



2026 ●

INGENIOUS INSIGHT

Understanding air pollution in homes



INGENIOUS

**INGENIOUS – Understanding the sources, transformations
and fates of indoor air pollutants) 2021–2026, UKRI**

The air we breathe indoors

Each day, we breathe in about 11,000 litres of air. With 80% of our time spent inside, our indoor environment plays a major role in our respiratory health. In indoor spaces, harmful pollutants can often go undetected, disproportionately affecting those who spend more time indoors. Despite this, awareness of Indoor Air Quality (IAQ) lags significantly behind our understanding of outdoor pollution.

To bridge this gap, the INGENIOUS project conducted a comprehensive study of over 300 homes in Bradford in partnership with the Born in Bradford study. Sampling in homes in this diverse city allowed us to investigate how housing quality, ventilation, and lifestyle habits influence indoor air quality, including in lower-income households.

Photo credit: Nic Carslaw/ University of York

The INGENIOUS project highlights that everyday indoor activities, such as cooking and cleaning, can be significant sources of air pollutants.

Through experiments, INGENIOUS mapped the main sources, transformations, and fate of air pollutants in typical UK homes. It also analysed inequalities in exposure and the associated health impacts across diverse populations. The project investigated the intersection between indoor air pollution, health, and human behaviour and provided practical strategies to mitigate the health impacts of the air we breathe every day.

Meet the project lead

Nicola Carslaw is a Professor of Indoor Air Chemistry at the University of York. Her research investigates how pollutants from everyday indoor sources interact and affect air quality. As Principal Investigator of INGENIOUS, she led an interdisciplinary team to understand indoor air pollution and inform guidance and policy.



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The project has improved understanding of indoor air pollution and generated evidence to support healthier living environments.

Prof Nicola Carslaw
Professor of Indoor Air Chemistry
University of York

Why indoor air quality matters

Indoor air contains a complex mixture of pollutants originating from activities and products commonly used in homes. These sources release particulate matter (PM) and volatile organic compounds (VOCs), which undergo chemical reactions indoors, forming new pollutants.

Results from the INGENIOUS project add to the growing body of evidence that indoor air quality poses a potential risk to public health and that the full nature and extent of this risk need to be better understood.

Which activities cause pollution indoors?

Cooking emissions	Building materials
Cleaning products	Combustion appliances
Fragranced products	External pollutants



Figure 1: Toby Carter, University of York

INGENIOUS research approach

Our approach integrated rigorous research and evidence with monitoring, technology deployment and active community engagement.

Conducted controlled indoor emission experiments measuring emissions from common household activities, including cooking, cleaning, and use of fragranced products, to inform indoor emission inventories.



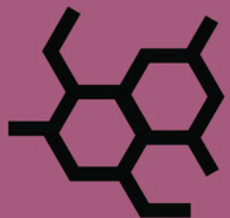
Monitored indoor air quality across 309 homes in Bradford, examining how behaviour, ventilation practices, socio-economic factors, and seasonal variations influence exposure.



Carried out mobile air quality measurements in Bradford and York to assess emissions from buildings and local businesses and the impact of outdoor pollution on indoor environments.



Used advanced chemical models (PyCHAM and INCHEM-Py) to simulate indoor chemical changes and explore effects on outdoor air quality.



Studied ventilation behaviours in homes and tested behavioural insights to see how simple interventions could help reduce indoor air pollution exposure.



Organised engagement and knowledge exchange activities to raise awareness of indoor air quality issues and support policy development and public dialogue.



Figure 2: INGENIOUS Research Approach: Visual design by Anjali Vyas-Branick/University of York

INGENIOUS in numbers

A look at the INGENIOUS project by numbers, reflecting the scale of our monitoring efforts and community impact in Bradford and the UK.

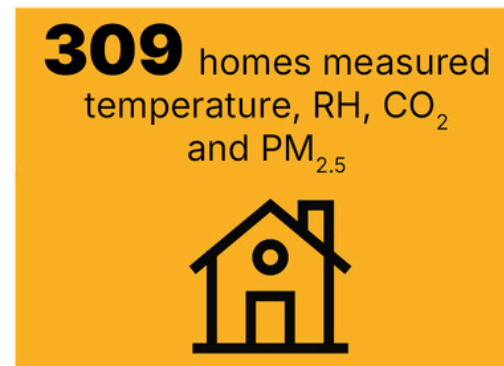
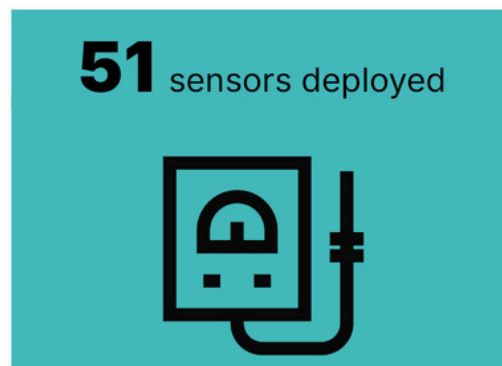
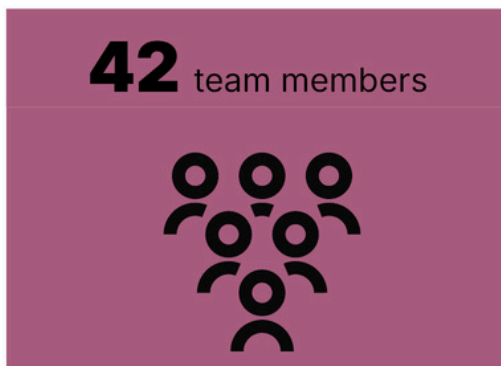
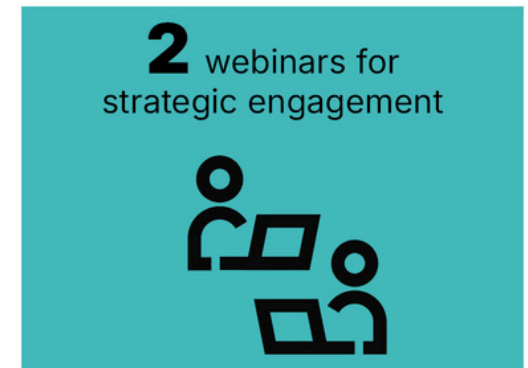


Figure 3: INGENIOUS Research Approach: Visual design by Anjali Vyas-Branick/University of York

What we learned

- Indoor air pollution was rarely considered a personal concern.
- Although ventilation was recognised as beneficial, concerns about cost, comfort, security, outdoor pollution, and housing constraints often limited its use.
- Cooking emissions resulted in measured concentrations exceeding WHO guidelines.
- High CO₂ levels were recorded in bedrooms overnight.
- Pollution levels varied significantly based on ventilation practices, occupant behavior, and housing types.
- IAQ was influenced by seasonal variations; for instance, pollutant concentrations were higher in winter due to reduced ventilation and increased indoor heating use.
- Indoor air was often found to be more polluted than outdoor air.
- The research highlighted a lack of UK statutory limits for indoor PM_{2.5}.
- Airtight homes tended to trap pollutants, leading to higher indoor concentrations.
- IAQ was heavily influenced by socio-economic inequalities:
 - a. The most deprived households had PM_{2.5} levels that were twice as high as those of the least deprived households.
 - b. Homes with gas stoves showed higher pollution levels than those without.
 - c. Indoor air pollutant levels were higher in rented and smoking households.
 - d. Fuel poverty was found to trigger conditions leading to damp and mould.



How to improve indoor air quality

Based on our research findings (and those in other recent projects), the following actions were identified as effective interventions to reduce exposure to indoor air pollution:

1

Cooking practice

- Ventilation: Opening windows during and after cooking significantly reduces the buildup of pollutants.
- Optimise extractor use: Using the cooker's extraction hood consistently helps clear the air of emissions.
- Hob use: Using back rings (burners) and reducing frying activities lowers direct exposure.
- Upgrade appliances: Transitioning to electric or induction hobs is recommended to eliminate combustion pollutants associated with gas hobs.

2

Cleaning habits

- Switch formats: Using liquid cleaners instead of sprays reduces the inhalation of aerosolised particles.
- Practice safety: Avoid mixing different cleaning products to prevent dangerous chemical reactions.
- Apply critical thinking: Remain cautious of "chemical-free" claims, which are often misleading, and ensure ventilation while cleaning.

3

General ventilation and air flow

- Increase regular airflow: Implementing a habit of opening windows regularly helps flush out trapped pollutants, particularly in airtight homes.
- Leverage mechanical aids: Using extractor fans beyond just the kitchen (e.g., in bathrooms) supported overall home air exchange.

What next

We gained valuable insights from INGENIOUS, but our measurements were limited to a short time period and only a few indoor pollutants, using low-cost sensors in occupied homes.

“Now, we aim to study a broader range of pollutants over longer periods at the new INTERIORS (Interdisciplinary Facility for Indoor Air Quality Research) facility at the University of York.

INTERIORS includes two three-bedroom houses on either side of an integrated air sampling lab. One house is highly energy-efficient, while the other reflects typical 1990 UK building standards. A custom gas sampling system allows us to collect air samples from any room in either house, as well as from outside.

In the coming years, research at this facility will help us better understand how emissions from human activities and indoor materials affect indoor air quality.” - Nic Carslaw, University of York



Publications

Research from INGENIOUS has produced several scientific publications, including studies on:

1. The INGENIOUS project: towards understanding air pollution in homes:
<https://pubs.rsc.org/en/content/articlelanding/2025/em/d4em00634h#!divAbstract>
2. Understanding the patterns and health impact of indoor air pollutant exposures in Bradford, UK: a study protocol: <https://bmjopen.bmj.com/content/13/12/e081099.info>
3. Understanding air pollution in homes, 2025:
https://drive.google.com/file/d/154KNlq13McEXb0xQ_MqbanXZ_NQw-42R/view
4. Inequalities and indoor air pollution: a prospective observational study of particulate matter (PM2.5) levels in 309 UK homes from the Born in Bradford cohort study:
<https://link.springer.com/article/10.1186/s12889-025-25182-x>
5. Chemical fingerprints of cooking emissions and their impact on indoor air quality:
<https://pubs.rsc.org/en/content/articlelanding/2025/em/d5em00385g>
6. The chemist using curry to understand indoor air pollution:
<https://www.chemistryworld.com/news/the-chemist-using-curry-to-understand-indoor-air-pollution/4022539.article>
7. Yearlong study of indoor VOC variability:
<https://pubs.rsc.org/en/content/articlelanding/2025/em/d4em00756e>
8. Fingerprinting the emissions of volatile organic compounds emitted from the cooking of oils, herbs, and spices:
<https://pubs.rsc.org/en/content/articlelanding/2025/em/d4em00579a>
9. Toward linking indoor commercial source emissions to outdoor volatile organic compounds using mobile measurements:
<https://pubs.acs.org/doi/10.1021/acsestair.5c00290>

Find other collaborative publications here:



“

The indoor environment is the new frontier for uncovering air pollution effects on health.

INGENIOUS delivers a rigorous scientific examination of how everyday household activities transform indoor air. By focusing on fundamental processes in real-world environments, it provides much-needed experimental evidence in a complex and under-characterised field. Its strength lies in capturing real-life conditions, offering valuable insight into indoor air dynamics and informing future research.

As part of the UKRI Clean Air Programme, it has been a privilege to see this essential work develop and contribute to it.

PROF SIR STEPHEN HOLGATE

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Further resources

Additional content and resources from the INGENIOUS project.



Animated video with tips on ventilation to reduce indoor air pollution.

[Video](#)



House of Commons interview raises awareness of indoor air quality.

[Video](#)



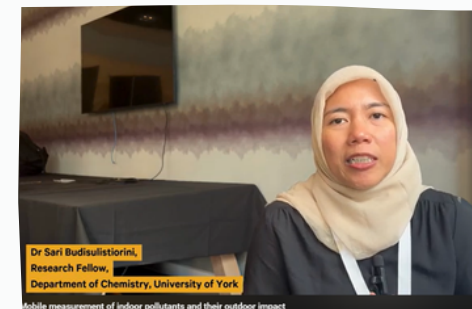
Clean Air Day tips for a healthier indoor air.

[Video](#)



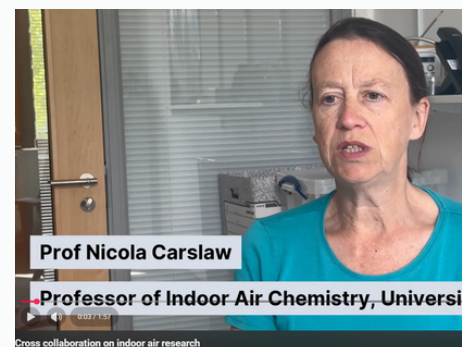
Presentation on mobile measurements linking indoor and outdoor air pollution.

[Video](#)



Collaborative research investigating indoor air pollution and healthier environments.

[Video](#)



Addressing multifaceted indoor air pollution challenges through research.

[Video](#)



Partnership and people

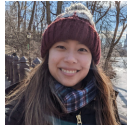
Meet the team



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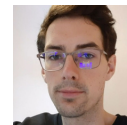
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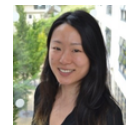
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Simon O'Meara



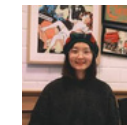
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Participating institutions



Funding organisation



Partnerships

The project funded by UKRI is a collaborative project involving partners including



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Born in Bradford is only possible because of the enthusiasm and commitment of the children and parents in BiB. We are grateful to all the participants, health professionals, schools and researchers who have made Born in Bradford happen. We want to extend our sincere thanks to the 309 Born in Bradford families who welcomed us into their homes and made this research possible.

We also thank our core partners, professional collaborators, and the members of the INGENIOUS Impact Panel for their expertise, guidance, and invaluable contributions throughout the project's duration.

The collective effort, shared knowledge, and collaborative spirit of all contributors have been central to the INGENIOUS project's success.

To hear more about us, visit:

[www.https://ingenious.york.ac.uk/](https://ingenious.york.ac.uk/)

The Impact Panel includes representatives from:

Scottish Government

Impact on Urban Health

University of York

AirViz

Policy Connect

Hywel Dda University Health Board

ADPH Yorkshire and Humber Public Health Network

Air Pollution All-Party Parliamentary Group

Ethos Partnership

The Ella Roberta Family Foundation

Housing LIN

TAPAS Network

Global Action Plan

IFRA UK

City of Bradford Metropolitan District Council

Department of Archaeology, University of York

UCL Faculty of the Built Environment

British Aerosol Manufacturers' Association (BAMA)

The Cosmetic, Toiletry and Perfumery Association (CTPA)

UK Health Security Agency (UKHSA)

Department for Environment, Food & Rural Affairs (DEFRA)

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