
Clean Air Networks' Conference 2023
5-6 July 2023, University of Birmingham
BioAirNet
Breathing City
Future Urban Ventilation Network
CleanAir4V
EICCAM
Clean Air Research Network
NPL
National Physical Laboratory
SAQN
STFC AIR QUALITY NETWORK
TAPAS
Tackling air pollution at school
TRANSITION
CLEAN AIR NETWORK
UKRI
Natural Environment Research Council
Met Office
Clean Air Programme

Abstracts

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Conference foreword

The Clean Air Networks Conference will bring together a culmination of 8 clean air networks and showcase the latest advances in clean air research. Our unified aim is to deliver health centred, evidence-based solutions to improve air quality inside our buildings and out, which will ultimately improve quality of life for all. By bringing together our knowledge and expertise from across the multi-disciplinary clean air networks, we hope to establish evidence-based, outcome-led solutions that reflect what the science is telling us. By mobilising this knowledge into practice, we hope to create a national strategy to identify gaps in research and provide indications for the future of clean air research in the UK.

Individual Clean Air Network slogans:

- Clean Air Programme: The Clean Air Programme aims to bring together leading researchers from across atmospheric, medical and social science to better predict exposure to air pollution and its effects on vulnerable groups such as children and the elderly.
- HEICCAM towards a healthy and equitable low-carbon future.
- SAQN bringing together research, industry and policy to address air quality challenges.
- TAPAS Working together to deliver healthy schools.
- FUVN developing a technical framework to enable a new integrated health evidenced approach to urban building design and technology innovation – the breathing city.
- CleanAir4V – network on air pollution solutions for vulnerable groups. An interdisciplinary network of academics, stakeholders and industry with the aim of developing and delivering co-designed air pollution solutions.
- BioAirNet – Indoor/Outdoor bioaerosols interface and relationships network- taking a transdisciplinary approach to identify and inform the future directions for tackling the societal challenge and health impacts posed by particulate matter of biological origins (BioPM)
- Metrology Network - NPL are supporting the metrological activities within the Clean Air projects and coordinating the development of consistent methods to help ensure the outcomes from the programme are fit for purpose.
- TRANSITION Clean Air Network – Interdisciplinary network undertaking innovative research to address emerging indoor/outdoor air quality challenges across UK surface transport

Abstracts

Wednesday, 5th July 2023

Martin Williams Memorial Lecture
The past, present, and future prospects for air quality management and health in the UK
Roy Harrison, University of Birmingham, UK

The Environment Act of 1995 set a new paradigm for air quality management in the UK which has been rather successful for some pollutants, but notably less so for others. Trends in pollutant concentrations will be examined, and the successes and failures highlighted, with the underlying reasons evaluated. Future prospects will be considered, taking account of current legislative proposals and the likely implementation of Net Zero greenhouse gas policies, some of which raise issues for local air quality. Health-based air quality standards have evolved considerably over past decades as the evidence base has increased. Consideration will be given to the role of air quality objectives/standards and the likely impact of the 2021 revisions to the WHO Guidelines in the context of both indoor and outdoor pollution.

Session 1: Current State of Play (12:30 - 13:30)

A brief overview of the themes which will be carried through session 1 and session 2:

1. **Air quality and Net Zero**

This theme will explore how current and future air quality interventions affect the net zero agenda and vice versa, in terms of (i) direct emissions (e.g., changing from fossil-fuel car travel to electric vehicle/public transport/bike/foot) or (ii) increased/decreased energy use from using various indoor air quality improvement solutions (e.g., natural/mechanical ventilation, air purifiers, dehumidifiers.) which in turn will affect the GHG emissions related with energy production, or (iii) increased air tightness of buildings and concerns over energy consumption which can lead to poor indoor air quality. This theme will also consider any new inadvertent pollutants from emerging technologies and behavioural change in response to the net zero agenda and climate resilience strategies.

2. **Measurements, Mechanisms and Modelling**

This theme will discuss different methods of measuring and modelling pollutant emission and transport mechanisms through the indoor-outdoor continuum across different scales. It will explore the challenges and opportunities for characterising and quantifying pollutants in the context of public health and wellbeing and highlight the role of computational models and simulation tools in better understanding air flow, pollutant transport and exposure risk. It will showcase the range of air quality measurement campaigns which have been carried out across the networks and how they demonstrate different intervention options in diverse environments and conditions for a variety of groups (especially vulnerable groups) and stakeholders. There will be an opportunity to discuss how to better connect this data and knowledge to improve policy and air quality intervention strategies, what the role of innovative technologies are in the future of measurements and modelling, and whether pollutant sampling and analysis standardisation approaches need updating.

3. **Health and inequalities**

This theme will consider the links between air quality data, human exposure, and physical and mental health data and how this linked understanding can be applied to wider societal inequalities. Topics discussed and studies shared will include, but are not limited to: specific pollutant exposure risks to

vulnerable groups in different environments (e.g., damp in social housing, repeat exposure to traffic pollution, elderly people in poorly ventilated care homes) and the interventions needed to reduce these risks; general health impacts of different pollutants; the role of human behaviour on air quality; the availability and role of green and blue spaces to different demographic groups; and methods of communicating the most promising intervention options to vulnerable groups.

4. Lived experience and public engagement

This theme is focussed on the engagement and outreach activities that have been ongoing in the networks. This encompasses stakeholder and public engagement for targeted policy, industry and educational activities. Outputs showcased will include citizen science based co-designed air quality studies, mitigation recommendations, raising-awareness campaigns, and educational and guidance material. The theme will also explore how to effectively connect behavioural science understandings to pollutant source/exposure data, and the public perception of (and response to) air quality intervention strategies.

Theme 1: Air quality and Net Zero (12:30 - 13:30)

1. The Dynamic Classroom: Using smart monitoring systems to improve air quality in schools (TAPAS)

Emmanuel Aboagye-Nimo, Birmingham City University, UK

The Dynamic Classroom is an interdisciplinary pilot project that is investigating how the school classroom learning environment can be improved by reducing the indoor air pollution exposure of school children and staff. The project is being run by interdisciplinary teams from six universities and two industry partners, with expertise in air quality, atmospheric science, instrument development, building services management, building information systems, modelling, project management, and social science methods. Over one-year, with two intensive 'deep-dive' phases, the team aim to implement and monitor one pilot 'dynamic classroom', in a pre-existing primary school classroom, where ventilation is controlled via an automated window system connected to air quality and weather sensors both inside and outside the classroom. The outcome of the project includes developing a best practice approach on improving air quality in classrooms that can potentially high levels of indoor air pollutants and sensitising stakeholders of the importance of air quality.

The project is based on three central research questions:

RQ1: Can a simple, automated, 'dynamic' approach to building management (e.g. ventilation) and alerting (dashboard), governed by air quality sensor data improve indoor air quality in a typical UK primary school classroom?

RQ2: What are the primary air pollutants (gases and particles) in and around the test classroom during the average school day, week and year?

RQ3: Can the dynamic classroom improve teachers' and other stakeholders' perceptions of air quality and student learning outcomes?

2. Ventilation in retrofitting (FUVN)

Malcolm Cook, Loughborough University, UK

Retrofit projects offer a great opportunity to get ventilation right! There is so much that can be done during a retrofit project – and it's not rocket science. Many of the modern methods of working such as hot-desking and open-plan lend themselves to good air movement and ventilation. The secrets to success often lie in the benefits of the tried and tested methods of thermal mass, nighttime ventilation, user control, solar shading and cross ventilation. In this flash talk, I will give a brief overview of the opportunities we have when considering ventilation in retrofitting, with a focus on natural ventilation and passive cooling.

3. Consumer Product Volatile Organic Compounds: Indoor pollutants trapped in our homes (HEICCAM)

Amber Yeoman, University of York, UK

A large source of indoor air pollutants are volatile organic compounds (VOCs) emitted from everyday consumer products. These products emit a multitude of different volatile species, namely solvents such as ethanol, aerosol propellants propane and butane, and fragrance compounds, which can react to produce SOA and contribute to particulate matter, promoting negative health effects. In my work I analyse both qualitatively and quantitatively the VOCs emitted from consumer products, and assess

inhalation exposure and the influence of occupant behaviour. My knowledge of source apportionment and identification of VOC pollutant species supports HEICCAM's research objective of assessing the indoor air quality impacts of climate change mitigation, in this case improvements in home energy efficiency under net zero, and understanding that ventilation cannot be the sole solution to poor indoor air quality. Pollutants need to be controlled at the source and which requires occupant behaviour change, legislation, and product reformulation.

4. Towards a balanced position on biological particulate matter as a component of healthy air (BioAirNet)

Sean Tyrrel, Cranfield University, UK

Healthy lives require a healthy environment and therefore healthy air. However, there is no common conception of what biologically healthy air is and this is a barrier to network and public engagement. It is understandable that people associate inhaling airborne biological particles with health problems. The reality is, however, that every breath we have taken since birth has exposed our respiratory tract to bioaerosol. BioAirNet is exploring if it can secure a consensus for a balanced position that puts the risks associated with airborne biological hazards into perspective and accepts exposure to bioaerosols as part of a healthy life.This presentation describes an independently facilitated "thought experiment" in which experts external to BioAirNet, but part of the Clean Air Network community, reacted to a BioAirNet co-designed provocation statement. The process casts light on what we know, don't know, and what we are able to say openly about our bioaerosol knowledge.

5. Enabling the remote measurement of air pollutant emissions in UK ports (SAQN)

Shona Wilde, University of York, UK

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The challenge in measuring emissions from ships makes the level of compliance with new regulations difficult to robustly determine. This project aimed to assess the potential of low cost sensors (LSCs) to monitor air pollution within ports and calculate emissions ratios from individual ships. A LCS package was developed to measure SO_2, NO_2, CO_2 and PM at UK ports. We present measurements from ships arriving and departing the Port of Tyne. The sensor performance was validated using reference instruments contained within the University of York's mobile laboratory. We find that our point-sampling strategy was suitable for sampling ship plumes, however the low sensitivity of LCSs meant they were unable to detect highly dispersed plumes of SO_2. Enhancements of NO_2 and CO_2 were generally larger and hence LCSs could play a promising role in determining NOx emission factors, for which there are likely to be stricter regulations in the future.

6. The Non-Exhaust Particulate Emissions Impact of EURO VI to Battery Electric Bus Fleet Transitions (TRANSITION)

Karl Ropkins (University of Leeds), **Jon Tivey** (FirstBus)

There is already strong evidence that non-exhaust emissions (NEEs) are a significant source of transport-related particulates, and an expectation that this will increase as we transition from

conventional to heavier alternative technology vehicles. (1) Therefore, we need to ensure that our existing commitment to zero (at tailpipe) emissions is complemented by an active effort to mitigate any unintended consequences for NEEs. (2)

This work, led by FirstBus, and funded by the TRANSITION Clean Air Network funded by the Natural Environment Research Council within the UKRI Clean Air Programme (3), uses the EURO VI-to-Battery Electric Bus transition as a case study to explore options to: (a) improve inventorying information available to fleet managers considering fleet upgrade options; and, (b) gather evidence on the potential divergence between regulatory metrics, conventional emission factors, inventory model predictions and the real-world outcomes as we migrate to what need to be significantly cleaner technologies.

(1) https://doi.org/10.1016/j.atmosenv.2021.118592; (2) https://transition-air.org.uk/news/letter-re-cop26-declaration-cars/; (3) https://transition-air.org.uk

Theme 2: Measurements, Mechanisms and Modelling (12:30 - 13:30)

1. Role of CO2 monitors in classrooms (TAPAS)

Carolanne Vouriot, University of Cambridge, UK

The COVID-19 pandemic highlighted the essential role that ventilation systems play in limiting the spread of airborne diseases and consumer CO_2 monitors were deployed in UK classrooms as a cost-effective tool to help manage ventilation. In this talk, I will discuss the use of CO_2 measurements to assess the ventilation provision and risk of airborne infection in classrooms and how the representativeness of a single point measurement can be determined.

2. Modelling UK Housing Stock (HEICCAM)

Phil Symonds, University College London IEDE, UK

The aim of our research is to investigate the impact that home energy efficiency (HEE) interventions have on indoor environmental quality (IEQ). We have developed a UK housing stock model to predict IEQ exposures under various retrofit and climate change scenarios. Metamodeling techniques are used to develop the stock model based on EnergyPlus building simulations. The housing stock model predicts exposures to indoor and outdoor sourced PM2.5, radon, mould, overheating and other variables. Several datasets can be used as input into housing stock model including the English Housing Survey (EHS). The Energy Follow-Up survey has previously been used to verify model estimates of overheating. Larger and more linked up datasets are required to improve the predictions of these models.

3. Integrated technological and computational tools to capture detailed personal exposure and dose (HEICCAM)

Lia Chatzidiakou, University of Cambridge, UK

A key challenge in modern epidemiology is understanding the source-related effects of air pollution on health. Large-scale studies traditionally use measurements of outdoor reference monitoring stations as metrics of exposure. However, these measurements are often poorly correlated with personal exposure levels due to varying local sources, microenvironmental settings, attenuation effects of the building envelope and individual behavioural patterns. My research expands the capabilities of low-cost sensors by developing analytical techniques to maximise extracted information:

1) A time-activity model to classify major exposure-related microenvironments using as input readily gathered parameters from smartphone technologies to provide a comprehensive picture of environmental health risks during daily life.

2) A novel source apportionment method to characterise local and regional emission sources, and review how the low-cost sensor measurements can be used as proxies for more detailed measurements.

This integrated technological and analytical framework can revolutionise the fields of indoor exposure, building science and human health.

4. Computational Fluid Dynamic Modelling for Indoor Air Quality (SAQN)
Stefano Rolfo, STFC Scientific Computing, UK

In the field of pollutant dispersion modelling, Lagrangian Particle Tracking (LPT) is predominant for small-scale scenarios in which transient, localised concentrations are required. However, the application of LPT coupled with high-performance computing and high-fidelity computational fluid dynamics modelling to emission events generated by domestic cooking is, as of yet, relatively unexplored. In this work, a combination of practical experiments within the DOMESTIC test house and high-fidelity computational fluid dynamics modelling are used to characterise and investigate the dispersion of fine particulate matter (PM2.5) during cooking.

5. Detection and characterisation of biological material in PM (BioAirNet)
Zaheer Nasar, Cranfield University, UK

Information on the spatio-temporal characteristics of biological materials in particulate matter (BioPM) and intra and inter BioPM interaction mechanisms and transformation processes under varying gaseous air pollutants and environmental factors across indoor - outdoor continuum is critical to understand the role and impact of PM on public and planetary health. For example, what is the role of BioPM in health burden associated with overall PM exposure? Current limitations in detection and characterisation of BioPM are key barriers to understanding the spatio-temporal characteristics of BioPM as well as complex physico-chemical and biological matrix of PM. This presentation will offer an overview of the capabilities of single particle ultraviolet light- induced fluorescence detection systems combined with optical particle measurements to provide real time quantification and temporal characterisation of BioPM and how this can provide a step change in understanding of BioPM in public and planetary health.

6. Efficacy evaluation for air handling system in mitigating exposure in lifts and enclosed waiting spaces at a transport hub (TRANSITION)
Abhishek Tiwary, De Montfort University, UK

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During the COVID-19 pandemic, transport hubs were identified as potential locations for infection transmission. At the same time, the release of health-implicating Volatile Organic Compounds (VOCs) and transport aerosols in micro-environments such as enclosed public transport spaces, is a long-standing air quality challenge. This is particularly concerning for vulnerable people, who are frequently reliant on using enclosed facilities at public transport facilities (e.g., waiting lounges, lifts, or toilet facilities). Our project, jointly supported by TRANSITION and BioAirNet Networks, addresses this policy need by exploring the efficacy of an air-handling unit, capable of regulating both air quality and pathogens in constrained spaces.

The bioaerosol sampling focuses on smaller common cold virus aerosols, which tend to remain airborne for a longer time, unlike larger bacterial and fungal spores with higher deposition rates. Ongoing experiments have conducted efficacy estimates for respiratory syncytial virus strains using real-time quantitative PCR (RT qPCR) and culture analysis.

7. Air Quality Coupling Indoor and Outdoor Environments (FUVN)

Maarten Van Reeuwijk, Imperial College London, UK

Indoor and outdoor environments are inextricably linked. Accurate consideration of the inter-relationships between indoor-outdoor air pollutions can be related to parameters such as external and internal pollutant generation, atmospheric conditions, temporal (daily and seasonal), spatial (nationally, regionally, and locally), type of building, building design and operation, occupant behaviour and many other factors. Therefore, to provide acceptable IAQ, indoor and outdoor environments must be coupled appropriately in terms of design, assessment, and operation. In this flash-talk I will give a brief overview of these processes and discuss some of the challenges and opportunities associated with indoor-outdoor exchange.

Theme 3: Health and Inequalities (12:30 - 13:30)

1. UKHSA towards IAQ solutions (FUVN)

Jim Stewart-Evans, UKHSA, UK

Health inequalities arise from differences in indoor environments that include indoor air quality and housing condition. This is illustrated by the recent case of Awaab Ishak, a child who died due to prolonged exposure to mould in social housing. This short presentation highlights the role of evidence-based recommendations, standards, and guidance in tackling health inequalities, drawing on examples from recent initiatives involving the UK Health Security Agency. These include collaborations reviewing housing sector guidance on the health impacts of damp and mould and research investigating systemic inequalities in indoor air pollution exposure in London and identifying potential interventions.

2. Mitigating Cooking Emissions: The Role of Rapeseed Oil in Frying on Induction Hobs (CleanAir4V)

Ruijie Tang, University of Birmingham, UK

Ruijie Tang, Ravi Sahu, Yizhou Su, Zongbo Shi and Christian Pfrang

The detrimental effects of cooking emissions on indoor air quality and health warrant urgent attention. This study, involving over 80 cooking activities on induction hobs, aims to investigate the relationship between cooking methods and resultant particulate matter (PM) concentrations. The PM concentrations were found to be the highest in pan-frying, followed by stir-frying, deep-frying and boiling, with air-frying leading to the lowest PM levels. An intriguing trend was revealed: an increase in the volume of rapeseed oil used in pan-frying and stir-frying appears to be inversely correlated with both cooking temperatures and PM concentrations. This finding may open up opportunities for modifying cooking strategies as a practical approach to reducing indoor air pollution. The outcomes of this study offer valuable contributions to the CleanAir4V network, highlighting the significance of everyday activities in shaping indoor air quality and public health.

3. Understanding how inhaled particles impact the brain-blood-barrier (SAQN)

Chang Guo, UKHSA, UK

Chang Guo[1], Andy Ward[2], Sanghamitra Mukhopadhyay[3], Laura Zanetti Domingues[2], Robert

Lees[2], Esther Garcia Gonzalez[2], Benji Bateman[2], Rachel Smith[1], Tim Gant[1], Ian Mudway[4]

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Accumulating observations based on epidemiological studies have shown that exposure to air pollution, especially ambient particulate matter (PM), is an important environmental risk factor for neurodegenerative and neurological disorders, such as Dementia. Given the significant impact of brain diseases on individuals, the population at large and the economy this is considered an area worthy of investigation.

This study will employ ambient PM, as well as source specific samples (diesel exhaust PM) combined with the focused ion beam scanning electron microscopy (FIB-SEM) and Confocal microscopy at central laser facility (CLF) to explore if and how particles translocate across the blood-brain-barrier (BBB). We will also apply the ISIS Neutron and Muon Source facilities to investigate the effects of particulate exposure on lipid dynamics. All these would contribute to the growing scientific understanding of the mechanisms by which inhaled particles reach and impact upon the brain.

4. Impacts of ambient air quality on acute asthma hospital admissions during the COVID-19 pandemic in Oxford City (TRANSITION)

Ajit Singh (on behalf of the OxAria study team), University of Birmingham, UK

This study explored impacts of ambient air quality on asthma hospital admissions among adults from 1 January 2015 to 31 December 2020 in Oxford, UK. The overall five-year average asthma admissions rate was 78/100,000. The annual average admissions rate decreased to 46/100,000 during 2020 (Incidence Rate Ratio, 0.58, 95% CI 0.42 to 0.81, p <0.001) compared to pre-pandemic years (2015 – 2019). In single pollutant analysis, we observed a significantly increased risk of asthma admission associated with each 1 μg m-3 increase in monthly NO_2 (4%, 95% CI 1.009 to 1.072), $PM_{2.5}$ (3%, 95% CI 1.006 – 1.052) and PM_{10} (1.8%, 95% CI 0.999 – 1.038) concentrations. Effects of individual pollutants were attenuated in multipollutant models. Air quality improvements during COVID-19 lockdown may have contributed to a reduced burden of severe asthma requiring hospital admission in this setting.

5. Analysis of inequalities in personal exposure to PM2.5: A modelling study for the Greater London school-aged population (HEICCAM)

Lauren Ferguson, University College London, UK

Exposure to air pollution can lead to negative health impacts, with children highly susceptible due to their immature immune and lung systems. Here, we present a model that estimates personal exposure to PM2.5 for ~1.3 million children aged 4 – 16 years old in the Greater London region from different income groups. The model combines 1) A national time-activity database, which gives the percentage of each group in different microenvironments; 2) Distributions of modelled outdoor PM2.5 concentrations; 3) Detailed estimates of domestic indoor concentrations for different housing and occupant typologies from the building physics model, EnergyPlus, and; 4) Non-domestic concentrations derived from the INDAIR mass-balance approach. The results show differences in personal exposure across socio-economic groups for children, where the median daily exposure is 16.0 μg/m3 (CI: 95%, 15.3 – 16.7 μg/m3) for children from households in the lowest income quintile versus 13.9 ug/m3 (CI: 95%, 13.2 – 14.5 mg/m3) for those in the highest income quintile.

6. What would Beyoncé do? Outputs from a BioAirNet workshop on exposure and health mechanisms (BioAirNet)

Pippa Douglas, Environment Agency, UK

Assessing exposure to BioPM and determining the underlying biological pathways that link exposures to outcomes are critical steps when considering health impacts. We held three multidisciplinary, international, virtual workshops to engage with experts to share insights, assess current research gaps and generate ideas to address future research questions. Day 1 focussed on exploring and conceptualising, Day 2 on prioritisation and Day 3 on consolidation and action planning. Five areas of work were identified to take forwards: 1) Developing a knowledge transfer network, including training and exchange of samples and data; 2) Identifying routes of exposure using a conceptual framework; 3) Reviewing emerging opportunities to improve translation of BioPM measurements into exposure

assessment and associated health impacts; 4) Organising a conference type event to facilitate continued collaboration and progress; and 5) Mapping of key bioaerosol-related stakeholders, their level of interest and influence, and how we can engage with them moving forwards.

Theme 4: Involvement and Engagement (12:30 - 13:30)

1. Future Urban Ventilation Network (FUVN) Open Repository (FUVN)

Zheng-Tong Xie, University of Southampton, UK

Vitor Lavor, Saad Inam, Janet Barlow and Zheng-Tong Xie

Scientists and stakeholders working towards clean air in both outdoor and indoor environments need good quality data from reliable studies on which to base conclusions. One way of providing this and engaging members of the FUVN network has been to establish an Open Repository: a web-based portal for ventilation-related work. The beta-version of the Open Repository, providing information & links for the latest available datasets of Future Urban Ventilation Network (FUVN) was funded by the network. Following surveys and workshops with FUVN network members, we have designed the Repository in the current format (breathingcity.org (google.com)), with 20 datasets so far and 21 associated journal papers.

The Repository contains information from field experiments, laboratory & physical modelling and CFD studies. Three ways to search for datasets are available: 1) all datasets shown on the Repository can be searched and filtered according to a variety of criteria; 2) a geographical representation can be found in the Map section and 3) Scientific articles related to the datasets are listed chronologically in Papers. We aim to double the number of datasets to about 50 in the coming year, with a short review paper of the datasets.

2. Power to the people: The importance of public engagement on indoor air quality (HEICCAM)

Malina Modlich, University of Edinburgh, UK

Compared to outdoor air pollution, there appears to be very low awareness and knowledge in the general public about the issue of indoor air pollution and its health effects. And yet, we found those people we spoke to very receptive to such information and willing to adapt behaviours to improve air quality in their home. This talk will briefly outline what we have learned so far about engaging the public with the best available science on indoor air pollution and what initiatives the HEICCAM network plans on putting into practice moving forward.

3. TRANSITION Clean Air Network Briefing Notes (TRANSITION)

Charlotte Landeg-Cox, UKHSA, UK

TRANSITION Clean Air Network has produced a series of briefing notes on topics related to emerging air quality challenges across UK surface transport: These include: (1) Air Quality in Transport Hubs; (2) Low Emission (Clean Air) Zones; (3) Non-Exhaust Emissions; (4) Environmental and Health Impacts of E-Cycling; (5) UK Rail Freight and Emissions (6) Air Pollution in Different Transport Modes; (7) Speed Limits, Air Quality and Health; (8) Barriers to Modal Shift to Active Travel.

In this session, we will outline the background, purpose, and intended audience of the eight peer reviewed briefing notes published by the network. The lessons learned during development, the challenges faced and how they were overcome will be discussed. We will also present the opportunities used to promote the briefing notes and how their impact will be evaluated. Finally, we will report on the future of the briefing notes beyond the network.

Briefing notes available at: https://transition-air.org.uk/briefing-notes/.

4. Attending COP26 with the TRANSITION Clean Air Network team (TRANSITION)
Kayla Schulte, Imperial College London, UK

During COP26 held in Glasgow in November 2021, the TRANSITION Clean Air Network team showcased 'low to zero' emissions solutions for public transport as a part of the COP26 Universities Network. This collaborative activity was undertaken in partnership with the Birmingham Centre for Railway Research and Education and was supported by Clean Air Champion Dr Suzanne Bartington, Professor Stuart Hillmansen, Dr James Levine, Dr Ajit Singh & PhD candidate Rabee Jibrin. Dr Kayla Schulte will speak about this experience from the perspective of an early career researcher, whose work is dedicated to supporting global transitions towards less polluting and more equitable forms of transport, technology and society at large. In addition to highlighting the solutions presented by the TRANSITION Clean Air Network at COP-26, Kayla will discuss the air of dissonance present at the COP conference from an environmental-sociological standpoint.

5. Mapping our stakeholders: Engaging with others beyond BioAirNet (BioAirNet)
Emma Marczylo, The UK Health Security Agency

High quality research requires multi-disciplinary collaborations. BioPM is an area that overlaps multiple disciplines (aerosol and exposure science, epidemiology, clinical medicine, toxicology and public health policy). We aim to create a Stakeholder map of current and future stakeholders to identify and understand the individuals, groups, and organisations that have an interest or influence in BioPM. An online questionnaire was developed to capture existing and future stakeholders and includes questions on; the interests of each of the stakeholders (e.g. indoor air, fungal BioPM), the sector of stakeholder (e.g., academia), the type of engagement, (e.g., commissioner), and the frequency of engagement, with analyses considering the level of importance and influence of each stakeholder and interactions between stakeholders. The questionnaire was disseminated among our BioAirNet community. The map will be invaluable for the facilitation of collaborative multi-disciplinary bioaerosol research projects, risk communications and dissemination of research findings, and impact on policy.

6. Towards developing an indoor air pollution emission inventory for the UK: present challenges and future directions (Clean Air4V)
Andrea Mazzeo, University of Birmingham, UK

Andrea Mazzeo[1,3], Christian Pfrang[1], Zaheer Ahmad Nasir[2]

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Information on air quality across different indoor and outdoor environments is critical to quantify the totality of exposures and resultant health impacts. While outdoor air pollution has been extensively investigated, still little is known about indoor air contaminants, their sources, mechanisms of formation and transformation under varying indoor environments, activities and environmental parameters. The lack of information on how different sources, built environment characteristics and occupants' activities affect air pollutants, hinders the estimation of the impact of exposure across the

indoor-outdoor continuum. There is an urgent need to develop indoor air pollution inventories for different environments to understand the contribution of multiple and time-dependent sources and activities to air pollutant emissions. This presentation will offer an overview of the development of an indoor air pollution emission inventory for the UK, showcasing the methodological approach, modules, options and functions provided by the "Indoor Air Pollutants Inventory Tool". Opportunities, challenges, and future directions will also be discussed.

7. Engaging students by building and deploying air quality monitors (TAPAS)
Achim Haug, Air Gradient Ltd, Thailand

From the beginning AirGradient worked with students and educators to build accurate low-cost air quality monitors. For this AirGradient developed an open-source, open-hardware air quality monitoring kit using industry grade sensor modules that can measure CO2, PM, TVOCs, Temperature and Humidity. Building this kit can engage students not only in the science of air quality pollutants but also cover areas like basic electronics, sensor technologies, simple coding, health aspects and community engagement.

Day 1, Session 2: Current State of Play (14:30 - 15:30)

Theme 1: Air quality and Net Zero

1. Characterising changing travel patterns during COVID-19 and beyond (TRANSITION)
Fiona Crawford, University of Crawford, UK

Bill David, Barry Latter, Fiona Crawford

The Covid-19 pandemic resulted in an unprecedented 'shock' to regular traffic levels and therefore, due to the strong relationship between transport and air quality, this period can provide valuable insights into transport choices to inform policies related to air quality and decarbonisation.

This project examined aggregate-level and individual-level travel behaviour between 2019 and 2021 alongside information about vehicle types and emissions. Automatic Number Plate Recognition (ANPR) data from 64 cameras at 29 locations in Bristol and associated data about vehicle types were analysed.

The analysis identified that cars travelling very frequently in Bristol during spring 2020 had lower emissions standards than the very frequent travellers in 2019 or 2021. Whilst at an aggregate level, traffic in Bristol had returned to pre-pandemic levels by mid-2021, this masked more complex changes in behaviour. Heterogeneity in the impact of the pandemic was observed spatially and at an individual level, suggesting that further work is required to understand the competing behavioural influences

Project report: https://transition-air.org.uk/wp-content/uploads/TRANSITION-DI-Project-Report-Dr-Fiona-Crawford.pdf

2. Balancing Energy-Efficiency and Health: Achieving Optimal Indoor Air Quality in Net Zero Homes (HEICCAM)
Alejandro Moreno-Rangel, University of Strathclyde, UK

The relationship between indoor air quality (IAQ) and net zero homes is intricate, as it needs to consider the challenges and strategies for achieving optimal IAQ while maintaining energy efficiency. The national focus shifts towards net-zero homes for climate change concerns, addressing the potential trade-offs between energy-saving measures and ensuring healthy indoor environments becomes crucial.

The presentation explores key factors impacting IAQ in net zero homes, including ventilation systems, retrofitting, building materials, occupant behaviour, and environmental conditions. It looks at the risks associated with reduced natural ventilation and airtight building envelopes associated with net-zero homes, particularly Passivhaus dwellings, and the future travel of net zero homes in the UK.

Furthermore, it emphasises the need to integrate IAQ considerations throughout net zero homes' design, construction, and operation. It discusses innovative approaches such as mechanical ventilation with heat recovery, air quality monitoring, and low-emission materials to harmonise energy efficiency and IAQ.

3. RAL Space/NCEO satellite observations for use in air quality monitoring and research (SAQN)
Barry Latter, UKRI-STFC RAL Space / NCEO

Barry Latter, Brian Kerridge, Elisa Carboni, Gareth Thomas, Ioana Circu, Lok Chan, Lucy Ventress, Richard Siddans, Annelisa Sheehan.

RAL Space Remote Sensing Group produces data on atmospheric pollutants and other constituents using state-of-the-art schemes applied to satellite observations, both in near-real time and off-line for multi-year data sets. These include global distributions of eg tropospheric ozone, ammonia, CO, other VOCs and aerosol which have been exploited in scientific studies. New generation satellite sounders in geostationary as well as polar orbit will provide significant advances in spatial and temporal sampling of benefit to air quality applications.

In this overview, RAL data sets of relevance to air quality will be illustrated along with the public webtool for visualisation of NRT data http://rsg.rl.ac.uk/vistool and example applications eg SAQN project with Imperial College on ammonia. Advanced capabilities and anticipated benefits of new generation satellite instruments to operate 2025-45 will also be outlined.

4. Green ammonia as a fuel (SAQN)
Bill David

TBC

Theme 2: Measurements, Mechanisms and Modelling

1. Developing an Indoor Air Quality Emissions & Modelling System (IAQ-EMS) (CleanAir4V)
Christian Pfrang

Christian Pfrang[1], Suzanne Bartington[2], William Bloss[1], Bruno Fraga[3], Hassan Hemida[3], James Levine[1], Zhen Liu[3], Zhiwen Luo[4], Andrea Mazzeo[1,5], Zaheer Ahmad Nasir[6], Ravi Sahu[1], Zongbo Shi[1], Roberto Sommariva[1].

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2. University of Birmingham - Institute of Applied Health Research, Edgbaston Campus B15 2TT, UK

3. University of Birmingham - Department of Civil Engineering, Edgbaston Campus B15 2TT, UK

4. Cardiff University - Welsh School of Architecture, King Edward VII Avenue, Cardiff, CF10 3NB, UK

5. (now at) Lancaster University - Lancaster Environmental Centre, LA14YQ, UK

6. Cranfield Environmental Centre - School of Water energy and Environment, College Road Cranfield MK43 0AL, UK

The project Indoor Air Quality Emissions & Modelling System (IAQ-EMS) aims to improve the understanding of indoor air pollutants and enable planning or assessing indoor spaces to build an accurate picture of the likely pollutant sources, levels and risks. While significant progress has been made in measuring outdoor air quality, the indoor environment poses additional challenges with multiple and time-dependent pollution sources, different sized spaces and varying levels of ventilation. We deploy high-performance mobile air quality measurement instruments at different sites in the region and create a detailed inventory of indoor pollutants including cleaning products, pollution from cooking and heating, and volatile organic compounds e.g. from carpets or furniture. We also describe the distribution of pollutants and model how they break down in the environment and are dispersed throughout an indoor space. The locations to be modelled include homes, offices, schools and transport spaces. This presentation will offer an overview of IAQ-EMS showcasing the methodological approach, opportunities, challenges and future directions.

2. Challenges and opportunities of sampling and characterizing bioaerosols (BioAirNet)
Corinne Whitby, University of Essex, UK

Bioaerosols are suspensions of airborne microorganisms (i.e. bacteria, fungi, archaea, viruses) and their products. They are an important transmission route for infectious and sensitization agents. Yet, despite the impacts of bioaerosols on human health, their role in the environment remains poorly understood. Although there are a wide variety of air samplers and sampling methods available, no standardised procedures have been firmly established. Recently, molecular tools (e.g. High Throughput Sequencing), have advanced bioaerosol research, but there is still much debate surrounding which downstream analysis methods to use. Consequently, it is difficult for bioaerosol researchers to compare studies, and for regulators to set meaningful exposure limits. Comprehensive methods to detect, characterize and quantify airborne microorganisms are therefore urgently needed. This presentation describes the challenges and opportunities surrounding bioaerosol sampling and analysis, with emphasis on how BiAirNet is exploring the development of bespoke approaches for particular environments to address these issues going forward.

3. Controlled Active Ventilation Environment (CAVE) - Resilient Buildings and Indoor Environments (TAPAS)

Liora Malki-Epshtein, University College London, UK

UCL's CAVE is a new laboratory which just completed construction in East London, which specialises in urban fluid mechanics, air pollution, Indoor Air Quality (IAQ), and thermal comfort. The lab is designed to measure, quantify risks, provide data for model calibration and test solutions at full scale.

CAVE is a complex climate- and ventilation-controlled indoor laboratory. With a plan area of 206 m^2 and height of 9 m, CAVE's large size allows fully monitored and full scale "living labs" to be built inside the laboratory space. The laboratory systems enable simultaneous creation of independent "interior" and "exterior" environments within the lab at a large temperature range (-5°C to 43°C) to reproduce a wide range of realistic climate and air quality scenarios.

CAVE can be used to simulate indoor classroom environments to test impacts of building ventilation and climate control technologies or strategies, low-cost technologies and green infrastructure, for a wide range of climate conditions. The lab can enable people to participate in experiments so as to understand the user's response to those in terms of usability, thermal comfort, social and cognitive impacts and wellbeing.

4. Low cost source apportionment of urban air pollution (TRANSITION)

Dimitrios Bousiotis, University of Birmingham, UK

Over the last 10 years, there has been a revolution in the use of low cost sensors to measure air pollution concentrations. These sensors are not without problems, but it is now possible to get high quality measurements of air pollutants. In particular, the use of low cost optical particle counters (OPCs) for the measurement of particulate matter (PM) in regulatory size ranges has been successfully achieved in many urban areas worldwide, with an associated cost that is far less than regulatory instruments.

Successful air quality management and control not only requires measurement of air pollution levels, but it also requires information on the sources and their relative importance. Without this critical, targeted information on pollution sources, it is difficult to plan and enact control measures with which to reduce air pollution. This talk will present new work on using low cost PM sensors to achieve low cost source identification and apportionment.

Project report: https://transition-air.org.uk/wp-content/uploads/TRANSITION-DI-Project-Report-Gordon-Allison.pdf

Theme 3: Health and Inequalities

1. Class-ACT: The effects of air cleaning technologies (ACT) in Bradford Schools (FUVN)

Henry Burridge, Imperial College London, UK

At the height of the pandemic, air quality monitoring equipment was installed in 253 classrooms within 21 Bradford schools. Schools were divided into two groups: (i) 10 'HEPA-ACT schools' equipped with standalone HEPA filter units; (ii) 11 'control schools'. The groups were balanced regarding building type, ethnic demographic, socioeconomic composition, and pupil numbers. Analysis of data from Sept 2021 to March 2022 showed comparable (naturally driven) ventilation rates between control and HEPA-ACT schools, but the mean PM2.5 concentrations in HEPA-ACT schools were approximately half the values within control schools. A regression model, accounting for local covid-19 incidence rates and measured classroom carbon dioxide levels, indicated that the lower illness absence rates in the HEPA-ACT schools (~20%) were statistically significant. These findings show that filter-based ACT can improve air quality in classrooms. Furthermore, ACT was associated with lower school illness absences during the pandemic, suggesting these technologies could reduce airborne disease transmission in schools.

2. Measuring the impact of indoor air pollution in people with respiratory disease (CleanAir4V)

Alice Turner, University of Birmingham, UK

The CleanAir4V team in Birmingham has been conducting a pilot study in patients who have asthma or chronic obstructive pulmonary disease (COPD) to determine how they perceive indoor air quality issues, and how indoor air quality affects their health. The study has 3 parts: a qualitative interview study which explores perceptions and impacts of air quality at a deep level with up to 20 people, a survey about the same topic which explores in less detail, but with a wider number of people (currently over 300), and finally an observational study in up to 60 people. This third part involves low cost sensor deployment in patients' homes, and completion of daily symptom diaries, which will enable us to relate air quality to symptom burden.

3. Laser Applications relevant to Clean Air Technologies (SAQN)

Andy Ward, STFC, UK

The Central Laser Facility hosts a range of laser techniques available to the academic community that have been applied to improving Air Quality. We will look at examples of laser-based research that have been applied to improving clean air technologies in the fields of catalysis, photovoltaics and high speed x-ray imaging. Aerosol and biological imaging studies will also be discussed that are relevant to airborne pollution and respiratory therapy.

4. Air quality and mental health: evidence, challenges and future directions (BioAirNet)

Kam Bhui, University of Oxford, UK

Poor air quality is associated with poor health. Little attention is given to the complex array of environmental exposures and air pollutants that impact mental health during the life course. We gather interdisciplinary expertise and knowledge across the air pollution and mental health fields. We seek to propose future research priorities and how to address them. Through a rapid narrative review, we summarise the key scientific findings, knowledge gaps, and methodological challenges. There is emerging evidence of associations between poor air quality, both indoors and outdoors, and poor mental health more generally as well as specific mental disorders. Furthermore, pre-existing long term

conditions appear to deteriorate requiring more health care. Evidence of critical periods for exposures among children and adolescents highlights the need for more longitudinal data as the basis of early preventive actions and policies. Particulate matter, including bioaerosols, are implicated, but form part of a complex exposome influenced by geography, deprivation, socio-economic conditions, and biological and individual vulnerabilities. Critical knowledge gaps need to be addressed to design interventions for mitigation and prevention, reflecting ever-changing sources of air pollution. The evidence base can inform and motivate multi-sector and interdisciplinary efforts of researchers, practitioners, policy-makers, industry, community groups, and campaigners to take informed action. There are knowledge gaps and a need for more research, for example, around bioaerosols exposure, indoor and outdoor pollution, urban design, and mental health impacts over the life course.

Theme 4: Involvement and Engagement

1. Engaging with small business owners to improve indoor air quality (FUVN)

Abigail Hathway, University of Sheffield, UK

Hospitality businesses saw significant losses following lockdowns and social distancing requirements during the Covid-19 pandemic. As places reopened there was concern about some customers being reluctant to share crowded, potentially poorly ventilated spaces, with others. Sick leave amongst staff caused additional challenges to business owners. During this time we have been supporting our local Environmental health team to provide guidance on improving ventilation to business venues. Research has encompassed understanding the challenges of providing ventilation, both technical and behavioural, and we have created bespoke guidance in response to this. This talk will cover the later stages of this work where we developed bespoke guidance for this sector based on our conversations with business owners and trialled the use of the guidance alongside CO_2 monitors evaluating ventilation changes, behavioural change, and acceptability.

2. Democratising Air Quality Models (HEICCAM)

Sumil Thakrar, University of Minnesota, USA

Exposure to poor air quality causes millions of deaths each year, mostly in low-/middle-income countries. Designing policies to reduce these deaths relies on air quality modeling; however, air quality models typically have substantial requirements for computation and expertise, which limits policy design, especially in countries where most pollution-related deaths occur. Lower requirement reduced-complexity models exist, but are generally unavailable worldwide. Here, I present Global InMAP, a global, open-source reduced-complexity air quality model, that estimates PM2.5 concentrations at 4–500km resolution. InMAP predicts total PM2.5 concentrations with a normalized mean error of 62% (GEOS-Chem: 41%). For the emission scenarios considered, Global InMAP reproduced GEOS-Chem pollutant concentrations with a normalized mean bias of 59%–121%. Global InMAP can be run on a desktop computer; simulations here took 2.6–8.4 hours. This work advances attempts to “democratize” air pollution health impact assessment, making data, models, and monitors available where they are most needed.

3. Communicating air quality with a sense of audience (BioAirNet)

Andrew Mitchell, De Montfort University, UK

During the recent pandemic people became increasingly aware of vulnerabilities, and risks, of exposure to air-borne pathogens. This awareness manifest itself through multiple perspectives, ranging from those who denied the existence of the virus to more holistic and cautionary responses from policy-makers and health professionals. What this range of perspectives also highlighted was the difficulty in communicating a consistent message to a highly diverse audience, each with different levels of knowledge, receptivity and attitudes to risk. In addition, these perspectives were and are informed by differing experiences of the virus; something that is relevant to the management of bioaerosols more widely This paper will build on insights generated by the BioAirNet research group about how different stakeholders engage with the issues of bioaerosols and will explore how to communicate with those stakeholders in ways that reflect a range of perceptions and understanding of the topic. It will consider the mechanisms, messages and styles of communication that align with different stakeholders through a sense of audience.

4. Air quality monitoring in UK schools: The SAMHE project (TAPAS)

Sarah West, Stockholm Environment Institute, University of York, UK

Citizen science is an excellent approach for collecting air quality data from places that researchers wouldn't usually be able to access, such as school classrooms, whilst having benefits for those participating in the research. In SAMHE (Schools' Air quality Monitoring for Health and Education), pupils (and their teachers) will gain knowledge and understanding of what affects air quality, scientific enquiry skills, skills such as persuasive writing, and importantly, knowledge about what to do to improve air quality. The scientists get to collect data from school classrooms about particulate matter and total volatile organic compounds, as well as temperature, relative humidity, and CO_2. SAMHE launched at the end of April and is aiming to send 2000 monitors out to schools across the UK, meaning this will be the largest school air quality monitoring scheme in the world. I'll talk about our approach and what we are hoping to achieve.

Thursday, 6th July 2023

Paul Wilkinson Memorial Lecture – The need for action and engagement in science
Anna Hansell, University of Leicester, UK

The late Professor Paul Wilkinson was a renowned environmental epidemiologist, whose original thinking and insights greatly benefitted the field. He put particular emphasis on the need for research to be translated into policy, in order to improve public health and reduce inequalities. The first part of this Memorial Lecture will pay tribute to Paul's working on teaching and training, his leadership of the Clean Air Research Network HEICCAM and the NIHR Health Protection Research Unit in Environmental Change and Health, and acknowledge his work as a member of the UK government independent advisory committee, the Committee on the Medical Effects of Air Pollution. The main part of the lecture will consider examples of various efforts to tackle environmental health hazards. Drawing on Paul's ability to think outside the box, the examples will be used to illustrate issues and to provide tips on negotiating the journey from research to action.

Session 1: Strategic Direction of Future Research (10:30-11:30)

Theme 1: Monitoring and Facilities

Chair: Liora Malki-Epshtein

This session will discuss existing, planned, and proposed air quality monitoring programmes. Both indoor and outdoor air quality will be considered to include monitoring programmes from a single-room/street to a national scale. The importance of taking a holistic approach to monitoring will bring thermal comfort, energy consumption and noise pollution (plus more) into the conversation and allow experts in whole-systems approaches to share their experiences. There will also be discussions around connecting air quality data to public health data to identify areas where pollution mitigation strategies can have positive health impacts.

1. IAQ local and national observatories (FUVN)
Cath Noakes, University of Leeds, UK

Understanding the impacts of air quality on health and wellbeing requires significant data on both health and the physical environments where people spend time and the pollutants that are present. The concerted effort to measure outdoor air quality at national and global scale has provided the means to develop correlations between pollutants and health, which has led to evidence-based guidelines on pollutant concentrations. It is essential that we now also do this for indoor air, however this is limited by the lack of longitudinal indoor air quality (IAQ) data at sufficient scale. This presentation considers the potential for developing IAQ observatories to build this evidence base. It draws on examples from the UK, USA and France to highlight the benefits of measurement for individuals, industry, researchers and policy makers, and considers some of the challenges and complexities with establishing IAQ observations at scale.

2. Future directions for outdoor air quality monitoring (SAQN)
Ally Lewis, University of York, UK

Understanding the human and ecosystems impacts of air pollution, and assessing attainment of air quality standards relies fundamentally on measurements. The UK has a substantial network of

monitoring of basic parameters with a strong emphasis on data that supports regulatory obligations. For complex pollutants such as particulate matter measuring simple properties, such as mass of particles, gives little insight into where those particles came from, or how harmful they might be. Metrics such as PM2.5 or PM10 provide no early warning of emerging classes of pollutant that may be produced from novel materials or processes. A more holistic approach to outdoor air quality monitoring is urgently needed. Measurements can shed light on how emissions sources changing, with faster feedback to policymakers on the effects of policies. More granular detail on gases and particles - chemical speciation, size and shape - may support a more nuanced interpretation of what causes the greatest health impacts. Investment in multi-species monitoring may be a small upfront investment that pays huge dividends later, allowing financial investment in emissions reduction to be targeted where the benefits will be greatest.

3. What do we know about the air we breathe? The Exposure Case for Indoor Air Quality (HEICCAM)

Miranda Loh, Institute of Occupational Medicine (IOM), UK

Air pollution is often thought of as part of the outdoors, coming from smokestacks and cars. Most people spend around 80% of their time indoors, whether working, eating, or sleeping. The air people breathe in is best defined by the microenvironments, or places that they spend their time in. Personal exposure is a function of the air quality in different microenvironments people spend time in, and the amount of time spent in them. Quantifying and characterising the contributions of these microenvironments to a person's overall exposure allows better understanding of the drivers of exposure to air pollutants. Exposure reduction measures can be better targeted based on exposure-related information. In particular, when examining reducing air pollution health risks from an exposure perspective, indoor microenvironments (including both buildings and transport) present a potentially undervalued area for intervention.

Theme 2: Exposure and Health Linkage

Chair: Dr David Green

This session will discuss air pollution challenges, assessments, and review studies, particularly on vulnerable communities.

1. The Science and Technology Facilities Council (STFC) Air Quality Network to Stimulate Multidisciplinary Approaches to Unmet Air Pollution Challenges (SAQN).

Ian Mudway, Imperial College London, UK

The Science and Technology Facilities Council (STFC) Air Quality Network was established – lead by Dr Sarah Moller, was funded under the STFC 21st Century Challenge Network+ call and ran from January 2020 until Summer 2023. It was established with the aim of highlighting STFC capacity to members of the UK's air pollution community, and to promote multidisciplinary collaborations, that maximised the use of the UKs core science facilities. This was achieved by the award of small funding pots, for scoping studies at £10k and proof of concept at £40k, following sandpit discussions, project development with mentors, and peer review. These projects aimed to support academic, STFC collaboration, and provide preliminary data to support future more ambitious proposals. Throughout its course it supported a diverse range of projects including improved modelling of indoor air pollutants; the development of sensors for ammonia and improved satellite quantification of secondary inorganic aerosols; sensors development for assessing emissions from shipping and volcanoes, and a study examining nanoparticle translocation across the blood brain barrier. Throughout its course it attempted to identify barriers to the use of STFC facilities, and address under appreciation of their capacity amongst certain communities. One key area identified where it was felt enhance collaboration could catalyse significant progress in air pollution science was in the toxicological assessment of chemically complex particulate matter, cell/tissue interactions and in refining our understanding of in vivo dosimetry. In the networks final year significant effort was made to address this issue and to communicate STFC capacity and promote interactions with air pollution toxicologists.

2. Designing surveillance for air pollution assessment (BioAirNet)

Rob Kinnersley, Environment Agency, UK

The growth in resistance of pathogens to antibiotics and antifungal agents is a matter of great concern globally. Attention is mainly focused on clinical settings, but there is recognition that natural microorganisms can be incubators for or accumulators of AMR, especially where presence of antimicrobials (for example from waste water or agricultural activities) provides a selection pressure. Concerns include direct infection with AMR pathogens, and horizontal transfer of resistance genes from non-pathogens to pathogens. The Environment Agency has designed projects to study the issue. Current knowledge was reviewed, and methods for collecting samples for AMR analysis trialled for practicality and cost. Information on AMR in bioPM was sparse; substantially more work is needed to assess potential risk from bioPM, its spatial variation, and to inform design of statistically robust surveillance. BioAirNet's work, particularly in compiling the Compendium of Monitoring Methods, have been of great value in informing this work.

3. Indoor Air Quality and Vulnerable Groups (CleanAir4V)

Alice Turner, University of Birmingham, UK

This session will give an overview from systematic reviews conducted by a Team who are part of the CleanAir4V Network of the scale and impact of indoor air quality issues on vulnerable populations, together with an overview of key interventional studies to date. Potential study designs for a definitive study of an air filtration system in patients with respiratory disease in the UK will be proposed and opened to discussion.

Theme 3: Behaviour

Chair: Sarah West

This session will discuss the impacts of pollutants on the indoor environment which is currently far less well understood than the outdoor environment. How human behaviour can be modified to mitigate against pollutant exposure is an interesting topic which will be explored as well as how we can influence a change in behaviour through simple, low cost methods.

1. Pollutant Indoor Exposure from Stoves and Fireplaces (CleanAir4V)
Roy Harrison, University of Birmingham, UK

The impact of the burning of domestic fuels, including both solid fossil fuels and biomass, upon outdoor air quality is reasonably well quantified. However, the risk indoors from releases from combustion appliances is far less well appreciated, and data are limited. This talk will give a brief overview of some of the published work on this topic, and seek to place the exposures in context.

2. Reflections on Air Quality Focus Groups (HEICCAM)
Connor Smith, University of Edinburgh, UK

Research aim: The aim of this study was to explore London residents' perceptions of, and attitudes towards, indoor and outdoor air quality. In particular, we wanted to better understand the extent to which there might be scope for individual behaviour change to mitigate against exposure, vis-à-vis the need for systemic change, and whether or not this differs in indoor versus outdoor environments. *Methodology:* 6 focus group discussions with 31 participants in total. Sessions lasted approximately 1 hour and 45 minutes each and were held online via the Zoom platform. Groups were categorised by geography (inner/outer London) and vulnerabilities (elderly; parent with young child; pre-existing health condition). *Results and conclusions*: our preliminary findings suggest that participants may more willing and better able to take individual responsibility indoors (at home) than outdoors (when travelling); however, publics first need to be made aware about the impacts of indoor air pollution on human health and scenarios to avoid (e.g. cooking indoors without ventilation).

3. Act Now Project (TAPAS)
Mike Holland, EMRC, UK

ActNow is a sub project of the TAPAS (Tackling Air Pollution At School) Network. The name emphasises the need to take action to protect the current cohort of children attending UK schools. The purpose of the project is to disseminate information on a limited number of activities designed to raise awareness of both indoor and outdoor air pollution at school, including low-input (low cost, low time-demand) measures for reducing exposure. Through these activities it is hoped that schools will become engaged in air quality management, and may continue with further measures using, for example, the Clean Air for Schools Framework. A promotional campaign is underway using educational communications experts at BeeDigital to disseminate the information pack and other materials to schools to enhance adoption of the ActNow programme.

Session 2: Key messages for policy, industry and public stakeholders (12:00-13:00)

Theme 1: Informing Regulation

Chair: Gary Fuller

In the UK, legally binding regulations seek to control human exposure to ambient air pollution to protect human health. However, as our knowledge of air pollution sources and health impacts advances –in both indoor and outdoor settings – it is essential to consider implications for future regulatory changes which may further reduce health harms. Indoor air quality regulation presents several complex related challenges. Buildings Regulations include standards for acceptable ventilation rates, but these are less well defined for indoor air pollutant concentrations and existing WHO health-based air quality guidelines have no statutory underpinning. In addition, a complex mix of product emission regulations and guidelines also impact on indoor air quality, but these are not well integrated or widely understood among the general public. Transport environments (including bus and railway stations) are commonly areas of elevated pollutant concentrations, however existing regulation is focused on occupational limit values which are higher than ambient standards. In this context, we invite speakers from TRANSITION Clean Air Network, Future Urban Ventilation Network and National Physical Laboratory to share novel advances in understanding of air pollution in indoor and transport environments and to consider how this knowledge can be used to inform future air quality regulation.

1. **Exposures to Particles and Volatile Organic Compounds across Multiple Transportation Modes (TRANSITION)**

Nick Molden, Emissions Analytics

Travellers may be exposed to a wide range of different air pollutants during their journeys. In this study funded by the TRANSITION Clean Air Network, personal exposures within vehicles and during active travel were tested in real-world conditions across nine different transport modes on journeys from London Paddington to Oxford City Centre. The modes tested covered cycling, walking, buses, coaches, trains and private cars. Such exposures are relevant to questions of traveller comfort and safety in the context of airborne diseases such as COVID-19 and a growing awareness of the health, safety and productivity effects of interior air quality. Pollutants measured were particle number, particle mass, carbon dioxide and speciated volatile organic compounds, using devices carried on or with the traveller, with pumped sampling. Likely sources were both combustion products entering the vehicle and pollution from interior materials and other travellers.

Article: https://doi.org/10.3390/su15054005

2. **Building regulations and compliance (FUVN)**

Hywel Davies, CIBSE, UK

Heating, ventilating and air conditioning systems are all defined as fixed building services and work on them is controlled under the building regulations. There is a growing realisation that ventilation really is critical to the health of building occupants and that inadequate ventilation can, in extremis, have fatal consequences. This presentation will outline what the building regulations cover, key issues relating to ventilation and how changes to the building control system coming into effect now in the aftermath of the Building Safety Act could and should influence work on buildings that affects energy efficiency and ventilation.

3. An update on standardization for low-cost air quality monitors (Metrology Network - NPL)

Nicholas A Martin, National Physical Laboratory, UK

National Physical Laboratory (NPL), Atmospheric Environmental Science Department, Hampton Road, Teddington, Middlesex, TW11 0LW, UK

Traditionally air quality measurements have been carried out with a small number of well characterised reference instruments supplemented by cheaper diffusive samplers which can be deployed over a wide geographical area. Documented performance standards for these technologies have been developed to support UK legislation and EU Air Quality Directives.

Low-cost monitors are increasingly being used, with advantages including ease of deployment in large networks, rapid time sampling, and near-real-time access to data through “apps”. However, data generated from such devices often varies in quality with a lack of traceability of the measurements, which is an important barrier to wider uptake of newer technologies.

These issues are being addressed by standardization bodies. This presentation covers updates on the development of Technical Specifications by CEN TC264 WG42 “Air Quality Sensors”, facilities at NPL for sensor evaluation and a UK Publicly Available Specification to aid stakeholders in the deployment of low-cost monitors.

Theme 2: Environment and Net Zero

Chair: Frederic Coulon

The UK is bound (by the Climate Change Act 2019) to reduce its overall emissions to net zero by 2050. This law-binding commitment means that the UK's greenhouse gas emissions have to be fully negated, by either emissions reductions or through the implementation of methods to absorb greenhouse gases from the atmosphere. To achieve this, it will be necessary to perform country-scale changes in multiple sectors including energy, infrastructure, agriculture and transport.

The move towards net zero will have wide-ranging impacts upon air pollution in the UK, and therefore will impact population health and the environment. These impacts can be both positive (for example, reduced transport emissions leading to cleaner urban air) and negative (for example, increased home energy efficiency measures can lead to increased concentrations of air pollution from indoor sources). It is therefore key to understand the consequences of moving towards net zero, in order to understand future air pollution trends.

This session explores the impact of net zero upon the environment (specifically, clean air) from a variety of perspectives. Speakers will cover future UK policy around net zero (Ruth Doherty, HEICCAM), transport decarbonisation (Alex Penn, TRANSITION) and provide a stakeholder's (the Environment Agency) perspective on the net zero transition (Rob Kinnersley, SAQN).

1. The Future of Net-Zero Policies for air pollution in the UK (HEICCAM)

Ruth Doherty, University of Edinburgh, UK

The UK is legally bound to reduce overall emissions to net zero by 2050. This will have wide-ranging impacts on diverse sectors including agriculture and building design, and will be implemented through a series of policy decisions. The move towards net zero has the potential for co-benefits for climate change mitigation and improving air quality. The unintended consequences of policy measures such as home energy saving measures in particular for indoor air quality need also to be assessed. This talk will discuss the UK's path to net zero: specifically, how outdoor and indoor air quality will be impacted over the next few decades. The importance of protecting clean air in an equitable manner will be discussed in the context of the path towards net zero.

2. Adopting a Whole Systems Approach to Transport Decarbonisation, Air Quality and Health (TRANSITION)

Alex Penn, CECAN, University of Surrey, UK

In a drive to achieve net zero emissions, U.K. transport decarbonisation policies are focussed on promoting the uptake and use of electric vehicles (EVs). However, emerging evidence suggests that EVs present multiple challenges for air quality, mobility and health, including risks from non-exhaust emissions (NEEs) and increasing reliance on vehicles for short trips. Understanding the interconnected links between electric mobility, human health and the environment, including synergies and trade-offs, requires a whole systems approach to transport policymaking. I describe use of Participatory Systems Mapping (PSM), whereby a diverse group of stakeholders collaboratively constructed a causal model of the U.K. surface transport system, as an approach to address this. I discuss map analysis which illustrates how unintended consequences of EV-focussed policies may impact on air quality, human health and important social functions of the transport system. Further, how PSM could be used to facilitate effective policy design, appraisal, learning and adaptation.

Article: https://doi.org/10.3390/atmos13030492

3. Air Pollution Policy: Ongoing and Emerging Challenges (SAQN)

John Newington, Defra - Air Quality & Industrial Emissions (AQIE)

TBC

Theme 3: Solutions

Chair: Douglas Booker

The challenge of air pollution requires effective solutions – policy, technical and behavioural – to deliver cleaner air. Many of these solutions sit at the nexus of different disciplines, spanning life, physical and social sciences, and require impact focussed research undertaken in partnership with policy and industry partners. In this session we consider a selection of potential solutions, with a focus on protecting those most vulnerable to air pollution, including contributions from the TAPAS and TRANSITION Clean Air Networks.

Firstly we consider school settings, and how our knowledge from air quality monitoring undertaken within TAPAS can inform structural and behavioural changes to reduce pollutant emissions and protect pupils and staff. Secondly, we explore advances in urban design, including the role of green infrastructure as a means of reducing roadside exposure to vehicular emissions. Finally we reflect on how technological advances could reduce pollution arising from internal combustion engine vehicles, and whether these have potential to clean ambient air. We will also discuss the barriers and facilitators for 'real-world' delivery and the critical role of relevant public, commercial and not-for-profit partners.

1. **Green Infrastructure for Roadside Air Quality: modifying pollution dispersion to reduce local exposure (TRANSITION)**

James Levine, University of Birmingham, UK

Levine, J. G., H. Pearce, X. Cai, G. Phillips, G. Wilson, S. Littlewood, K. Sheldon, A. Fitch, D. Fletcher, L. Jones, and A. R. MacKenzie

Green Infrastructure for Roadside Air Quality (GI4RAQ) is an initiative led by the University of Birmingham following the Air Quality Expert Group's (2018) review of the Impacts of Vegetation on Urban Air Pollution. With stakeholder partners, including the Greater London Authority, Transport for London, Birmingham City Council and AEA Ricardo, we have co-developed prototype, open-source software enabling non-experts to estimate quantitatively the local impacts of roadside planting on public exposure to vehicular pollution via changes in local patterns of polluted air flow and mixing close to source (see www.bit.ly/GI4RAQpress). Here, we present the results to early comparisons with observations, and introduce you to an extension to the software currently underway. Via a Future of UK Treescapes Fellowship, in partnership with Trees for Cities and UKCEH, we are integrating the GI4RAQ code into GIS for city-region planning and Natural Capital accounting: Advancing a planning Framework FOr Regionally Enhanced and Equitable Ecosystem Services from urban Treescapes (AFFORE3ST; see https://www.uktreescapes.org/projects/dr-james-levine).

2. **Practical recommendations to mitigate air pollution exposure to school children (TAPAS)**

Prashant Kumar, Global Centre for Clean Air Research, University of Surrey, UK

Children are exposed to higher concentrations due to their low breathing height. They are more vulnerable to exposure to vehicular emissions due to their incomplete lung development, low breathing height, and high physical activity and breathing rates. Therefore, they are more likely to suffer from short and long-term health conditions due to traffic-related air pollution, including asthma, bronchitis, and stunted lung development. Our studies have found high levels of harmful $PM_{2.5}$ (particles less than 2.5 micrometres in diameter) pollution from traffic emissions near schools and nurseries, endangering the health and well-being of nearby children. This talk will present the key findings from the CO-TRACE/SAMHE & TAPAS Network supported research on indoor environments

of classrooms, in combination with the extensive body of work done by the GCARE team around this topic area, including a school guidance, to discuss the following question: how the exposure to children can be mitigated in and around schools?

3. A negative emission internal combustion engine vehicle? (TRANSITION)

Felix Leach, University of Oxford, UK

Modern internal combustion engine (ICE) vehicles carry extensive exhaust aftertreatment systems that can reduce their tailpipe pollutant emissions to near-zero, or even within the zero levels of measurement equipment, in real-world conditions. It has been reported, therefore, that such vehicles can have tailpipe pollutant levels lower than the air intake of the vehicle – that they are cleaning the ambient air. This study investigates this using different ICEs and real-world emissions data alongside pollutant (nitrogen dioxide and particulate matter) data from around the world and the accuracy of the instrumentation typically used to measure tailpipe emissions. The results show that it is unlikely that a modern ICE vehicle will clean ambient air, even at extreme pollution levels, although it is possible. However, where a vehicle inlet is in the plume of a dirtier vehicle or the pollution measured is among the highest values recorded globally, the pollution reduction can be substantial.

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Clean Air Networks Current State of Play

TAPAS

The Tackling Air Pollution At School network is a multidisciplinary network designed to bring together stakeholders from across academia, education, public policy, civil society and business. We work together to support the development of healthy schools by improving air quality.

The TAPAS network was designed to look at air pollution in schools by bringing together the outdoor and indoor air pollution communities in the UK. Our aim is to develop the research base to design and operate healthy schools now and in the environment of the future. We're doing this by funding research projects, holding seminars from a wide variety of experts, and regularly meeting with our stakeholders and members to further our knowledge base and disseminate information. A short Research Visit Scheme was established to support our early career researchers to further this transfer of knowledge. TAPAS members have also contributed to the Chief Medical Officers report on indoor air quality and the EAC enquiry on outdoor and indoor air quality targets.

A vision of the TAPAS network is for schools to be empowered to reduce their own exposure to pollution. By giving staff, students and parents the correct tools and knowledge, we can equip them to tackle air pollution in and around their schools.

FUVN

The Future Urban Ventilation Network (FUVN), also known as Breathing City, focuses on health evidence approaches for urban and building ventilation design. We consider a holistic approach to the coupled indoor and outdoor airflows that lead to exposure to air pollution, alongside the impacts on thermal comfort, noise and energy use. FUVN brings together stakeholders from research, clinicians, industry, policy and the public to understand the current state of building ventilation and urban airflow and explore technology and behavioural solutions to improve air quality.

The pandemic has had a significant impact on our activities, with the international focus on ventilation and air cleaning in the context of mitigating infection transmission. Alongside this there has been a growing interest in the wider health impacts of indoor air quality and a call for solutions. These national and international priorities have led to a number of opportunities within FUVN, including authorship of a chapter in the Chief Medical Officer's annual report 2022 on improving indoor air quality, contribution to the Royal Academy of Engineering Infection Resilient Environments work, a national ventilation survey to understand the adequacy and knowledge of ventilation in people's homes, and ongoing work together with other clean air networks to scope a national plan for developing indoor air observatories to provide essential missing data on indoor environments and health.

CleanAir4V

CleanAir4V is an interdisciplinary network of academics, stakeholders and industry with the aim of developing and delivering co-designed air pollution solutions for vulnerable groups. The network focuses on two vulnerable groups: people with underlying respiratory conditions (such as COPD and asthma) and children. These groups are most strongly affected by poor indoor air quality but have limited autonomy to escape their indoor environments.

Our aim is to build a self-sustaining and interdisciplinary network capable of delivering co-designed research and innovation for developing robust solutions that reduce the impact of air pollution on vulnerable groups. We also aim to link UK and international expertise to establish research gaps, cost-effective behaviour and technology intervention opportunities and catalyse future cross-disciplinary research in the field of air pollution solution research.

A highlight of the CleanAir4V network activities is a pilot study which has being conducted to assess the correlation between indoor air quality and the symptoms experienced by those with diagnosed respiratory conditions, aiming to establish the participants' perceptions and key air quality challenges, and to ultimately offer solutions to reduce the symptoms of people with respiratory conditions. We also have published a literature review (Maung et al., *Int J Environ Res Public Health,* 2022) which focussed on studies which assessed how children and those with respiratory conditions are affected by indoor air pollution, rather than outdoor air pollution, which has previously been a key focus for most research in this area.

HEICCAM

HEICCAM (Health and Equity Impacts of Climate Change Adaptation Measures on indoor and outdoor air pollution) is a multidisciplinary network looking at the effect that increasing home energy efficiency measures has upon air pollution.

The transition to a low carbon economy and policies to improve air quality have important implications for exposure to air pollutants in the connected indoor and outdoor environments. Measures to improve home energy efficiency typically entail reducing ventilation and hence air exchange. While beneficial in decreasing the penetration of pollutants from the outdoor environment, they may increase gaseous and particulate pollutants from indoor sources. The limited understanding of these impacts reflects an evidence gap that is especially important for vulnerable groups including children, the elderly and those with pre-existing illness. The HEICCAM network seeks to address this gap.

The network has ongoing work to develop a measurement protocol for residential air pollution measurements and is producing literature reviews around the topic of home energy efficiency and air pollution, as well as contributing to public-facing events such as workshops and focus groups. HEICCAM past and future events include webinars, retreats and in-person assemblies. Early-career researchers are at the heart of the network, running seminars and in-person events. HEICCAM members have also contributed to reports for groups such as DEFRA and the Chief Medical Officers' report on indoor air quality.

TRANSITION Clean Air Network

The TRANSITION Clean Air Network is a UK-wide network comprising ten universities and over 20 cross-sector partners, which seeks to deliver air quality and health benefits associated with the UK transition to a low emission transport economy.

The network undertakes collaborative, innovative and imaginative research activities to advance contemporary understanding of air quality challenges and solutions across UK surface transport systems, drawing upon knowledge and perspectives from academics, public, not-for-profit and commercial stakeholders. Network activities span four key themes: (i) Characterising emerging air quality challenges and risks; (ii) Understanding transport choices and behaviours; (iii) Supporting industry led research and innovation; (iv) Co-creating a framework for policy solutions.

Network highlights include five collaborative Discovery and Innovation projects spanning primary assessment of air pollution exposure in transport environments, application of novel methodological approaches for air quality analysis and development of impact focused solutions. The network has also produced a series of eight policy briefing notes including air quality in transport hubs, low emission zones, non-exhaust emissions, e-cycling, and rail freight emissions. The network convenes a quarterly webinar series led by academic, industry and policy experts, providing an opportunity to gain new insights and engage in topical debate regarding contemporary transport and air quality issues and challenges.

Clean Air Metrology Network

The fundamental goal of metrology, the science of measurement, is to ensure that the result of any measurement is fit for purpose. This quality assurance activity usually involves characterising, and ideally quantifying, the level of confidence in the result – this is often expressed in terms of the measurement uncertainty. Establishing a metrology infrastructure across an area of scientific activity enables three key properties to be realised, ensuring that the results are:

- Stable – allowing comparison over time.
- Comparable – allowing comparison across different locations.
- Coherent – allowing direct exchange of information across disciplines.

All three of these properties are critical across the Clean Air research and development activities. The Metrology network is aiming to support this goal with the linked development of consistent methods to help ensure the outcomes from the programme are fit for purpose. This is being delivered through a series of workshops and case studies, primarily focussed on the internal research activities within the Clean Air Programme. A key outcome from these activities, beyond their immediate scientific impact, will be a set of best practice guidance documents to summarise common methodologies, the first of which is focusing on the assessment and reporting of uncertainties across different timescales.

SAQN

The STFC Air Quality Network (SAQN) has created a multidisciplinary community of experts, researchers, policy makers and businesses to leverage Science and Technology Facilities Council (STFC) research, capabilities and facilities to address air quality challenges. The SAQN aimed to facilitate the exploitation of the currently untapped potential of STFC capabilities to enhance and progress research into air pollution, particularly with relevance to impacts on human health and the environment. It has initiated new collaborations to achieve these aims through small funding awards and bringing people together to network and develop relationships and ideas for future collaborations.

BioAirNet

BioAirNet is adopting a transdisciplinary approach to identify and inform research and innovation strategies aimed at addressing current and future societal challenges related to biological particle matter (BioPM) in various indoor and outdoor environments. Currently, there are substantial gaps in our knowledge regarding how BioPM sources and emission characteristics are influenced by different factors in indoor and outdoor physical and social environments, as well as occupant behaviour. Equally important is understanding the resulting exposure patterns and the subsequent health impacts of BioPM. To bridge these knowledge gaps, BioAirNet operates through four interconnected interdisciplinary themes: 1) BioPM sources and dynamics, 2) BioPM sampling and characterisation, 3) Human health, behaviour, and well-being, and 4) Policy and public engagement. Through a series of

dedicated workshops, translational research, and outreach efforts targeting the public and stakeholders, BioAirNet conducted research gap analyses within these thematic areas to identify key topics for future investigation. Furthermore, BioAirNet is developing evidence-based review papers and toolboxes to support both research and policy development, as well as communication frameworks aimed at engaging the wider public, policy makers, and professionals. The outcomes of these activities will contribute to a comprehensive understanding of total human exposure to BioPM and its associated health burdens, thus providing valuable insights and guiding future research directions. For further details, please visit https://bioairnet.co.uk/news/.