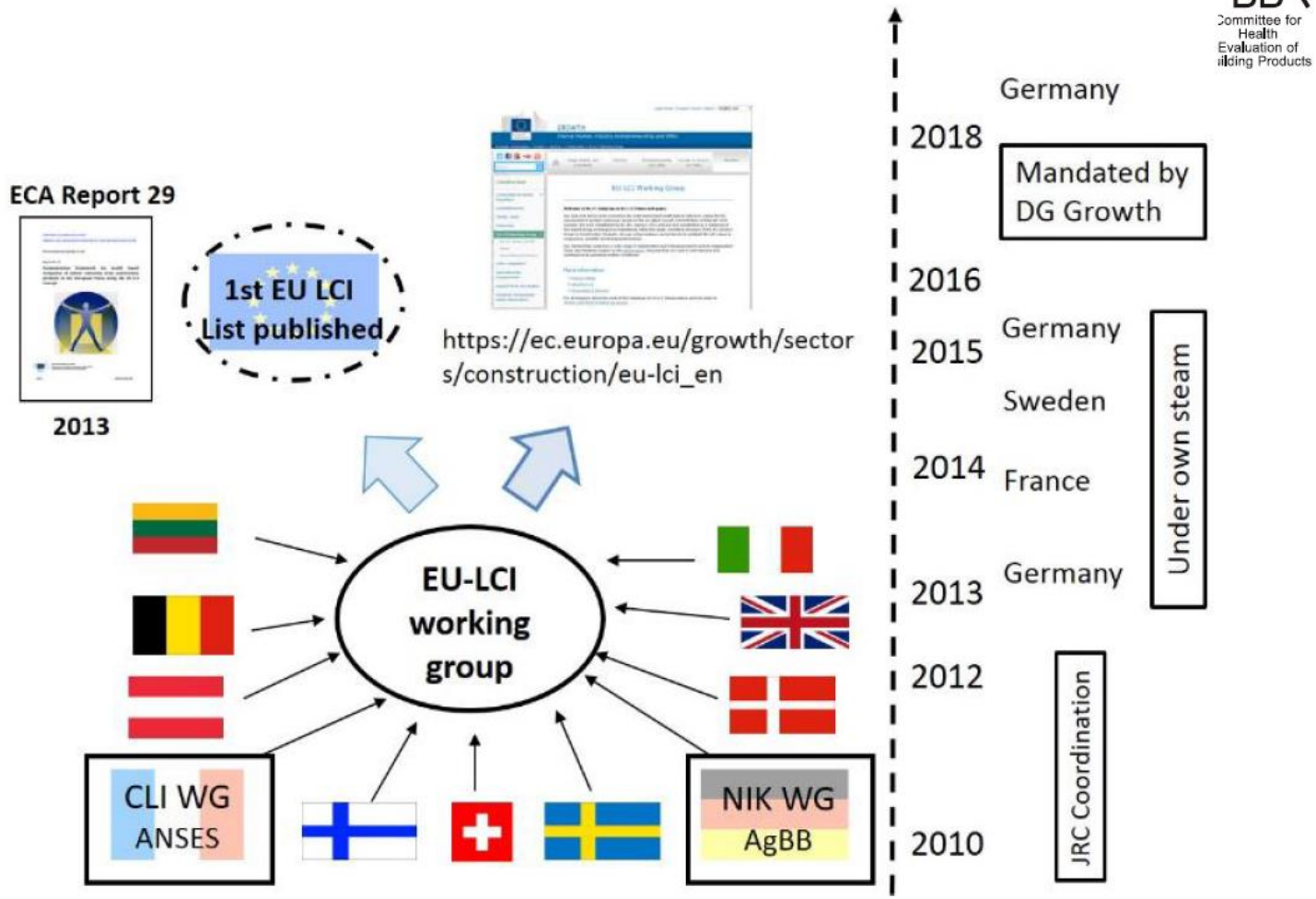
Currently, with the exception of the Paints Regulations, there are few provisions limiting the VOC content of products used in the home.

"We will work with industry to identify an appropriate test standard for new solid fuels entering the market."

"We will explore a range of options including the development of a *voluntary labelling scheme for NMVOC containing products,* and assess its potential effectiveness."



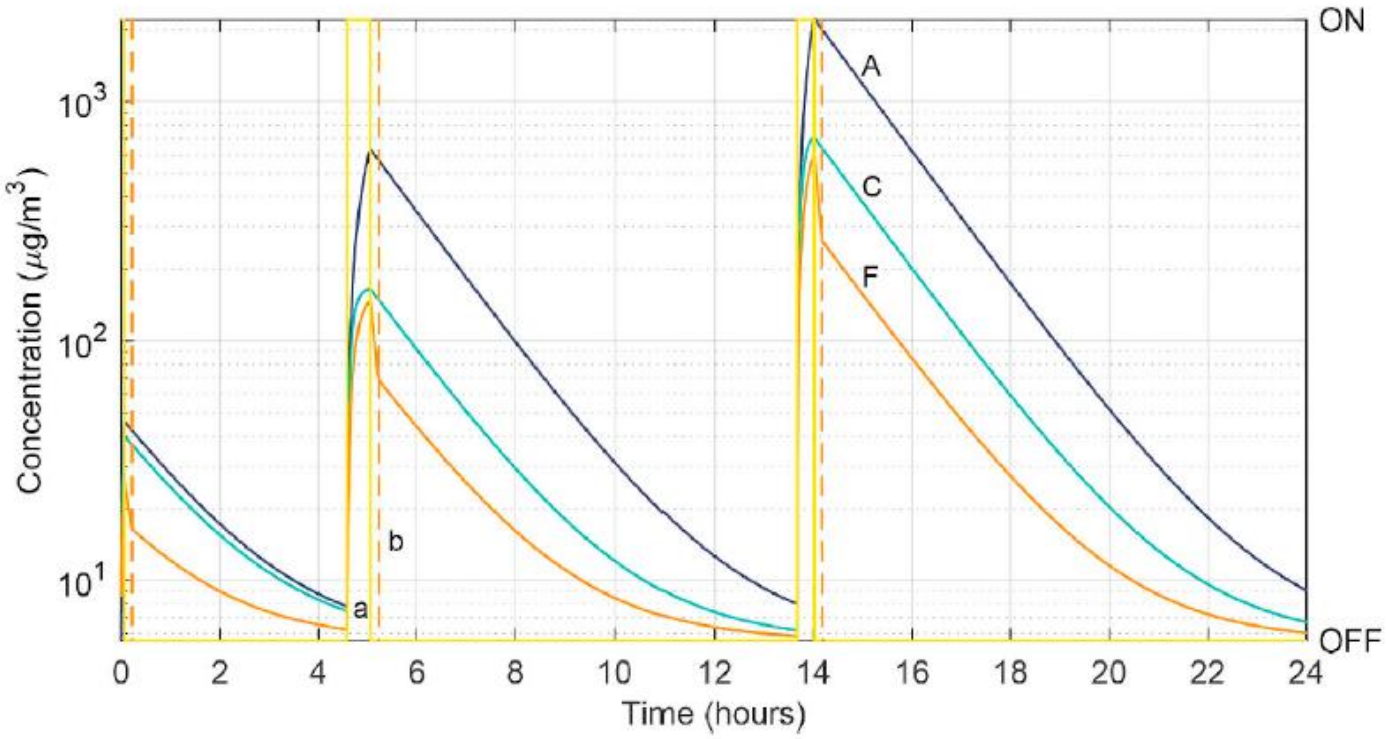
Development of harmonized EU-LCI values



Kindly provided by Ana Maria Scutaru (UBA)

Setting the standard: The acceptability of kitchen ventilation for the English housing stock

O'Leary C, Jones B, Dimitroulopoulou S, Hall IP (2019)



- All houses are too airtight to dilute $PM_{2.5}$ emissions from cooking by infiltration alone.
- Controlled ventilation is required in all domestic kitchens.
- Ventilating during cooking plus 10 minutes has a significant effect and can be used to lower prescribed airflow rates.
- A cooker hood is the most effective method of pollutant control.
- Hood airflow rate and capture efficiency combinations must be specified in standards.

https://www.sciencedirect.com/science/article/pii/S0360132319306274

Portable air purification: review of impacts on indoor air quality and health

Cheek E, Guercio, Shrubsole C, Dimitroulopoulou S (2020)

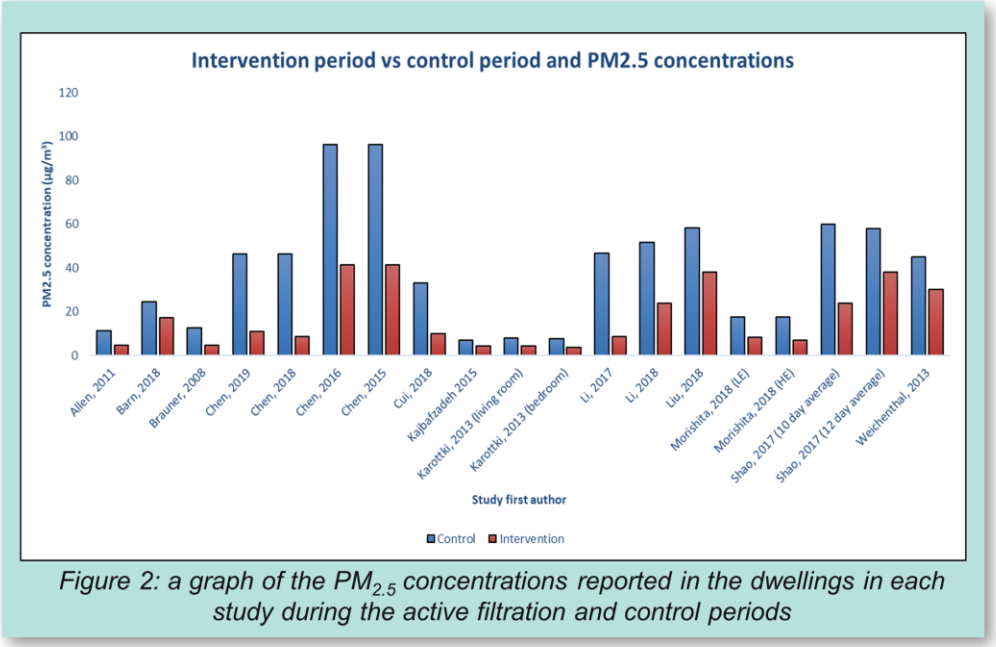
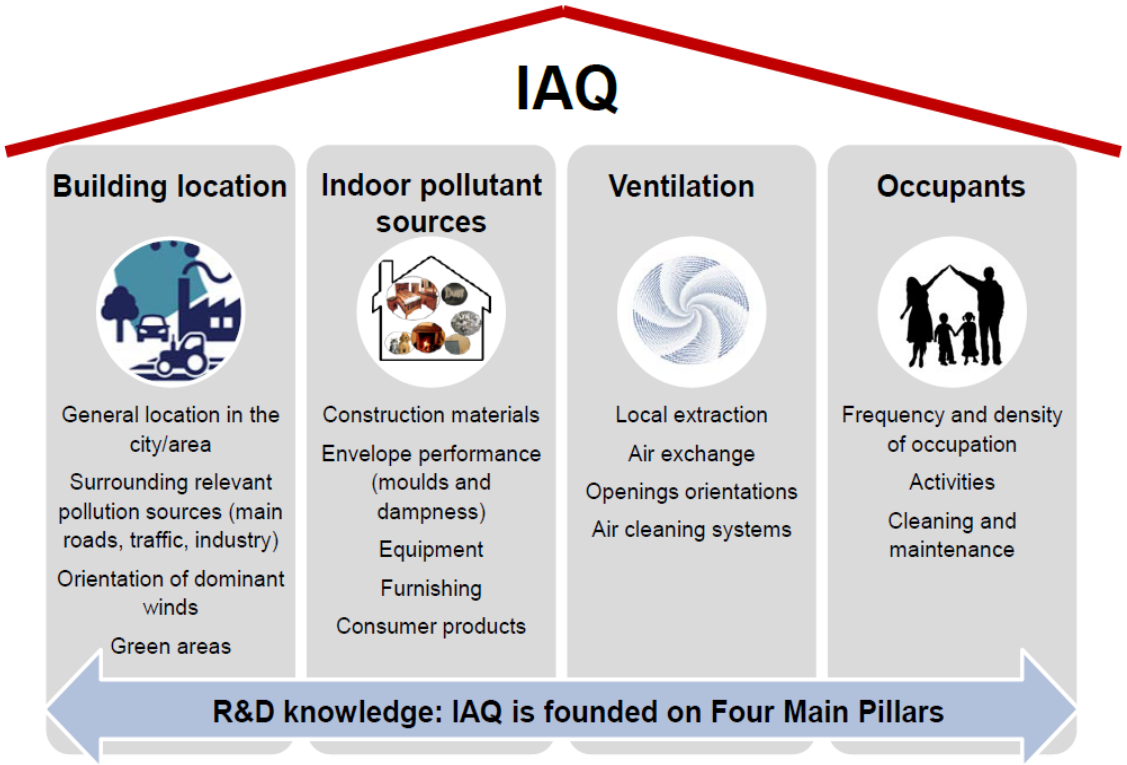


Figure 2: a graph of the $PM_{2.5}$ concentrations reported in the dwellings in each study during the active filtration and control periods

- *This review shows that portable air cleaners can improve indoor air quality significantly by reducing particulate air pollution.*
- *There is currently not enough evidence to confirm health benefits because there are so few properly designed studies. But given that there is strong evidence that the exposure to particulate pollutants is harmful to health, there are likely to be positive impacts.*

https://doi.org/10.1016/j.scitotenv.2020.142585

Strategy for Healthy Indoor Air



DLUHC (planning)	Defra	DLUHC (Building Regs)	DHSC
Defra	DLUHC (building Regs)	HSE	UKHSA
DfE	HSE		LAs
LAs	BEIS		

Kindly provided by
Prof E. De Oliveira Fernandes

UKHSA new IAQ activities

UKHSA

- NIHR/HPRU – Environmental exposures and health - Development of VOC/SVOC exposure models (2020 – 2023)
- HECC 2023 report – Impact of Climate Change on indoor environmental quality and Health
- UKRI funded Networks

Organisations

- BS 40102-1 Development of new standard “Health and wellbeing, thermal comfort, IAQ, and overheating in buildings”

Government

- DLUHC – Revision of HHSRS (Housing Health and Safety Rating System)
- Defra - AQEG report on IAQ
- CMO’s report on Air Quality

Let’s work together

to reduce our exposure to indoor air pollution

Thank you!

www.gov.uk/ukhsa

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