



UK Health
Security
Agency

Health and Indoor Air Quality

focussing on CO

Prof. Sani Dimitroulopoulou

Principal Environmental Public Health Scientist - Indoor Environments,
Air Quality and Public Health, Environmental Hazards and Emergencies Dept, UK Health Security Agency
Visiting Professor, The Bartlett School, University College London
Vice Chair, UK Indoor Environments Group

CO Research Conference, 14 June 2023, Sheffield Hallam University

Indoor air – Health effects

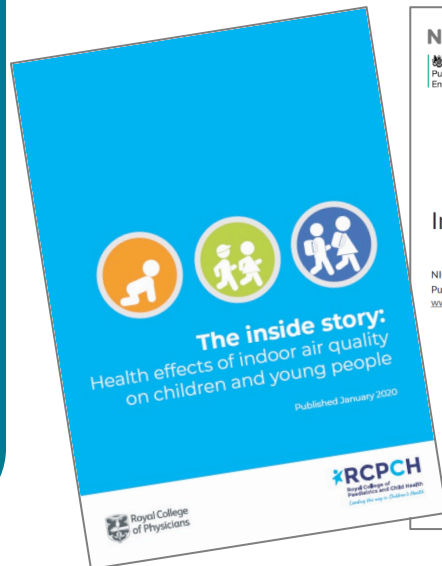
Exposure to indoor air pollutants, chemicals and biological contamination is associated with

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

Challenge:

❑ *Associations between indoor air pollution exposure and health*

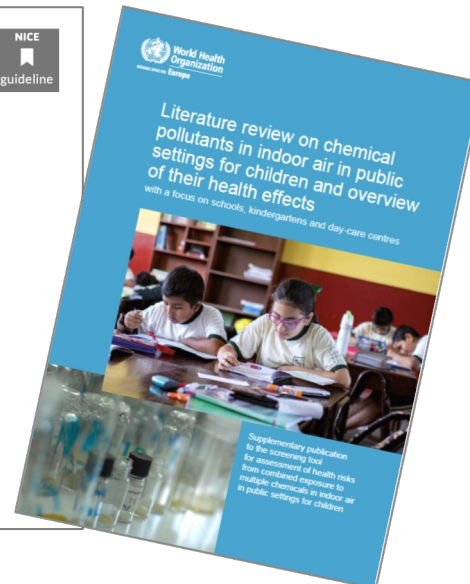
- Current assessments are mainly based on toxicological studies, animal studies, few human cohort studies;
- Short-term health impacts are better characterised than long-term ones;
- Need to understand the health risks from exposure to both “classic” and “emerging” pollutants (e.g. SVOC) as well as secondary pollutants generated from indoor chemistry (secondary reactions);
- Need for cohort studies and citizen science approaches, with collection of indoor and outdoor air quality data, exposure and health data.



RCPCH (2020)



NICE (2020)



WHO (2021)

CO symptoms and health effects



Justboilers.com

Symptoms are non-specific and can be easily mis-diagnosed

[Carbon monoxide: toxicological overview - GOV.UK \(www.gov.uk\)](http://www.gov.uk)

COCGG – Annual report 2021 (UKHSA)

Number of deaths from accidental poisoning by carbon monoxide, England and Wales										
Code	Cause	2012	2013	2014	2015	2016	2017	2018	2019	2020
V01-X59	All accidental carbon monoxide poisonings	65	60	55	53	49	59	42	53	46
X47	Accidental poisoning by other gases & vapours	25	24	26	25	16	17	16	23	21
	Occurrence at home	18	16	18	24	13	11	10	17	16
	Occurrence in residential institution	0	0	0	0	0	0	0	0	0
	Occurrence at school/other institution/pub/admin area	0	0	0	0	0	0	0	0	0
	Occurrence at sports/athletics area	0	0	0	0	0	0	0	0	0
	Occurrence on street/highway	1	0	0	0	0	0	0	3	1
	Occurrence at trade/service area	0	0	1	0	0	0	0	0	1
	Occurrence at industrial/construction area	0	1	0	0	1	0	0	0	0
	Occurrence on farm	0	0	0	0	0	0	0	0	0
	Occurrence at other specified place	5	6	5	1	1	4	5	1	2
	Occurrence at unspecified place	1	1	2	0	1	2	1	2	1
V01-V99	Transport accident	0	0	0	1	1	2	0	1	0
X00-X09	Accidental exposure to smoke, fire & flames	40	36	29	27	32	40	26	29	25
Cause of death was defined using the International Classification of Diseases, Tenth Revision (ICD-10). Deaths were selected where the underlying cause of death was accidental (ICD-10 codes V01-X59), and where the secondary cause of death was the toxic effect of carbon monoxide (ICD-10 code T58). The original underlying cause of death has been used.										
Figures for England and Wales include deaths of non-residents.										
Figures are for deaths registered, rather than deaths occurring in each calendar year. Due to the length of time it takes to complete a coroner's inquest, it can take months or even years for a carbon monoxide poisoning death to be registered.										
<i>Source: Office for National Statistics</i>										

[Cross government group on gas safety and carbon monoxide \(CO\) awareness \(hse.gov.uk\)](https://www.hse.gov.uk/crossgov/)

UK Health Security Agency

National Poisons Information Service (NPIS)

Location and source of unintentional non-fire related CO exposures (Gentile et al., 2021)

Location of unintentional non-fire related CO exposures			Source of unintentional non-fire related CO exposures		
Category	N	%	Sources	N	%
Home	1777	59.8 ^c	Boiler	813	27.4 ^b
Business - non-office	153	5.2	Gas appliance (excluding boilers)	218	7.3
Car	127	4.3	Vehicle exhaust	204	6.9
Business - office	39	1.3	Wood/coal fire burner	148	5
Caravan	32	1.1	Cooker	89	3
Public space	30	1	Gas heater	61	2.1
Garage	27	0.9	Industrial/work appliances	60	2
Leisure accommodation	18	0.6	Gas fire	53	1.8
Tent	6	0.2	Generator exhaust	33	1.1
Boat	4	0.1	BBQ	26	0.9
Other ^a	61	2.1	Camping stoves	21	0.7
Unknown	696	23.4	Other ^c	184	6.2
Total	2970	-	Unknown	1060	35.7
			Total	2970	-

a e.g. Restaurant kitchen, industrial site, school (<0.1%).

b p < 0.0001, compared to other variables in the group.

c e.g. Fire pit, scuba diving tank, paint stripper, shisha (<0.5%).

Journal of Public Health | pp. 1–10 | doi:10.1093/pubmed/ckab132

Carbon monoxide exposures reported to the UK National Poisons Information Service: a 4-year study

Daniela Gentile¹, Richard Adams¹, Michal Klatka¹, Sally Bradberry², Laurence Gray³, Ruben Thanacoody⁴, Gillian Jackson⁵, Euan A. Sandilands¹

¹National Poisons Information Service (Ridleybank Unit), Royal Infirmary of Edinburgh, Edinburgh EH16 4SA, UK
²National Poisons Information Service (Birmingham Unit), City Hospital, Birmingham B15 7QJ, UK
³National Poisons Information Service (Cardiff Unit), University Hospital Llandough, Penarth CF34 2DX, UK
⁴National Poisons Information Service (Newcastle Unit), Regional Drug and Therapeutics Centre, Newcastle upon Tyne NE2 6AX, UK
 Address correspondence to Daniela Gentile, E-mail: daniela.gentile@nps.ukhs.nhs.uk

ABSTRACT

Background Unintentional carbon monoxide (CO) poisoning poses a public health challenge. The UK National Poisons Information Service (NPIS) provides advice to healthcare professionals via the online database, TOXBASE®, and a 24-hour telephone line. Our aim was to analyse all CO-related enquiries to the NPIS.

Methods We analysed enquiries regarding unintentional CO exposure (1st July 2015–30th June 2019). Information on patient demographics, CO source and location, clinical features and poisoning severity was collected from telephone enquiries and TOXBASE accesses.

Results 2970 unintentional non-fire-related CO exposures were reported. Exposures occurred commonly in the home (60%) with faulty boilers frequently implicated (27.4%). Although five fatalities were reported, 68.7% of patients experienced no or minor symptoms only (headache most frequently reported). Despite being the gold standard measurement, blood carboxyhaemoglobin concentration was only recorded in 25.6% patients, with no statistically significant correlation with severity.

Conclusions Unintentional CO exposures in the UK commonly occur in domestic settings and although are generally of low severity, fatalities continue to occur. Carboxyhaemoglobin measurement is important to confirm exposure but further work is required to assess its validity as a prognostic indicator in CO exposure. Public health policy should continue to focus on raising awareness of the dangers of CO.

Keywords carbon monoxide, CO, carboxyhaemoglobin, poisoning, TOXBASE

Introduction

Carbon monoxide (CO) is a colourless, odourless, non-irritant gas produced following the incomplete combustion of carbon-containing compounds. Common sources include house fires, defective generators or heating appliances and vehicle exhaust emissions.¹ CO is also present in cigarette smoke and produced endogenously through the breakdown of haem.^{2,3} Exposure to CO may be acute or chronic and can occur either unintentionally or intentionally through an act of self-harm.² Unintentional exposures may be further subdivided into those related to fires (where additional toxicity such as cyanide may contribute) and non-fire related CO exposures. Unintentional non-fire related CO exposures pose a serious public health challenge and as such are the primary focus of this study. Patients are often unaware of the presence of the poisonous gas even after they begin to experience symptoms. Public health policy is focused on raising awareness of this hidden danger while identifying and eliminating potential sources of CO.

The epidemiology of CO exposures is difficult to elucidate accurately, in part due to the complexity of how exposures are categorized. The World Health Organisation (WHO) reported a total of 140 490 CO-related deaths across 28 European member states between 1980 and 2008 (annual death rate of 2.2/100 000).⁴ A study in the USA (1999–2012) reported 438 deaths/annum from unintentional

Daniela Gentile PhD, Specialist in Poisons Information
 Richard Adams, Assistant Information Services Manager
 Michal Klatka, Project Assistant
 Bradberry Sally, Consultant Clinical Toxicologist
 Gray Laurence, Consultant Clinical Toxicologist
 Thanacoody Ruben, Consultant Clinical Toxicologist
 Gillian Jackson PhD, Information Services Manager
 Euan A. Sandilands, Consultant Clinical Toxicologist

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<https://pubmed.ncbi.nlm.nih.gov/33993287/>

Awaab Ishak Coroner's Inquest – 15/11/22

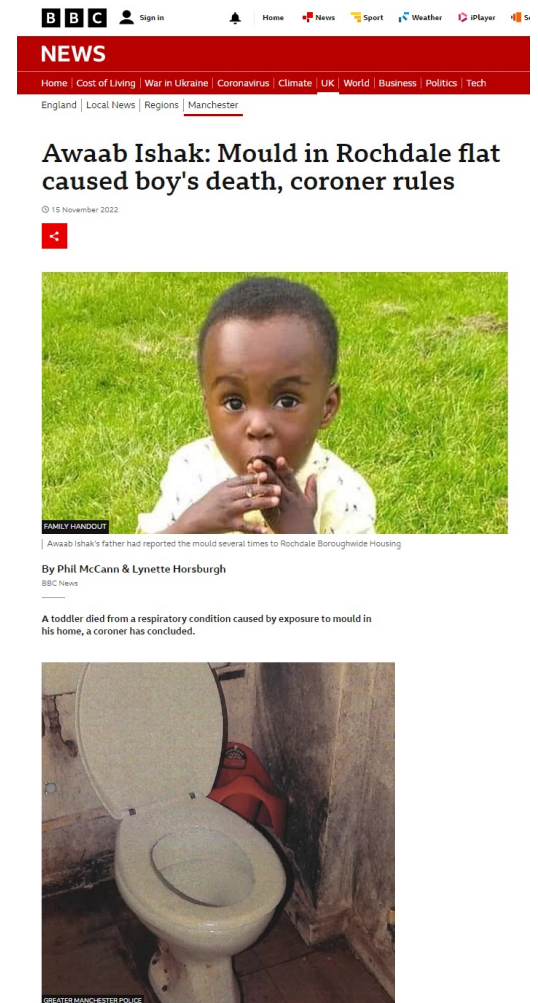
- Awaab Ishak, 2 years old, died 21 Dec 2020
- Cause of death
 - 1a) Acute airway oedema with severe granulomatous tracheobronchitis due to
 - 1b) Environmental mould exposure

Matters of Concern

3 - Lack of health information on damp and mould risks for housing associations

DHSC to lead on response in collaboration with UKHSA and DLUHC

- A review of existing guidance
- Engagement with interested parties
- New consolidated guidance tailored to landlords (social housing, privately rented homes)



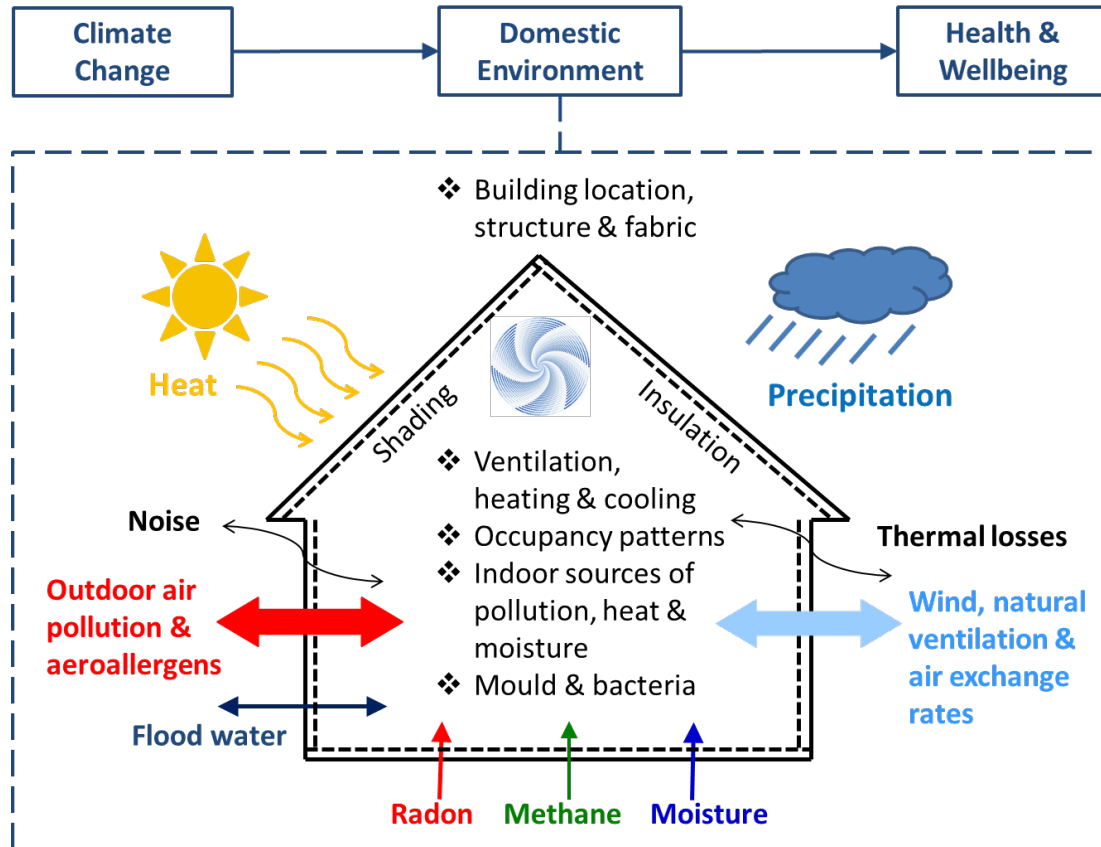
Exposure to indoor air pollution across socio-economic groups in high-income countries: A review of the literature and a modelling methodology

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



- *Households of low socio-economic status experienced higher levels of indoor PM, NO₂, 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.*

Climate Change and IEQ



Vardoulakis et al., 2015: Environment International, 85: 299-313

Impact of net-zero policies

- Require significant changes in the performance of both **new** and **retrofitted buildings**
- Need to understand how current and emerging **building infrastructure design, construction, and materials used** may affect IEQ parameters and hence our health and wellbeing.

Impact of climate change policies on indoor environmental quality and health in the UK housing

Sani Dimitroulopoulou^{1,2}, Sierra Clark¹, Mike Davies², Benjamin Fenech³, Tracy Gooding⁴, Ben Jones⁵, Anna Mavrogianni², Kaja Milczewska¹, Luke Price⁶, Georgia Rodgers³, Tim Sharpe⁷, Marcella Ucci², Paul Wilkinson^{8,†}, John Thorne⁹

- 1: Air Quality and Public Health, EHE Dept, RCE, UK Health Security Agency
- 2: UCL Institute for Environmental Design and Engineering, BSEER, University College London
- 3: Noise and Public Health, EHE Dept, RCE, UK Health Security Agency
- 4: Radon Group, Dosimetry Services Dept, RCE, UK Health Security Agency
- 5: Department of Architecture and Built Environment, Faculty of Engineering, University of Nottingham
- 6: Laser and Optical Radiation Dosimetry Group, Radiation Dosimetry Dept, RCE, UK Health Security Agency
- 7: Department of Architecture, Faculty of Engineering, University of Strathclyde
- 8: London School of Hygiene and Tropical Medicine, London
- 9: Center for Climate and Health Security, RCE, UK Health Security Agency

Dedicated to the memory of the invaluable collaborator Paul Wilkinson

Algorithms

Carbon monoxide (CO) - GOV.UK (www.gov.uk)

Public Health England

Diagnosing Poisoning: Carbon Monoxide (CO)

Patient presenting with:
Headache, nausea/vomiting, drowsiness, dizziness, dyspnoea, chest pain
Could this be a case of CO poisoning?

Ask the patient:

	YES/NO
C Cohabitees/companions Is anyone else in the property affected (including pets)?	Y/N
O Outdoors Do your symptoms improve when out of the building? ('better outdoors')	Y/N
M Maintenance Are your fuel-burning appliances and vents properly maintained?	Y/N
A Alarm Do you have a carbon monoxide alarm?	Y/N

If you are suspicious then ask:
Have you recently had a heating or cooking appliance installed?
Do you ever use your oven or gas stove for heating purposes as well as for cooking?
Has there been any change in ventilation in your home recently (eg fitting double glazing)?
Have you noticed any sooty stains around appliances or an increase in condensation?
Does your work involve possible exposure to smoke, fumes or motor vehicle exhaust?
Is your home detached, semi-detached, terraced, flat, bedsit, hostel or mobile home?

You are suspicious: Could this be a case of CO poisoning?

You are confident: This is NOT a case of CO poisoning

Action to take: GP: general practice ED: emergency department

- Test for CO**
GP: breath test for exhaled CO if device is available. (Note that this only indicates recent exposure; interpretation is difficult in smokers. For interpretation of results see TOXBASE®.)
ED: heparinised venous blood sample for COHb estimation. For interpretation of results see TOXBASE and contact the National Poisons Information Service (NPIS).
- Management – commence oxygen therapy**
GP: follow advice on TOXBASE; refer to ED if required.
ED: follow advice on TOXBASE. Contact the NPIS for severe poisoning. See CMO/CNO letter (11/2013): www.gov.uk/government/publications/carbon-monoxide-poisoning.
- Protect your patient and others** – contact your local PHE centre, which will coordinate services for your patient and provide further guidance on CO.
Provide your patient with the phone number for gas, oil or solid fuel helplines (see the notes).
- DO NOT** allow your patient to go home without a warning **NOT** to use the suspect appliances.
- Follow-up**
GP: note that symptoms may persist or develop later.
ED: advise the patient to see their GP for follow-up. Note this advice in discharge letter.

If the patient does not improve:

- contact the NPIS for advice
- contact your local PHE centre for advice
- reconsider diagnosis

See over for notes on boxes 1–4

Public Health England

Residential Inspection Aid: Carbon Monoxide (CO)

You are:

- ☐ Inspecting a privately rented, owner occupier or social housing property
- ☐ Following up reported exposure to CO
- ☐ Following up a reported odour complaint

Could the premises you are inspecting contain a low level source of CO which is making the occupants ill?

Be aware that you could be entering a contaminated environment and that you should take appropriate precautions. Do not put yourself at risk.
If you suspect high levels of CO in the property and/or serious occupant exposure phone:
Ambulance/police: 999 National gas emergency service: 0800 111 999

Look for:

- ☐ Presence of gas (flued or unflued), oil or solid fuel burning appliances (including cookers)
- ☐ Presence of sooty stains/deposits around the fuel burning appliance
- ☐ Sufficient means of ventilation for combustion appliances to work properly (see the notes)
- ☐ Sufficient means of ventilation for the room – extract fan, trickle vents, openable windows
- ☐ Flames to gas appliances burning yellow instead of mostly blue
- ☐ Flues and appliances sited safely and well maintained by a registered engineer (see the notes)
- ☐ A properly sited and working CO alarm (test it and take a reading if possible)
- ☐ An integral garage

Take readings if you have a device to measure CO

Ask the occupant:

- ☐ Do you ever use your oven or gas stove for heating purposes as well as for cooking?
- ☐ Has the double glazing been recently fitted (if present)? (see the notes)
- ☐ Do you feel in better health at home or at your place of work? (see the notes)
- ☐ Do you or any other occupants suffer from headache, flu-like symptoms, drowsiness, nausea?
- ☐ Do you notice odours coming from adjacent properties?
- ☐ Have you started using appliances after a long break?

Could the problem originate from an adjoining property?

Stopping further exposure:

- ☐ Make sure appliances are turned off and windows are opened
- ☐ Make sure the relevant safety service is contacted
- ☐ Advise the occupant to have all appliances checked by a registered engineer before using again
- ☐ Notify your local PHE centre

Recommend that the occupant:

- installs a CO alarm (BS EN 50291 compliant)
- contacts other agencies for assistance, eg social services
- contacts their GP or attends a hospital emergency department immediately, especially if they have young children or babies

Follow-up actions to take:

- check adjoining properties under the appropriate legislation
- consider serving a notice on the landlord of a rented property (see the notes)

See over for notes on boxes 1–6

Public Health England

Antenatal Checks: Carbon Monoxide (CO)

Testing for exposure to CO from smoking or other sources
Inform the woman Why the test is important, what the procedure is for taking the test and that you will provide solutions to reducing her exposure to CO, if levels are higher than expected

Ask the woman Approximately what time did you leave home?
Are you lactose intolerant? (if not already known)

Woman breathes into analyser

Reading above 5 ppm Tell the woman her reading is higher than 5 ppm and she is exposed to sources of CO

Reading is 5 ppm Tell the woman her reading is 5 ppm and she could be exposed to sources of CO

Reading below 5 ppm Tell the woman her reading is less than 5 ppm and she is unlikely to be exposed to smoke or other sources of CO

Compare the reading with previous readings (if none available, go to box 4)
Reading is higher or the same as previous readings The woman may not be compliant with her smoking cessation programme
OR She could be exposed to other sources of CO, especially if the reading has stabilised at a level over 5 ppm

Reading is lower than previous readings The woman is compliant with her smoking cessation programme
OR A previously identified environmental exposure has ceased

You are suspicious: Could this be a case of CO poisoning?

Ask the woman:
Have you smoked or been exposed to smoke in the last 12 hours?

No You are confident: the woman is not exposed to other environmental sources of CO

- if the woman is an active smoker refer her to NHS stop smoking services
- if the woman's partner is an active smoker discuss ways to reduce her exposure and advice on quitting for her partner

Yes

Could this be a case of environmental CO poisoning? (Positive responses raise suspicion)
Ask the woman:
Does your work involve possible exposure to smoke, fumes or motor vehicle exhaust?
Do you have gas, oil or solid fuel appliances in your home?
Do you ever use your gas stove or oven for heating purposes as well as cooking?
Has there been any change in ventilation in your home recently (eg fitting double glazing)?
Do you or any other occupants in your home suffer from headache, flu-like symptoms, drowsiness, nausea?
Is your home detached, semi-detached, terraced, flat, bedsit, hostel or mobile home?

You are suspicious: Could this be a case of CO poisoning?

Recommend that the woman:

- does not use any appliance she identifies as being a possible source of CO
- contacts an appropriately registered engineer to check all household gas, oil or solid fuel appliances
- contacts her GP or attends a hospital emergency department, especially if she also has young children
- installs a CO alarm (BS EN 50291 compliant) or asks her landlord to install a CO alarm in the case of rented properties with solid fuel appliances

You should notify your local PHE centre

- **Screening patients for CO exposure** (using the COMA tool) in A&E to determine prevalence
- **Test novel analytical methods** for the quantification of CO-Hb using GC/MS8 and high-resolutions mass spectrometry
- **Surveillance** of unintentional CO poisoning (hospitalizations and fatalities) and its risk factors (sources and behaviours)
- **CO monitoring** studies in homes
 - HPRU project on indoor air quality in homes in London (Imperial College London)
 - HPRU project monitoring CO in homes of asthmatics (University of Leicester)

Contacts

- Rebecca Close (Environmental Epidemiology, UKHSA)
- Giovanni Leonardi (Environmental Epidemiology, UKHSA)
- Tim Marczylo (Toxicology, UKHSA)

Recent publications

Screening patients for unintentional carbon monoxide exposure in the Emergency Department: a cross-sectional multi-centre study

Heather Jarman^{1,2,5}, Richard W. Atkinson², Desislava Baramova¹, Timothy W. Gant³, Tim Marczylo³, Isabella Myers⁴, Shirley Price⁴, Tom Quinn⁵

¹Emergency Department Clinical Research Group, St George's University Hospitals NHS Foundation Trust, London SW17 0QT, UK

²Population Health Research Institute, St George's, University of London, London SW17 0RE, UK

³Radiation, Chemical and Environmental Hazards, UK Health Security Agency, Oxford OX11 0RQ, UK

⁴University of Surrey, Surrey GU2 7XH, UK

⁵Centre for Health and Social Care Research, Kingston University, Kingston KT1 1LQ, UK

Address correspondence to Heather Jarman, E-mail: hjarman@sgul.ac.uk

<https://pubmed.ncbi.nlm.nih.gov/36721987/>



Article

Fatal Unintentional Non-Fire Related Carbon Monoxide Poisoning: Data from Narrative Verdicts in England and Wales, 1998–2019

Rebecca M. Close^{1,*}, Neelam Iqbal¹, Sarah J. Jones², Andrew Kibble^{2,3}, Robert J. Flanagan⁴, Helen Crabbe¹ and Giovanni S. Leonardi^{1,5}

¹ Radiation, Chemicals and Environment Directorate, UK Health Security Agency, Didcot OX11 0RQ, UK; neelam.iqbal@phe.gov.uk (N.I.); helen.crabbe@phe.gov.uk (H.C.); giovanni.leonardi@phe.gov.uk (G.S.L.)

² Environmental Public Health Team, Health Protection Division, Public Health Wales, Cardiff CF10 3NW, UK; sarah.jones@wales.nhs.uk (S.J.J.); andrew.kibble@phe.gov.uk (A.K.)

³ Radiation, Chemicals and Environment Directorate (Wales), UK Health Security Agency, Cardiff CF5 2YB, UK

⁴ Precision Medicine, King's College Hospital NHS Foundation Trust, London SE5 9RS, UK; robert.flanagan@khs.net

⁵ Department of Public Health, Environments and Society, London School of Hygiene and Tropical Medicine, London WC1E 7HT, UK

* Correspondence: rebecca.close@phe.gov.uk

<https://pubmed.ncbi.nlm.nih.gov/35409782/>

List of UKHSA publications - IAQ and health

Ferguson L, Taylor J, Davies M, Shrubsole C, Phil Symonds, Dimitroulopoulou S (2020) Exposure to indoor air pollution across socio-economic groups in high-income countries: A review of the literature and a modelling methodology. *Environment International*; 143: 105748. [10.1016/j.envint.2020.105748 \(doi.org\)](https://doi.org/10.1016/j.envint.2020.105748)

Cheek E, Guercio V, Shrubsole C, Dimitroulopoulou C (2021). Portable air purification: a systematic literature review of impacts on indoor air quality and health, *Science of the Total Environment*, <https://doi.org/10.1016/j.scitotenv.2020.142585>

Guercio V, Pojum I, Leonardi G, Shrubsole C, Gowers A, Dimitroulopoulou S, Exley K (2021) 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. *Science of the Total Environment*, *Science of the Total Environment* 755, 142187, <https://doi.org/10.1016/j.scitotenv.2020.142187>

Ferguson L, Taylor J, Zhou K., Shrubsole C, Symonds P, Davies M, Dimitroulopoulou S (2021) Systemic inequalities in indoor air pollution exposure in London, UK. *Building and Cities*, 2(1), pp. 425–448. DOI: <https://doi.org/10.5334/bc.100>

Lowther SD, Dimitroulopoulou S, Foxall K, Shrubsole C, Cheek E, Gadeberg B, Sepai O (2021). Low level carbon dioxide indoors – a pollution indicator or a pollutant? A health-based perspective. *Environments - Special Issue on IAQ and Health*; 8(11), 125; <https://doi.org/10.3390/environments8110125>

Halios CH, Landeg-Cox, Lowther SD, Middleton A., Marczylo T, Dimitroulopoulou S. (2022). Chemicals in European Residences – Part I: a review of emissions, concentrations, and health effects of Volatile Organic Compounds (VOCs). *Science of the Total Environment*, 156201 <https://doi.org/10.1016/j.scitotenv.2022.156201>

Toyinbo O, Hägerhed L, Dimitroulopoulou S, Dudzinska M, Emmerich S, Hemming D, Park J-H, Haverinen-Shaughnessy U, on behalf of the Scientific Technical Committee 34 of the International Society of Indoor Air Quality, Climate (ISIAQ) (2022). Open database for international and national indoor environmental quality guidelines. Editorial; *Indoor Air*. 2022;32:e13028. <https://doi.org/10.1111/ina.13028>

Landeg-Cox C, Middleton A, Halios CH, Marczylo T, Dimitroulopoulou S. Chemicals in European Residences – Part II: a review of emissions, concentrations, and health effects of Semi Volatile Organic Compounds (SVOCs). *To be submitted*

Clark SN, Holly Lam, Emma-Jane Goode, Emma Marczylo, Karen Exley, Sani Dimitroulopoulou. The burden of respiratory disease from damp and mould and formaldehyde in English housing. *Submitted to Environments, under review*

Contribution to IAQ work of other Gov Depts and Organisations

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 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 and babies under 12
• Advise on the increased poor indoor air quality
• Explain the risks of tobacco
• 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
• Advise on avoiding smoke in the home or around the work

Health and wellbeing in building services



TM40: 2020



Methods for sampling and analysis of chemical pollutants in indoor air

Supplementary publication to the screening tool
health risks from combined exposure to multiple chemicals



Educational course

Chemical pollution of indoor air
and its risk for children's health



Supplementary publication
to the screening tool
for assessment of health risks
from combined exposure to
multiple chemicals in indoor air
in public settings for children

Technical Memorandum

TM68 Monitoring indoor
environmental quality (2022)



Chief Medical Officer's Annual Report 2022 Air pollution

AIR QUALITY EXPERT GROUP

Indoor Air Quality



Prepared for:

Department for Environment, Food and Rural Affairs;
Scottish Government, Welsh Government,
and Department of Agriculture, Environment and Rural Affairs in Northern Ireland



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

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