2024 Clean Air Conference

Abstracts

Analysis and Solutions: Responding to the Clean Air Challenge

2nd and 3rd October

Edgbaston Park Hotel and
Conference Centre, Birmingham

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Natural Environment Research Council

Integrated particle generation protocol for in vivo/vitro studies: emissions from diesel engine, wood combustion, cooking, and cleaning products

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Keywords: air pollution, aerosol generation protocol, health study, indoor/outdoor pollutants.

Associated conference topics: 1.2, 1.3

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Ambient particulate matter (PM) exposure poses a significant global environmental health risk, with an estimated 91% of the world's population living in areas where air quality exceeds WHO guideline limits (WHO, 2018). To understand the impact of air pollutants on human health, both in vivo and in vitro research methods are crucial. However, the generation of pollutants suitable for the in vivo/vitro exposure studies is technically challenging. Safety is the over-riding concern, especially in vivo studies involving human exposure experiments. Critical to this is the precise control and monitoring of reproducible concentrations of pollutants, sufficiently low (normally within environmentally relevant parameters), to avoid harm, but sufficiently high as to elicit a biochemical/physiological/psychological response.

During the "Assessing the toxicity of indoor and outdoor air pollutants using an integrated Hazard Identification Platform (HIP-TOX)" project, we developed a protocol to characterize the PM concentration and chemical composition of pollutants emitted from various sources, including diesel engine, wood combustions, cooking, and cleaning products. Additionally, we ensured the protocol was able to generate desirable and reproducible PM concentrations from each source for in vivo/vitro exposures. An example of the setup and characterization results from the cooking experiment is presented in Figure 1 and Figure 2, respectively.

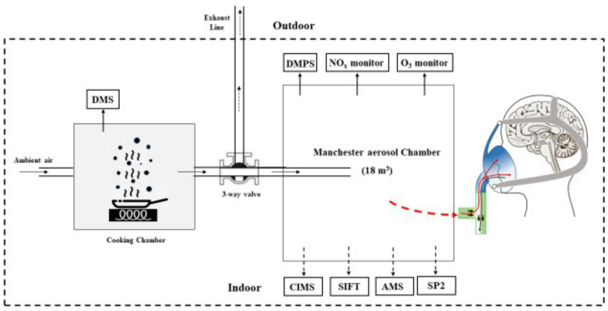

Figure 1. Cooking experiment setup for human exposure study.

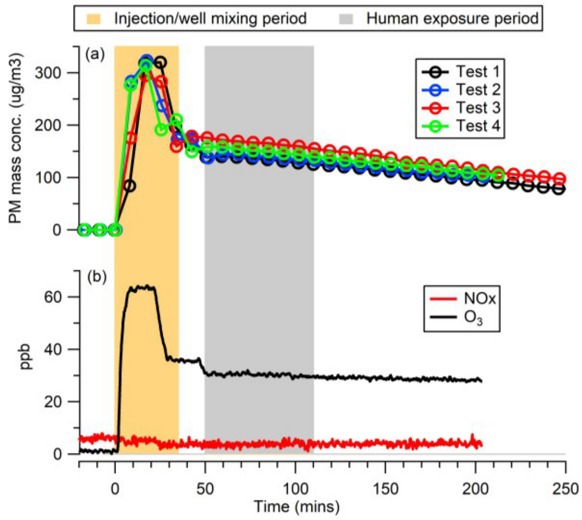

Figure 2: Cooking emissions post-injection into the Manchester Aerosol Chamber: (a) Time series of particle mass concentration; (b) Example of time series of NO_x and O_3 concentrations.

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Translocation of inhaled particulate matter to red blood cells after real-life ambient exposure during commute

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Keywords: particulate matter, translocation, red blood cells
Associated conference topics: 1.3, 1.2, 2.1
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Inhaled particulate matter (PM) can adversely impact on not only the airways and lungs, but also extra-pulmonary organs, across the life-course. One mechanism for this distant effect is that inhaled ultrafine nanoparticles can escape airway macrophage phagocytosis, and translocate across the air-tissue barrier, through the bloodstream and interact with other organs, as evidenced by the detection of exogenous metal-bearing nanoparticles in healthy human placental tissue resident phagocytes (Liu, Miyashita, Maher, et al. 2021). PM exposure is known to be associated with reduced haemoglobin levels and anaemia (Hwang and Kim 2024), although the underlying mechanism remains unclear. Previous animal and *in vitro* models showed uptake and adsorption of ultrafine particles by erythrocytes, with evidence of haemolysis (Nemmar et al. 2012). We seek evidence of translocation of inhaled PM to human red cells following real-life ambient exposure.

Informed consent (sponsor ethical approval reference: QME24.0041) was obtained from healthy adults (n=4), aged 25-45 years, residing and working in London. Each participant donated blood samples at baseline (staying in an indoor clean environment for 4 hours), and immediately following their commute to work by cycling, underground trains, or overground trains, with commute duration ranging from 20 to 60 min. Figure 1 shows an example of pollution exposure of one of the participants, measured by a Dyson's air quality backpack.

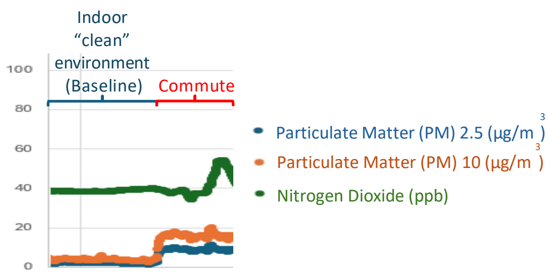

Figure 1. Air pollutants (particulate matter and nitrogen dioxide) exposure measured by a Dyson's air quality backpack, carried by one participant at baseline (4 hours of staying indoor) and during commute by cycling.

3000 randomly selected red blood cells from each participant were examined under light microscopy (x60 objective). Areas occupied by black aggregates were measured using ImageJ software, and mean black area of 3000 cells was determined. Differences between baseline and post-commute were compared using Mann-Whitney test. We found evidence of nano-sized black aggregates associated with red blood cells in all participants (Figures 2A-D), with appearance compatible with inhaled carbonaceous PM seen in airway macrophages (Figure 2, panel E, (Liu, Miyashita, Sanak, et al. 2021)); with increased areas of black aggregates after commute, compared to baseline (median area 0.0009 μm^2 at vs 0.0020 μm^2, $p<0.05$, Figure 3).

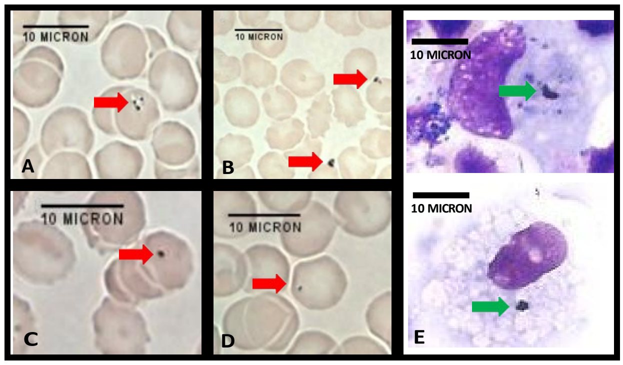

Figure 2. A-D: Red cells from different healthy adult participants, associated with irregularly shaped black aggregates (red arrows), with appearances compatible with inhaled carbonaceous particulate matter (green arrows) seen in airway macrophages from healthy individuals (panel E (Liu, Miyashita, Sanak, et al. 2021)).

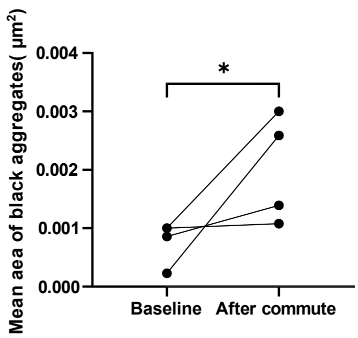

Figure 3. Mean area of black aggregates in 3000 randomly selected red blood cells from each participant, at baseline and after commute.

We conclude that inhaled nanosized PM can translocate via the bloodstream and interact with red blood cells. Increase in amount of black aggregates associated with red cells was seen as soon as 20 min after a routine commute with ambient air pollution exposure. Further work to determine the composition of these aggregates, how they interact with red cells, and their effects on red cell function is to be carried out.

Acute particulate matter exposure diminishes executive cognitive functioning after 4 hours, regardless of inhalation pathway

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Keywords: particulate matter, cognition, air pollution, brain health
Associated conference topics: 1.ii, 3.i, and 2.ii
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Globally, air pollution is a leading environmental risk factor linked to cardiovascular and respiratory issues. Particulate matter, particularly with diameter ≤ 2.5 µm ($PM_{2.5}$), is also linked to the onset of neurodegenerative disease. Recent evidence highlights that exposure to $PM_{2.5}$ affects multiple cognitive functions including attention, executive function, and memory, crucial for daily tasks like supermarket shopping. Mechanistically, it is proposed that air pollution impacts the brain either through direct neuronal damage or indirect processes from systemic inflammation. Evidence suggests a time lag between exposure and cognitive effects of a few hours from exposure through both olfactory and respiratory pathways. Studying these pathways' effects independently could aid in further understanding the mechanisms relating to PM air pollution exposure on cognition. This study investigates whether high PM concentrations affect cognitive function after 4 hours and if inhalation pathway influences this effect.

In this study 26 adults (M_{age} = 27.7, SD_{age} = 10.6) were exposed to high PM concentrations resulting from the burning and subsequent extinction of candles, or clean air conditions, using either normal inhalation or restricted nasal inhalation and olfaction, via use of a nose clip, for 1 hour. Each participant took part in all four condition combinations of high PM versus clean air, and normal versus restricted breathing. Participants completed four cognitive tests that assessed different cognitive functions: working memory; selective attention; emotion expression discrimination; and psychomotor vigilance. The tests were administered before and four hours after the exposure.

Selective attention, the ability to remain task focused and avoid distraction, was significantly diminished following PM air pollution exposure comparative to clean air. See Figure 1.

Emotion expression discrimination, the ability to distinguish between positive-affective and negative-affective emotional expressions, was significantly diminished after enhanced PM versus clean air exposure. See Figure 2.

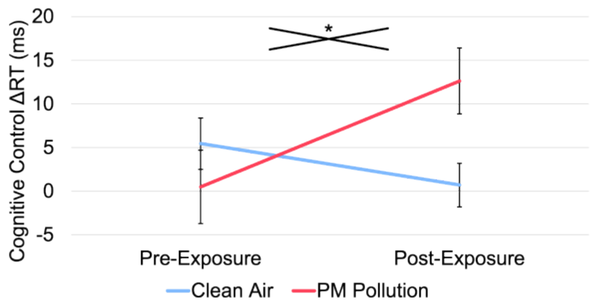

Figure 1: Significant pollution*time interaction. A rise in the cognitive control (ΔRT) metric between pre- and post-exposure indicates decline of selective attention. Error bars indicate standard error.

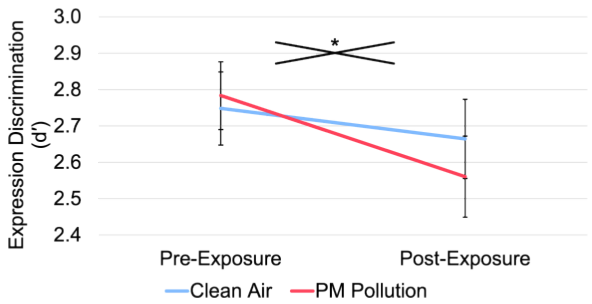

Figure 2: Significant pollution*time interaction. A decline in the d' metric between pre- and post-exposure indicates worsening of expression discrimination. Error bars indicate standard error.

Air quality did not significantly impact psychomotor vigilance, and contrary to expectations, there were no identified changes in working memory. Results indicate a reduction in cognitive processing four hours after exposure to high concentrations of PM, corroborating previous evidence. The inhalation method did not significantly mediate effects, suggesting that short-term effects of PM pollution on cognitive function manifest through lung-brain mechanisms.

This data was used to support a large-scale follow-up study focusing on exposure to air from four common indoor and outdoor sources: diesel exhaust; cooking emissions; wood smoke; and cleaning products.

Nooku: The Evolving Air Quality Landscape
Presented by: Danny Kane, Filament PD

Project Partners: Arceptive, Orvio, University of Strathclyde

Most adults spend more than 90% of their time indoors and today's children spend only half of the time outdoors that their parents did. Respiratory disease is the third biggest cause of death in the UK, currently 5.4 million people are receiving treatment for asthma in the UK (1 in 12 Adults and 1 in 11 children). There is, however, a general lack of understanding amongst the public of the factors that affect indoor air quality and their health impacts.

The aim of the FamilyAIR project is to develop a domestic, human-centred air quality monitoring system that engages, educates, and learns from everyone within a household to promote positive behavioural change.

The project will particularly focus on the identification and categorisation of indoor pollution events, providing contextual actionable advice for users and a rich source of aggregated data helping to uncover new research insights.

A Novel Mobile Air Quality Measurement for Emerging Indoor Emission Sources

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Keywords: mobile measurement, indoor-outdoor pollutant exchange

Associated conference topics: 2.2, 1.1, 1.2

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Indoor air pollution has been asserted as an emerging source, yet its contribution to air quality is poorly understood. While regional and scattered measurements have identified tracers associated with indoor sources like cooking emissions, these approaches fall short in identifying localised sources and assessing their significance over time and the combined impact of multiple sources.

This study presents a novel air quality observation method designed to characterise localised and persistent pollutants. Utilising a mobile laboratory equipped with a selective ion flow tube mass spectrometry (SIFT-MS), we conducted comprehensive measurements of volatile organic compounds (VOCs) from cooking and traffic emissions, volatile chemical products (VCPs), and personal care products (PCPs) in Bradford and York, United Kingdom. Using the fast response data encompassing over 30 species from a minimum of 20 mobile measurements in each city across summer and winter, we developed metrics to identify indoor sources in the atmosphere.

Using this approach, we found that acetone, a PCPs tracer, exhibited high concentrations in areas densely populated by beauty salons. Moreover, the concentration profile of acetaldehyde, originating from vehicle and cooking emissions, was associated with the density of restaurants. The contribution of indoor sources to urban air quality was further confirmed by elevated nonanal concentrations, a unique cooking tracer, in densely populated restaurant areas (Figure 1). Notably, our approach could isolate traffic emissions contribution from indoor emissions, even when they share similar emission profiles.

Our method offers a new perspective on air quality monitoring, characterised by flexibility and robustness. This approach will be invaluable in evaluating pollutants across diverse contexts, from urban to rural areas. Furthermore, it can characterise air pollutants with multiple sources. Notably, this method provides policymakers with insights to develop effective mitigation strategies and assess the efficacy of implemented measures.

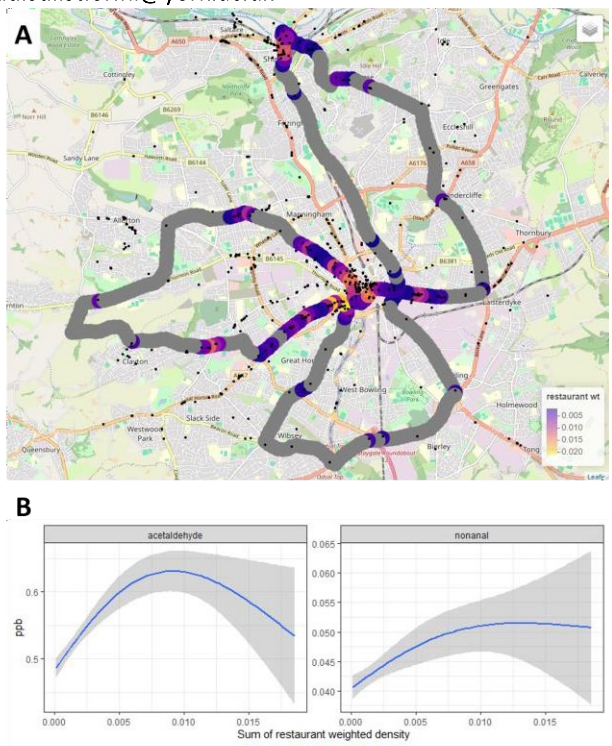

Figure 1. The metric of restaurant-weighted density along the road network (A) and the relationships between VOCs and the sum of restaurant-weighted density in Bradford, UK (B).

This study is part of the INGENIOUS project (Understand**ING** the sourc**E**s, tra**N**sformations and fate of **I**nd**O**or air poll**U**tant**S**) funded by the Clean Air Programme UKRI Strategic Priorities Fund (SPF)

Does the location of sensors matter when monitoring indoor air pollutant exposure in UK homes?

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Keywords: Monitoring, modelling, indoor air quality, energy efficiency, retrofit
Associated conference topics: 2.3, 3.2, 4.1
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Characterising air pollutant exposure at home is a complex and challenging task, with air pollutant concentrations varying substantially over space and time, between and within homes. A dwelling's ventilation characteristics are key determinants of indoor pollutant concentrations, and energy efficiency measures (such as double-glazing) can modify these characteristics. To characterise air pollutant exposure in the UK housing stock, determine how this changes following energy efficiency retrofit, and improve our understanding of the relationship between indoor pollutant exposure and health, a large-scale monitoring campaign is required at the early stages of our net zero transition (1).

An important consideration when monitoring indoor air quality is the number of sensors to be used and their placement. Despite a growing body of research on this topic, work that focuses on UK homes is lacking. Motivated by this gap, research carried out as part of the HEICCAM network explored the effect of sensor placement on quantifying air pollutant exposure using a case study approach (2).

Particulate matter with aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$) and radon, were simulated using built environment models for four common domestic archetypes: a semi-detached, a mid-terrace, a bungalow, and a low-rise flat. The models were assumed to be naturally ventilated, with intermittent extract fans in the bathroom and kitchen, located in Plymouth – an area with high geological radon levels – and with thermophysical and airtightness characteristics typical of pre-retrofit UK dwellings.

Air pollutant concentrations were simulated at 5-minute timesteps over an entire year and reported separately for each room. Both indoor (from cooking) and outdoor sources (based on empirical data for Plymouth in 2019) were modelled for $PM_{2.5}$. Radon was modelled as entering the house through the air leakage of soil gas radon from the ground using a pressure-driven model.

Air pollutant exposure was first estimated for up to four occupants for each archetype, by considering the time spent in each room based on previously published occupancy profiles. This exposure was then compared against approximate measures of exposure; estimated using subsets of the data to represent the exposure that would be estimated if only some of these rooms were being monitored.

The modelling revealed that in the case of $PM_{2.5}$, where exposure was largely driven by cooking activities, collecting data only from the kitchen exaggerated the exposure for occupants who were not present during cooking. On the other hand, not monitoring the kitchen was shown to underestimate the exposure of someone present during cooking activities by up to 63% (normalised mean bias error - NMBE). Monitoring radon concentration in the main bedroom was found to be important in quantifying the radon exposure of occupants that sleep in that bedroom. However, substantial differences (NMBE: -56-30%) were observed when data from the main bedroom were used to estimate radon exposure for occupants not sleeping in the main bedroom, even when the bedrooms were on the same storey.

In summary, sensor placement can have a substantial impact on the estimated exposure, and varies with the pollutant, occupant and dwelling typology considered.

References

1. Petrou G, Hutchinson E, Mavrogianni A, et al. Home energy efficiency under net zero: time to monitor UK indoor air. BMJ. 2022 May 9;e069435.

2. Petrou G, Wang Y, Chalabi Z, et al. Placement of monitors for quantifying indoor air pollutant exposure in UK homes: issues for consideration. In: Fit for 2050 - Delivering buildings and defining performance for a net zero built environment. Cardiff, Wales; 2024.

Investigating how ventilation alters particulate matter concentrations in classrooms

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Keywords: Indoor air quality, Par7culate MaJer, Ven7la7on

Associated conference topics: 2.3, 1.2, 2.2

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Inhala7on of par7culate maJer (PM) has been closely linked to a myriad of poor health outcomes. Understanding the sources of PM is of cri7cal importance to mi7ga7ng these health outcomes, and in par7cular, it is important to understand the *indoor* air quality with respect to PM as we typically spend upwards of 80% of our 7me indoors. The health effects on children can be more pronounced, and apart from the home, school is where many children spend most of their 7me indoors. As such, the Schools' Air quality Monitoring for Health and Educa7on (SAMHE) project has set out to bring together teachers, students and researchers to build a na7onal dataset of air quality in schools. Par7cipa7ng schools receive a free high-spec monitor that measures PM, CO_2 and temperature amongst other metrics. We present findings from air quality data collected from over 400 schools over the 2023-2024 academic year. By comparing $PM_{2.5}$ concentra7ons in this data set to the outdoor $PM_{2.5}$ concentra7ons as recorded by background Defra AURN sta7ons, we show that the classroom $PM_{2.5}$ concentra7on is closely linked to the outdoor concentra7on. We inves7gate the role that classroom ven7la7on plays in indoor $PM_{2.5}$ concentra7on. Ven7la7on rates are inferred from classroom CO_2 measurements and compared to the indoor-outdoor $PM_{2.5}$ ra7os. Ven7la7on is a key mechanism by which schools can alter their indoor air quality, and flush pollutants from classrooms. Therefore, it is essen7al to determine how the ra7o of indoor to outdoor par7culate maJer varies with classroom ven7la7on, and the factors that influence it. This development in understanding can provide an evidence base for future guidance for opera7on of school buildings and contribute to shaping future school design and retrofit programs.

WellHome – Aerosol size distribution, PM chemical composition and gaseous measurements in homes

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Keywords: indoor air, $PM_{2.5}$, ultrafine particles, cooking, asthma
Associated conference topics: 2.2, 2.3
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The WellHome project is a co-designed study with a local community in West London and focuses on the air quality inside and outside of over 100 homes, including those of children with asthma. The aim of the study is to identify dominant air pollution exposures across the indoor: outdoor air pollution continuum within vulnerable and diverse urban communities, and to identify behavioural changes that can reduce this exposure and improve health outcomes.

As well as the air quality measurements in 100 homes over 2 seasons - 10 additional 'Priority Homes' were monitored for 12 months and studied intensively for five days on two occasions during the year. These higher quality measurements (Air YX ICAD for NO_2, Microaethalometer for black carbon and Grimm MINIWRAS for aerosol size distribution) were installed in the living room to better understand how the small sensors performed in the home environment and offer insight into the sources contributing to air quality in the homes; this system is shown in Figure 1.

Figure 1: Laboratory preparation of monitoring system (left), installation in home (right)

The methodological challenges of designing the monitoring system will be discussed, including the issues of safety and participant outreach will be reported. The influence of different indoor sources such as cooking have been identified through analysis of the aerosol size distribution, and the influence of ambient air ingress through comparison to local outdoor monitors – examples are shown in Figure 2. Their relative contribution to particle number concentration ultrafine particles (UFP) and $PM_{2.5}$ will be discussed.

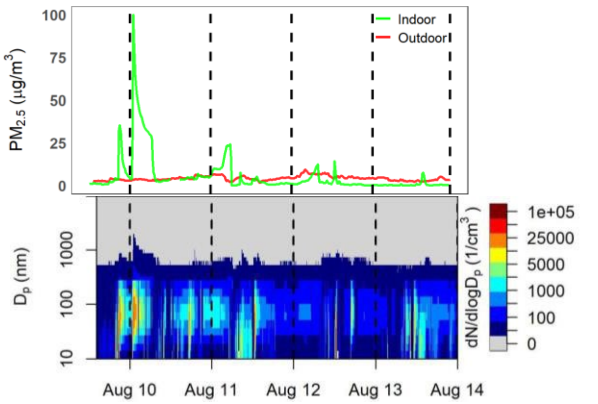

Figure 2: $PM_{2.5}$ concentrations indoors and outdoors (top), aerosol size distribution (bottom)

Will declining condensation sinks lead to enhanced New Particle Formation?

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Keywords: NPF, Nucleation, Growth, Ultrafine particles, Traffic.
Associated conference topics: 2.1, 2.2, 4.1
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Particulate matter (PM) mass concentrations, and by extension particle surface area concentrations have been declining across Europe across the last decade. New particle formation (NPF) is a key source of atmospheric aerosol particles, **especially ultrafine particles (UFP, particles <100 nm). Unlike PM mass, UFP are not subject to any legal limits, despite their potential health effects**. The occurrence of NPF is driven by **photochemistry** and is inhibited by the presence of pre-existing PM surface area. NPF is therefore most common on clean-air days. We analyzed size-distribution data at several measurement sites across Europe. The condensation sink (CS) has shown a decline at all sites over the past decade, a function of clean-air policy. At the sites with the most rapid decline in CS, the NPF frequency has increased. We estimate that the quantity of particles that form and grow to 75 nm before being lost to coagulation is also increasing. Specifically, the annual total of 75 nm particles generated through NPF is growing by 120% per year at the roadside in Leipzig, Germany, a significant increase from nearly zero in 2012. The reduction in CS, primarily driven by diminishing secondary aerosols, is leading to an increase in NPF frequency and increased survival probability of newly formed particles in central Europe and suggest that this could lead to increased human exposures to UFP.

Calculation of NOx/CO_2 emission ratios from high resolution roadside data

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Keywords: traffic emissions, NOx ratios, policy.
Associated conference topics: 2.2
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Over the last decade, the UK has seen the implementation of air quality policies, such as Clean Air Zones and Low Emission Zones, in many urban areas. It is essential to better understand how urban air pollution sources are changing so that we can continue to develop targeted and effective policies. Ambient measurements of the enhancement of NOx and CO_2 concentrations above background can be linked to direct emissions via the calculation of emission ratios (ΔNOx/ΔCO_2), which in turn provide insight into emission sources. This work builds on measurements of NOx fluxes taken at the BT tower in London during the SPF OSCA project.

We use a regression analysis method to quantify emission ratios from high time resolution roadside measurements of NOx and CO_2 taken at two sites: Marylebone Road in London and Fishergate in York. Calculated emission ratios allow us to gain understanding of the effect of factors such as fleet composition and vehicle operating conditions on roadside NOx emissions. A comparison of emission ratios across the two cities allows for an interesting discussion on the differences in traffic behaviour and effectiveness of local traffic-related policy (e.g. low emission zones). Calculated emission ratios are compared to emission inventory estimates.

This work aims to highlight the benefit of long-term high time resolution measurements of CO2 to develop an advanced understanding of local traffic-related NOx emissions.

UKRI/MET 2024 Clean Air Conference Abstract

Good for soil, grim for the air: ammonia emissions from nitrogen fertilised soils and their controlling factors

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Keywords: Ammonia emissions; nitrogen fertilisers, Urea, Urease Inhibitors, Emission control
.
Associated conference topics: 4.2, 3.1 and 3.2
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Ammonia (NH_3) emissions from the use of inorganic nitrogen (N) fertilisers in agriculture have negative impacts for environmental quality, biodiversity and human health. Despite the importance of reducing NH_3 emissions, efforts to reduce NH_3 emissions in the UK have achieved limited success. This research provides an overview of NH_3 emissions from agricultural soils receiving N fertilisers in the UK and Ireland and discusses the regulating factors and the potential role of inhibitors in reducing current NH_3 losses from soils.

This work relied on a systematic search and review, which was performed to identify relevant field experimental data and studies. A total of 298 field fertilization events data was categorised and analysed systematically (Rathbone and Ullah, 2023).

Overall, NH_3 emissions ranged from -4.00 to 77.00% of applied N fertiliser lost as NH_3. In addition to fertilizer type, losses of ammonia were also influenced significantly by land-use type and soil pH. Urease and combined urease and nitrification inhibitors which are used by farmers to reduce N losses from soils resulted in significant reduction in NH3 emissions by 74 % and 70 % compared to uninhibited-urea, respectively.

In addition to fertilizer types, land-use and soil pH were found as key factors for consideration as modifiers to the maximum NH_3 emission factor (EF_{max}) values currently used by the Department of Environment, Food and Rural Affairs (DEFRA), UK, in order to improve estimations of NH_3 emissions from N fertilisers. Further refinement fo the EFmax is important as NH_3 losses exceeded current EF_{max} limits particularly in case of non-urea fertilizers by ~34%, implying that NH_3 emissions estimated from UK synthetic fertiliser require further adjustments. Inhibitors did not completely inhibited NH_3 losses and thus cannot be solely relied upon for constraining NH_3 emissions from soils. The overall loss of NH3 as fraction of applied fertilizer is high and thus a good and plant available nutrient is lost into air with grim implications for environmental quality and human health. This is mainly due to poor nitrogen use efficiency of agricultural crops, excessive fertilization and lack of soil nutrient demands versus availability data at farm scale for sustainable nutrient management on land. Therefore, more detailed, site and soil specific measures in relation to crop types and their nitrogen use efficiencies are needed for effective mitigation strategies and methods to further reduce NH_3 losses.

Reference

Rathbone, C. and S. Ullah. 2023. Ammonia emissions from agricultural soils fertilized with nitrogen fertilizers: controlling factors and solutions for emission reduction. *EVNRIONMENTAL CHEMISTRY,* ***doi:*** ***https://doi.org/10.1071/EN23010***

Telematics data to estimate the impacts of calendar and meteorological events on transport emissions at high spatio-temporal resolutions

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Keywords: Road emission, Air pollution, Resilient cities, Telematics data.
Associated conference topics: 2.4, 1.6, 3.5 (up to three conference topics for review and allocation)
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The impact of extreme meteorological phenomena and calendar events upon the urban mobility and transport environment has not been adequately explored, despite its importance in the context of resilient cities. This is particularly relevant for urban planning purposes and adapting to climate change. This research offers a crucial perspective on the ramifications of such events on traffic dynamics and emissions, underlining their significance in a time when urban areas are increasingly vulnerable to climate variability.

This study employs vehicle telematics data collected from the streets in Birmingham, UK, to examine road parameters, including average speed, acceleration, vehicle-specific power (VSP), carbon dioxide (CO_2) and nitrogen oxides (NOx) emission factors (EFs). We investigate the role of calendar events (Easter and summer holiday periods) and meteorological events (heatwaves, cold waves and flooding) over the years 2016, 2018, 2021 and 2022. The results were analysed across a range of road types, including major and urban roads. Major roads encompass motorways, trunk, and primary roads, while secondary and tertiary roads were categorised as urban roads.

The data employed in this study were derived from GPS black boxes installed within the cabins of passenger vehicles. The estimated proportion of GPS-connected vehicles is between 3 and 7% of the total fleet, with the precise figure varying according to the time and location of sampling. The data were anonymised in accordance with the General Data Protection Regulation (GDPR) and then converted into urban mobility and transport environment parameters using the recently published approach of geospatial and temporal mapping of urban mobility (https://doi.org/10.1038/s41598-024-53717-6).

During the heatwaves, the analysis reveals an approximate 5% increase in vehicle speed relative differences (RFs). Figure 1 provides the NO_x EF RDs over the period studied. In 2016, the spread of NOx EF shows an aggregation around 16%, with several outliers indicating substantial deviations. 2018 presents a tighter clustering around a median value just above 10%, whereas 2021 reveals an extended distribution with a marked increase in variation, which may be indicative of the anomalous conditions of the pandemic.

As for the calendar events, the impact on urban mobility and emissions is also significant, with the overall NO_x EFs showing around 11% higher compared to annual averages.

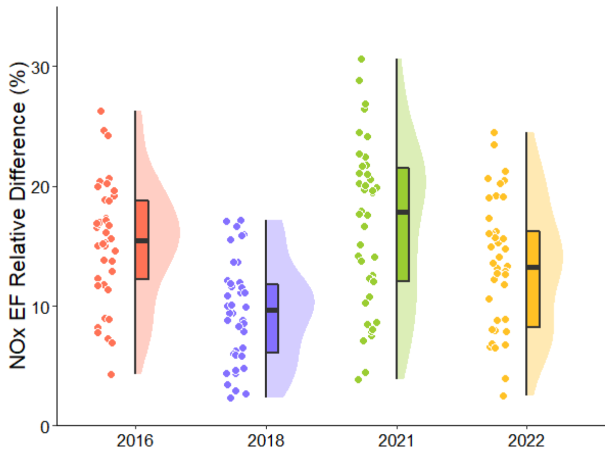

Figure 1. The box-violin-scatter plots for the relative difference between heatwaves and annual values for NOx EF for the studied years of 2016, 2018, 2021 and 2022, on both major and urban roads.

The findings of this study demonstrate that the impact of calendar and meteorological events on urban mobility and transport environment is significant. Emission factors of pollutant NOx and CO_2 show a consistent elevation during these periods compared to annual averages. The combined effect of calendar and meteorological events exemplifies the sensitivity of urban air quality to behavioural changes in driving patterns. This reinforces the necessity for comprehensive monitoring and adaptive traffic management strategies to mitigate adverse environmental impacts.

Improving air quality and environmental health inequalities in a metropolitan area of the United Kingdom

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Keywords: air quality, population weighted exposure, index of multiple deprivation, inequalities

Associated conference topics: 1.1, 1.3

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There is growing evidence of substantial public health impacts of air pollution at low levels, leading to the update of the WHO Global Air Quality Guidelines in 2021, significantly reducing the guideline concentrations of pollutants above which health impacts occur. The UK Environment Act 2021 established a legally binding duty on UK Government to bring forward new Environmental Targets for fine particulate matter ($PM_{2.5}$) comprising both an annual mean concentration and Population Exposure Reduction Target for achievement by 31 December 2040. However, the benefits of these targets for reducing inequalities related to air pollution exposure remain undefined. Using the West Midlands Combined Authority (WMCA) population (~2.9 million) as an example, we demonstrate impacts of population exposure to $PM_{2.5}$ and implications for air quality related inequality in this diverse, metropolitan UK region. We identified that ~41% of the WMCA population in 2019 live in areas where $PM_{2.5}$ concentrations exceeded the long-term annual mean concentration target of 10 μg/m^3, to be achieved by 2040. We identify the Population Weighted Exposure Level (PWEL) for $PM_{2.5}$ concentrations to be significantly higher for those living in areas of high socio-economic deprivation. We further applied three different air quality scenarios to assess population impacts. The greatest benefits of regional air quality policies which reduce $PM_{2.5}$ concentrations will be delivered in the most deprived and densely populated areas. Those living in Birmingham and Sandwell local authority areas will experience the greatest population-level benefits from reduced $PM_{2.5}$ concentrations. Our findings suggest that coordinated regional actions to improve air quality, which deliver $PM_{2.5}$ reductions in areas of both high baseline exposure and population density, will deliver the greatest benefit for reducing health inequities.

Towards a just transition: Delivering healthy net zero homes

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Associated conference topics: 4.1, 1.1, 2.3
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Housing in the UK is responsible for ~20% of total UK greenhouse gas emissions [1]. With the UK Government committed to achieving Net Zero by 2050 [2], decarbonising the UK housing stock is essential to meet these goals. To do so the UK Government has already outlined a strategy for as many homes as possible to achieve an EPC band C by 2035 [3]. This will require a huge campaign of retrofitting, with The Climate Change Committee estimating 15 million homes requiring insulation, and 8 million draughtproofing [4]. Both the scale and quality of the implementation of these retrofits will play a critical role in the UK achieving its Net Zero targets.

To ensure that Net Zero is achieved fairly, and that no people, places, sectors, or regions are left behind, there are several UK Government and devolved government administration commitments aimed at delivering a 'just transition' [5]. For the housing sector, this includes ensuring that financial support schemes are in place to lower-income households to both help them to bear the costs of retrofit, and to benefit financially from lower energy costs.

The quality of these retrofits will also play a critical role in safeguarding people's health and wellbeing. The pursuit of more energy efficient homes requires high levels of air tightness to prevent heat loss. However, high levels of air tightness can result in a significant unintended consequence: poor indoor air quality (IAQ). This dichotomy complicates the delivery of a just transition in decarbonising the UK housing stock, as without considering the potential effects of retrofit on IAQ, attempts to provide a just energy transition may lead to poorer public health. Moreover, with increasing evidence that deprived communities in the UK experience poorer IAQ [6], without careful consideration, net zero policies may exacerbate current health inequalities.

With the important goals of simultaneously decarbonising the UK housing stock, and promoting good IAQ in mind, this presentation will introduce the Clean Air Programme community to a collaborative position paper from the HEICCAM network on delivering healthy net zero homes. The presentation will outline the current state of the UK building stock with regards to energy efficiency and IAQ, how this might change with projected future retrofit scenarios under Net Zero policies, and the need for regulatory action across the different tiers of government to ensure that a just transition maximises health and climate co-benefits while leaving no one behind.

References

[1] DESNZ (2022). 2022 UK Greenhouse Gas Emissions, Final Figures. National Statistics
[2] Hirst, D., et al. (2019). Net zero in the UK. House of Commons Library.
[3] UK Government (2021). Improving Energy Performance Certificates: action plan - progress report. UK Government.
[4] CCC (2020). The Sixth Carbon Budget: The UK's path to Net Zero. CCC.
[5] Grub, H., & Wentworth, J. (2023). What is a just transition for environmental targets?. UK Parliament POST, 706.
[6] Ferguson, L., et al. (2021). Systemic inequalities in indoor air pollution exposure in London, UK. Buildings & cities, 2(1), 425.

Modelling the impacts of net zero policies on air quality and health equity in the West Midlands, UK

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Keywords: Net Zero, Air Quality, Health, Modelling.
Associated conference topics: Theme 4i or Theme 1i
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Introduction

Climate change and air pollution are closely interlinked since carbon dioxide and air pollutants are co-emitted from fossil fuel combustion. Net Zero (NZ) policies aiming to reduce carbon emissions will likely bring co-benefits in air quality and associated health. However, it is unknown whether regional NZ policies alone will be sufficient to reduce air pollutant levels to meet the latest 2021 World Health Organisation (WHO) guidelines. The purpose of this paper is to quantify air quality co-benefits of regional/local Net Zero policies at a high spatial resolution, and to assess their contribution to population attainment of 2021 WHO interim targets and air quality guideline levels and mortality and morbidity impacts, using the West Midlands, UK as a case study. Applying this approach we provide a specific example of the linkage between climate change mitigation options, air quality and health equity.

Methods

We applied the high resolution ADMS-Urban air quality model for the West Midlands (the baseline model configuration for the year of 2016 was described in Zhong et al., 2021) in this study. ADMS-Urban is an advanced air dispersion model based on Gaussian plume distribution. This model implements a physics-based approach to represent the characteristics of the atmospheric boundary layer. It can represent a variety of source types (such as road and grid emissions) occurring in urban environments and requires a range of input data (e.g. emissions, meteorological, background, street canyon and urban canopy data). The modelling cases were run on the University of Birmingham's BlueBEAR HPC using a task farming option in the model. Here, four modelling scenarios were constructed:

(1) Case "2021 BAU" represents a business-as-usual scenario (BAU) for 2021

(2) Case "2030 BAU" represents the business-as-usual scenario for 2030

(3) Case "2030 NZS" (Net Zero Scenario) takes into account further emission reductions

(4) Case "2030 EV" reflects a modification of the 2030 NZS scenario, in which we only consider transport decarbonisation actions.

We used our publicly available decision tool, the Air quality Life Assessment Tool (AQ-LAT) (Hall et al. 2024) to estimate the economic benefit of the four modelling scenarios within the WMCA.

Results

Figure 1 shows the impacts of 2030 Net Zero and road transport decarbonisation policies on NO_2 concentrations over the West Midlands compared with the 2030 BAU scenario (Zhong et al., 2023). The modelling for the Net Zero Scenario demonstrates that improved air quality will have significant public health benefits with an estimated 1,500 lives saved and 13,000 less diseases cases over the next 20 years. Further research will explore implications of different net zero policy options for reducing premature mortality and morbidity across the region, enabling prioritisation of policy pathways which optimise health co-benefits.

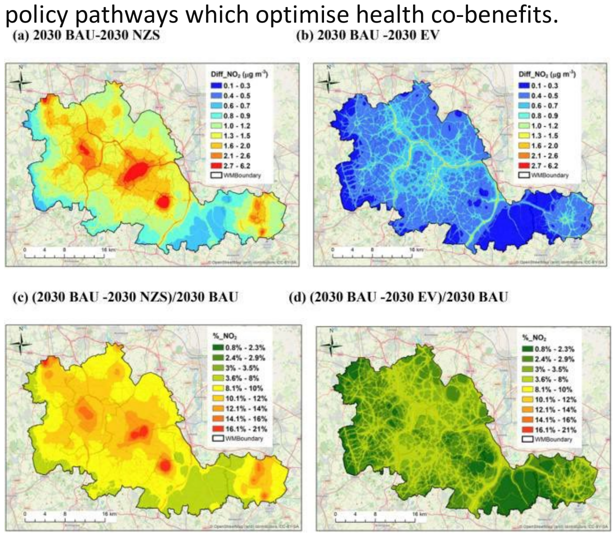

Figure 1. Reduction in annual mean NO2 (in µg m^{-3}) for (a) 2030 NZS and (b) 2030 EV scenario relative to 2030 BAU scenario; and percentage change for (c) 2030 NZS and (d) 2030 EV scenario relative to 2030 BAU scenario.

This work has been supported by Wellcome Trust WM-Net Zero (Ref: 227150/Z/23/Z), NERC WM-Air project (grant number NE/S003487/1), and NERC COP-AQ projects (grant number 2021GRIP02COP-AQ).

References

HALL, J.A., ZHONG, J., JOWETT, S ET AL. 2024. Regional Impact Assessment of Air Quality Improvement: The Air Quality Lifecourse Assessment Tool (AQ-LAT) for the West Midlands Combined Authority (WMCA). Environmental Pollution (due for release 07/05/24).

ZHONG, J., HODGSON, J. R., JAMES BLOSS, W. & SHI, Z. 2023. Impacts of net zero policies on air quality in a metropolitan area of the United Kingdom: Towards world health organization air quality guidelines. *Environmental Research,* 236**,** 116704.

ZHONG, J., HOOD, C., JOHNSON, K., STOCKER, J., HANDLEY, J., WOLSTENCROFT, M., MAZZEO, A., CAI, X. & BLOSS, W. J. 2021. Using Task Farming to Optimise a Street-Scale Resolution Air Quality Model of the West Midlands (UK). *Atmosphere,* 12**,** 983.

Adopting a whole systems approach to net zero: a participatory systems mapping case study

Authors: Naomi Bennett-Steele, Suzanne Bartington, Sarah Moller, Nigel Gilbert, Alex Penn
Keywords:
Presenting author email:

Abstract

Achieving environmental targets requires complex and multifaceted policy actions operating across multiple sectors. Understanding the interconnected links between these actions, including synergies and trade-offs requires a whole systems approach to policymaking.

The ANTICIPATE project funded by the SPF Clean Air Programme brought together policymakers, policy analysts, researchers, stakeholders from business and civil society organisations to explore policy initiatives for their consequences on air quality. The project applied Participatory Systems Mapping (PSM) in which a diverse group of stakeholders collaboratively constructed a causal model of the UK surface transport system through a series of online workshops undertaken in collaboration with the TRANSITION Clean Air Network[1].

This collaboration led to a further Wellcome Trust funded study 'Health-centred Systems Approach towards Net-Zero: Transforming regional climate mitigation policies (WM Net Zero)'. Within WM Net Zero PSM is being applied to explore stakeholder perspectives on the transition to net-zero in the West Midlands and generate policy focused outputs.

In this session we present the arising net-zero systems map and its preliminary analysis, exploring how unintended consequences of policy actions may emerge in a regional context. We conclude by considering how PSM could be integrated with policy toolkits to facilitate holistic and effective net zero policy design and appraisal.

[1]Penn, A.S.; Bartington, S.E.; Moller, S.J.; Hamilton, I.; Levine, J.G.; Hatcher, K.; Gilbert, N. Adopting a Whole Systems Approach to Transport Decarbonisation, Air Quality and Health: An Online Participatory Systems Mapping Case Study in the UK. Atmosphere 2022, 13, 492. https://doi.org/10.3

Sessions 1.5 – 1.8

Thermal comfort, air change rates and levels of particulate matter in 300 homes in Bradford: preliminary results of the INGENIOUS project

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Keywords: low-cost sensors, health inequalities, ventilation rates, thermal comfort, particulate matter.
Associated conference topics: 4.1, 2.1, 1.2
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Background

Air pollution is estimated to result in 28,000 to 36,000 deaths annually in the UK alone [1]. The UK population spends a significant fraction of their time indoors at home making this environment a significant exposure site. The INGENIOUS (understandING the sourcEs, traNsformations and fate of IndOor air pollUtantS) project has been initiated (https://ingenious.york.ac.uk/) to provide the necessary evidence for efficient behavioural, technological or policy interventions to reduce future household exposures to air pollution in the UK.

Study area

A total of 310 families have been recruited (March 2023- April 2024) from the Growing Up study [2] nested within the Born in Bradford cohort (BiB). This cohort is highly suitable from a health and exposure inequality perspective because of its sociodemographic diversity.

Methodology

Low-cost sensors: In each household, we monitor three rooms (living room, kitchen, child's bedroom) for two weeks with commercially available low-cost sensors AirGradient to measure carbon dioxide, three size fractions of particulate matter (PM) concentration (PM_1, $PM_{2.5}$, PM_{10}); total volatile organic compounds (TVOCs); and temperature and relative humidity.

Environmental, behavioural factors and health: We have collected a comprehensive database of building characteristics, behavioural patterns, health responses (and social variables), and a time-activity diary [3]

Outdoor air pollution measurements: Collected from an outdoor air pollution network around the Bradford area.

Results

Thermal conditions in Bradford homes were often below 18°C which is recommended by the World Health Organization (WHO) [4]. Below this threshold, risks for hypertension, cardiovascular disease and susceptibility to infections increase. Indoor CO_2 levels in children's bedrooms often exceeded 1,000ppm indicating reduced ventilation rates potentially resulting in the built-up of indoor pollutants. A novel method has been developed to separate the indoor- and outdoor-generated components of total indoor exposure to PM (Figure 1).

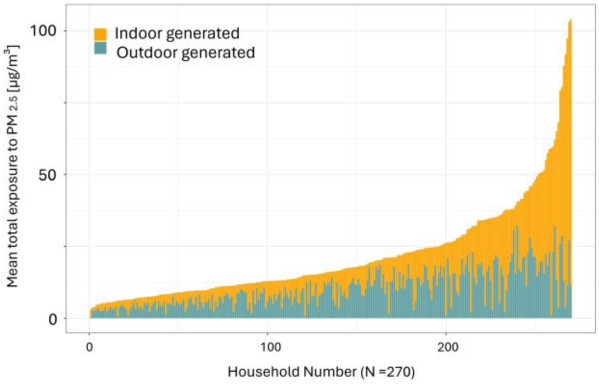

Figure 1. Mean residential exposure to PM2.5 in 270 households in Bradford. Daily mean concentrations often exceed the recommended 15 µg/m³ guideline value [5]

We found large variability between houses driven by environmental, behavioural and meteorological factors. Both indoor and outdoor sources contribute significantly to total residential exposure.

Future work

The UK still has one of Europe's oldest and least energy-efficient housing stocks. The INGENIOUS comprehensive database enables us to investigate potential interactions between thermal comfort, ventilation rates, particulate matter and health and inequalities now and as we adapt to a changing climate.

INGENIOUS is funded by UK Research and Innovation Natural Environment Research Council (NE/W002256/1). Ethical approval has been obtained from the NHS Health Research Authority Yorkshire and the Humber (Bradford Leeds) Research Ethics Committee (22/YH/0288).

References

[1] Office for Health Improvement & Disparities. (2022)
[2] Bird, P.K., et al. (2019) *BMC Public Health*, **19**, 939.
[3] Ikeda, E., et al (2023) *BMJ open*, **13**(12), e081099
[4] WHO, 2018
[5] WHO, 2023

Transforming the real-time detection and characterisation of bioaerosols

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Keywords: Bioaerosols, Real-time, Fluorescence, environmental sources, Data Analytics
Associated conference topics: 2.2, 3.2, 4.2
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Understanding both the physico-chemical and the biological properties of particulate matter (PM) is crucial for comprehending its effects on the biosphere. While substantial progress has been made in characterising the physical properties (mass, number, size) and chemical composition of PM, its biological characteristics and interactions between living and non-living components remain insufficiently studied. Specifically, there is a lack of knowledge on the identity, diversity, abundance, size distribution, spatio-temporal dynamics, and transformation of the biological component of PM, as well as the governing factors influencing cell viability, toxicity and infectivity during airborne transport. This significantly limits our understanding of the role and impact of biological PM (also termed as bioaerosols) in the context of public health (e.g. allergenicity, toxicity, infectivity), climate (e.g., light absorption/scattering) and ecosystems (e.g., nutrient transport, dispersal of reproductive units).

Current research on bioaerosols stems from disconnected scientific disciplines and the use of diverse methods designed to focus on specific characteristics. These methods include culture-based microbiology for viable cells, microscopy for spore counts and morphology, immunoassays for toxins, chromatography and mass spectroscopy for biomarkers and molecular microbiology for specific pathogens detection and quantification. While all these analytical approaches have advanced our understanding of the nature and composition of bioaerosols in different environments, they are hindered by labour-intensive sampling, complex offline laboratory analysis, limited temporal resolution due to “snapshot” sampling, and the inability to provide a comprehensive picture of the individual particles.

A paradigm shift can only be achieved through the characterisation of single particles in real-time. Among the methods developed for this purpose, single particle ultraviolet light-induced fluorescence (UV-LIF) detection systems combined with optical particle measurement (size and shape) in real-time show the greatest promise. A novel bioaerosol sensor, known as (Spectral Intensity Bioaerosol Sensor (SIBS) providing information on size, shape and highly resolved spectral information of single particles in real-time has been deployed in diverse ambient environments spanning various seasons and environmental sources. The findings demonstrate that UV-LIF based systems can detect, count and categorise different fluorescent particle types based on their size, shape and fluorophore signatures. However, the confidence in discriminating biological from non-biological particles and meaningfully classifying bioaerosols is currently limited by the relatively basic data analytics approaches currently available and the lack of well-defined, laboratory-generated training data. Addressing these challenges necessitates extensive laboratory studies to develop and validate environmentally relevant spectral libraries, advance fluorescence threshold strategies for distinguishing biological signals from non-biological noise, and develop new data analytics for discriminating between different bioaerosol classes and establishing the relationship between particle size and fluorescence spectral profiles.

This will facilitate addressing critical knowledge gaps related to discriminating interferants, elucidating the particle size-resolved molecular origin of fluorescence, assigning spectral responses to bioaerosol classes, understanding atmospheric transformations, and ageing processes, as well as enhancing our understanding of the role and impact of bioaerosols in public and planetary health. Furthermore, it will support the development of rapid bioaerosol detection and characterisation systems and forecasting platforms for public health, agriculture, and biosecurity across indoor and outdoor environments.

This work was supported by the UKRI Natural Environment Research Council (NERC) through the Environmental Microbiology and Human Health Programme (Grant references NE/M01163/1 and NE/M010961/1) and the UKRI Strategic Priorities Fund (SPF) Clean Air Programme (Grant reference NE/V002171/1).

RESPIRE: Unraveling Maternal Vulnerabilities to Indoor Air Pollution

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Keywords: Pregnancy, pollution, placenta, inflammation, cytokines, RESPIRE.
Associated conference topics: 1.3, 1.1
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Air pollution is a growing health threat, significantly impacting pregnant women who are among the most vulnerable populations to their effects.

Maternal air pollution exposure during pregnancy has associations with numerous adverse pregnancy outcomes including preterm birth, low birth weight and preeclampsia. Nevertheless, the fundamental biological mechanisms underpinning these consequences remain largely unknown. Our research consortium, RESPIRE (Relating Environment-use Scenarios in Pregnancy/ Infanthood and Resulting airborne material Exposures to child health outcomes), aims to investigate the response of pregnant women to airborne material exposures and elaborate the contribution of these to adverse birth and child health outcomes.

Building on previous work by the consortium on diesel exhaust particle exposure of the placenta, the effects of the dominant indoor volatile organic compounds (VOCs) on placental and fetal membrane explant cultures are being investigated. Acetone, (-)-limonene and ethanol were tested along with metabolites of butane. Preliminary findings reveal a dose-dependent reduction in inflammatory cytokine release (IL-1α, IL-1β, TNF-α) with increasing VOC exposure concentration, when co-exposed to the prototypic inflammatory stimuli lipopolysaccharide (LPS; 10 ng/mL). No inflammatory response was stimulate d with VOC exposure alone, revealing a potential heightened vulnerability to infection in the presence of VOC pollution, which requires further investigation. The intersection with hypoxic conditions will now be explored as a model of pre-eclampsia and fetal growth restriction.

Additionally, a variety of primary samples are being collected from healthy pregnant and non-pregnant individuals including nasal epithelial lining fluid (NELF), nasal epithelial cells, exhaled breath condensate (EBC), saliva, blood and urine for a systemic analysis of barrier function, pollutant metabolism and excretion.

Current ongoing work includes air-liquid interface (ALI) culture of nasal epithelial cells from pregnant and non-pregnant donors. Aerosolised pollutant exposures will be applied to ALI cultures and barrier function and inflammatory responses compared between pregnant and non-pregnant donor groups.

Overall, preliminary findings suggest that indoor VOCs induce a reduction in LPS-stimulated pro-inflammatory cytokine release from placental and fetal membrane explants with implications for host defence at this important interface between mother and baby.

A Mixed Methods Study to Determine the Sources and Impact of Indoor Air Pollution in Patients with Chronic Respiratory Disease.

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Keywords: Asthma, Chronic Obstructive Pulmonary Disease (COPD), Indoor Air Pollution, Quality of Life, Respiratory
Associated conference topics: 1.1, 1.2, 2.3
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Patients with Chronic Obstructive Pulmonary Disease (COPD) are adversely affected by indoor air pollution (Li et al., 2016). However, a recent systematic review literature showed that there is little research into vulnerable groups more broadly, and that there are gaps in knowledge on specific indoor exposures (Maung et al., 2022). This study aims to identify environments and locations that contribute to the exposure of patients with chronic respiratory disease to poor air quality indoors and suggest practical methods for indoor air quality improvement.

This mixed methods study is based on qualitative data from 14 interviews while quantitative data was obtained from an online survey with 332 participants with either COPD or asthma. The interviews were recorded, transcribed and analysed using thematic analysis methods. Codes and categories were developed using the themes in participant opinion which the survey data highlighted. Survey data was analysed using descriptive statistics.

We found that participants generally had a good understanding of the sources of pollutants that affect their symptoms, and also had a good awareness of the locations where their symptoms generally worsen. Most participants related exposure to polluted air to a change in their respiratory symptoms (coughing, shortness of breath, etc.). However, knowledge of indoor air pollution sources and methods to reduce exposure was variable.

Overall, while respiratory patients have a good understanding of their specific symptoms and triggers, they do not have a clear understanding of sources of indoor air pollution. We have also found that a lack of knowledge, which is often caused by an age-related digital divide, could be restricting access to technological interventions which could help to improve indoor air quality.

This work was supported by Strategic Priorities Fund (SPF) UKRI Clean Air programme through the NERC network grant “Air Pollution Solutions for Vulnerable Groups (CleanAir4V)”.

References

Li, J., et al., *Major air pollutants and risk of COPD exacerbations: a systematic review and meta analysis*. Int J Chron Obstruct Pulmon Dis, 2016. **11**: p. 3079-3091.

Maung, T.Z., et al., *Indoor Air Pollution and the Health of Vulnerable Groups: A Systematic Review Focused on Particulate Matter (PM), Volatile Organic Compounds (VOCs) and Their Effects on Children and People with Pre-Existing Lung Disease*. Int. J. Environ. Res. Public Health 2022, **19**(14), 875

Challenges associated with personalising air pollution exposure models – Experience gained from the APEx study

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Keywords: indoor air quality, exposure, modelling, vulnerabilities
Associated conference topics: 1.1, 2.2, 2.3
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Background

The risk to health of poor air quality and its impacts is disproportionally suffered by vulnerable groups, such as children, the elderly and those with underlying health problems. This risk is heightened by the impact of poor quality buildings and other unavoidable socio-economic vulnerabilities. Despite this, current methods for assessing the impact of clean air policies are entirely based on outdoor air quality, without considering human behaviours or susceptibility. The SPF APEx study ("An Air Pollution Exposure model to integrate protection of vulnerable groups into the UK Clean Air Programme") aimed to place people at the centre of the problem by creating an exposure model that more accurately reflects the air that people breathe as they interact with their city. This fundamental shift in the way that the impacts of air pollution exposure is assessed creates significant methodological problems that need to be overcome.

Methods

The APEx study merged existing advanced urban models of air pollution, meteorology, buildings and urban form and (agent-based) human behaviour to create a framework for estimating how the different micro-environments experienced by people in their everyday lives would impact on profiles of exposure to air pollution. The model was evaluated using an extensive database of personal exposure measurements gathered from campaigns carried out in London and Birmingham. Surveys comprising representative samples of London and Birmingham were carried out to ensure that human behaviour was correctly reflected in the model, including how citizens perceive the risk of exposure to air pollution and how they may (or may not) change their behaviour in response to exposure. The model was applied to specific policy scenarios, including the London Ultra Low Emission Zone.

Results

The merging of four established urban models incorporating physiochemical, behavioural and geographical processes required complex alterations to software structure. These adjustments were required to ensure compatibility of spatial and temporal scales. The use of increasingly individualised administrative datasets led to barriers to data sharing relating to ethical and GDPR restrictions. These practicalities prevented the creation of a singular model hosted by one organisation.

Personal exposure models do not aim to recreate exact duplicates of individuals and their behaviours, more patterns of exposure representative of population subgroups. This makes evaluation of such models very challenging – as measured exposures (time and space) are not directly comparable to modelled exposures. Similarly, model outputs are a function of the parameterisations used (e.g. representative of only a subset or aggregation of the full range of individual behaviours and perceptions). Thus, observational data typically will have a larger range than model outputs, which often produce fractional differences in exposure categories, making interpretation of results challenging.

Conclusion

While personal pollution exposure models present many opportunities to improve the equity and impact of environmental assessments and policy evidence, they have significant challenges relating to complexity, interpretation, ethical constraints (e.g. data availability) and numerous compounding model uncertainties.

WellHome: A Community-Based Study for Investigating Indoor Air Pollution in an Urban Community in London

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Keywords: indoor air quality, community engagement
Associated conference topics: 2.3, 3.1, 1.2
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Objective

While indoor environments are integral to daily life, air pollution research predominantly centres on ambient measurements. The scarcity of indoor air pollution studies is, in part, because conducting research in home settings demands active public participation. The WellHome study aims to identify predominant indoor air pollution exposures to children and adults in vulnerable urban communities, emphasising community involvement in co-designing feasible and acceptable research methodologies.

Methods

Engagement activities were conducted with the local community to raise awareness of air pollution and its impacts on health. Collaboratively, a sampling methodology was developed with input from recruited families, to measure particulate matter ($PM_{2.5}$) at a high time resolution (1 minute) in kitchens, child bedrooms, and living rooms across 100 households over two seasonal 28-day periods. The first measurement period has been completed. Data on household sociodemographic characteristics, housing types, ventilation practices, and cleaning behaviours were recorded.

Preliminary Results

Over 60% of recruited households are from minority ethnic groups, with 62% of the families reporting at least one child with asthma or allergies. On average, $PM_{2.5}$ concentrations were higher at weekends than weekdays: bedroom (23%), kitchen (32%), living room (30%). During the week, evening mealtime increased $PM_{2.5}$ in most homes. Between midnight and 7am $PM_{2.5}$ were lower in the bedroom (-9% vs. daily mean), kitchen (-42%), and living room (-33%), suggesting a lower ventilation rate in the bedroom, resulting in a slower decline in evening sources. Ongoing analysis will explore connections between these findings and participant behaviours and health symptoms. Initial results are now being communicated to participants through co-designed reports, incorporating clear recommendations for improving their household air quality.

Conclusion

These preliminary findings highlight locations and times within participating households where air pollution peaks are most prevalent and emphasise the importance of adequate ventilation in the home.

Next steps

$PM_{2.5}$ results will be combined with a suite of additional metrics simultaneously gathered in each home, including bioaerosols, chemical contaminants, microplastics, temperature and humidity. Outcomes will be used to investigate links between childhood asthma symptoms and home environment and produce improved air quality models incorporating resident behaviours, ambient infiltration and indoor sources.

The impact of air change rates on the indoor air chemistry of homes in Bradford: a modelling study within the INGENIOUS project

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Keywords: Indoor air quality, air change rate, ventilation, VOCs, modelling.
Associated conference topics: 2.3, 1.2
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A major parameter in driving indoor air quality (IAQ) is the air change rate (ACR)[1], the rate at which the air volume of a room exchanges with outdoor air. As we adapt to a changing climate, the decarbonisation of the residential building stock to reduce energy consumption is a priority and requires us to build and retrofit our houses to more airtight standards with lower ACR[2].

Estimating dynamic ACR in occupied buildings can be challenging as they are often modified by occupants primarily in response to thermal comfort or perceived poor indoor air quality, typically by opening windows or adjusting the mechanical ventilation systems[2].

While increasing ACR can generally reduce indoor-generated pollutants, it can also increase indoor levels of outdoor-generated harmful pollutants. Outdoor air has higher levels of ozone, which leads to higher ozonolysis reactions, transforming the double-bonded volatile organic compounds (VOCs) from anthropogenic indoor sources into further VOCs (Fig. 1) and particulates[3,4]. It can also deposit onto indoor surfaces, oxidising the surface chemistry and releasing further products into the atmosphere[5].

The complex system of indoor air chemistry can only be fully understood through a holistic approach using lab-based experiments, in-home measurements, modelling and behavioural analysis of occupants. This work was conducted as part of the INGENIOUS study in collaboration with Born In Bradford[6].

In this study we investigate the impact of ACR on the IAQ of homes in Bradford while cooking using the Indoor Chemical Model in Python (INCHEM-Py)[7,8]. The model predicts the evolution of indoor air chemistry in zero dimensions by creating and solving a series of ordinary differential equations representing over 6000 chemical species. We analyse the primary and secondary pollutants created via cooking typical meals using laboratory measured and calculated emission rates input into INCHEM-Py. ACRs are calculated from the decay of CO_2, measured by low-cost sensors in real homes in Bradford. Primary and secondary indoor pollutants are varied within the model to both typical background levels and reactively to high indoor air pollution. Outdoor air quality is also adjusted to resolve its impact on IAQ using measured pollutant concentrations taken by Bradford City Council.

Results from the modelling study are discussed in relation to occupant behaviour, modelled with an automated classification method using measurements from the low cost sensors and validated through occupant diaries and questionnaires[6].

As currently there is little understanding on the effects of indoor chemistry on health, this revolutionary approach integrates low-cost measurements with detailed chemical speciation to create a powerful modelling framework of exposure during daily life that would be impossible to capture with reference-grade instruments at large-scale.

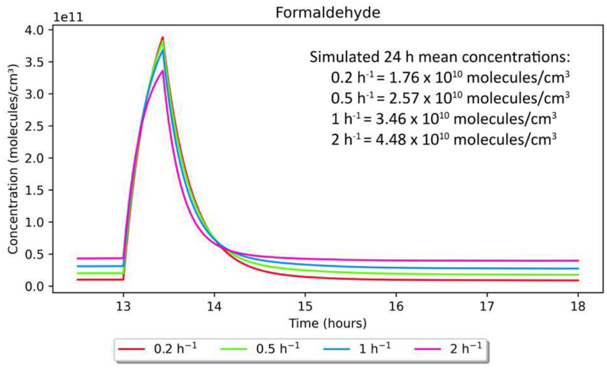

Figure 1: Formaldehyde peak from cooking a beef chilli with different ACRs.

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1 Kruza, M. *et al. Atmos. Environ.* 262, 118625 (2021)
2 Crawley, J. *et al. Build. Serv. Eng. Res. Technol.* 40, 274–289 (2019)
3 Davies, Helen. L. *et al. Environ. Sci. Process. Impacts* 25, 1532–1548 (2023)
4 Carslaw, N. *et al. Environ. Sci. Process. Impacts* 21, 1313–1322 (2019)
5 Carter, T. J. *et al. Atmos. Environ.* 297, 119598 (2023)
6 Ikeda, E. *et al. BMJ Open* 13, e081099 (2023)
7 Shaw, D. R. *et al. Geosci. Model Dev.* 16, 7411–7431 (2023)
8 Shaw, D. *et al. J. Open Source Softw.* 6, 3224 (2021)

Exploring the Chemical Characteristics of Particulate Matter in Real Household Environments in Bradford, UK

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Keywords: indoor particulate matter, particulate matter composition, two-dimensional gas chromatography, Chemical Ionization Mass Spectrometer, computer modelling
Associated conference topics: 2.iii, 2.ii, 1.ii
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Exposure to particulate matter is a significant contributor to ill health and mortality in the UK and globally, with a significant fraction inhaled indoors (UK Chief Medical Officer, 2022). In addition to the ingress of particles of outdoor origin, indoor sources of particulate matter enhance exposure (National Academies, 2024). Understanding the properties of particulate matter present in residences is therefore key to quantifying health impacts of poor air quality. Here we present detailed observations of particulate matter (PM) chemical characteristics from UK households and test their reproducibility with an indoor air quality model as part of the Understanding the sources, transformations and fates of indoor air pollutants (INGENIOUS) project.

To observe the chemical profile of indoor PM and provide insights of the primary contributors to indoor PM pollution, two measurement techniques were employed.

First, Minivol Tactical Air Samplers were deployed within the kitchens of residential homes, operating at a flow rate of 3 litres per minute (l/min) for 72-hour intervals in order to collect particulate matter onto PTFE filters. Following this, sample filters from 50 homes were extracted and analyzed by two-dimensional gas chromatography coupled to time-of-flight mass spectrometry (GCxGC-TOFMS). Targeted quantification analysis was conducted by using calibration standards of known toxic compounds.

Second, sample filters from 100 homes underwent analysis using a thermal desorption approach, wherein a 25mm punch was cut and analysed using the Filter Inlet for Gases and Aerosols coupled to a Chemical Ionization Mass Spectrometer (FIGAERO-CIMS). Mass spectra obtained from laboratory experiments of different emission sources, including biomass burning, cooking activities and cleaning, were utilised as references for source apportionment of the FIGAERO-CIMS results.

Using emission data from literature, and household activity diaries, the CHemistry with Aerosol Microphysics in Python model (PyCHAM) (O'Meara et al. 2021) was tested against these new observations for: i) presence of specific compounds, ii) abundance of specific compounds and compound groups, and iii) estimated toxicity of PM.

This study provides unparalleled chemical detail of particulate matter in UK residences, improving both the accuracy for toxicity estimates and the benchmark for testing models against. These findings will assist policy-making processes aimed at mitigating the harmful effects of indoor air pollution, ultimately safeguarding public health, and promoting healthier indoor environments for all.

This work is part of the INGENIOUS (UnderstandING the sourcEs, traNsformations and fates of IndOor air pollUtantS) project and has been funded by the Natural Environment Research Council (NERC) under grant numbers: NE/W001993/1; NE/W002019/1; NE/W002159/1; NE/W002248/1; NE/W002256/1.

Health Risks of Indoor Exposure to Fine Particulate Matter and Practical Mitigation Solutions. National Academies of Sciences, Engineering, and Medicine; Committee on Health Risks of Indoor Exposures to Fine Particulate Matter and Practical Mitigation Solutions, National Academies Press (US), 2024
O'Meara, S.P., et al. (2021) *Geo. Mod. Dev.* 14, 675-702.
UK Chief Medical Officer's annual report: air pollution, Department of Health and Social Care, 2022

A study of cooking and cleaning activities with the MBM-Flex indoor air quality model

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Keywords: indoor, cooking, cleaning, emissions, modelling.
Associated conference topics: 2.3, 1.2, 1.3 (up to three conference topics for review and allocation)
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Indoor air quality is an important health concern, given the most people typically spend the majority of their time inside homes and workplaces.

The processes that control the emissions, formation and removal of pollutants indoors are significantly different than the equivalent processes outdoors, and therefore different modelling tools are needed to study them.

In this study, a new model was developed to investigate indoor air quality. The MultiBox-Flexible Model (MBM-Flex), includes chemical reactions, emissions, indoor-outdoor exchange, inter-room transport, and other relevant indoor processes in a series of connected rooms that represent a house or a building.

The MBM-Flex model can use chemical mechanisms of variable complexity, based upon the Master Chemical Mechanism (MCM v3.3.1), and the INCHEM-Py single room model (v1.2), from which it is derived. These features make the model scalable and flexible, with the ability to represent indoor processes in a wide range of building configurations.

The MBM-Flex model was used to analyze a dataset of observations made inside the kitchen of a residential home near Birmingham (UK). During the measurement period, cooking and cleaning activities were taking place, identified by chemical markers and the activity log. Emissions for specific activities were calculated by the model to match the observations and compared to values reported in the literature. The model was able to reproduce the broad features of the measurements, using both complete and simplified chemical mechanisms.

The combination of measurements and modelling allowed a detailed investigation of the air quality impacts of cooking and cleaning activities inside a typical kitchen, including an evaluation of the exposure of occupants to potentially harmful pollutants.

Facilitated workshops to promote global collaboration for improved exposure and health impact assessment of bioaerosols

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Keywords: Bioaerosols, Collaboration, Exposure, Health.
Associated conference topics: 3.1 & 1.2/1.3
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Background

BioAirNet, one of the Strategic Priorities Fund Clean Air Programme Networks, has recognised the need for the bioaerosol community to reflect on the current challenges facing bioaerosol exposure assessment and determination of the associated cellular/molecular responses driving specific health outcomes.

Despite their ubiquitous nature and our constant exposure, our understanding of their diversity and composition in various environments remains largely incomplete. Thus, we have limited insights into exactly what we are exposed to during our daily lives and how this impacts our health, either positively or negatively. Addressing this gap requires a multidisciplinary approach to identify and prioritise and develop effective solutions.

Aim and approach

A series of virtual online workshops were conducted to bring together worldwide experts to discuss the current challenges by considering where we are now, where we need to be, and how we would get there.

We took advantage of the technological advancements and changes to working cultures over the last few years that have enabled effective remote working and facilitated the connection of larger communities from organisations across the globe.

We used professional facilitators and online tools such as Mural to enhance inclusivity, focus, reflection and productivity. Our aim was to stimulate collaborative efforts and create achievable action plans to maintain momentum beyond the workshops.

Outcomes

Our facilitated workshop approach successfully engaged 32 experts from the bioaerosol community, including delegates from across the UK, and international community (Canada, The Netherlands, Greece, Switzerland, Spain and Portugal).

Five themes were prioritised: 1) A conceptual model research tool for bioaerosol exposure and human health to better understand and link specific exposure and health outcomes; 2) A stakeholder mapping exercise combining knowledge transfer and networking to ensure the right people come together at the right time; 3) A draft proposal to allow easier knowledge transfer to facilitate sharing and collaboration; 4) A writing project to review emerging opportunities for bioaerosol measurement, and raise awareness of, and summarise current knowledge for, research prioritisation; 5) A conference style event for bioaerosols to maintain momentum by providing an opportunity to share progress and develop new ideas (Figure 1).

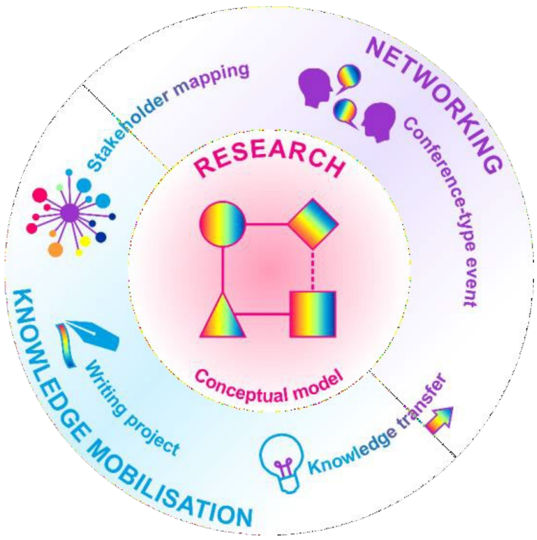

***Figure 1**. The five prioritised themes, the areas they cover and how they interact.*

All of these activities are in line with BioAirNet's aim to act as the leading voice for the UK bioaerosols science community. By adopting a transdisciplinary approach, BioAirNet seeks to unfold the complexities and connectivity between people, bioaerosol exposure and resultant health effects across the indoor-outdoor continuum.

Conclusions

Professional facilitation was a critical factor in the success of our efforts, ensuring focus, inclusivity, and the generation of actionable and achievable plans to maintain momentum post-workshops. This approach not only fosters insightful and impactful science but also contributes to consolidating partnerships tailored to address important public health challenges. With this foundation, BioAirNet is advancing bioaerosols science within the context of air quality.

The Met Office Air Quality Data Portal

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Keywords: reanalysis, website, pollution, GIS.
Associated conference topics: 1.2, 2.2, 3.1
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Clean Air Wave 1 enabled the production of a UK Air Quality Reanalysis, providing hourly gridded pollution fields for the period 2003 to 2019. The Air Quality Data Portal (AQDP) has now also been developed by the Met Office to allow users an easy route to access and interact with this dataset. The AQDP is a publicly available website, built using Esri software and uses ArcGIS mapping tools.

Reanalysis data uploaded onto the website has been aggregated into monthly time periods (although some short examples of hourly data are included), with both gridded and spatially aggregated regional data made available for download via a data catalogue functionality. Data is provided in ArcGIS feature layer format but can be converted to other formats such as csv or shapefiles for download. Users can view data in ArcGIS online maps, into which layers can be added from other datasets, for example population or health data to allow easy comparison.

Aggregated reanalysis data can be visualised and interacted with using applications built using ArcGIS online tools, such as shown in Figure 1. These include the ability to view i) timeseries for the entire reanalysis period at a specific, or a collection of grid points – this data can also be exported, ii) how the regional maps change over time, iii) filtering of maps by user defined values such as health impact limit values.

Educational content is also included on the AQDP, with story maps built using reanalysis data to describe features of air quality and science that will be of interest to a wide audience. Some maps and applications are included within these webpages to help explain the features and to allow the user to understand potential uses of the reanalysis data. These story maps include aspects such as pollutant emissions and the difference in air quality between urban and rural areas, alongside a more in-depth analysis of the August 2003 ozone episode and the April 2014 particulate matter episode.

The Air Quality Data Portal has been built with pre-existing software from Esri: this has allowed for quick development and should be simple to maintain. It is hoped that the AQDP will be useful to a wide range of users to allow them to gain greater understanding of air quality and make use of the benefits of the Clean Air UK Air Quality Reanalysis.

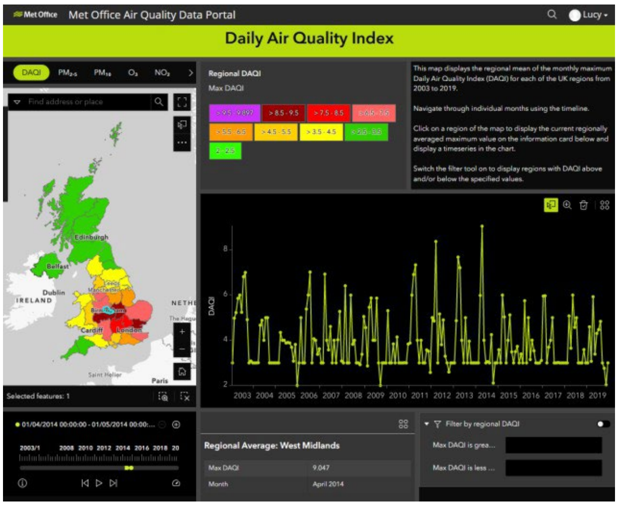

Figure 1. Example screenshot of data visualization tools used to interact with reanalysis data. This tool shows regionally averaged monthly maximum daily air quality index, with the map displaying values for April 2014 and the timeseries shown for the selected West Midlands area.

Breathe London: Evaluating behavioural and civic outcomes associated with co-designed air pollution data visualisations and messaging

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Keywords: community research, air sensors, data visualisation, hybrid network.
Associated conference topics: 3.1, 3.2, 4.2
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Presentation preference: Oral

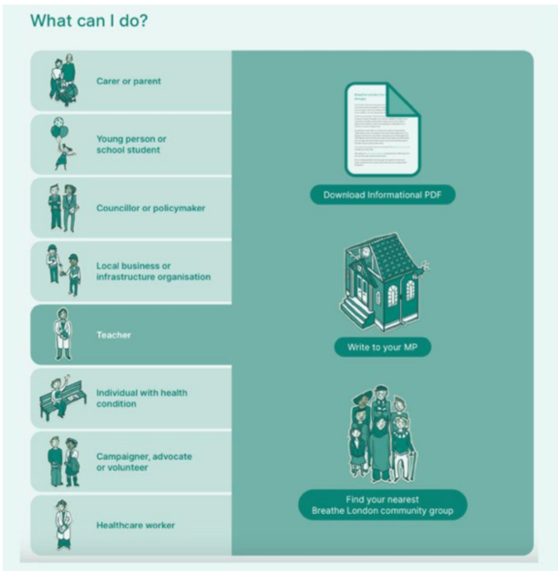
The deployment of lower capital cost sensors (LCCS) for research and non-regulatory assessments continues to expand, being applied to variety of novel conditions including those spearheaded by the SPF Clean Air Networks. However, there remains a gap in knowledge around how data from air sensors is best communicated among diverse, non-technical audiences. This presentation builds on evidence from the first three years of the Breathe London project, in addition to lessons learned around targeted knowledge exchange through the TRANSITION Clean Air network, to examine how co-designed air sensor data visualisations and action-oriented messaging are taken up by those interacting with the Breathe London platform.

Breathe London is a Greater London Authority (Mayor of London) initiative launched in Autumn 2020 comprising over 500 LCCS sensors calibrated remotely with reference monitoring stations across London. Sponsored by Bloomberg Philanthropies, 60 individuals and groups across London were awarded free sensors, ongoing technical support, and access to communal, knowledge sharing activities, with the aim of democratising air quality data generation and governance. This activity is under the banner the Breathe London Community Programme (BLCP).

Mixed methods are employed to evaluate behavioural and civic outcomes associated with access to air quality visualisations and messaging delivered via the Breathe London website. This includes a London-wide survey of 2000 individuals, a secondary survey administered through the website, user analytics data and focus groups. Regression models are estimated to understand associations between updates to the Breathe London website and specific behavioural outcomes, and whether they are mediated by social, demographic or geographic factors. Interview transcript data from focus groups with members of the BLCP was examined to generate qualitative, contextualising insight by employing discourse analysis.

Preliminary results indicate an increase in diversity of groups interacting with the Breathe London website following the implementation of updates. This reinforces the efficacy of participatory approaches in enhancing access and interaction with data and information available on the website. Ultimately, these insights serve to bolster uptake and action across the Breathe London network and related SPF Clean Air Programme initiatives where LCCS data is accessible to diverse audiences.

Figure 1. Action-oriented messaging on revised Breathe London website.



Lessons Learnt on Establishing Communities and Engaging Participants in Air Quality Studies

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Keywords: Engagement, Participants, Interdisciplinary, Communities, Cross-Programme.
Associated conference topics: 3.1, 3.2, 4.2 (up to three conference topics for review and allocation)
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In tackling the Clean Air Challenge, it is essential to understand real-world exposure to pollution, and therefore, this involves conducting research with communities and individuals. Working with members of the public can provide a wealth of information on air pollution exposure, as well as raising awareness of the topic.

Amongst the Wave 2 Consortia projects funded by the SPF Clean Air Programme: HIPTox, INGENIOUS, WellHome and RESPIRE, substantial time and energies have been dedicated to this key component of the work. In doing so, a series of challenges have been encountered. Difficulties faced include identifying how best to contact participants and how to maintain engagement. A specific problem found was that tackling indoor air pollutants in the home can be a low priority for vulnerable populations who may be living in cold homes or with damp and mould.

Collectively the Wave 2 projects have come together with the Clean Air Champions and the Clean Air Programme Knowledge Exchange Team to share their experiences on working with communities. The aim of this collaboration is the generation of a publication and "how-to" guide on what challenges can be expected and how to mitigate or minimise these. Ultimately through the sharing of ideas, the outputs generated here can aid future projects and reduce time spent on tackling challenges that have already had solutions and workarounds established.

In order to generate these outputs a scoping workshop was held between the Clean Air Programme and the Wave 2 Consortia projects in which participants shared:

i) The biggest challenges they have faced.
ii) What steps they implemented to overcome these challenges.
iii) What they wish they knew at the start of the project and what they would do differently if starting over.

As a secondary component the barriers surrounding interdisciplinary research were also addressed. In the sphere of Air Quality Research working across the Physical Science/Health Science boundary gives insight into the bigger picture surrounding air pollution, its composition and its potential health implications. However, seeking ethical approval, accessing existing cohorts and health data remains challenging for those unaccustomed to it. Key lessons from those working in this space will be presented to support physical scientists to navigate working in a health-oriented project.

Facilitating future air quality research is a key objective for establishing legacy of the SPF Clean Air Programme. The co-operative efforts presented here contribute to the achievement of this goal.

Innovate UK, Kevin O'Malley

1. **Name of SPF project:** This covers the whole innovation workstream
2. **Title of abstract:** Realising the Potential of the UK's Clean Air Tech Sector
3. **Name of Author(s):** Kevin O'Malley
4. **Theme(s) chosen in order of priority:** Innovation, clean air tech, business, jobs and growth, export
5. **Presentation preference: Oral, Poster, No preference:** Oral
6. **Multiple oral presentation, priority order:** Innovate UK introduction followed by 4 business case study presentations

Abstract

The UK has an internationally respected business innovation ecosystem well equipped to develop new products and services to address complex strategic challenges like harmful air pollution. Bringing the Clean Air Tech communities creative entrepreneurism to bare against the Clean Air challenge will not only deliver better health outcomes but could also see significant economic benefits for the country, and even unlock international opportunities for UK businesses to prosper abroad while improving air quality across the world.

This presentation will set out an introduction to the nature of the Clean Air Technology sector in the UK, its economic and environmental potential in the UK and abroad, and some of the steps we all might take to help the sector be more successful.

This 10 minute introduction will be followed by 4 case studies (10 mins each) from businesses who are prospering and delivering impact as a result of their support from the Clean Air SPF Programme.

Air pollution and children's respiratory health: What we know and what we need to know.

Professor Jonathan Grigg
Queen Mary University of London

The most important chemical pollutants in outdoor air are; particulate matter (PM) i.e. soot (carbon)-containing PM, which in urban areas is mainly from traffic (especially diesel engines), nitrogen oxides, which are generated either by traffic, or by chemical reactions in the atmosphere, and ozone, formed when other pollutants react in the atmosphere. PM under 10 microns in aerodynamic diameter (PM_{10}) is the size fraction that is inhalable and therefore most likely to reach lower airway cells. Epidemiological studies have identified a wide range of associations between either PM_{10} or nitrogen dioxide (NO_2) and adverse effects on children. These studies have found; i) children living in highly polluted areas are four times more likely to have reduced lung function in adulthood, and improving air quality halts and reverses this effect, ii) young children living in polluted areas have more coughs, wheeze, and pneumonia. And at school-age, children exposed to traffic-related air pollution (TRAP) are at increased risk of not only developing atopic asthma but also of more serve symptoms. Effects on mental and physical development have also been reported.

Some of these epidemiological findings are supported by mechanistic studies. For example, we have shown that exposure of airway epithelial cells to PM_{10} increases expression of the receptors used by bacteria and viruses to adhere to airway cells, and in an animal model, have shown that exposure to PM_{10} increases pneumococcal airway infection. Associations have also been reported in healthy children between an increased amount of black carbon (i.e. PM_{10}) in lower airway macrophages and reduced lung function.

Children are not only also exposed to air pollution outdoors, but also in homes. Our review of indoor air pollution focussed on indoor-generated emissions such as volatile organic compounds (VOCs) and formaldehyde from materials used to construct and decorate buildings, and emissions from fires, candles and cooking creates which generate PM_{10}, gases, and VOCs, and emissions from cleaning products. From epidemiological data, we concluded that effects of indoor pollution in infancy includes increased risk of wheeze, rhinitis, and respiratory infections, and a wide range of respiratory problems, as well as eczema, and reduced cognitive performance in older children.

Although we do not need any more epidemiological studies for policy makers to act to reduce toxic emissions from traffic, some questions remain. First, is PM from different sources equally toxic to children? This is a key question when considering the effects of, for example, yellow dust generated from the deserts of Northern China, a proportion of which falls into the PM_{10} size range. Significant exposure to non-fossil fuel PM also occurs in some subway systems such as the London Underground, and indoor PM from cooking with biomass is a major problem in the Global South. Second, what is the effect of NO_2 *per se*? Although there is no doubt NO_2 is an excellent marker for traffic-derived pollution, epidemiological studies have found it difficult to tease out its independent effect from PM_{10}. However, studies of indoor-generated NO_2 provide convincing evidence that it is toxic to children. Third, what are the emerging air pollution threats due to climate change? In some areas, increased exposure to natural dusts will occur, in other areas there will be increased exposure to a mix of pollutants and allergens.

References

https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution

https://www.rcpch.ac.uk/resources/inside-story-health-effects-indoor-air-quality-children-young-people

Innovate UK, Kevin O’Malley

1. **Name of SPF project:** This covers the whole innovation workstream
2. **Title of abstract:** Realising the Potential of the UK’s Clean Air Tech Sector
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Title: Educating Health Professionals on Clean Air - Reflections and Evidence from 5 + pilot projects. Considering Next Steps in this Campaign

Authors: Dr Malcolm White, Catherine Kenyon, Laura Burgess

Global Action Plan have successfully taught hundreds of healthcare staff and students about the health harms of air pollution since 2020, both in formalised projects and by speaking for numerous webinars of national significance. The greatest success has been in demonstrably, significantly increasing the knowledge and confidence of those we teach about air pollution, and the ways in which they can pass this learning on to their colleagues and patients. Our pilots have covered respiratory, paediatric, primary care and maternity staff groups, with plans for cardiology staff in 2024. We have also run pilots focused locally, or nationally. In Islington, London a wraparound air pollution awareness campaign ran, and from surveying patients it implied that these measures help change patient behaviours to breath cleaner air.

We have created numerous resources including leaflets, posters, banners, etc. for use by healthcare staff when talking to their patients. These are all reviewed by the UKHSA for scientific rigour and validity. The resources have proved very popular with organisations such as the royal colleges of physicians, etc and are freely available. Clean Air Knowledge Hub for the Health Sector (actionforcleanair.org.uk). The resources have gone through several iterations in order to consistently improve for staff and patients. We have often partnered with other organisations such as Imperial College London, many local authorities, DEFRA, the UK health Alliance on Climate Change and more.

GAP's wider campaign goal in this space is that learning about air pollution is included in the curricula of healthcare staff at all levels. We are onboarding likeminded colleagues and organisations who understand the issue to join our call for air quality knowledge placement in the education of our staff and students.

Ten questions concerning the future of residential indoor air quality and its environmental justice implications - HEICCAM Early Career Researchers collaboration

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Keywords: Indoor air quality, environmental justice, net zero impacts, social and material infrastructures
Associated conference topics: 1.1, 2.3, 4.1
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This work has been conceptualised by an early career researcher forum with the HEICCAM network. The 16 authors encompass a number of career stages from PhD student, to postdoctoral research associates, to lecturers, with contributions from investigators within the network. The collective interdisciplinary expertise of this work spans atmospheric sciences and technology, the built environment including building physics and architecture, public health epidemiology, social science, and stakeholder engagement.

We have combined our expertise in indoor and outdoor air pollution measurements and modelling, building design and airflow, exposure assessment in the indoor and outdoor environment and health effects of air pollution, social responsibility around occupant behaviour, and environmental justice to address ten questions concerning the future of residential indoor air quality and its environmental justice implications.

Humans spend a large proportion of their time at home, where exposure to indoor air pollution has detrimental and unequal impacts on health and wellbeing. Dramatic changes to residential environments are expected in the coming decades, including from the effects of net zero policies, technology, and climate change. However, it is unclear how changes to residential environments will affect indoor air quality, and whether they will differentially impact people of different socioeconomic groups, and vulnerabilities.

When addressing the questions e pay attention to diverse forms of environmental justice in relation to indoor air quality exposures, including distributive, procedural, recognition, capabilities, and epistemic dimensions.

The ten questions specifically address; the importance of indoor air quality, including its sources, modifiers, and health impacts; how changes in climate, policies, behaviours, technologies, populations and demographics might affect residential indoor air quality; and the role that different physical and social infrastructures and sectors of society can play in improving indoor air quality, including buildings and technologies, behaviour change, policy, and research.

Sessions 2.1 – 2.5

A reanalysis of air quality in the UK

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Keywords: long-term, hourly, pollutants, consistent, dataset
Associated conference topics: 2.2, 1.2
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Pollutant concentrations can be measured in a wide variety of ways, ranging from ground-based monitoring stations to satellite instruments, but these observations are often limited in time, or space, or both. Atmospheric chemical transport models provide an opportunity to study pollutant concentrations over long timescales and over a large spatial area. Rapid advancements in computational capabilities and scientific understanding mean that these models can quickly evolve, so model datasets often lack consistency over long timescales. This lack of coverage and lack of consistency across both observational and modelled air quality datasets make long term investigations, particularly health impact assessments, very challenging.

Under Wave 1 of the SPF Clean Air Programme, a reanalysis of air quality across the UK has been produced. This combines both model data and air quality measurements to generate a long-term, consistent air quality dataset covering the whole of the UK. The model and statistical post-processing system that the Met Office uses to generate the national air quality forecast is ideally suited for this purpose. In reanalysis mode, the system uses analysis meteorology and pollutant observations valid at the same time to produce an improved representation of atmospheric pollution at the time in question.

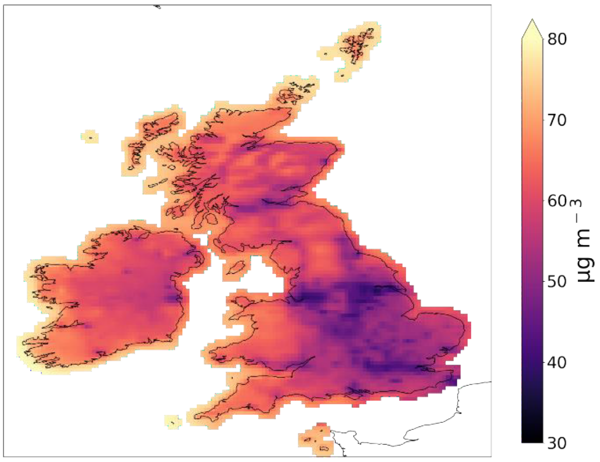

Figure 1. Map of the annual mean ozone (O_3) concentrations for 2019 from the UK air quality reanalysis, illustrating the horizontal domain and resolution of the dataset.

The reanalysis configuration of the model has currently been run from 1st January 2003 to 31st December 2019, and will be extended forwards in due course to cover more recent years. The surface level model data is constrained using observations from ground-based monitoring networks to generate an hourly, gridded dataset of atmospheric composition over the UK. These reanalysed surface concentrations provide significantly improved representations over raw model output, whilst also providing the spatial and temporal coverage that is not possible from the observational data alone.

The temporal and spatial coverage of the reanalysis data, as well as its consistency, make it suited for use in a wide range of applications. It is especially suited for studies looking at the relationships between ambient air quality and health impacts and can be used to provide air concentration information at individual locations (representative of ambient background) up to national level. It is also well suited for investigating long term trends in pollution levels as well as looking at short term episodes of elevated pollution in greater detail.

The Multi-model Air Quality System (MAQS): description and applications

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Keywords: Air pollution, modelling, MAQS, ADMS, coupled.
Associated conference topics: 2.(i)
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Introduction

MAQS development was funded under Wave 1 of the SPF Clean Air programme to provide 'high resolution prediction capability to support personal exposure for health impacts, through national and local model developments'. Cambridge Environmental Research Consultants (CERC) developed this coupled air quality modelling system, with beta testing during the project by academic partners from the universities of Lancaster, Edinburgh and Birmingham, who also ran evaluation using measurement datasets.

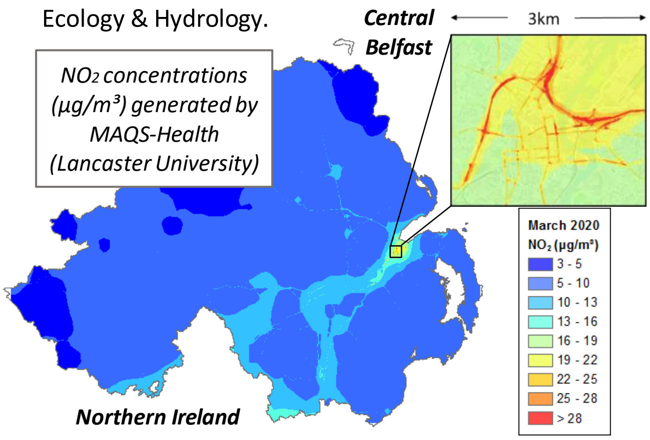
System description

MAQS novelly links a range of advanced regional atmospheric chemical transport models (CTMs), including CMAQ, CAMx, EMEP, AQUM/UKCA and WRF-Chem, to a new street-scale dispersion model, ADMS-Local, and to CERC's established ADMS-Urban model. ADMS-Local calculates spatial gradients in pollutant concentrations at street-scale resolution. The MAQS verification module enables validation of predictions against measurements especially where there are large gradients in concentration (as often found in urban environments). System outputs are available at a wide range of spatial (metres to kilometres) and temporal (hourly to yearly) resolutions; a full range of pollutants can be modelled including NO_2, $PM_{2.5}$, PM_{10} and O_3. Associated post-processing tools facilitate personal exposure and population health impact modelling using relevant metrics at local to national scales. Researchers can use the system to assess national and local policy measures, such as Clean Air Zones and reduced agricultural ammonia emissions, and also investigate health inequalities.

The Clean Air programme has a strong focus on the impact of transport on personal exposure. The ADMS-Local component within MAQS is a quasi-Gaussian dispersion model which calculates the transport of individual road source emissions. Near-field chemical reactions are modelled, and the influence of urban geometries on pollutant dispersion is included through urban canopy and street canyon features.

System applications under the Clean Air programme

During the project, MAQS was applied in Northern Ireland, Scotland and the West Midlands, coupling with CTM outputs from WRF-Chem, EMEP and CMAQ respectively. An annual average version of MAQS linked to Defra background maps was also run to generate UK-wide, regional-to-local scale air quality predictions. All system applications required spatially varying meteorological data as input; data from the Weather Research and Forecasting (WRF) model was used, supplied for some applications by the UK Centre for Ecology & Hydrology.



System potential and ongoing usage

MAQS produces comprehensive air pollutant data, and includes analysis tools that can generate metrics appropriate for health research. The tool can be used to investigate 'What if?' emissions scenarios, for example researchers from MIT / LSE / Sciences Po are working on a project investigating health and economic outcomes of road building in the Punjab (Pakistan).

MAQS has not received support funding since project completion in March 2022. The system remains a viable tool through other project applications including: a maritime transport study of the Southampton region by the University of Hertfordshire, as part of the EU EMERGE project; national air quality modelling of Ireland for the Irish Environmental Protection Agency; personal health exposure modelling by a group from HKUST; an ODA-funded air quality forecasting feasibility project in southeast Asia.

Variability of anthropogenic emissions and exposure in London: model results

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Keywords: modelling, neighbourhood scale, spatial variability, multi-scale, heat
Associated conference topics: 1.3 4.1, 2.2
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Poor air quality and heat stress are two factors with significant impacts on human health. In 2019, 99% of the global population lived in places that do not meet the World Health Organization's (WHO, 2024) air quality guideline limits, and ambient outdoor air pollution is believed to have caused 4.2 million premature deaths in 2019 alone. During the series of heatwaves between June and August in 2022 there was a 6% rise in UK deaths (*cf.* 5-year average, ONS, 2022). In urban areas, both heat and pollution are impacted by anthropogenic heat flux and emissions from vehicles and buildings.

In this contribution, we model the temporal variations by day type and age cohort of where people are likely to be, to determine how exposure will vary and derive feedbacks on anthropogenic heat fluxes.

As part of NERC APEx[1] we developed a modelling system building on DASH (Capel-Timms et al., 2020 GMD), which includes (McGrory et al. 2024):

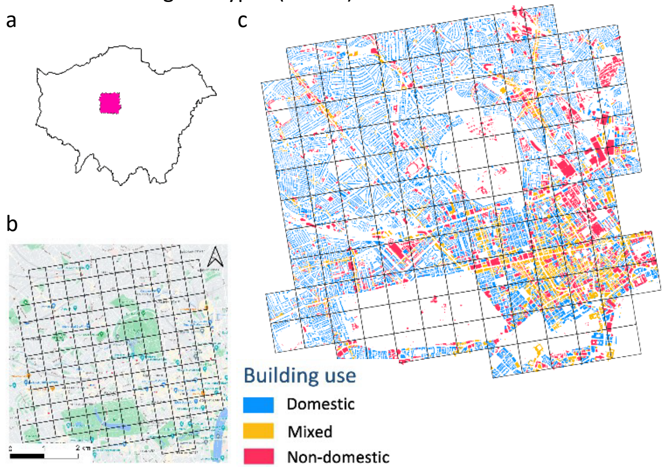
a) STEBBS: a building energy model
b) MATSDA: a transport model
c) DAVE (Dynamic Anthropogenic actiVities and feedback to Emissions): an agent-based model which captures people's behaviour and time spent in different microenvironments

The modelling system is two-way coupled to a local scale urban canopy model (e.g., SUEWS, Sun et al. 2019 GMD) which provides the meteorological forcing at appropriate heights within the canopy for each neighbourhood considering the building characteristics (e.g. height, density).

Data preparation to use this model system involves extensive data mining for each of the three sub-models (Hertwig et al. 2024), with people's dynamic behaviour informed by probabilities derived from time use surveys (Gershuny and Sullivan 2017).

We show results from a central London area (Fig. 1). In this simulation there are 327,330 individuals belonging to four age cohorts (Table 1). Peoples age impacts the likely activities that each individual undertakes and where they are likely to occur (Fig. 2). Here we aggregate results into five categories (Fig. 3), so an individual is assumed to always be in one activity type but can be at a wide range of micro-environments within this (e.g. for leisure: shops, outdoor and indoor leisure locations, other people's home; and for work: offices, primary/secondary school, university). These locations each have different characteristics that modify emissions by, for example, impacting appliances being used.

Fig. 1: London with (a) focus area (pink), (b) model domain with a grid-cell resolution of 500 m, and (c) with different building use types (colour).



Each individual is tracked in time and space (Fig. 2) so the emissions they are responsible for and exposed to, can be assessed. Individuals can change or continue their activities every 10 minutes (Fig. 2, change in colour on an individual row in time). This includes different types of activities within a home (Fig. 2). Information is additionally available of the different types of domestic buildings (e.g., terraced or semi-detached houses) and the age of the building. The latter influences building materials in the model with impact on, e.g., indoor air temperatures which affects ventilation schedules (indoor-outdoor air exchange).

[1] Also funded by ERC urbisphere, NERC ASSURE, EPSRC CREDS

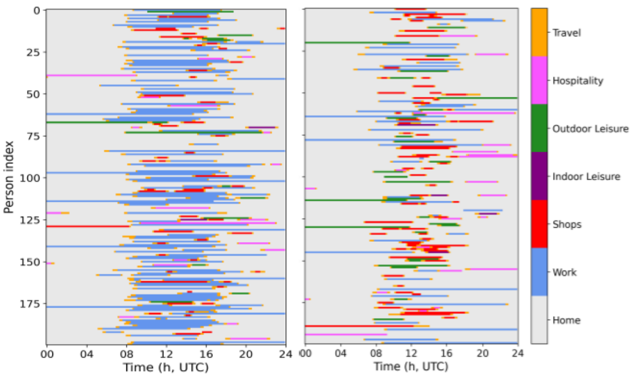
People's activities differ depending on the type of day. For example, many more adults are in work on a weekday than a weekend (blue, Fig. 2). This varies by age cohort (Fig. 3), simplified here to four activity classes (home, work, leisure and travel).

Although realistic individuals and buildings are simulated for each area, these are all probabilistic and so not 'true' individuals. The model, therefore, provides insight on the range of emissions and exposure associated to different population cohorts.

Table 1: Characteristics of the simulation undertaken.

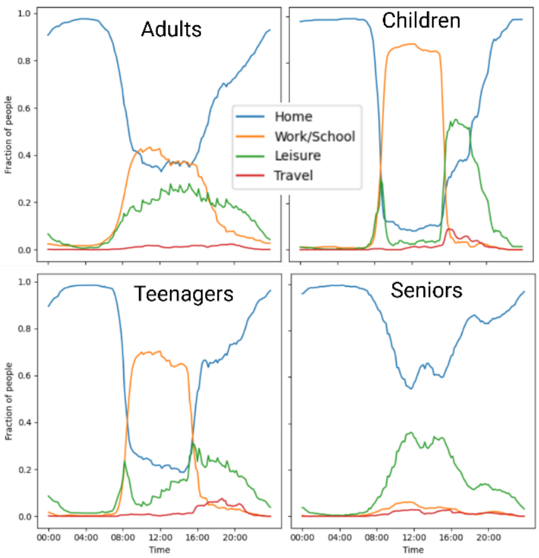
Cohort name	Age (year)	Number
Children	5-11	21,962
Teenagers	12-18	21,209
Adults	19-64	247,562
Seniors	>65	36,597

Figure 2: Example of where (colour) 200 individual adults (Table 1) spent their time (i.e. microenvironments of activity, Table 2) on two different types of day (a) weekday and (b) weekend in the same season.



(a) Weekday (b) Weekend

Figure 3: Fraction of four cohorts (Table 1) who are involved in different activities (colour) on one winter workday.



Using Machine Learning and Causal inference to evaluate the effects of London Ultra Low Emission Zone

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Keywords: Ultra Low Emission Zone, Machine learning, Weather normalization, Augmented synthetic control, Air quality policy evaluation

Associated conference topics: 3.2, 3.1, 2.1

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On 8th April 2019, London introduced the Ultra Low Emission Zone (ULEZ) (with expansion on 25th October 2021) which aims at improving urban air quality by regulating vehicular access based on stringent emission criteria. Despite the policy's ambition, investigating its effectiveness remains challenging due to the confounding weather conditions and socio-economic factors.

Here we adopt a ML-ASCM method to quantify its effectiveness. We use Machine learning method to remove the weather impact on observed air pollution concentration, coupled with the augmented synthetic control method (ASCM) to quantify the casual effect of ULEZ.

Our finding suggests the ULEZ led to a (on average) 14% reduction in NO_2 levels at traffic sites within the ULEZ, with neglectable effects on $PM_{2.5}$ concentrations. Intriguingly, a spill-over effect manifests, elucidating reduced pollutant levels even at locales peripheral to the ULEZ boundaries.

While the effects of the ULEZ expansion are not immediately evident after its implementation, as the non-compliant vehicles are decreased before the expansion.

We also found the policy announcement did not lead a reduction on NO2, which means the ULEZ policy effect is robust.

While ULEZ stands as a commendable stratagem in controlling vehicular emissions, the empirical evidence underscores an imperative for ancillary strategies to address particulate matter issues.

A Data Integration Approach to Estimating Personal Exposures to Air Pollution

Air pollution is the largest environmental risk to public health, with both ambient and household air pollution contributing substantial components of the overall global disease burden. The World Health Organization (WHO) estimates that 4.2 million premature deaths globally every year can be attributed to fine particulate matter (PM2.5). Research related to the health effects of air pollution has often been done at the population level, based on measured or modelled concentrations of ambient pollution where people reside. However, there is a need to increase our understanding of the (personal) exposures experienced by individuals as they move between different environments, such as the home, workplace or transport, throughout the day.

The Data Integration Model for Exposures (DIMEX) integrates data on daily travel patterns and activities with measurements and models of air pollution using agent-based modelling to simulate the daily exposures of different population groups. We present the results of a case study using DIMEX to model personal exposures to $PM_{2.5}$ in Greater Manchester, UK, and demonstrate its ability to explore differences in time activities and exposures for different population groups. DIMEX can also be used to assess the effects of reductions in ambient air pollution and when run with concentrations reduced to 5 $\mu g/m^3$ (new WHO guidelines) lead to an estimated (mean) reduction in personal exposures between 2.7 and 3.1 $\mu g/m^3$ across population (gender-age) groups.

$PM_{2.5}$ from domestic wood & solid fuel burning - impact from lounge to London-wide.

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Keywords: $PM_{2.5}$, Domestic wood burning, Domestic solid fuel burning, Indoor, Outdoor.

Associated conference topics: 1 (ii).

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Domestic wood and solid fuel burning (WSFB) is currently the second biggest source of $PM_{2.5}$ emissions in London and one of the main components of ambient $PM_{2.5}$ that can be influenced on a local level. This study investigated indoor, house adjacent, outdoor and city scale WSFB.

Burning was linked to $PM_{2.5}$ increases of ~175 µg m^{-3} indoors, associated with fire lighting and refuelling. However, the contribution of stoves and fireplaces to indoor $PM_{2.5}$ was found to be lower than from cooking and cigarette smoking. WSFB caused short-term peaks of up to 50 µg m^{-3} outside homes, typically up to a distance of ~10m from the chimney, again linked to fire lighting and refuelling.

Newer appliances, highly rated for efficiency and low emissions, may have advantages in terms of air quality compared with older appliances. However, emissions were detected from these also. Burning authorised and exempt fuels did not show benefits for indoor or outdoor air quality compared to burning seasoned wood in this study.

WSFB particulate concentrations were calculated from portable micro-aethalometer measurements. Hotspots detected along two transects in north and south London agreed well with modelled emissions. Agreement between measurements and reported WSFB odour demonstrated that smell can be a reliable indicator of WSFB pollution.

WSFB particulates contributed 8-9% of the total annual mean $PM_{2.5}$ at two urban background locations in London in 2022, both considered to be representative of the wider urban area. Over half was attributed to urban sources of WSFB within London with a slightly smaller contribution from WSFB in the regional background.

This study improves understanding of WSFB emissions and their role in the urban air quality landscape. Further observations and management are needed to enable progress towards meeting the WHO air quality guidelines 2021, especially for $PM_{2.5}$

Source analysis of organic compounds using flux measurements at the BT Tower, London

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Keywords: Volatile organic compounds, Traffic, eddy covariance, air pollution, particulate matter
Associated conference topics: 2.2, 2.1, 3.2
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The development of cost-effective solutions to mitigate air pollution relies of a robust understanding of the contribution from current sources. Emission estimates for many source sectors are still uncertain and this particularly applies to diffuse area sources such as those found in urban areas such as traffic, heating, domestic solid fuel/wood combustion, cooking activities, solvent use and construction activities. Although emission factors can be quantified under laboratory conditions, these may not reflect real-world conditions and little is known about some of the activity fields.

Emissions can be estimated from ambient concentration measurements, but this requires a modelling step and the relationship between emissions and concentrations depends on meteorology.

The direct measurement of emission fluxes with micrometeorological flux measurement approaches offers the opportunity to quantify and study sources more directly. Here we present fluxes of organic compounds in the gas and aerosol phase measured during the two intensive measurement periods (16-Jun to 2-Aug 2021 and 20-Dec-2021 to 22-Jan 2022) of the Clean Air SPF OSCA project (Integrated Research Observation System for Clean Air). Measurement were made from the top of London's BT Tower by combing turbulence measurements with fast-response measurements of volatile organic compounds by proton transfer reaction mass spectrometer (PTR-Qi-ToF-MS), organic aerosol components by high resolution aerosol mass spectrometer (HR-ToF-AMS) and black carbon by single particle soot photometer (SP2) to give a flux of pollutant per m^2 per hour. This flux represents the emission from an area that extends several kilometres from the tower.

These measurements were used to assess the completeness of the traditional bottom-up emission inventories for central London, for a wide range of compounds, such as primary combustion products like benzene, toluene, xylene, trimethylbenzene and acetonitrile as well as oxygenated compounds such as acetaldehyde, acetic acid, acetone, methanol and compounds with large biogenic contributions such as isoprene and monoterpenes.

In addition, we present a new analytical approach that combines pollutant fluxes to identify chemical signatures representative of specific pollutant sources such as traffic, cooking, biomass burning or solvent use, which provide source-sector specific emission estimates for the different pollutants.

For the aerosol components we show that vehicle emissions in particular have decreased significantly since earlier comparable measurements in 2007, with cooking emissions making a significant contribution to the organic aerosol flux, especially in summer.

Fluxes above London are compared with comparable measurements above Beijing, China, and Delhi, India.

Sources of the fine particulate matter ($PM_{2.5}$) in the West Midlands using multiple receptor modelling approaches

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Keywords: particulate matter, source apportionment, biomass burning, black carbon, secondary particles

Associated conference topics: 2.2, 1.2 (up to three conference topics for review and allocation)

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Atmospheric particulate matter (PM), comprising diverse chemical components, impacts air quality, visibility, and ecosystem health. $PM_{2.5}$ (diameter <2.5 µm) poses serious health risks due to its ability to penetrate deeply into the lungs upon inhalation. The World Health Organisation (WHO) recently updated its global guidelines for $PM_{2.5}$ concentration to 5 µg m^{-3} annually. Most urban areas in England exceed these standards. Current air quality action plans in the UK primarily focus on the reduction of nitrogen dioxide (NO_2), a major component of traffic emissions, through interventions such as clean air zones. However, $PM_{2.5}$ is a major driver of the health impacts of air pollution, and there are many sources of $PM_{2.5}$ other than road traffic, suggesting that other targeted measures are needed. Quantitative source apportionment, to determine the origins of the atmospheric $PM_{2.5}$ burden, provides key information to support such efforts.

This study presents a comprehensive overview on the sources of $PM_{2.5}$ in the West Midlands. The study also presents changes in $PM_{2.5}$ chemical composition and sources over time (2005-2020), comparison with independent measurements for certain sources (biomass burning vs traffic) and includes a health impact assessment. $PM_{2.5}$ samples were collected in 2021 and 2022 at two urban background sites: Birmingham Air Quality Supersite and Ladywood in Birmingham. Filter samples were analysed for OC/EC, inorganic ions, metals, and organic tracers. Black carbon measurements were also available. Positive matrix factorisation (PMF), the EC tracer method and the Aethalometer model were used for the source apportionment.

Results suggest that the majority of $PM_{2.5}$ comprised of organics (36-38%), secondary inorganics (35-36%), EC (7-10%), and dust (10-11%). Results indicate a notable decrease in the contribution (concentration) of $(NH_4)_2SO_4$ to $PM_{2.5}$, changing from 25% (2.93 µg m^{-3}) to 15% (1.5 µg m^{-3}) while the contribution of NH_4NO_3 (20-22%) to $PM_{2.5}$ remains consistent with previous findings in Birmingham. The PMF model identified seven factors: biomass burning-1 & -2, resuspended dust and traffic-related, sea salt, fuel oil combustion, secondary aerosols, and biogenic secondary organic aerosols. Biomass burning factors (25%), resuspended dust and traffic-related emissions (22%), and secondary aerosols (25%) are the major contributors to $PM_{2.5}$ mass (Figure 1). Among the identified biomass burning sources, one was associated with domestic heating, exhibiting significant temporal variation with high concentrations in winter, while the other contributed consistently throughout the year. A good agreement was observed (r^2 >0.7) between the total biomass burning contribution obtained from the PMF analysis and the Aethalometer method. Results indicate that 51% of winter primary emissions are from biomass burning activities. Based on the EC tracer method and PMF analysis, the majority of OC in Birmingham is suggested to be primary. Results of the health impact assessment, suggesting that locally targeted interventions on residential wood burning in the WMCA region could reduce the mortality attributable to air pollution and decrease life-years lost by 25%.

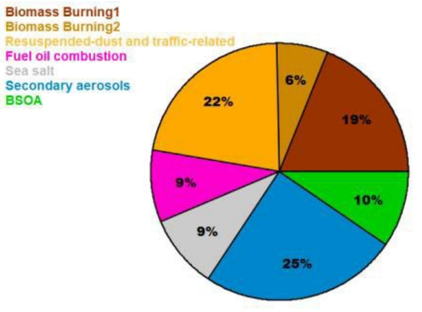

Figure 1: The average contribution of sources to the total $PM_{2.5}$ mass at both sites.

Acknowledgements: This work was funded in part through the OSCA SPF wave 1 Clean Air programme.

Urban NH_3 in the UK: Are we measuring in the right places?

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Keywords: Ammonia, long-term trends, urban environment, air quality

Associated conference topics: 2.1, 2.2, 4.2
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Ammonia (NH_3) is an unregulated gaseous pollutant in ambient air, involved in the formation of fine particulate matter (PM), known to have several health impacts. NH_3 main sources come from agricultural activities (livestock and fertilizers), but less known sources may also be important such as road traffic, biomass burning and waste management in urban environments. It is essential to improve our knowledge for a better understanding of the formation of secondary particles in urban areas, particularly for traffic sources, whose emissions could increase in the upcoming years.

NH_3 data have been collected at the air quality supersites (AQS) located at London, Manchester and Birmingham, using high time resolution instrumentation from 2019 to 2023 using automatic GLA331-EAA enhanced-performance economical NH_3 analyzer (ABB-Los Gatos Research, US) [1]. A spatial assessment of NH_3 sources near the AQS was conducted using ALPHA passive samplers [2] in Summer 2023 over three weeks in a three-day period sampling in Manchester and Birmingham.

Figure 1 shows the monthly profiles follow the expected NH_3 concentrations with spring and autumn months reflecting the impact of the regional agricultural activities background, however during winter months there are increasing concentrations in London and Manchester where biomass burning events for heating purposes may have impacted NH_3 concentrations.

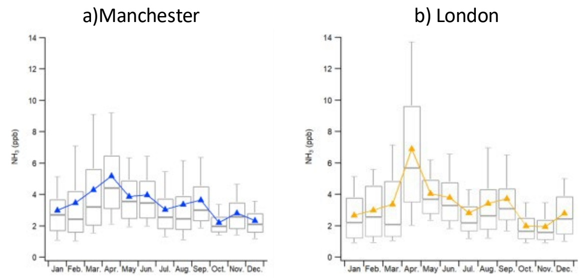

Figure 1. Monthly NH_3 profiles for London and Manchester AQS.

A spatial assessment of the potential NH_3 sources surrounding the AQS using ALPHA samplers during a three -week period showed increased concentrations in urban background sites, where point-located sources such as waste containers and urban allotments may produce occasional high NH_3 concentrations compared to background sites. Traffic sites are consistently showing higher concentrations than background and urban background sites, reflecting the impact that traffic has over NH_3 urban concentrations.

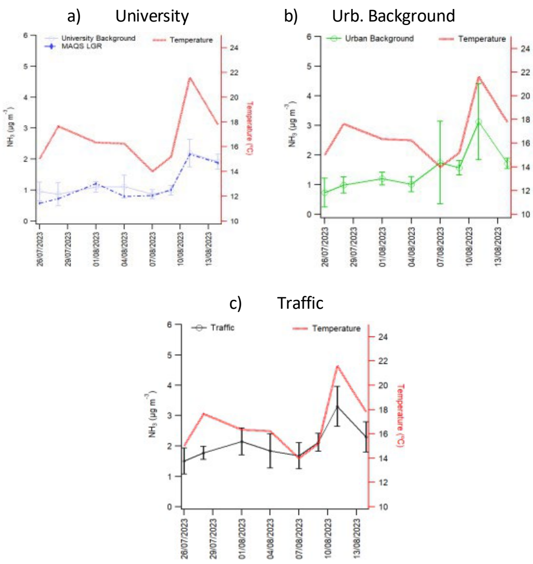

Figure 2. NH_3 averages during the spatial assessment at three site typologies in Manchester.

The findings of this work highlight the necessity for future targeting of NH_3 monitoring in UK urban areas, including new technological options and future sources of the pollution.

References

1. Twigg, M.M., et al., 2022. Intercomparison of in situ measurements of ambient NH_3: instrument performance and application under field conditions. Atmospheric Measurement Techniques 15, 6755–6787. https://doi.org/10.5194/amt-15-6755-2022
2. Tang, S., Cape, J.N., Sutton, M.A., 2001. Development and Types of Passive Samplers for Monitoring Atmospheric NO_2 and NH_3 Concentrations. TheScientificWorldJournal 1, 513–29. https://doi.org/10.1100/tsw.2001.82

Applying research to policy solutions for clean air

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Keywords: clean air, solutions, policy, evidence, advocacy.
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Global Action Plan is an environmental charity that combines research, campaigning and collective action to drive policy change on clean air. We are working in partnership with Health Equals to engage decision makers with clean air, including through opportunities such as our Clean Air Day campaign.

This session will provide participants with political insights and highlight opportunities to use their research to develop policy solutions and influence change in the real world. The session will be interactive so that participants have the time to answer some policy and advocacy challenges, which will then be fed into the clean air movement's advocacy plan for the next government.

Governments are looking for solutions to reduce the major sources of air pollution, be that from transport, domestic burning, industry and/or agriculture. They are looking for cost-effective policies that will make a difference, ideally with positive co-benefits (such as cutting carbon emissions or improving levels of physical activity) and minimal unintended consequences (such as increasing energy use). They also want to know that the solutions/policies will have public support. The work of researchers and academics is therefore critical in providing four things:

1) A strong rationale/evidence base for why air pollution is a problem and needs to be improved
2) New solutions to cut air pollutants
3) Evidence of the effectiveness of solutions/policies (new and existing) to cut air pollution
4) Evidence of the co-benefits or unintended consequences of air pollution policies/solutions.

In this session we will share the latest political insights on the priorities of those in power/likely to be in power, and the types of evidence and information they will need to receive. We will work with participants to share their evidence and insights to help build a strong case for action on air pollution.

We will then explore what are likely to be some of the priority policy areas for the next government, and how solutions for clean air can also deliver against these. We will work with participants to share their research on possible solutions to air pollution and how these could be communicated to decision makers.

Following the session, Global Action Plan will incorporate the insights, evidence and research shared into their advocacy programme, as appropriate, to influence and inform the next government following the General Election.

aqpet — An R package for air quality policy evaluation

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Keywords: Air quality policy evaluation, Machine learning, Weather normalization, Augmented synthetic control, Observational data analysis

Associated conference topics:

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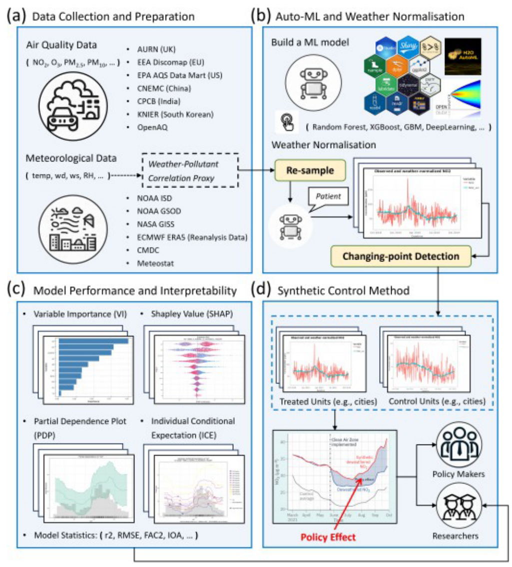
Evaluating the effectiveness of clean air policies is important in the cycle of air quality management, ensuring policy accountability and informing future policy-making processes. While understanding the effectiveness of air pollution control regulation is crucial, such evaluations are challenging to isolate the causal effect of a specific policy intervention on local air pollution concentrations due to complex confounding factors such as varying weather conditions or seasonal or annual changes in air quality unrelated to the policy implementation.

Recognising the limitations of currently available tools and the lack of comprehensive policy evaluation tools, we developed the aqpet, a R package with relatively high computational efficacy, advanced graphical delineations, and cross-platform operability for air quality policy evaluation, which enables researchers and policymakers to rapidly obtain reliable results.

The package 'aqpet' includes: (1) automated-machine learning to predict air pollutants under average weather conditions – a process term as "weather normalisation"; (2) augmented synthetic control method (ASCM) to quantify the actual policy impact on air pollution. 'aqpet' offers functions for data collection and preparation, building auto-machine learning models, conducting weather normalisation, model performance evaluation and explanation, and causal impact analysis using ASCM. 'aqpet' enables fast, efficient, and interactive policy analysis for air quality management.

'aqpet' workflow:



Presentation Preference Order:

Poster, Oral

Title: The Integrated Care System (ICS) Clean Air Framework and Clean Air Hospital Framework: Tools for the NHS to Tackle its Air Pollution Problem.
Development and the Emerging Evidence Base - Case Studies and Reflections on Challenges and Successes

Authors: Dr Malcolm White, Catherine Kenyon, Laura Burgess

Global Action Plan have been pushing for local, regional and systemic action on air pollution that helps tackle health inequalites within (and beyond) the NHS by means of both our 'Clean Air Hospital Framework' and our' ICS Clean Air Framework'.
These key tools are detailed guides on how healthcare systems at the trust or ICS level can tackle their own air pollution contributions, making their institutions safer for their patients, staff and the wider public. They align with trusts and ICS green plans for carbon emissions reduction.
You can find out more more about the ICS framework here: Action for Clean Air | ICS Framework
Only published in June 2022, the ICS framework has been downloaded by half of the ICSs in England. With those we have worked with more closely, they reflect that it has helped them gain a frame of reference of their starting point. It has helped them appreciate the many 'wins' that action on air pollution can realise, both health and financial. It has helped them establish connections with partner institutions including local authorities, create governance structures to tackle pollution together and move forward to create clean air action plans that help plan for short and long term goals.
There are many excellent examples of clean air action happening already which represent with case studies, and by upgrading the ICS framework into an online tool, these best practices are to be shared to colleagues across the country in a community of best practice.
The Clean Air Hospital Framework has been helping deliver clean air action for 5 years, indeed GAP will host a celebration event with Great Ormond Street Hospital and Camden council on Clean Air Day (June 20th, 2024).
With the chief medical officer Professor Sir Chris Whitty committing to reducing the air pollution that the NHS itself creates within 10 years (as of 2022) while addressing the great health inequalities it exacerbates, GAP are proud to be helping the NHS deliver with these key documents.

Quantifying changes in air pollution concentrations caused by traffic interventions

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Keywords: School Street, machine learning, Gradient boost, nitrogen dioxide, meteorology.
Associated conference topics: 2i, 2ii, 3ii
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The aim of interventions such as school streets and clean air zones is to reduce our exposure to pollutants. Efforts to measure the effectiveness of these interventions must account for unrelated changes in concentrations due to external factors, such as changes in weather and background pollutant concentrations.

Here we consider the effectiveness of two interventions; one in Leicester and on in Birmingham, that aim to reduce nitrogen dioxide concentrations. We use gradient boost models to minimise the influence of changes in background concentrations and meteorology. The first case was a school street in Rushey Mead, Leicester, and the second was the Birmingham Clean Air Zone (CAZ). For the school street a network of 10 Zephyr sensors was installed 16 months before the intervention, and remained in place afterwards. In the case of Birmingham, data came from a combination of Automatic Urban Rural Network (AURN) and Birmingham City Council.

Models were trained on data from before the interventions, with variables to account for temporal changes, meteorological changes, and changes in background concentrations. The optimum hyperparameters for the models were found using a grid search technique, which was applied separately for each sensor. Forward projections of modelled concentrations were compared to the measured concentrations for the same time period to quantify intervention effectiveness. The same approach was applied to data since the intervention; in this case the models built were projected backwards to predict the concentrations as if the intervention had been implemented earlier. The influence and partial dependencies of different variables were compared before and since the interventions to further understand what was driving changes in measured concentrations.

The optimum parameters varied between sensors and case study, demonstrating the need for the grid search process rather than using any pre-defined hyperparameter values. Both studies also showed that background concentrations had a significant influence, highlighting the importance of using gradient boost or similar models to remove the influence of externalities when assessing the effectiveness of an intervention. The results show that nitrogen dioxide decreased more than 10% in the case of the school street. However, it is unclear whether this decrease was attributable to the intervention as the decrease was observed across most sensors in the network rather than just when and where the school street was implemented. The decrease was also on the same scale as the uncertainty of the sensor, so a good understanding of how this uncertainty changes under different conditions is vital.

The results from modelling the CAZ showed improvements in air quality in most cases but predominantly within the zone. The uncertainties due to the sensors were lower than for the Rushey Mead case study. The interventions also took place during the Covid pandemic, and this was considered during the modelling.

As local authorities look for ways to improve air quality, they need a way to measure the effectiveness of what they are doing. These case studies show that Gradient boost models provide a means to assess the effectiveness of interventions, provided there is sufficient baseline data.

Sponsor: Cambustion
Author: Mark Peckham

***Innovative Developments driving Impact** – the new methods and technologies developed during the Clean Air programme that are improving our understanding of AQ issues and reducing their impact.*
We can produce a short presentation on the subject of the measurement of NOx pollution from passing vehicles. This involves roadside monitoring measurements, but also mobile measurements from within a child's push-chair and on a moving bicycle. The results show some short duration but very high concentrations of both NO and NO2 being produced from a few vehicles.

***The Evolving AQ Landscape** – positioning the AQ community to meet future challenges such as the transition to a low (net zero) carbon economy.*
Actually I'm not sure if the proposed talk belongs within this section or perhaps the one above but basically…
We have researched the effect of "defeat devices" fitted to Euro 6 diesel vehicles and how they can result in a nominally "clean" vehicle with full access to clean air zones becoming a gross emitter. We did this by taking a working vehicle to a "re-mapping" centre and measuring the emissions before and after the change. This practice is growing rapidly as the first generation fo Euro 6 vehicles age and their catalyst systems begin to develop faults. The cost of re-mapping is often 10 times lower than the cost of getting the engine fixed properly.

Air quality monitoring using sensor network and mobile transect at University Hospitals Plymouth

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Keywords: mobile monitoring, sensor network, low-cost sensor, urban air quality, clean air hospital
Associated conference topics: Novel approaches and new insights, Air quality and health in a net zero future
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Background

Air pollution leads to premature deaths in the UK, and exposure to particulate matter (PM), nitrogen dioxide (NO_2) and ozone (O_3) poses serious health concerns. Moreover, poor air quality at healthcare sites presents a health risk for the most vulnerable groups, including those with pre-existing health conditions such as coronary heart disease and respiratory disease. Yet, the relationship between outdoor air quality and hospital patients' health remains largely unexplored. To address this critical issue, we aimed to examine the indoor and outdoor air quality at University Hospitals Plymouth using a wireless sensor network and mobile air quality monitoring. Our research objectives are to i) identify the relationship between local meteorology and air quality, patient volume, and ambulance number and ii) investigate the impact of greenspace on air quality at the hospital.

Methods

Air quality data (PM, NO_2, O_3) and meteorological data (air temperature and relative humidity) were collected using a wireless sensor network at University Hospitals Plymouth for 12 months from June 2023. Time series analysis examined the association between air quality, bed occupancy in medical wards and ambulance waiting time. Furthermore, we used mobile transect measurements on foot around the hospital and city centre to understand the background of urban pollution and local pollution sources, such as emissions from visitor road transport, delivery, and ambulance. Geospatial analysis, integrating vegetation data from Sentinel 2 and traffic count data, was conducted to explore the relationship between greenspace and air quality at the hospital.

Results

In Plymouth, various associations between meteorological variables and air pollutants were found. We revealed significant differences in PM2.5 and PM10 concentrations between low and high-temperature conditions. There was a negative correlation between humidity and both PM10 and PM2.5 concentrations. Moreover, ozone levels were highest in the afternoons and on the warmer, low wind, low humidity days. These results highlight the role of local meteorology in affecting the concentrations of various air pollutants, which have implications for patients' health in hospital wards. Furthermore, geospatial analysis (using vegetation and traffic density raster images) showed that areas with more vegetation and low traffic density were associated with low NO_2 concentrations (Figure 1). This result supports the role of urban greenery in pollution mitigation, as vegetated areas can mitigate NO2 levels through a cooling effect on the microclimate and direct absorption of pollutants.

Practical implications

Our findings could inform targeted interventions and guidelines to improve indoor and outdoor air quality in hospitals, which protect the health and safety of patients and healthcare workers. It also promotes sustainable transport to hospitals and helps hospitals work with bus companies and the NHS supply chain to reduce congestion. Ultimately, it will help the hospital to achieve net zero goals by satisfying the targets of the clean air hospital framework.

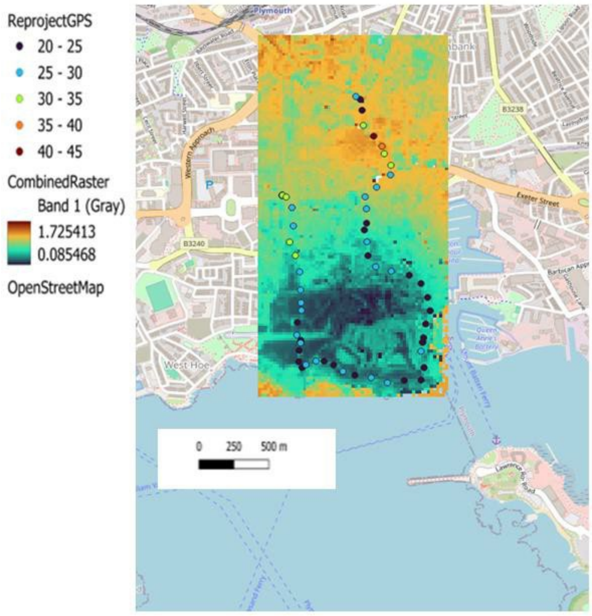

Figure 1 Combined raster image of vegetation and traffic density with NO_2 concentration in Plymouth city centre (9:30-10:30, 20/2/2024). In the raster band, greener colours mean more vegetation and less traffic.

Empirically measuring indoor air pollutants with low-cost and high-cost sensors in a low-carbon home retrofit

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Keywords: Indoor air quality, monitoring, occupant activity, energy retrofit, ventilation

Associated conference topics: 2.3, 3.2

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Home energy efficiency typically entails a reduction in unintended ventilation (lower air exchange). This may increase concentrations of air pollutants derived from indoor sources. The limited understanding of these impacts, especially for vulnerable groups, is what the HEICCAM research network seeks to address.

This preliminary investigation aimed to characterise and understand factors impacting the concentration of indoor air pollutants (IAP) in a naturally-ventilated energy-retrofitted dwelling in Oxford. The case study dwelling is a three-bedroom end-terrace house with an open-plan kitchen, occupied by a retired couple most of the time. A key aspect of the study was to examine trends in IAP measured using low-cost (lower accuracy) sensors versus high-cost (higher accuracy) sensors.

The study used a mixed methods approach that included monitoring of IAP and the environment (among others: indoor temperature and Volatile Organic Compounds (VOCs: Isobutylene)) using Airthinx devices between 6th-29th February 2024. Data on occupants' behaviours such as window opening, cooking, cleaning, personal care and smoking was collected using an activity diary undertaken from 12th to 18th February, as well as a household survey to provide contextual insights into the findings. Speciated VOCs were measured by a Vocus-PTR mass spectrometer using air bag spot samples during a ‘tracer release’ experiment and canister samples reflecting an 8-hour average concentration (13th February and 12th-14th February, respectively).

The findings revealed large variations in indoor environment variables measured by Airthinx. The mean indoor temperature was found to be higher in the kitchen and the living room, ranging between 19.1°C and 19.6°C, compared to bedroom with a mean indoor temperature of 17.6°C, likely reflecting occupants’ thermal preferences and more exposed positioning of the bedroom. The mean daily indoor CO_2 concentrations were found to be relatively high in the bedroom reaching a peak of 1,600ppm overnight, compared to the living room and the kitchen that peaked during cooking time, ranging between 950ppm and 1012ppm respectively. In contrast, indoor VOC (isobutylene) levels were found to be higher in the open-plan kitchen and living room than in the bedroom due to cooking and cleaning activities, reaching a peak of 0.8ppm and 0.2ppm respectively at 7:00 pm (Figure 1a). Similarly, indoor $PM_{2.5}$ and PM_{10} levels spiked in the kitchen and the living room during daytime due to cooking activities, reaching peaks of 50μg/m³ and 30μg/m³ respectively.

Canister samples confirmed the rise in indoor VOCs levels in the kitchen and living room during daytime. Benzene concentrations were also found to be higher than DEFRA national air quality objectives reaching to 3.7ppb (0.0037ppm) in the bedroom overnight, while reaching to 5.5ppb (0.0055ppm) in the living room during daytime. Other VOCs were found to be below exposure limits as per UKHSA guidelines. The ‘tracer release’ experiment revealed slow removal of some specific VOCs through background ventilation (Figure 1b). Despite this, it showed fast removal of all the speciated VOCs by purge ventilation. The magnitudes of isobutylene concentrations measured by Vocus-PTR (high-cost) were roughly 30-fold lower than reported by Airthinx (low-cost). This is because the low-cost sensor monitors isobutylene as a proxy for total VOCs and reports the total VOC concentration. Furthermore during the tracer release experiment the sensor was quenched as VOC concentrations exceeded its upper reporting limit. However, relative changes in isobutylene over time corresponded well with other VOCs, confirming it as a good proxy for total VOCs.

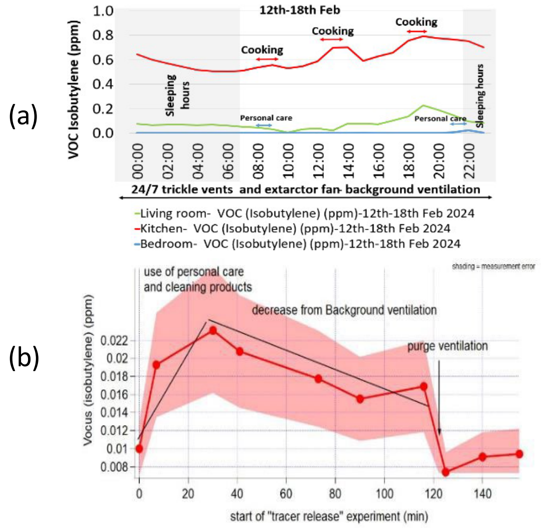

Figure 1: Daily indoor VOC (Isobutylene) levels between 12th and 18th February 2024 measured by Airthinx device (a), and during tracer release experiment measured by Vocus-PTR on the 13th February 2024 (b)

The findings underscore the necessity for integrating enhanced ventilation with occupant activities in energy retrofitted homes. The study is also an example of the added benefit of simultaneously deploying high-cost and low-cost sensors to gain complementary insights, particularly regarding speciated exposure limits.

Evaluating the impact of School Street Interventions on air quality at Primary Schools in Oxfordshire

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Keywords: School Street, Children, air quality, traffic, intervention.
Associated conference topics: 1.3, 2.1, 4.1

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Abstract

Background: Air pollution from traffic sources poses a significant health risk in the UK, with children particularly vulnerable to associated health harms. Children are typically exposed to high levels of traffic related nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$) while traveling to school or playing outdoors. ‘School Street’ schemes, comprising temporary restrictions on motorised traffic at school drop-off and pick-up times, are increasingly being adopted by local authorities to address air quality concerns around schools and improve active travel and road safety. However, benefits of these schemes for reducing short-term NO_2 and $PM_{2.5}$ exposure during peak school travel periods remain uncertain.

Study Design: This retrospective observational study explored the impact of timed road closure (School Street) schemes introduced during 2023 introduced at four Primary Schools in Oxfordshire, with comparisons of short-term air pollutant concentrations to six control school sites with no intervention within the study period (Figure 1).

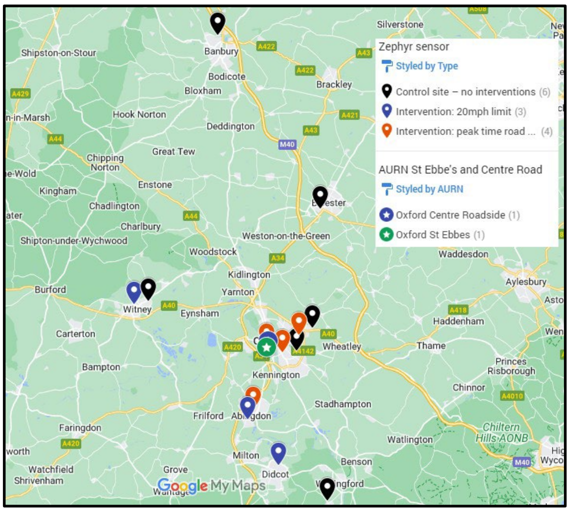

Figure 1 *Air quality monitoring locations (Zephyr sensors and AURN) - Online Map link*

Data Collection and Analysis: Air quality data for the pre- and post-intervention period were obtained using Earthsense Zephyr® sensors located at intervention (n=4) and control (n=6) locations and the Defra AURN urban background monitoring site Oxford St Ebbes (UKA00518), located adjacent to an intervention school site. Road closure timings were site specific, typically occurring between 08:00-09:00 (morning) and 14:30-15:30 (afternoon). Time-weighted average (TWA) pollutant concentrations were calculated for respective closure periods to enable pre-and post-intervention comparisons between intervention and control locations.

Results: Comparisons of co-located Zephyr sensor and AURN derived daily NO_2 and $PM_{2.5}$ concentrations indicated a consistent trend over the study period with Pearson correlation coefficient (r) of 0.92 ($p<2.2e^{-16}$) and 0.94 ($p<2.2e^{-16}$), respectively, suggesting reliability of sensor performance. A consistent diurnal pattern was observed for NO_2 and $PM_{2.5}$ pollutant concentrations at all study locations with typically higher peak concentrations in the morning compared to afternoon periods. Pre- and post-intervention comparisons of TWA NO_2 and $PM_{2.5}$ concentration profiles for morning/afternoon road closure periods identified reductions at all intervention sites, with the exception of afternoon $PM_{2.5}$ concentrations which increased at a school site in Abingdon. Mean TWA NO_2 concentrations for pre-/post intervention traffic restriction periods at intervention schools were 14.7 μgm^{-3}/7.2 μgm^{-3} (morning) and 8.6 μgm^{-3}/4.4 μgm^{-3} (afternoon) with the greatest concentration reductions of up to 13.1 μgm^{-3}/68% (morning) and 12 μgm^{-3}/76% (afternoon) observed at St Ebbe’s Primary School in Oxford City. Comparison to regulatory data at Oxford St Ebbe’s revealed a lesser magnitude TWA NO_2 concentration reduction of 3.5 μgm^{-3}/22% (morning) and 2.5 μgm^{-3}/26% (afternoon) for comparable time periods. Pre- and post-intervention reductions in TWA $PM_{2.5}$ concentrations were of lesser relative magnitude across all intervention sites at up to 4.2 μgm^{-3}/40% (morning) and 2.4 μgm^{-3}/31% (afternoon). Further analysis will undertake comparisons for equivalent exposure periods at control school locations.

Conclusion: These findings demonstrate utility of air quality sensor data for evaluation of localised timed traffic restriction interventions at Primary Schools. Preliminary findings suggest School Streets schemes may be effective for reducing short-term air pollution levels at peak school travel times with potential benefits for child health.

Land-use regression modelling of outdoor volatile organic compounds in Leicester, UK: improving spatial resolution of exposure assessment tools

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Keywords: geographic information systems (GIS), gas chromatography-mass spectrometry (GC-MS), passive sampling, monitoring network.

Associated conference topics: 2 (ii), 3 (i), 1 (ii)

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Volatile organic compounds (VOCs) are air pollutants, ubiquitous in outdoor and indoor environments. They are poorly monitored constituents of outdoor air pollution with sparse monitoring networks existing in the UK. Benzene, toluene, ethylbenzene, and xylene, a group of VOCs known as BTEX, have been widely used in exposure assessments to VOCs owing to their relatively high ambient outdoor concentrations and known health effects. Anthropogenic sources include solvent use, road transport, and industrial processes. Human health effects include; short-term central nervous system irritation, long-term neurological impairment, and cancer. Land-use regression (LUR) models have been utilised in environmental epidemiology as a tool for assigning levels of exposure, and have been used extensively for key primary air pollutants (NO_x and particulate matter). The modelling approach has been less widely applied to VOCs, particularly in the UK. This research aimed to create an intra-urban network of BTEX passive sampling devices across Leicester, providing valuable input data to inform an LUR model, which in turn can produce a high-resolution BTEX exposure assessment tool for health studies.

For this study, 22 sites across the city of Leicester, UK, were selected on the basis of co-location with continuous air quality (O_3, NO_2, NO, PM_1, $PM_{2.5}$, PM_{10}) and meteorological (temperature and relative humidity) measurements from Zephyr air quality monitors (EarthSense Systems Ltd, Leicester, UK). A 6-week winter campaign of passive sampling using sorbent tubes was conducted, with two samples at each site providing weekly averages. Sites in this monitoring network represent a range of land-use types, and therefore, potential sources of BTEX emissions. Sampled sorbent tubes were analysed via thermal desorption gas chromatography–mass spectrometry to identify and quantify VOCs. Land-use variables including road features, land cover type, and distances from point sources, were utilised to inform a regression model. Optimisation of the model was performed through statistical tests and validation methods, including principal components analysis, Moran's I, and four-fold cross-validation.

Measured concentrations of benzene (1-3 μg/m^3) provide valuable data for government regulatory targets, whilst toluene (1-5 μg/m^3), ethylbenzene (0.2-1 μg/m^3), and xylene (0.2-2 μg/m^3) concentrations offer insight into unregulated, potentially harmful compounds. The land-use regression modelling effectively explained 73% BTEX spatial variability, and 64% during four-fold cross-validation, making it comparable to existing VOC models from Europe, Canada and USA. Prediction surfaces at 100 m^2 resolution provide an exposure assessment tool for comparison to postcode-level health and social data for insight into health inequalities from BTEX exposure in deprived communities in Leicester, UK, presenting novel modelling and health assessment methods.

Assessing and enabling the use of low-cost air pollution sensors in UK urban environments – The QUANT study

Dr Pete Edwards & the QUANT team

Low-cost air pollution sensors have a potentially vital role to play in tackling air pollution in the UK, and globally. The high time resolution and ability to create dense networks of these devices offers a paradigm shift in the way we measure key pollutants, evaluate health impacts of air pollution exposure and assess potential solutions. The QUANT project aimed to assess and enable the use of low-cost sensors for UK clean air challenges through the delivery of a real-world open and traceable assessment of commercial low-cost sensor devices, and the development of novel data methods that enhance the information provided by these devices. This presentation will provide an overview of the QUANT study and discuss our research highlights and their implications for the use of these technologies in supporting UK air pollution strategies.