Child and adolescent **H**ealth **I**mpacts of **L**earning **I**ndoor environments under net zero (**CHILI**)

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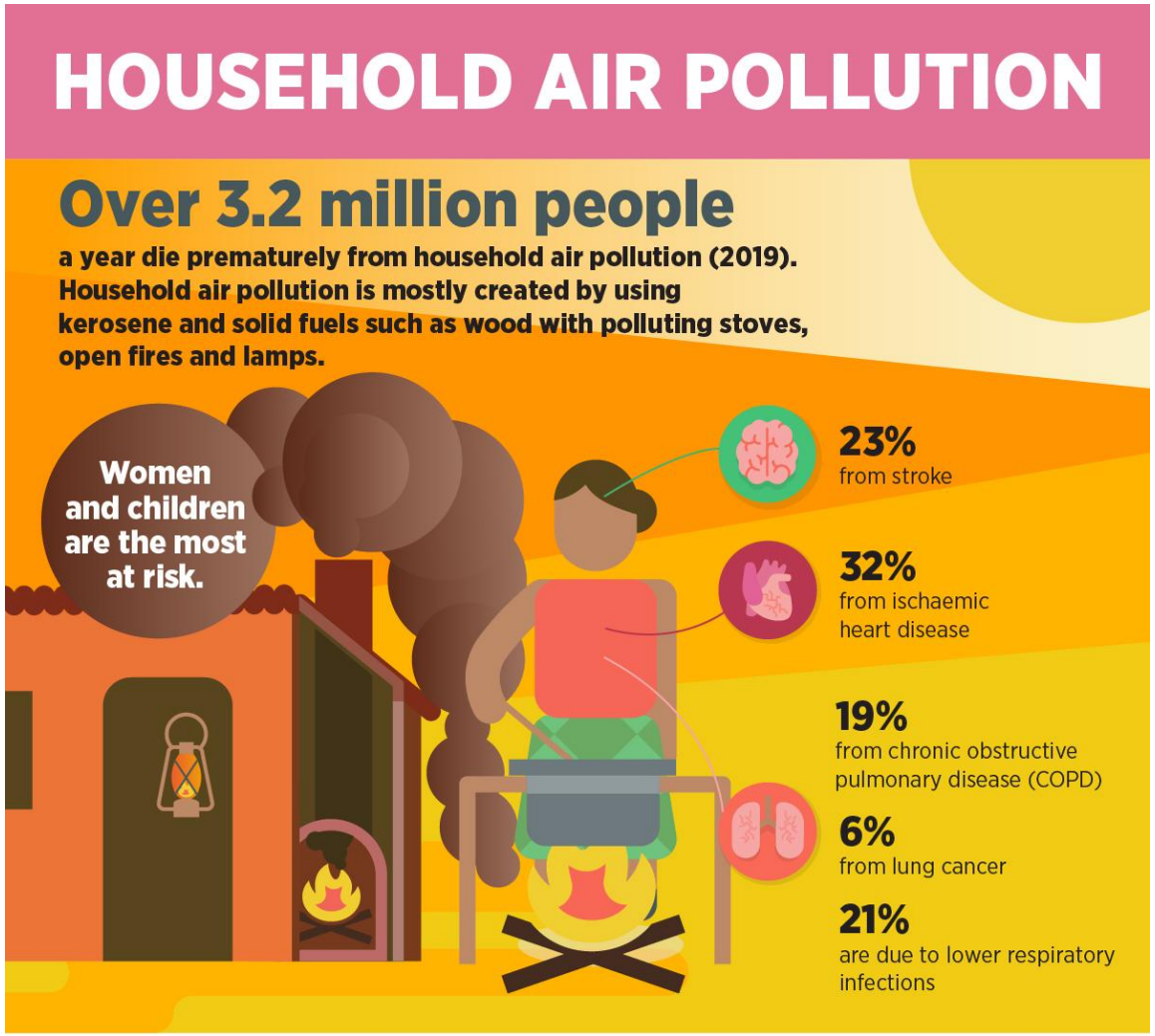
Welsh Government Indoor Air Quality Seminar

20.11.2025
Prof. Martin Clift

Child and Adolescent Health Impacts of Learning Indoor Environments Under Net Zero

Overview


HOUSEHOLD AIR POLLUTION
Over 3.2 million people
a year die prematurely from household air pollution (2019).
Household air pollution is mostly created by using
kerosene and solid fuels such as wood with polluting stoves,
open fires and lamps.
Women and children are the most at risk.
23%
from stroke
32%
from ischaemic heart disease
19%
from chronic obstructive pulmonary disease (COPD)
6%
from lung cancer
21%
are due to lower respiratory infections
CLEAN AIR FOR HEALTH
#AirPollution
World Health Organization

Overview

Sources of Indoor Pollutants

Bathroom
Mould, mildew, odours and other microbial pathogens

Air conditioning units
Unable to remove pathogens, VOC's and odours
Circulates without ventilating rooms

Living room
Animal hair dust and dander, tobacco smoke, diesel particles, VOC's from paint, varnishes, upholstery, furniture and carpet

Outdoor air
Particulate matters, pathogens, VOC's, odours and emmissions

Bedroom
VOC's from perfumes, hairspray, nail polish, upholstery, furniture and carpet, dust mites in bedsheets

Laundry room
VOC's from cleaning products, mould, mildew, odours and other microbial pathogens

Kitchen
Cooking devices
Fuel oil

Ionmax.com.au

Environmental Science Processes & Impacts

ROYAL SOCIETY OF CHEMISTRY

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Chemical fingerprints of cooking emissions and their impact on indoor air quality

Ashish Kumar, *[a] Catherine O'Leary, [a] Ruth Winkless, [a] Wael Dighriri,[a] Marvin Shaw,[ac] David Shaw, [bc] Nicola Carslaw [b] and Terry Dillon*[a]

Indoor environments host multiple sources of volatile organic compounds (VOCs) that influence the air quality, with cooking being one such significant and complex emission source. VOC emissions from cooking vary with the type of food cooked, ingredients used, cooking methodology, and ventilation, yet their speciation and impact on indoor air remain poorly understood. This study quantifies real-time emission rates of 39 VOCs from three frequently prepared UK meals: stir-fry, curry, and chilli, using a high-sensitivity selected ion flow tube mass spectrometer (SIFT-MS) in a room-scale, semi-realistic kitchen. Across 39 cooking experiments a distinct VOC emission profile for each meal was measured. The emissions were dominated by alcohols (methanol and ethanol, >50% of total emissions), harmful aldehydes (acetaldehyde, 7–23%), and highly reactive monoterpenes (up to 4%). The emissions were found to be influenced strongly by the use of different variants of the same ingredient (freshly chopped and packaged diced onions), spices and cooking behaviours. The secondary chemistry of the resultant VOC emissions was further investigated by simulating the hydroxyl (OH) reactivity and secondary product formation using INCHEM-Py. The model results show that the cooking plumes significantly perturbed the indoor chemistry, with OH reactivity ranging from 50–200 s^{-1} depending on VOC composition. Further simulations of a typical urban London kitchen revealed recipe-dependent impacts on radical (HO_2, RO_2) and secondary pollutant (O_3, PAN, organic nitrates, formaldehyde) formation. Among the meals tested, chillies exhibited the highest potential for secondary pollutant production, followed by curries. These findings l
secondary chemistry.

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Particle and Fibre Toxicology

RESEARCH Open Access

Determining the toxicological effects of indoor air pollution on both a healthy and an inflammatory-comprised model of the alveolar epithelial barrier in vitro

Kirsty Meldrum[1*], Stephen J. Evans[1], Michael J. Burgum[1], Shareen H. Doak[1] and Martin J. D. Clift[1*]

Abstract

Exposure to indoor air pollutants (IAP) has increased recently, with people spending more time indoors (i.e. homes, offices, schools and transportation). Increased exposures of IAP on a healthy population are poorly understood, and those with allergic respiratory conditions even less so. The objective of this study, therefore, was to implement a well-characterised in vitro model of the human alveolar epithelial barrier (A549 + PMA differentiated THP-1 incubated with and without IL-13, IL-5 and IL-4) to determine the effects of a standardised indoor particulate (NIST 2583) on both a healthy lung model and one modelling a type-II (stimulated with IL-13, IL-5 and IL-4) inflammatory response (such as asthma).

Using concentrations from the literature, and an environmentally appropriate exposure we investigated 232, 464 and 608ng/cm² of NIST 2583 respectively. Membrane integrity (blue dextran), viability (trypan blue), genotoxicity (micronucleus (Mn) assay) and (pro-)/(anti-)inflammatory effects (IL-6, IL-8, IL-33, IL-10) were then assessed 24 h post exposure to both models. Models were exposed using a physiologically relevant aerosolisation method (VitroCell Cloud 12 exposure system).

No changes in Mn frequency or membrane integrity in either model were noted when exposed to any of the tested concentrations of NIST 2583. A significant decrease ($p < 0.05$) in cell viability at the highest concentration was observed in the healthy model. Whilst cell viability in the "inflamed" model was decreased at the lower concentrations (significantly ($p < 0.05$) after 464ng/cm²). A significant reduction ($p < 0.05$) in IL-10 and a significant increase in IL-33 was seen after 24 h exposure to NIST 2583 (464, 608ng/cm²) in the "inflamed" model.

Collectively, the results indicate the potential for IAP to cause the onset of a type II response as well as exacerbating pre-existing allergic conditions. Furthermore, the data imposes the importance of considering unhealthy individuals when investigating the potential health effects of IAP. It also highlights that even in a healthy population these particles have the potential to induce this type II response and initiate an immune response following exposure to IAP.

Keywords Indoor air pollution, In vitro, Particulate matter, Inhalation, Lung, Disease model, Healthy

Clean Air Programme

UKRI Natural Environment Research Council

Indoor ‘HUB’

UK Research and Innovation

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£42m funding to ensure health is central to net zero strategies

Seven new transdisciplinary research hubs will explore ways to ensure the UK’s transition to net zero also protects and promotes physical and mental health.

The hubs are funded by UK Research and Innovation (UKRI) and the National Institute for Health and Care Research (NIHR).

Each hub will receive up to £6 million to deliver high impact research focused on reducing health inequalities.

Five challenge areas

The hubs are focused around five challenge areas, with significant opportunities to benefit people’s health and reduce the impact on the environment:

- transport and the built environment
- the indoor environment
- sustainable diets
- extreme weather
- decarbonising health and social care pathways

The hubs will work across these complex areas, together with other UKRI and NIHR investments, to identify areas for targeted interventions.

CHILI ‘HUB’ started as of February 2025 (5 year funded project)

SAMHE
SCHOOLS' AIR QUALITY MONITORING FOR HEALTH AND EDUCATION

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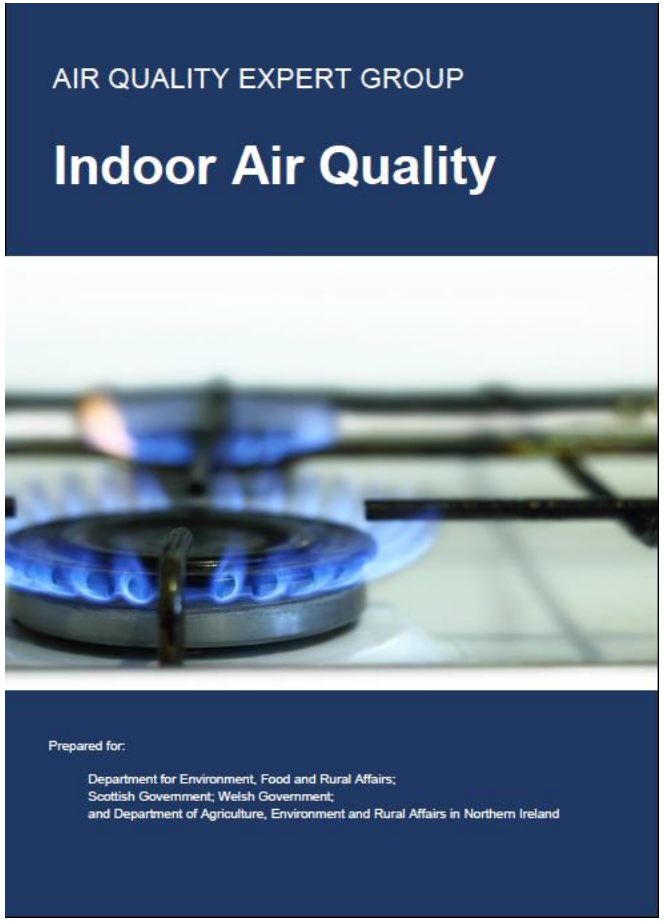
Current Status of the Field

- People spend >87% of time indoors
  - Private and Public spaces
  - Transport
  - Places of employment
  - Schools
- Most research is towards private spaces (homes).
- Children are an underrepresented (or even a ‘susceptible’) group in terms of knowledge about indoor air pollution effects.
- As all children will spend a significant amount of time in school, the exposure profile should be realised and linked to potential health hazards.
- Schools pose a complex hazard, due to their age, construction materials and building status.

https://www.gov.uk/government/publications/chief-medical-officers-annual-report-2022-air-pollution



https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2211011000_15062022_Indoor_Air_Quality_Report_Final.pdf

Aim and Objectives

Our proposed work programme will deliver pioneering, transdisciplinary, solution-driven methodology to:

1. Create the first ever national **Map** of combined monitored and modelled variations in indoor environmentalexposures in educational settings in England.

2. Understand the impact of indoor air quality (IAQ) and temperature in educational settings on CYP healthand education using globally unique, linked school-level environmental data to individual-level CYP health andeducation data nationally for England and Wales.

3. create the world's first dynamic, one-by-one school building stock **Model**, to evaluate the health andeconomic impacts of proposed adaptation and mitigation pathways for the school estate to reach net zero.

4. Evaluate and test the impact of various interventions in educational settings on IAQ, temperature, and CYPhealth impacts, integrating analyses of linked environment-health administrative data, qualitative interviews,challenge studies and citizen science.

Using novel, participatory citizen science methods we will **Involve** CYP and their school communities,empowering them to make positive changes to their indoor environments. We will **Engage** with multiplestakeholders to co-create impact and innovative, scaled-up solutions.

Overview

WP 5:
Involve CYP and school communities in CHILI activities, empowering them to improve indoor environmental quality

WP 6:
Engage a wide range of stakeholders to develop the research design and co-create impact

WP 1: **Map**	Map variations in indoor air quality and heat in educational settings
WP 2: **Understand**	Understand the impact of IAQ and heat in educational settings on CYP health and education, to inform the design of net zero interventions
WP 3: **Model**	Model various adaptation and mitigation net zero pathways in educational settings and associated population health outcomes, costs and inequalities
WP 4: **Evaluate & test**	Evaluate and test the impact of various interventions in educational settings on IAQ, heat exposure and associated health impacts

Maps
Infographics
Solution-based tools
Presentations
Papers

Knowledge Transfer / Co-creation

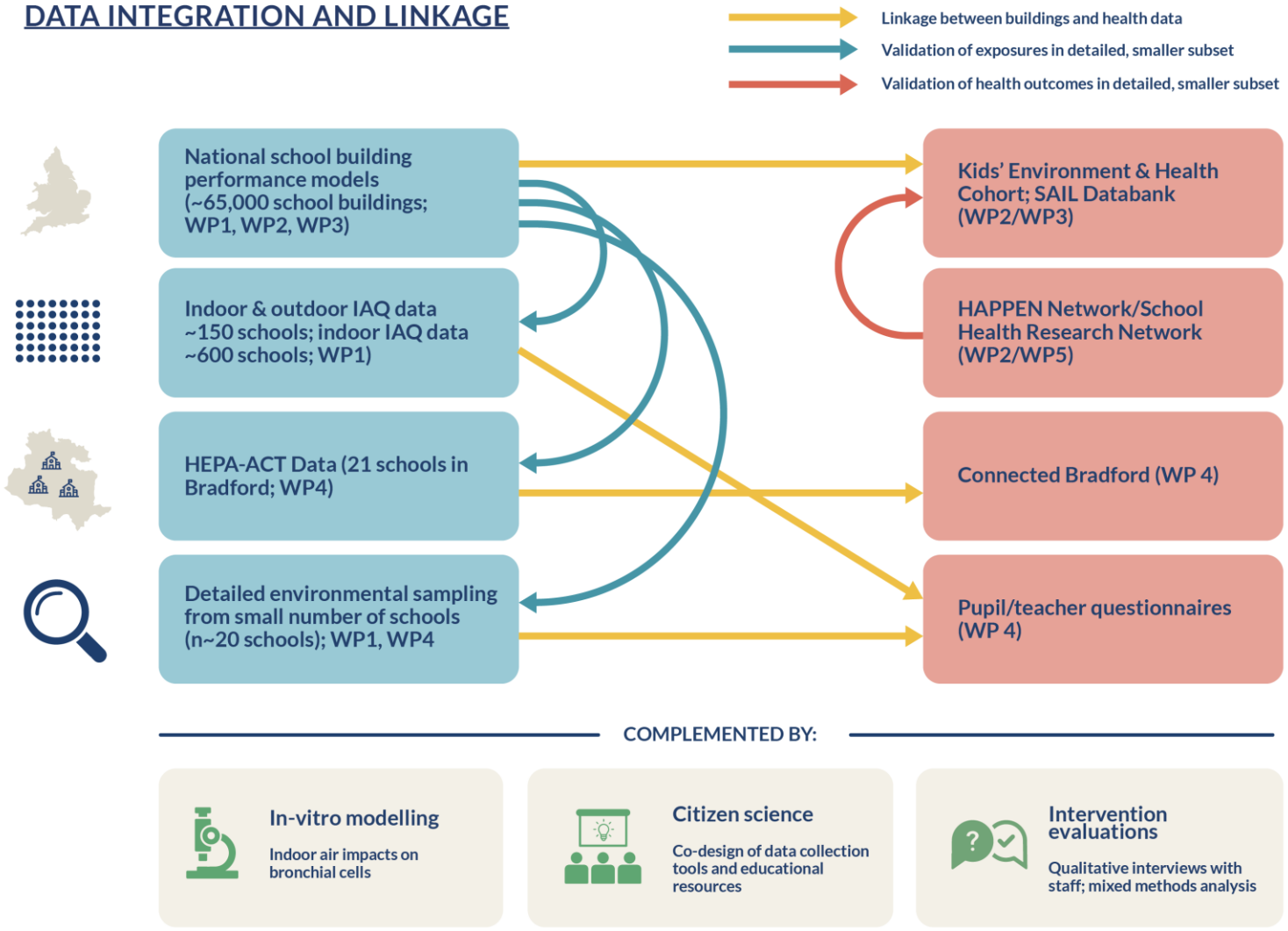
Briefings
Social Media
Meetings
Reports
Interactive web app

IMPACT

Development of trans-disciplinary methods for linking, analysing, modelling and validating buildings and health data at local, regional and national levels to produce CYP health metrics

Overview

DATA INTEGRATION AND LINKAGE



Health and Education Data (England)

Health

- NHS hospitals (inpatients, outpatients, A&E)

Education

- Examination results, special educational needs

Children's social care

- Child protection plans, foster care, adoption (not using for CHILI)

Education & Child Health Insights from Linked Data

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School Building Characteristics (England)

Building age % with glazed windows State of repair Area Heating fuel type	Unique Reference Number %FSM Number of pupils Location Expenditure	Modelled indoor temperature Modelled indoor air quality
DfE Condition Data Collection Display Energy Certificates	DfE Get Information About Schools, Financial Benchmarking Tool, School Performance Datasets	UCL IEDE Modelling platform for schools (MPS)

Link Building Data to Health & Education (England)

School Building Characteristics

School

ECHILD Data

Education & Child Health Insights from Linked Data

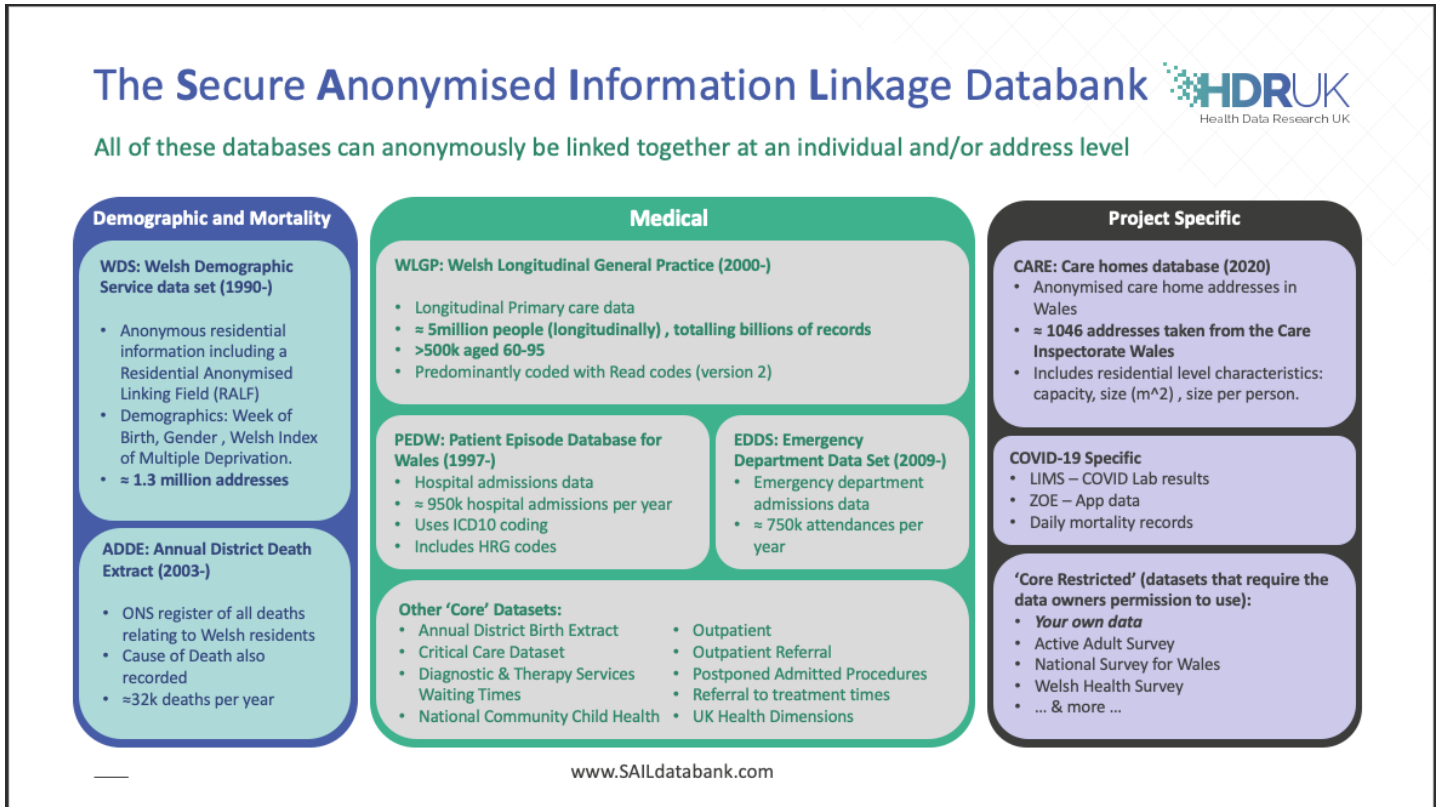
echild

Unique Reference Number

National level datasets linking school-level indoor environment and individual health and education data

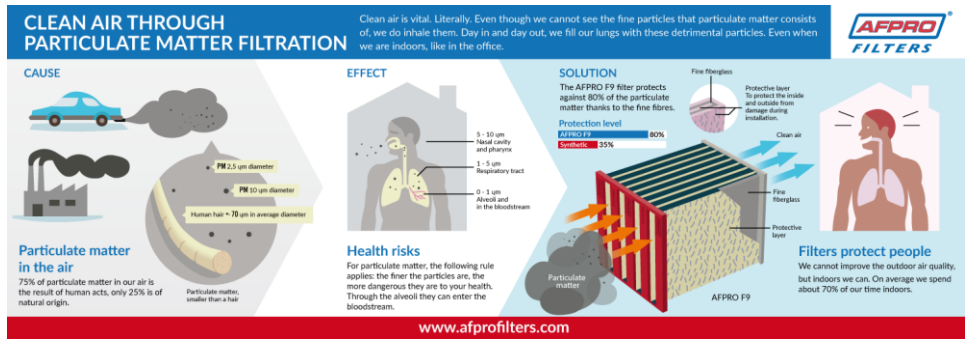
Problem: This doesn't exist for Wales

Data banks in Wales



- **HAPN:** Health and Attainment of Pupils in Primary Education Network.
- **HESA:** Demographic data of students in higher education.
- **EDUW:** Welsh attendance data, attainment data at age 7, 11, 14 and 16.
- **EDAD:** Education Daily Attendance Dataset. Detailed Welsh school attendance.
- **LLWR:** Life-Long Learning Wales Record. Learning activities and awards.
- **LACE:** Looked After Children Education. Attainment of care leavers.
- **CINW:** Children In Need Census Wales: Demographic data.
- **LACC:** Looked After Children Care Leavers. Demographic data.
- **LACW:** Looked After Children Wales. Demographic data.

'Wet Science' Approach



'Wet Science' Approach

- Comprehensive dataset of thermal conditions in classrooms across England & Wales (supplementing WP1b in-depth IAQ dataset)
- Long-term (2 years) and in-depth ('investigator weeks') monitoring
  - Exploring additional window-opening behaviour and noise monitoring
- (Supplemented by WP5 surveys) incorporating citizen science approaches to thermal condition surveys in schools

HOBO cellular weather station kit

Testo 400 IAQ and comfort kit

‘Wet Science’ Approach


www.nature.com/scientificreports

scientific reports

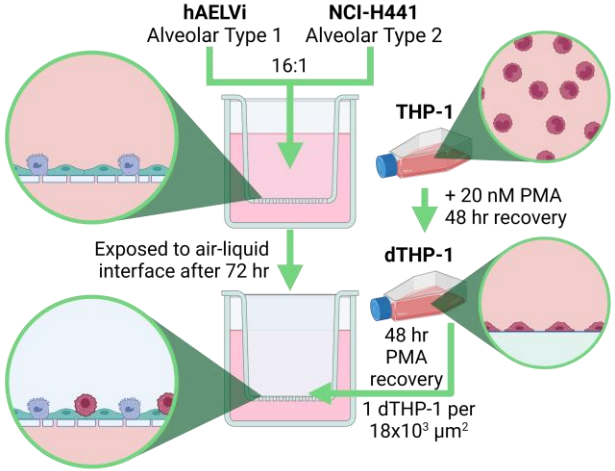
OPEN

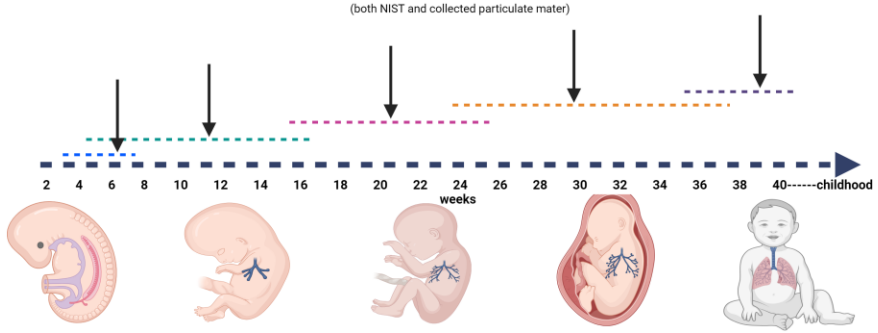
A human relevant in vitro alveolar epithelial barrier model to assess inhaled pollutant hazard

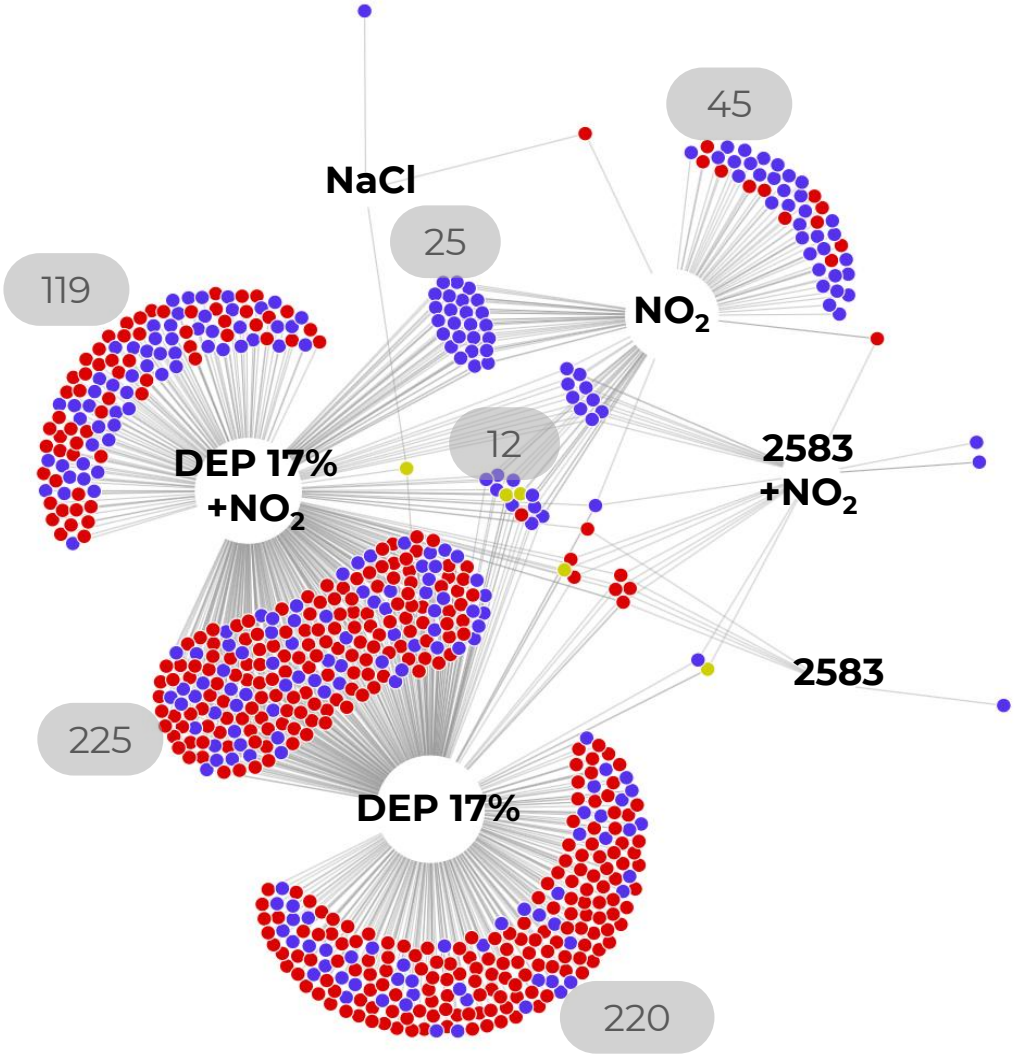
Joshua W. P. Bateman[1], Kirsty Meldrum[1], Sarah M. Mitchell[1], Ulla Vogel[2] & Martin J. D. Clift[1]

Relevant in vitro models could reduce the requirement for in vivo testing and allow higher throughput for imperative toxicological or pharmaceutical hazard testing. Models of the alveolar barrier are invaluable when assessing the toxicity of inhaled xenobiotics, though there is a requirement that these models are well-characterised and accurately resemble the relevant human cellular architecture. Here, a triple cell co-culture has been developed using hAELVi, NCI-H441 and differentiated THP-1 cells as models of type 1 and type 2 pneumocytes, and alveolar macrophages, respectively. Through pre-staining each cell type, confocal microscopy was first used to determine cell seeding ratios to hAELVi and NCI-H441 required to achieve a human-relevant 16.44:1 ± 3.29 ratio at the time of air-liquid interface exposure. CellTrackers were then used to ensure that the density of differentiated THP-1 cells was in line with previously published anatomical research at 1 cell/18 × 10³ µm². We were able to show that the triple culture forms a tight barrier and that the macrophages can respond to a (pro)-inflammatory stimulus (lipopolysaccharide). Given the anatomical relevancy and its ability to react to stimuli, this model may provide a useful platform to assess the toxicological hazard potential of a range of inhaled, respirable xenobiotics.

Keywords Multi-cellular model, Alveoli, In vitro, Toxicology







Created with BioRender.com

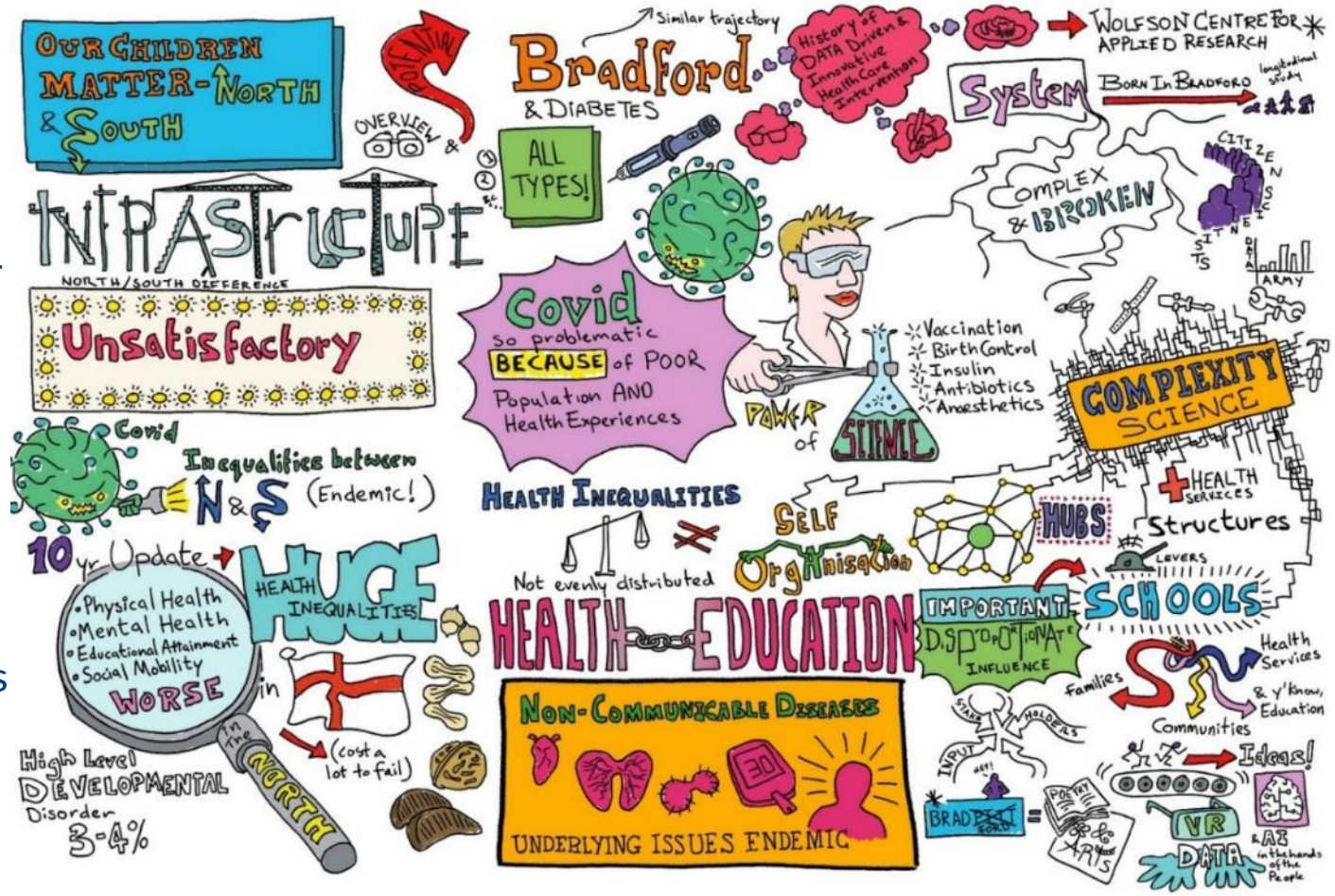
An *in vitro* and transcriptOMICs approach towards human health risk assessment

Citizen Science

- Leverage research relationships with 21 existing schools from Class-ACT.

- Semi-structured interviews with key school decision-makers to understand their views on:
  1. Balancing health, comfort, and energy aspects in schools (inc. IAQ and Net Zero priorities).
  2. IAQ awareness, and air cleaner cost, acceptability, operational challenges, and maintenance.

- Analyse in conjunction with the quantitative analyses to interpret air cleaner operational performance, and CYP health outcomes.



Theory of Change

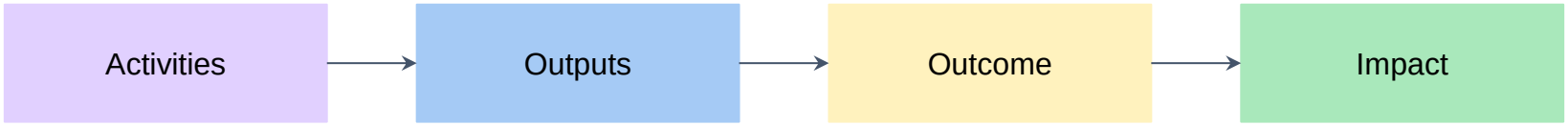
Designed to help us:

- Consider the impact and outcomes we are aiming for
- Think about the outputs we will need to create to achieve them
- Design activities to feed into the outputs and outcomes
- Consider the enabling factors we need to put in place

Impact statement

School community voices are amplified and actions supported in their journey to reach net zero and promote good health, wellbeing and learning

Theory of Change Structure



Summary

- CHILI is one of two indoor ‘air pollution’ hubs
- The only hub throughout the funding strategy of MRC/NIHR to be focussed upon child health
- A project that is fundamentally focussed upon Data Science
- Supported by a ‘wet science’ approach to assess key exposure levels to link to the biological impact; characterising the pollutant-biological impact effect
- Citizen Science approach to link schools/decision makers/children into the world of pollution.
- Aim to link building type, construction materials, indoor air quality and pollutants towards child health and contribute towards integrating interventions

Grant #: MR/Z50645X/1

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