Public Health England

Indoor Air Quality and health impacts

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Future Urban Ventilation Network kick off meeting – Monday 18 January 2021

Public Health England

Factors affecting IAQ

Ambient air

Urban planning

Building and Construction Materials, Furnishing and Consumer products

Ventilation

Design and maintenance Of buildings

Occupant activities

Sources of IA pollutants

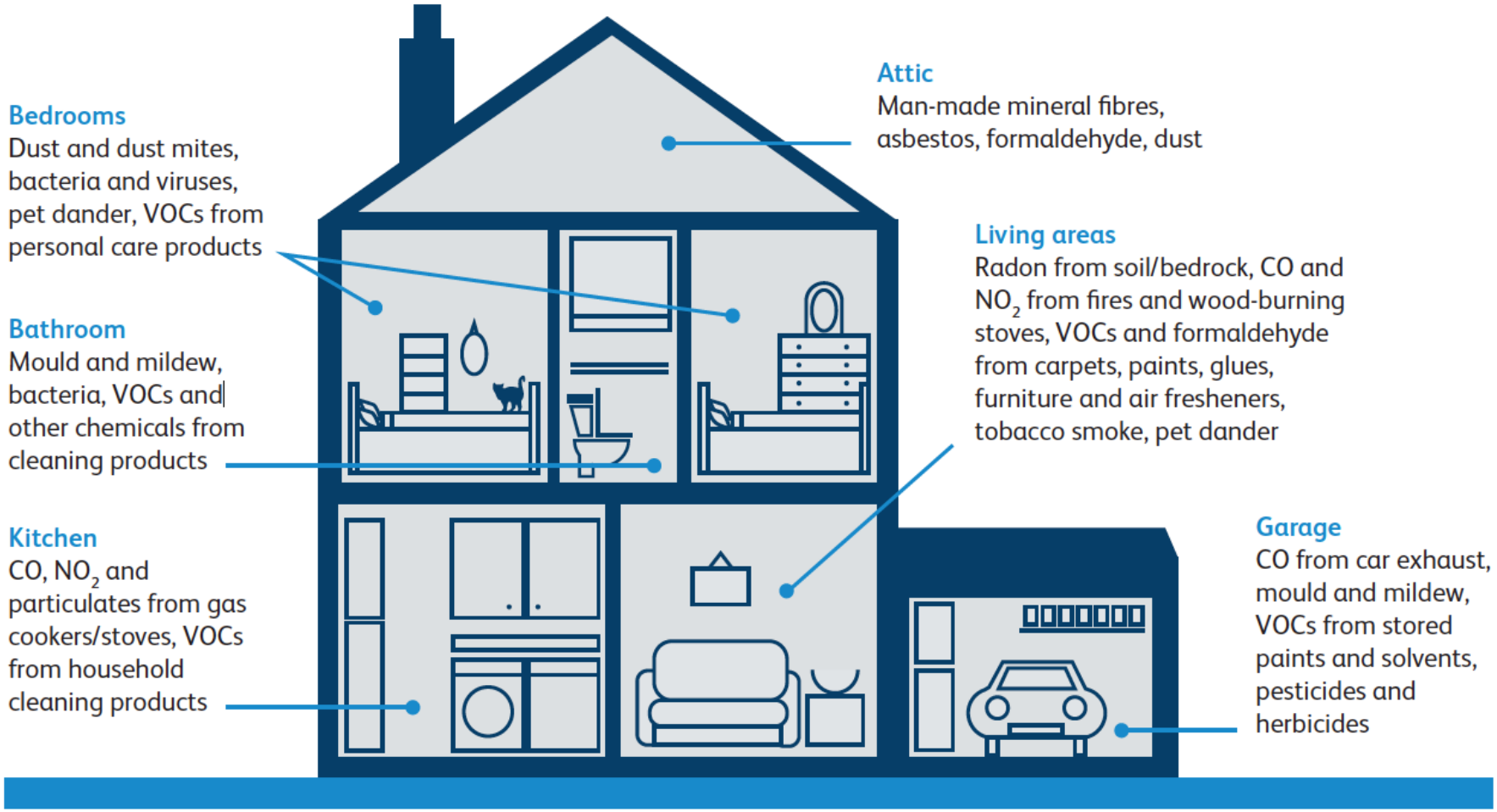

Fig 3. Sources and types of indoor pollution encountered in homes. VOCs = volatile organic compounds. Please note that these lists are not exhaustive and that the actual pollutants present, and their amounts, will vary from household to household.

RCP (2016); RCPCH / RCP (2020)

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NICE Guidelines: Indoor air quality at home

Evidence Reviews

- Studies that examined the association between individuals and building characteristics and health outcomes
- Studies that examined the association between
  - sources of pollutants and health outcomes
  - exposure levels and health outcomes

Interpreting the evidence

"Nitrogen dioxide (NO_2), volatile organic compounds (VOCs), particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs, naphthalene and benzo[a]pyrene) and biological agents (mould and pet dander)

are sometimes associated with respiratory, cardiovascular and neurological systems"

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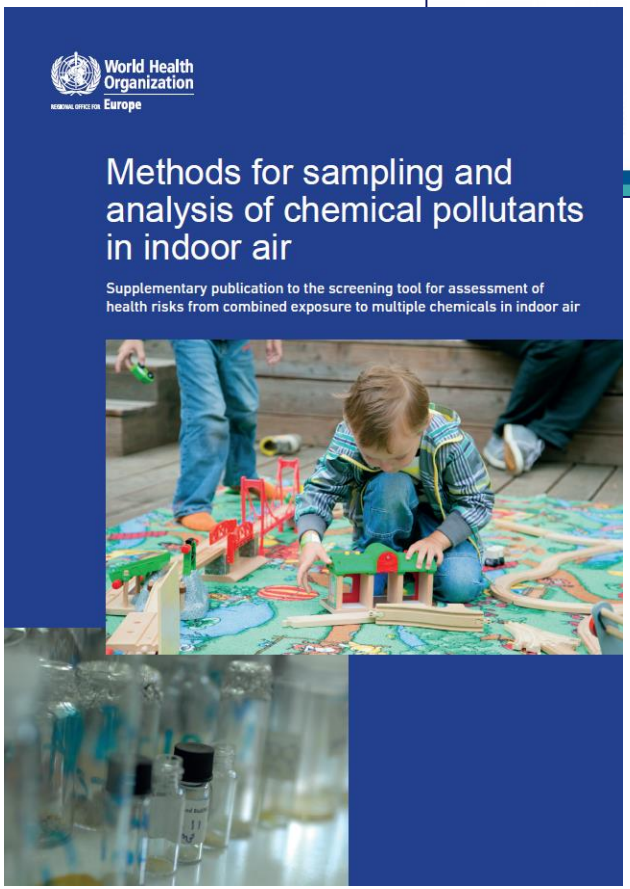
WHO - Development of a tool to assess cumulative risks from exposure to indoor chemicals in schools (WHO, 2018; WHO 2020)



- respiratory system;
- nervous system;
- cardiovascular system
- carcinogenicity
- respiratory irritation

https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications

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RCPCH and RCP

The inside story:
Health effects of indoor air quality on children and young people

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

Public Health England

Protecting and improving the nation's health

Indoor Air Quality Guidelines for selected Volatile Organic Compounds (VOCs) in the UK

Building and Environment 166 (2019) 106417

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Building and Environment

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

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ARTI

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

Lauren Ferguson[a,b,c,*], Jonathon Taylor[b], Michael Davies[b], Clive Shrubsole[c], Phil Symonds[b], Sani Dimitroulopoulou[c]

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IAQ guidelines for selected volatile organic compounds (VOCs) in the UK

C. Shrubsole[a], S. Dimitroulopoulou[a,*], K. Foxall[b], B. Gadeberg[b], A. Doutsi[a]

ARTICLE INFO

ABSTRACT

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Review

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

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Review

Exposure to indoor and outdoor air pollution from solid fuel combustion and respiratory outcomes in children in developed countries: a systematic review and meta-analysis

Valentina Guercio *, Iulia C. Pojum, Giovanni S. Leonardi, Clive Shrubsole, Alison M. Gowers, Sani Dimitroulopoulou, Karen S. Exley

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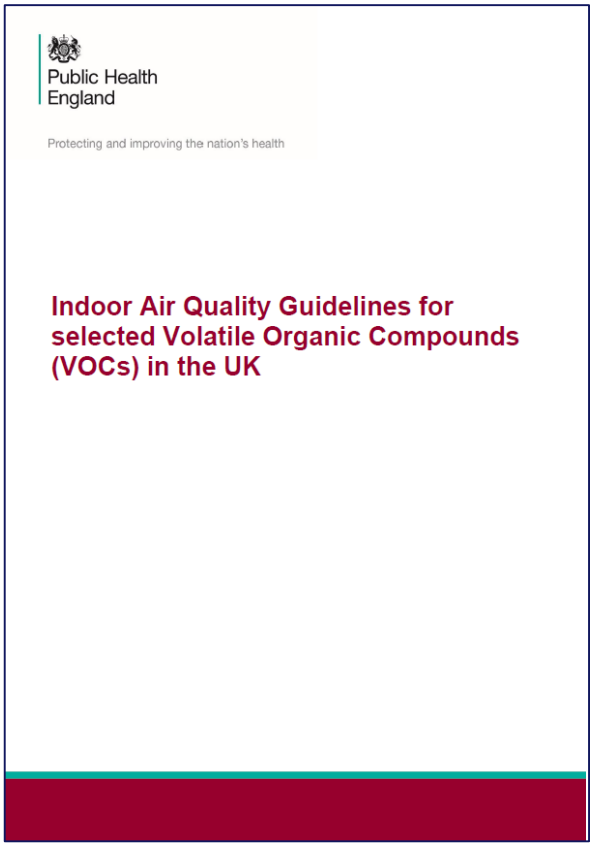
Public Health England

PHE indoor air quality guidelines for selected VOCs


Public Health England

Protecting and improving the nation's health

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IAQ guidelines for selected volatile organic compounds (VOCs) in the UK

C. Shrubsole[a], S. Dimitroulopoulou[a,*], K. Foxall[b], B. Gadeberg[b], A. Doutsi[a]

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ABSTRACT

Poor indoor air quality, can cause a variety of adverse health effects. Pollutant exposure levels inside buildings are likely due to pollutants from both indoor and outdoor sources. Although there are many indoor airborne pollutants, the current review focusses on Volatile Organic Compounds (VOCs), and considers the current Total Volatile Organic Compounds (TVOC) standards alongside other guideline values, to control levels within the indoor environment. We reviewed the current scientific data showing the occurrence of various VOCs in buildings internationally, and the available toxicological reviews for the individual VOCs with potential for adverse health effects that require attention. We considered available health-based general population indoor guidelines for long and short-term exposure in respect of individual compounds, including acetaldehyde, α-pinene, D-limonene, formaldehyde, naphthalene, styrene, tetrachloroethylene, toluene and xylenes (mixture).

We conclude individual VOC guidelines are the most appropriate way forward and that TVOC can be used as an indicator for indoor air quality. This study highlights which compounds should be prioritised for monitoring purposes. Our findings inform discussions around the improvement of general population health, source control and the need to raise awareness of the potential impacts of pollutants in the home.

1. Introduction

Given that the UK population spend around 80–90% of their time in buildings and around 60% in their homes [1,2], buildings are important modifiers of population health [3]. Overall exposure levels inside buildings are due to pollutants from both indoor and outdoor sources, although some attenuation by buildings occurs.

There are a variety of pollutants in the indoor environment, including gaseous pollutants (inorganic chemicals, radon and volatile organic compounds (VOCs)), biological pollutants (allergens, viruses and bacteria, mould) and particulate matter (PM). The current work focusses on VOCs in the indoor environment from both indoor and outdoor sources. The presence of VOCs in residential and public buildings are well reported (e.g. [4]. Health organisations (e.g. The World Health Organisation, The US Environmental Protection Agency and Public Health England) have assessed the evidence and listed the potential health effects of VOCs, including irritation of the eyes and respiratory tract, allergies and asthma, central nervous system symptoms, liver and kidney damage, as well as cancer risks. The health risks from VOCs are determined by the level of exposure experienced as well as the time spent within indoor environments (the focus of this study). Thus, there is a need for health-based guidance values.

As defined in the building standard [5], VOCs are the organic compounds eluting between and including n-hexane and n-hexadecane on the gas chromatographic column. *Very volatile organic compounds* (VVOCs) are the volatile organic compounds eluting before n-hexane on the gas chromatographic column. *Semi-volatile organic compounds* (SVOCs) are the organic compounds which elute after n-hexadecane, on the gas chromatographic column. *Total volatile organic compounds* (TVOCs) are the sum of the concentrations of the identified and unidentified VOCs. All compounds listed in Annex G of BS EN16516:2017 are to be regarded as VOC, even if they elute from the gas chromatographic system before n-hexane or after n-hexadecane. These include aromatic hydrocarbons, saturated aliphatic hydrocarbons (n, -iso, cyclo-), terpenes, aliphatic alcohols, aromatic alcohols, glycols, glycolethers and aldehydes. Formaldehyde (HCHO) is of greatest importance, due to its prevalence in the indoor environment and its known health impacts [6].

In *outdoor air*, the primary VOC sources include those from incomplete combustion e.g. road traffic exhaust gases and volatile by-products of various industrial and commercial operations, as well as biological metabolism, decay and degradation processes [7]. In *indoor*

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

Building and Environment, 2019, https://doi.org/10.1016/j.buildenv.2019.106382

Public Health England

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			
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]

Public Health England

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

Public Health England

Exposure to air pollution from indoor solid fuel combustion and respiratory outcomes in children in developed countries

Guercio V, Pojum I, Leonardi G, Shrubole C, Gowers A, Dimitroulopoulou S, Exley K (2020)

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Review

Exposure to indoor and outdoor air pollution from solid fuel combustion and respiratory outcomes in children in developed countries: a systematic review and meta-analysis

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HIGHLIGHTS

- Exposure to indoor wood burning is not associated with an increased risk of asthma in developed countries;
- Exposure to indoor wood burning is slightly associated with an increased risk of respiratory infections.
- The relationship between exposure to indoor coal burning and outdoor solid fuels and respiratory outcomes is limited.

GRAPHICAL ABSTRACT

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ABSTRACT

Epidemiological studies have shown a positive association between exposure to outdoor and indoor solid fuel combustion and adverse health effects.
We reviewed the epidemiological evidence from Europe, North America, Australia and New Zealand on the association between outdoor and indoor exposure to solid fuel combustion and respiratory outcomes in children.
We performed a systematic review and meta-analysis. Pooled relative risks (RRs) and 95% confidence intervals (CI) were calculated using random-effects models.
We identified 74 articles. Due to limited evidence on other exposures and outcomes, we performed meta-analyses on the association between indoor wood burning exposure and respiratory outcomes. The RR for the highest vs the lowest category of indoor wood exposure was 0.90 (95% CI 0.77–1.05) considering asthma as an outcome. The corresponding pooled RRs for lower respiratory infection (LRI) and upper respiratory infection (URI) were 1.11 (95% CI 0.88, 1.41) and 1.11 (95% CI 0.85, 1.44) respectively. No association was found between indoor wood burning exposure and risk of wheeze and cough.
Inconsistent and limited results were found considering the relationship between indoor wood burning exposure and other respiratory outcomes (rhinitis and hay fever, influenza) as well as indoor coal burning exposure and respiratory outcomes in children. Results from epidemiological studies that evaluated the relationship between the exposure to outdoor emissions derived from indoor combustion of solid fuels are too limited to allow firm conclusions.

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There is currently little evidence linking exposure to indoor coal or wood burning with asthma or other respiratory diseases in children.

This does not mean that exposure to these sources of air pollution is not having health effects, but rather that there is currently no strong scientific evidence showing this. Further research would be needed to establish whether there is a link.

The epidemiological evidence on the association between indoor wood, coal and all solid fuel use and lung cancer risk is still limited, as only a few studies evaluate such an association.

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Public Health England

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

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

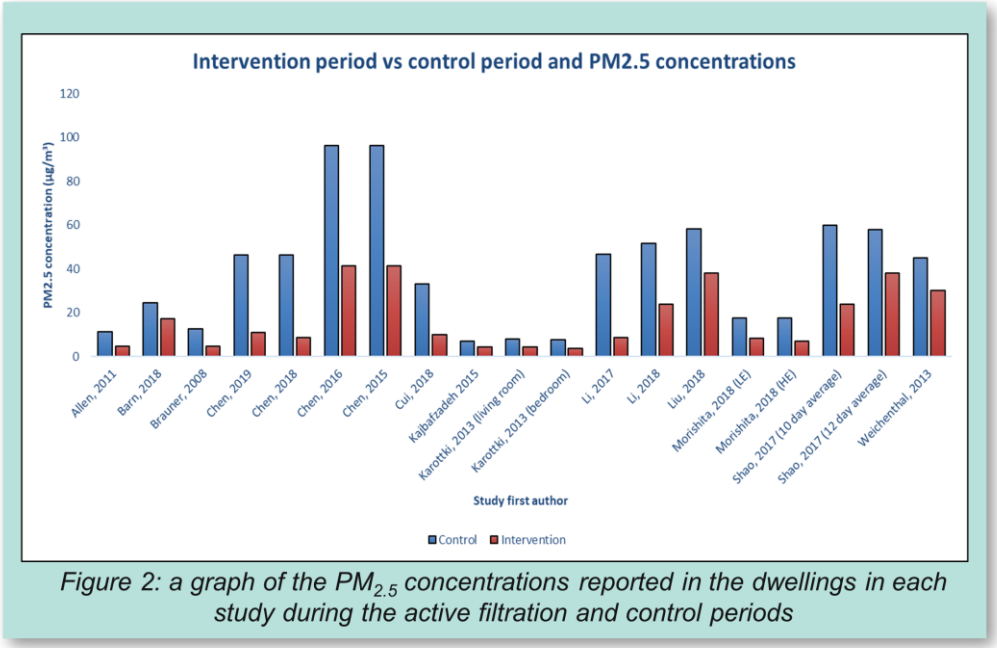

Figure 2: a graph of the $PM_{2.5}$ concentrations reported in the dwellings in each study during the active filtration and control periods

- *This review shows that portable air purifiers 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.*

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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

Public Health England

PHE work / contribution to new IAQ activities

PHE

- NIHR/HPRU – Environmental exposures and health - Development of VOC/SVOC exposure modelling tool (2020 – 2023)
- CO2 project: an indicator or a pollutant?
- HECC 2021 report – Impact of Climate Change on indoor environmental quality and Health
- UKRI funded Networks

Organisations

- WHO Experts Group on IAQ and children's health
- BSI – PAS3003 Development of new standard Non-domestic buildings – Health and wellbeing performance

Government

- MHCLG Revision of Building Regulations (Part L and Part F)
- MHCLG Planning – Revision of HHSRS (Housing Health and Safety Rating System)
- Defra - AQEG report on VOCs

Public Health England

Let's work together

to reduce our exposure to indoor air pollution

Thank you!

www.gov.uk/phe

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