Imperial College London

October 6th 2021

My perspectives on the transformative potential of small/portable sensors for air pollution management and research

Clean Air Research Futures Group: Making it personal - will small / portable sensors transform air pollution management and research?

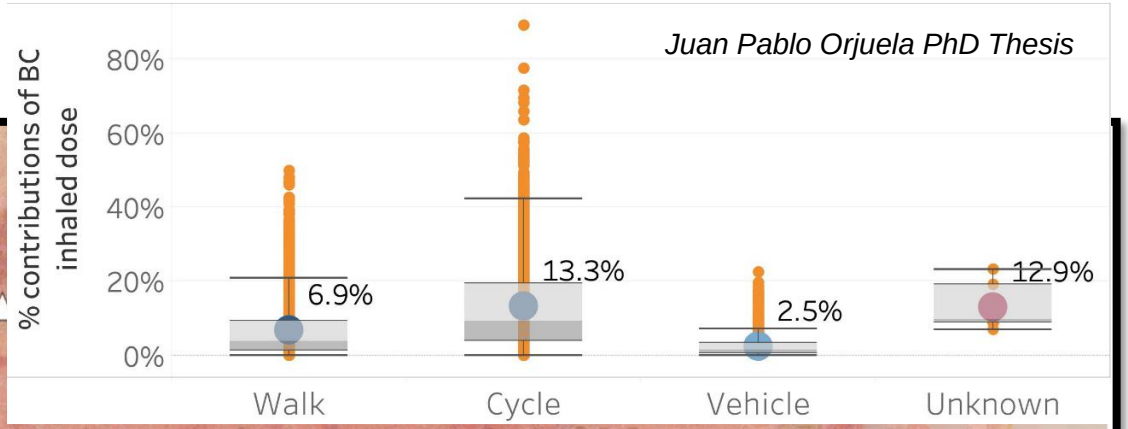
Audrey de Nazelle

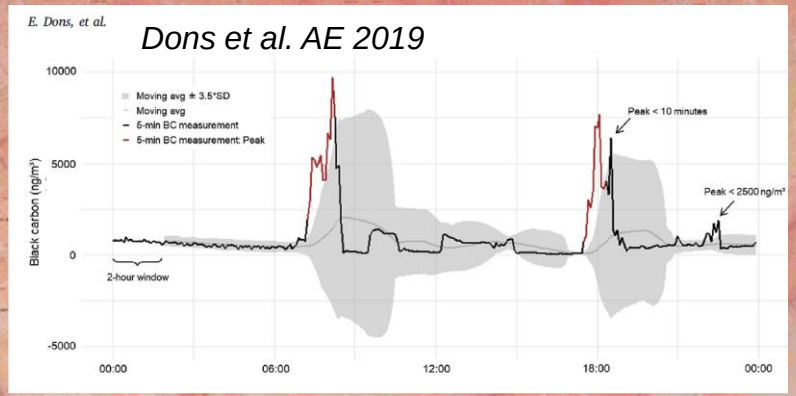
Centre for Environmental Policy

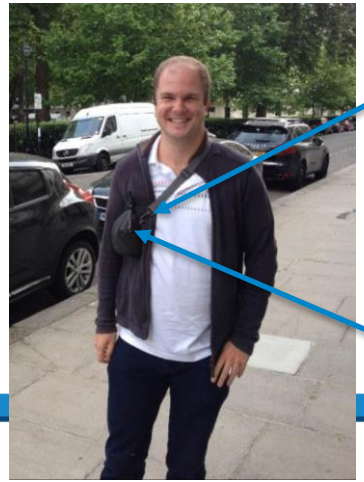
tapas ACTIVE TRANSPORTATION HEALTH IMPACT ASSESSMENT

PASTA PHYSICAL ACTIVITY THROUGH SUSTAINABLE TRANSPORT APPROACHES

Exposure research: uncover relevant times, locations, and activities



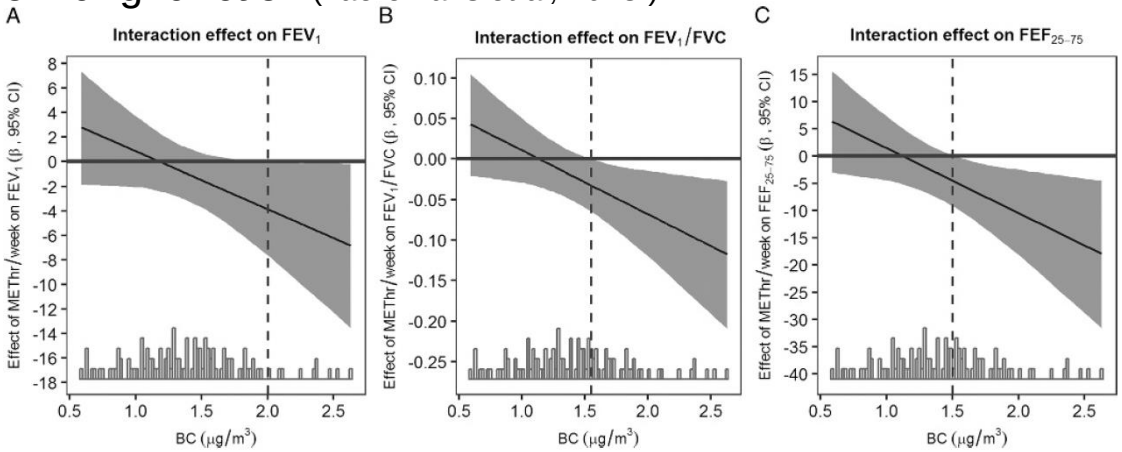




115 healthy adults,
3 European cities

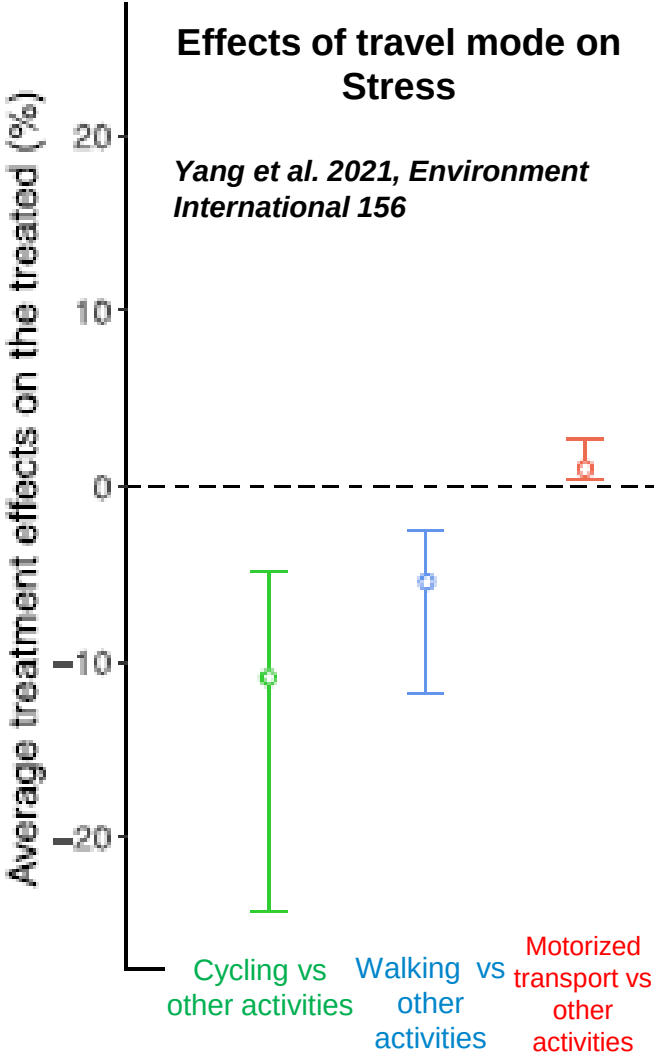
Health research: uncover relevant times, locations, and activities

Black carbon reduces beneficial effects of **physical activity** on lung function (*Laeremans et al, 2018*)



Effects of travel mode on Stress

Yang et al. 2021, Environment International 156



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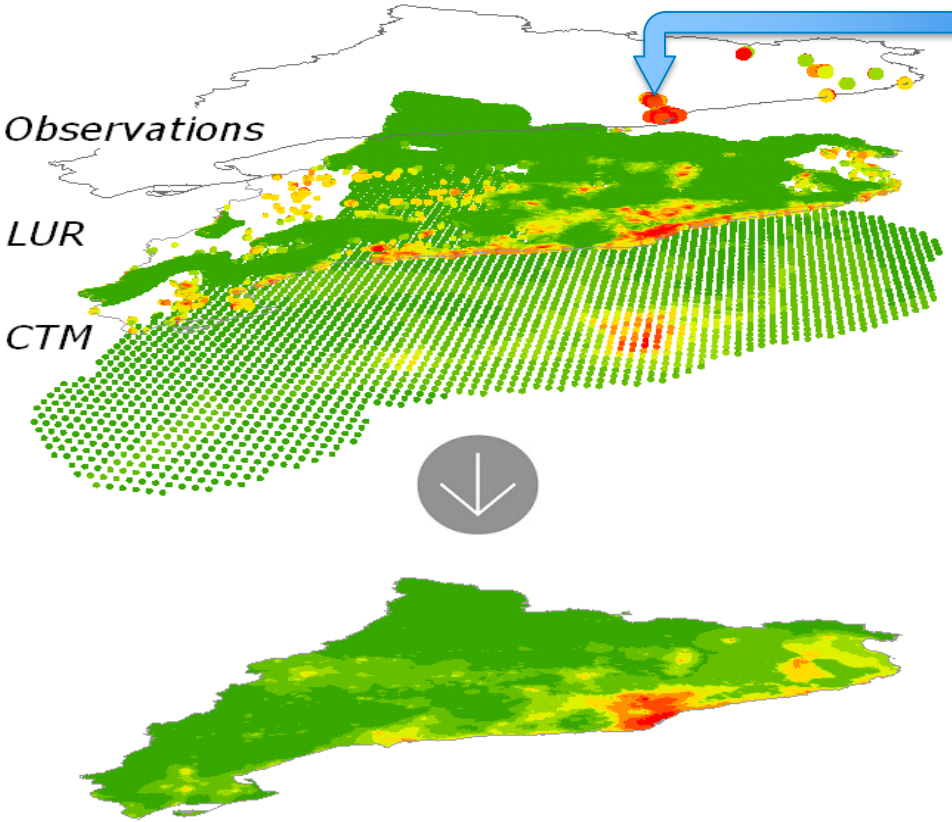
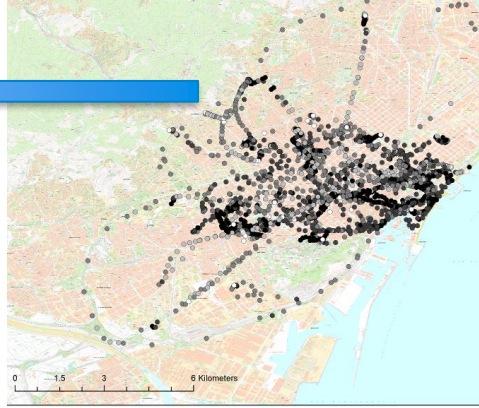
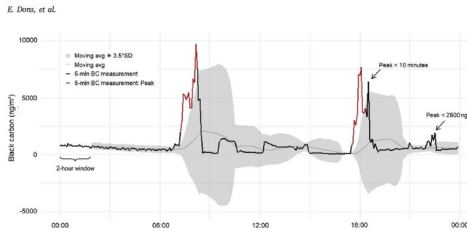
Research and management: Air quality models Integrating different sources of information







de Nazelle et al. 2010 *Environmental Science & Technology*, vol. 44; Akita et al. 2014, *Environmental Science & Technology*, vol.48

Management: Engagement opportunity

Beware of pitfalls!

Who's responsibility?

Sustainability Science
https://doi.org/10.1007/s11625-021-01038-2

REVIEW ARTICLE

How do we effectively communicate air pollution to change public attitudes and behaviours? A review

Rosie Riley[1] · Laure de Preux[2] · Peter Capella[1] · Cristian Mejia[3] · Yuya Kajikawa[3,4] · Audrey de Nazelle[1,5]

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

The role of personal air pollution sensors and smartphone technology in changing travel behaviour

Hebba Haddad*, Audrey de Nazelle

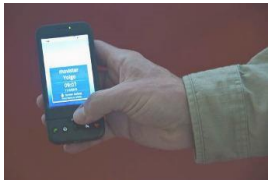
a. Screenshot of "My Exposure"

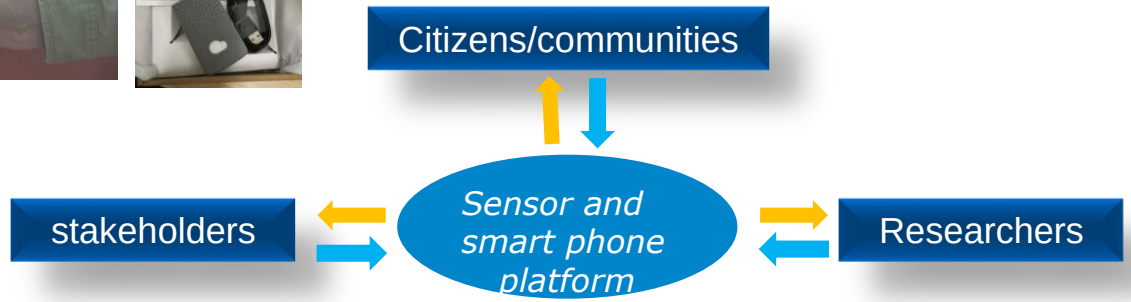
b. Screenshot of "Raw Measurements" indicating NO_2 and VOC levels

Only significant change before/after: Drop in trust in the performance of the sensor and ability to change behaviours

Key to successful communication:

- Relatable, understandable, local information
- Tailored and personal messaging
- Continuous communication
- Message that connects people and emphasises collective action
- Range of possible actions
- Positive framing
- Trusted sources





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Small / Portable Sensors & Air Pollution Management /Research

Ruth Calderwood

Air Quality Manager, City of London Corporation

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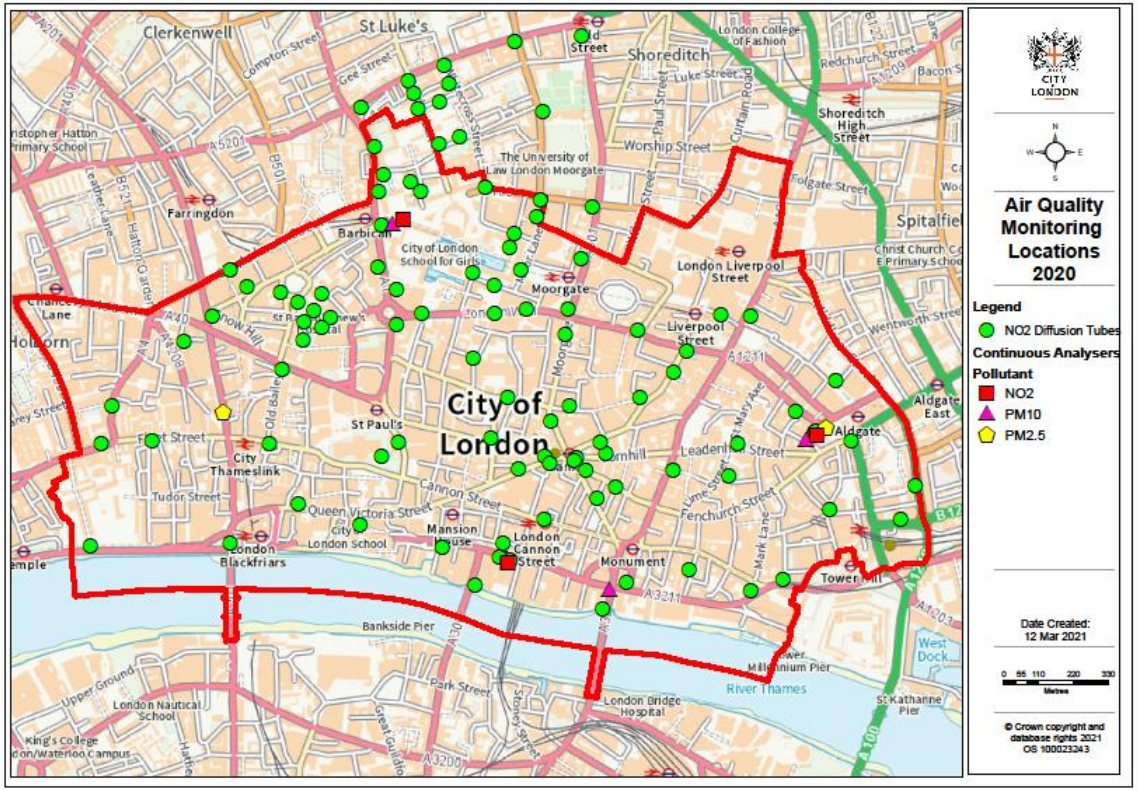
City of London

Air Quality Monitoring



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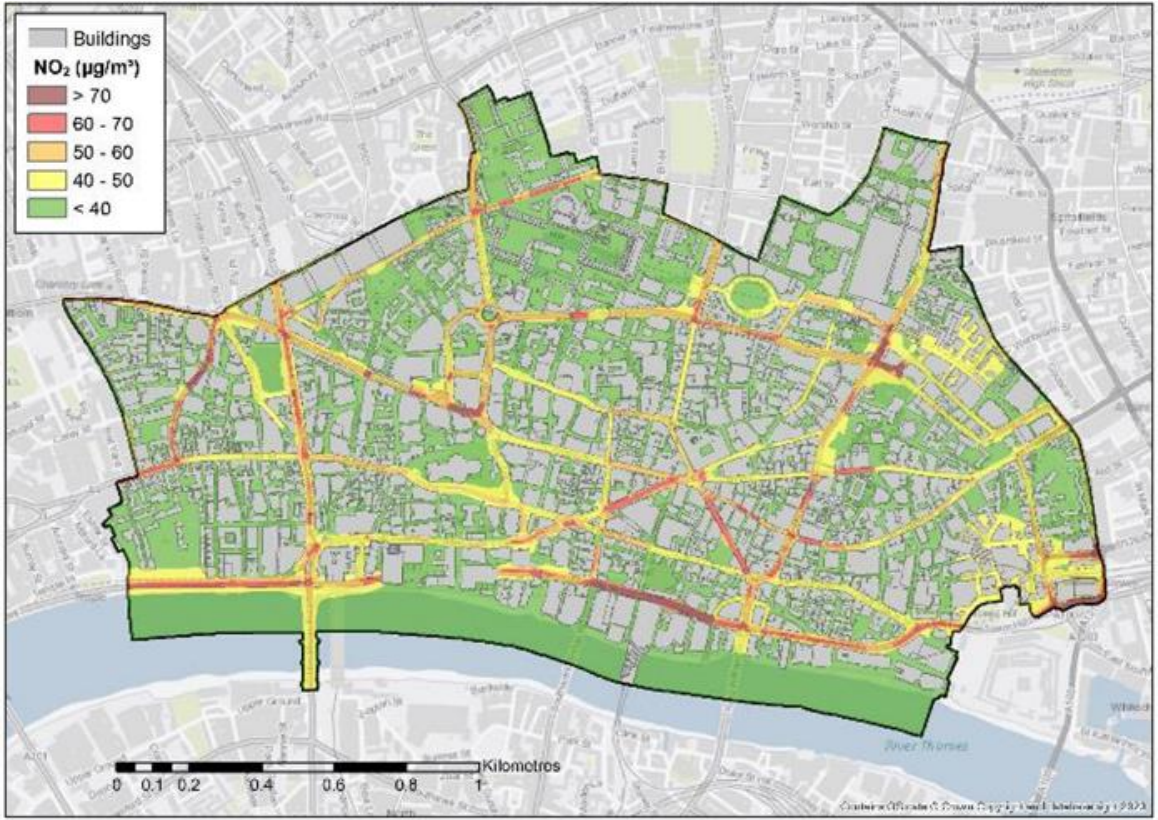
Model Output



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Challenges

- Air pollution in urban areas more nuanced than monitors/model suggests
  - microclimate
  - topography
  - localised sources not in AEI
- Small / portable sensors
  - cover large area over space and time
  - use incorporated into other activity – time and cost saving
  - detect issues for further investigation
  - personal exposure – good engagement tool
  - data relative rather than absolute
- Air quality monitoring
  - Need to be clear about end use of data, particularly how accurate data needs to be

City of London

20th May-15th June 2021: Saturday PM2.5 Sampling Points

PM2.5 Concentration (µg m^-3)

- 10.00 - 23.66
- 23.67 - 37.33
- 37.34 - 51.00
- 51.01 - 64.67
- 64.68 - 78.34
- 78.35 - 92.01
- 92.02 - 105.68
- 105.69 - 119.35
- 119.36 - 133.00

0 0.08 0.15 0.31 Kilometers

N

C

EPUK @ The Clean Air Futures Group,
Small Scale Sensors Meeting, 6/10/21

About EPUK: Environmental Protection UK is a national charity, with a vision for *a cleaner, healthier and more tranquil environment for all in the UK*.

Our membership is mostly drawn from environmental professionals, bringing together policy-makers, business, local authorities, third sector groups and academics, to foster partnerships for environmental action.

We provide expert policy analysis and information, including guidance, briefing notes and leaflets, on air quality, land quality and noise. We share best practice and support our members to deliver effective environmental protection.

Our current work includes a project on Air Quality & Climate Change interactions, focussing on the need for a coordinated approach and options for actions by local authorities and others; this project will be launched at our Annual Conference on 18 November.

Other work includes lobbying for effective environmental legislation and implementation, a robust Local Air Quality Management system, and supporting our Air Quality & Development Control planning guidance (produced with IAQM).

EPUK @ The Clean Air Futures Group,
Small Scale Sensors Meeting, 6/10/21

Comment on Small Scale Sensors

I am not an expert in small scale sensors, but…

We are interested in their use in helping develop (or critique) the evidence base for policies and actions, to monitor their effectiveness, and in public engagement, to empower, support and implement clean air measures, more sustainable behaviours and better air quality management.

Sarah Legge, Chair of the Air Quality Committee, Environmental Protection UK

Website: www.environmental-protection.org.uk
Email: secretariat@environmental-protection.org.uk
Direct email: sarah@slhenvironmental.co.uk

UK Health Security Agency

Clean Air Futures Group

Making it personal - will small / portable sensors transform air pollution management and research?

Jim Stewart-Evans
Environmental Hazards and Emergencies Department

Public health advice

- Considerations
  - Interpreting results
    - Location
    - Timescale
    - Contextual information
    - Sensor performance (trends versus comparison with absolute standards)
  - Individualisation versus generalisability of assessments (and advice)
    - Resources: many versus few assessments

Informing action

- Is the sensor…
  - In the right place…
  - At the right time…
  - Collecting the right data…
- Is information…
  - Available to the right person…
  - At the right time…
  - Understood…
  - Actionable…

Personal experiences

- Characterisation of exposure
  - Inconvenience (forgetfulness!)
  - Battery life
  - Data storage

- Data protection
- Post-hoc review (fine if history repeats)
- Interpretation (bandings, visualisations) and weight

- Increased awareness (lasting mindfulness)
- Changes to behaviour…

Opportunities

- Characterisation of specific environments (eg, streets, rooms)
  - Multiple sensors, multiple locations
  - *Delineation of hotspots (eg, air quality management areas)*
  - *Relationships between outdoor and indoor environments*

- Characterisation of specific activities (eg, driving, cooking)
  - *Managing exposure in specific settings and during specific activities*

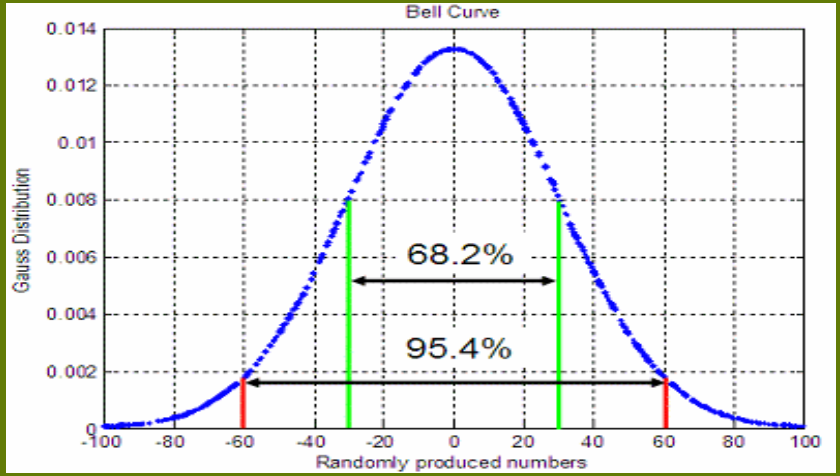
- Characterisation of individual exposure (including contributing **activities**, **places** and **times**)
  - *Managing personal exposure (and reappraising our own contribution to it)*
  - *“Roaming detection”: identifying local sources of pollution*
  - *Characterising population exposure by aggregating individual exposures…*

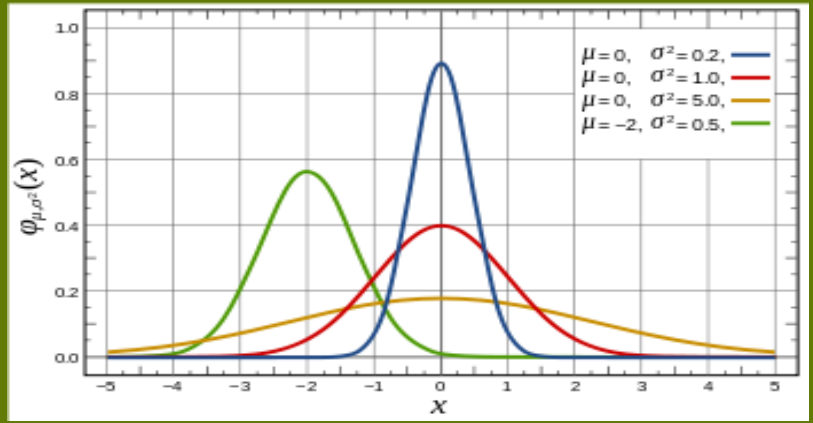
Uncertainty is one of the few things you can be sure of

For data to be fit-for-purpose we must

- Quantify
- Reduce
- Communicate

} Uncertainty





Environment Agency

Personal exposure monitoring of particulate matter, nitrogen dioxide, and carbon monoxide, including susceptible groups

R M Harrison, C A Thornton, R G Lawrence, D Mark, R P Kinnersley, J G Ayres

Occup Environ Med 2002;**59**:671–679

See end of article for authors' affiliations

Correspondence to: Prof. R M Harrison, Division of Environmental Health & Risk Management, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; R.M.Harrison.ipe@bham.ac.uk

Accepted 13 February 2002

Aims: To investigate the relation between personal exposures to nitrogen dioxide, carbon monoxide, and PM_{10}, and exposures estimated from static concentrations of these pollutants measured within the same microenvironments, for healthy individuals and members of susceptible groups.

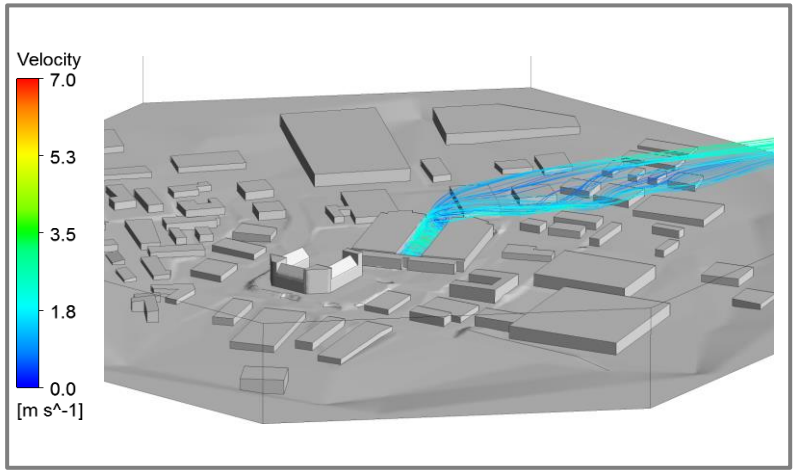
Methods: Eleven healthy adult subjects and 18 members of groups more susceptible to adverse health changes in response to a given level of exposure to nitrogen dioxide, carbon monoxide, and/or PM_{10} than the general population (six schoolchildren, six elderly subjects, and six with pre-existing disease—two with chronic obstructive pulmonary disease (COPD), two with left ventricular failure (LVF), and two with severe asthma) were recruited. Daytime personal exposures were determined either directly or through shadowing. Relations between personal exposures and simultaneously measured microenvironment concentrations were examined.

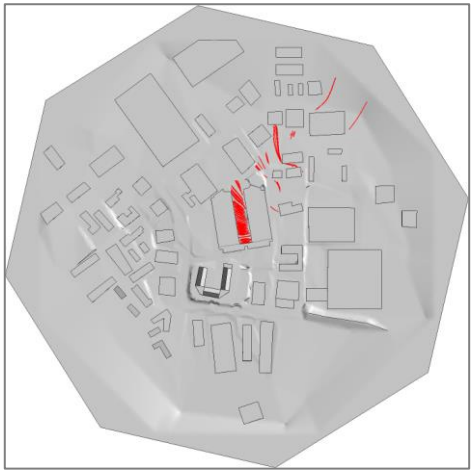
Results: Correlations between personal exposures and microenvironment concentration were frequently weak for individual subjects because of the small range in measured concentrations. However, when all subjects were pooled, excellent relations between measured personal exposure and microenvironment concentration were found for both carbon monoxide and nitrogen dioxide, with slopes of close to one and near zero intercepts. For PM_{10}, a good correlation was also found with an intercept of personal exposure (personal cloud) of 16.7 (SD 10.4) $\mu g/m^3$. Modelled and measured personal exposures were generally in reasonably good agreement, but modelling with generic mean microenvironment data was unable to represent the full range of measured concentrations.

Conclusions: Microenvironment measurements of carbon monoxide and nitrogen dioxide can well represent the personal exposures of individuals within that microenvironment. The same is true for PM_{10} with the addition of a personal cloud increment. Elderly subjects and those with pre-existing disease received generally lower PM_{10} exposures than the healthy adult subjects and schoolchildren by virtue of their less active lifestyles.

Environment Agency

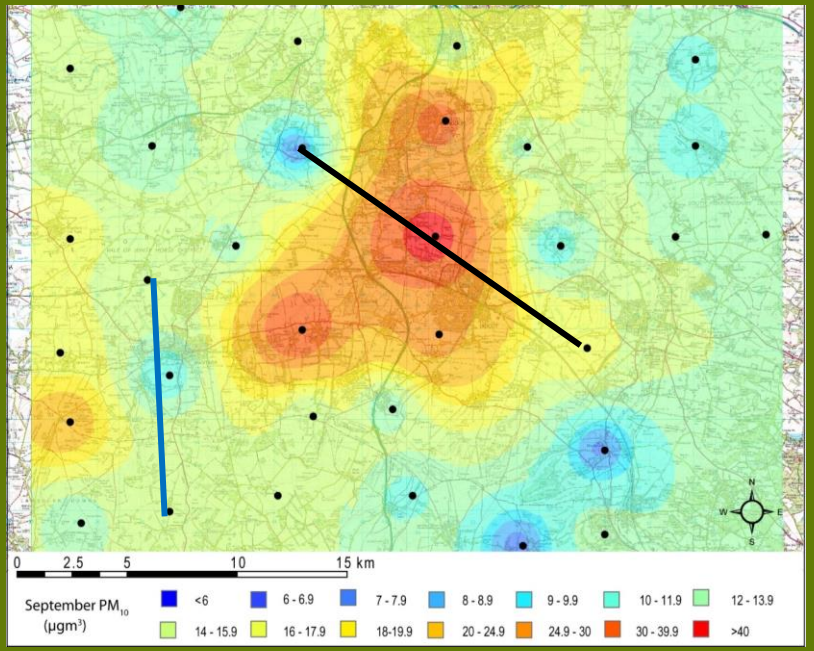
We've used our LIDAR data and CFD modelling to model the movement of pollutants in built environments

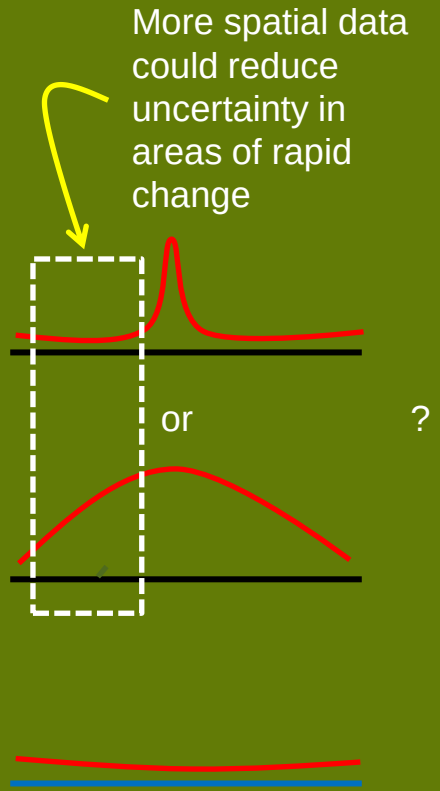




But how well can we validate?

Network design





Environment Agency

Making it personal - will small / portable sensors transform air pollution management and research?

Dr Matt Loxham

BBSRC David Phillips Fellow

University of Southampton

Why would we want to measure pollution?

Legal compliance

Health protection

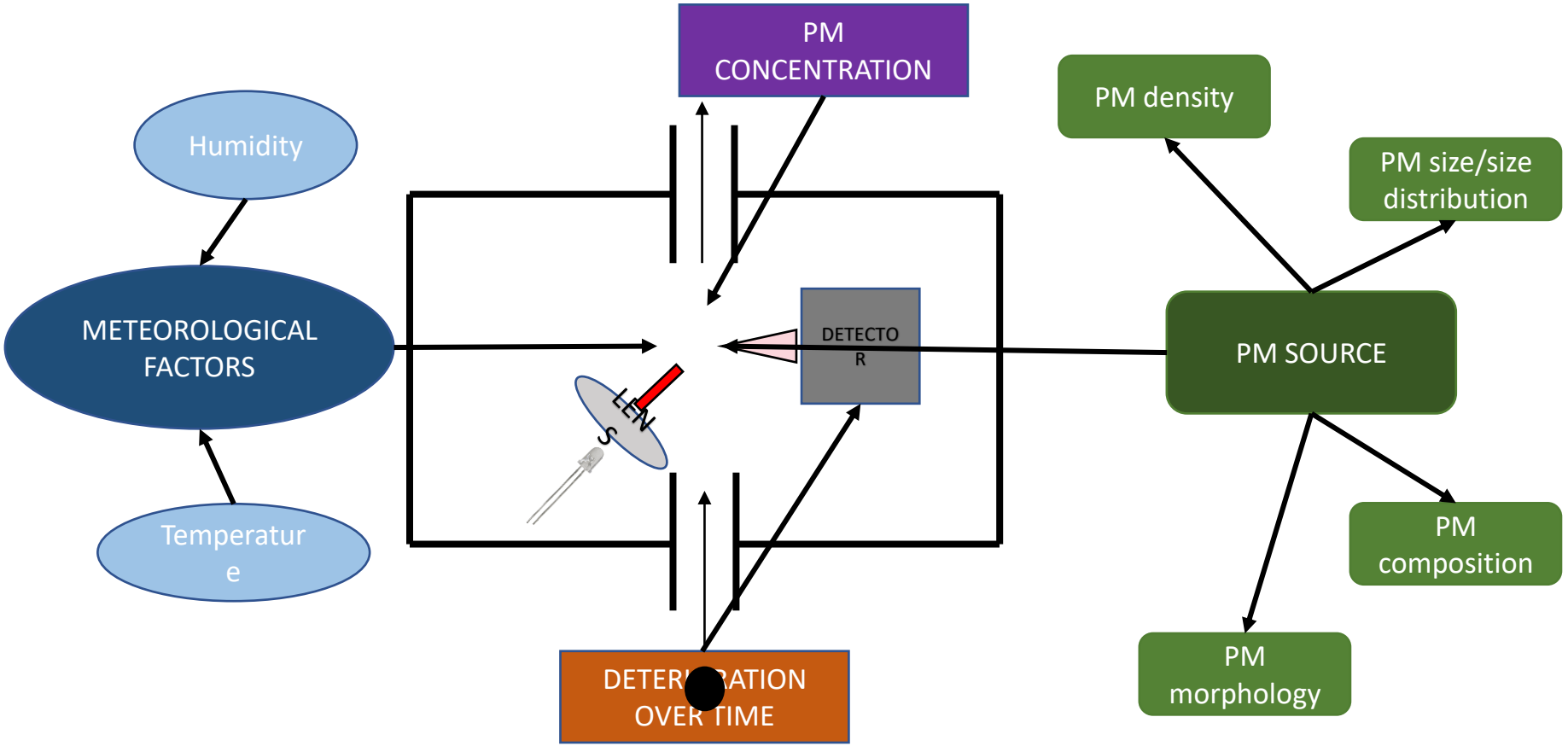
The NEW ENGLAND JOURNAL of MEDICINE

Health research

Assess effects of pollution-related decisions

Public engagement

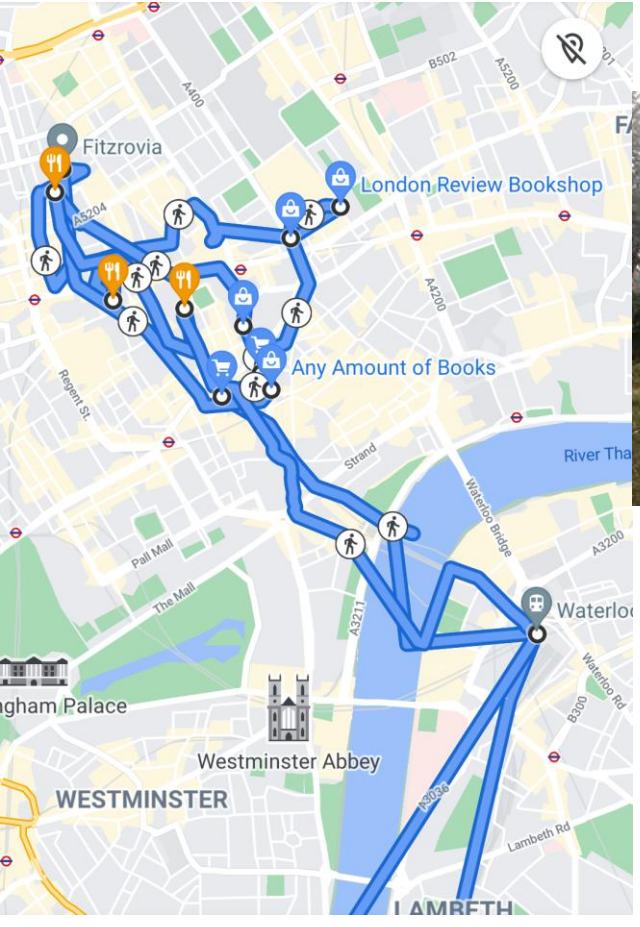
What's the problem with small sensors?



Low Cost Air Pollution Sensors – Why Not?

- Careful calibration required
- Poorer performance in “less polluted” areas
- Sensor drift
- Lack of transparency in data processing (scatter-response function)
- Data security?
- Potential to be regarded as medical devices
- No capacity to distinguish between PM components
- No ultrafine PM measurements

So are small sensors useless?

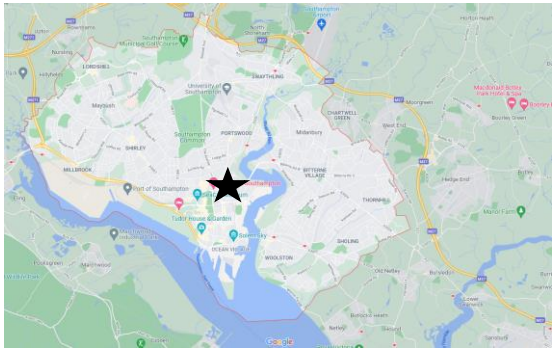


- **Mobile**
- **Highly time resolved**
- **On-person**
- **Can be supplemented with other technology**

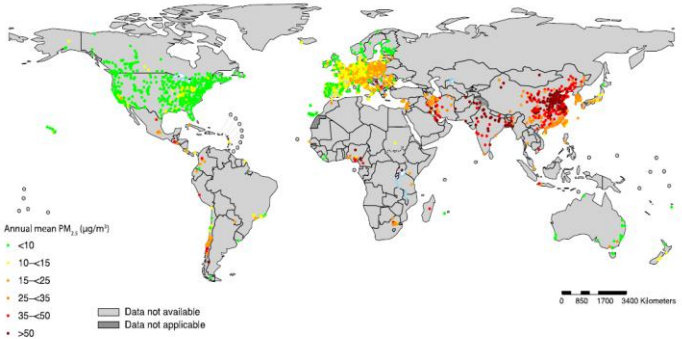
These devices WILL be transformative (as long as led by the science)

Mobile, uninvasive, easy-to-use

- **Indoors**
- **At work**
- **Personal**

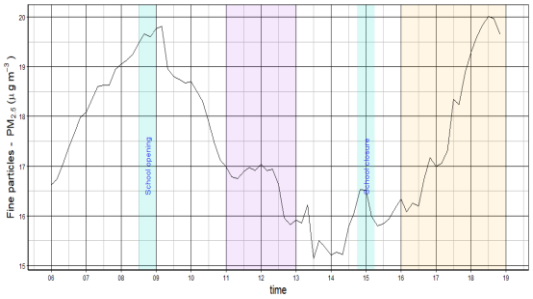


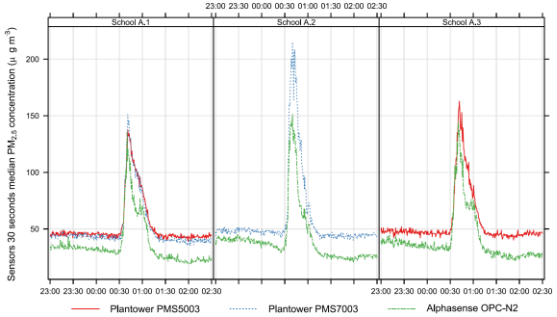
Lower cost = more nodes



Advantages in LEDCs

- **Compensate for poor infrastructure**





DEMOCRATISITION OF DATA

Personal air quality sensors: Towards a Participatory Research approach

Dr Diana Varaden | **Research Associate**
Exposure Science Team
Environmental Research Group
School of Public Health, Imperial College London

October 6th, 2021

MRC Centre for Environment & Health
Medical Research Council
Imperial College London

NIHR | Health Protection Research Unit in Chemical and Radiation Threats and Hazards at Imperial College London

NIHR | Health Protection Research Unit in Environmental Exposures and Health at Imperial College London

Personal air pollution monitoring can help us to:

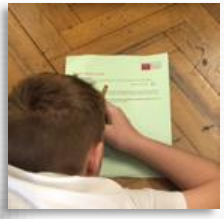
- Raise awareness
- Make it personal
- Make air pollution ‘visible’
- Raise understanding
- Provide choice

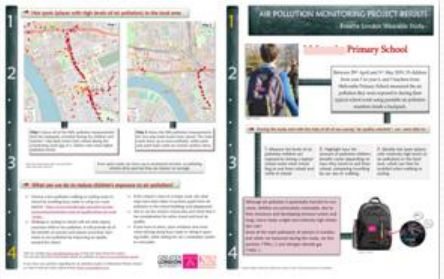
“I am an air quality scientist”– A Participatory approach to characterise school children’s exposure to air pollution

The Breathe London Wearables Study

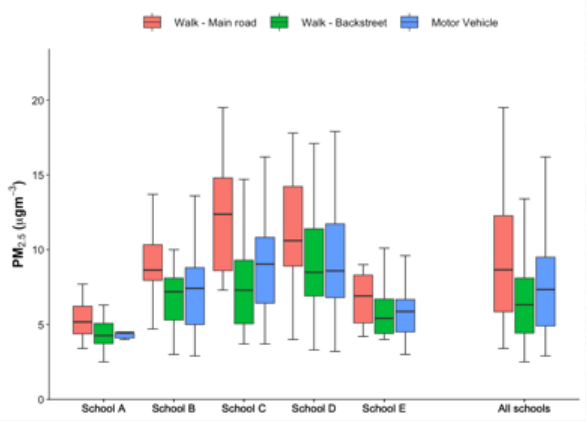
- 5 weeks
- 5 primary schools
- 258 children
- 30 teachers
- 80 Dyson sensor backpacks
- 2,000 school journeys
- 490 million measurements

- 10 education sessions
- 300 “I’m an air quality scientist” badges
- 700 surveys (children and parents)
- 20 focus groups (children and parents)
- 10 Interviews



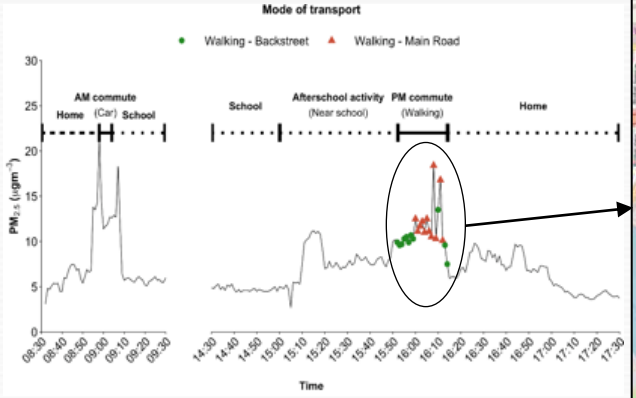


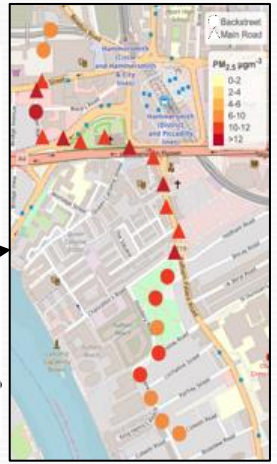
Transport activity patterns and exposure to $PM_{2.5}$



- Those walking along back streets were exposed to the lowest levels
- Some extremely high concentrations were recorded in cars and buses

Child's commute to and from school, on a typical school day





The impact of our approach

As a result of taking part in the study, 31% of the children and parents questioned changed the way they commute to and from school in order to reduce their exposure to air pollution

✓ Children learned about air quality

"With the project we found that is better to walk than drive and if you do drive to school, you could drive a bit, stop and get out of your car and walk the rest of the way. We also found out that is a lot more polluted on the main roads and that it is better to go through back streets to go wherever you are going" (Child, Year 3)

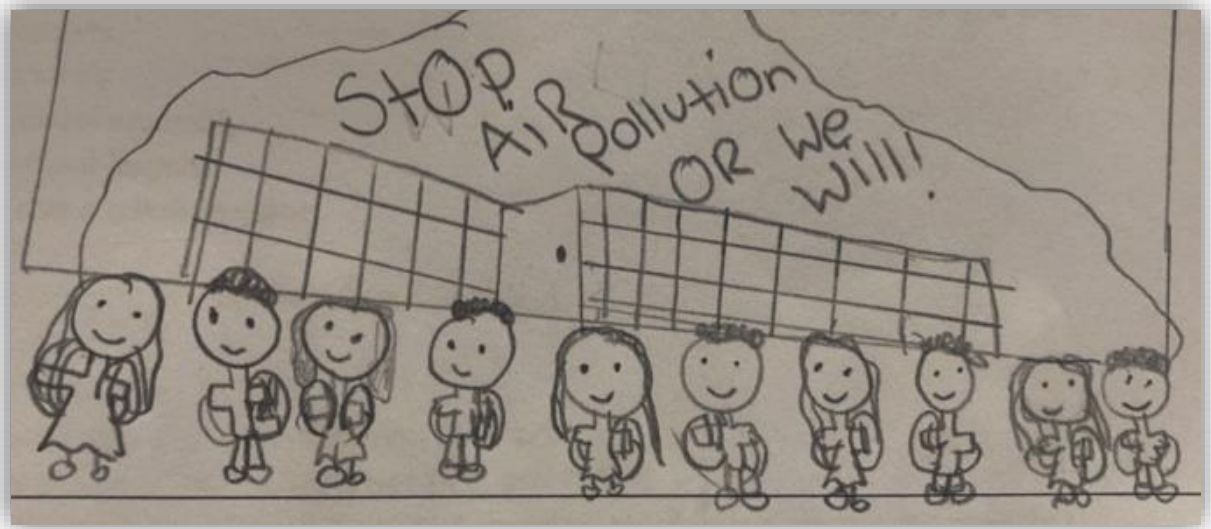
✓ Children conducted research in air quality

"My role in the project was to be a scientist and discover different types of pollution to help to see how much pollution is there and the difference in the different roads" (Child, Year 3)

✓ Children acted for air quality

I told my parents:
"Can we walk to school today?" "Let's go through a different route!"
(Child, Year 5)
"We need to don't make pollution, the earth is going to be a rubbish land" (Child, Year 5)
"I said to my dad – try to use your car less" (Child, Year 4)

Related Publications:
Varaden D, Leidland E, Lim S, et al., 2021, "I am an air quality scientist"– Using citizen science to characterise school children's exposure to air pollution, *Environmental Research*
Varaden D, Barratt B, Heather K, et al., 2021, Engaging primary students with the issue of air pollution through citizen science: lessons to be learnt, *Journal of Emergent Science*



Child, Year 3

Many thanks to all our air quality scientists (the children), their parents and teachers
Backpacks were designed and provided by Dyson Ltd following a competitive selection process.
Approved by the King's College Research Ethics Committee, King's College London.

Thank you

Nottingham Trent University

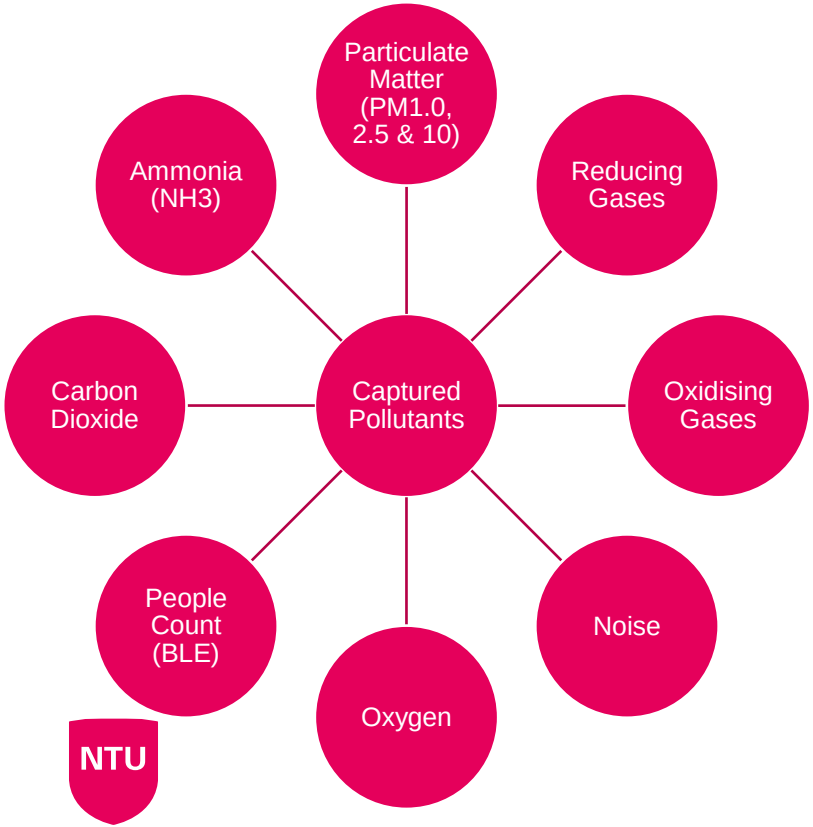
Department of Computer Science

“Making it personal - will small / portable sensors transform air pollution management and research?”

Thomas Johnson
thomas.johnson@ntu.ac.uk
Twitter: @tomwjohnson

01/12/2021

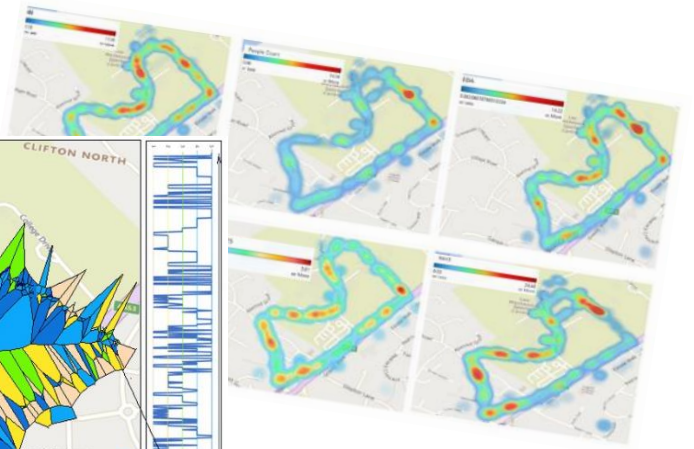
Research: Making it personal

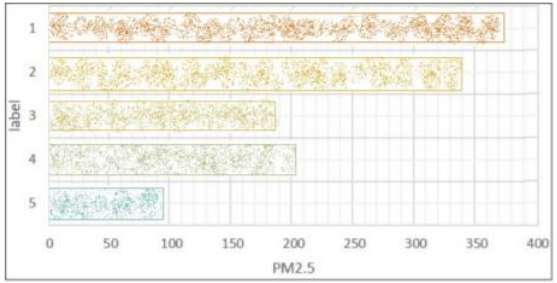


- Enviro-IoT edge device equipped with a Raspberry Pi records environmental data continually every 20 seconds.

Portable Sensing for Research

- Relationship between environment and mental wellbeing
  - Our studies have shown high levels of PM2.5, noise, reducing gases impacts:
    - ElectroDermal Activity / Heart-Rate Variability
    - Heart-Rate (HR)

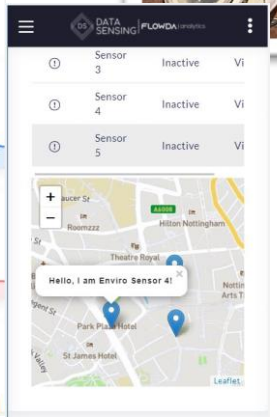




- Johnson T., Kanjo E. (2021) Sensor Fusion and The City: Visualisation and Aggregation of Environmental & Wellbeing Data. Proceedings of the 2021 IEEE International Smart Cities Conference.
- Johnson T., Kanjo E., & Woodward, K. (2021) DigitalExposome: Quantifying the Urban Environment Influence on Wellbeing based on Real-Time Multi-Sensor Fusion and Deep Belief Network.
- Johnson T. (2021) Real-time Environmental Changes Impacts Mental Wellbeing. (Published February 2021)

Transforming Air Pollution Management

- Enviro-IoT devices placed around a Nottinghamshire park monitoring 24/7.
- Nottingham City Council Project
- Enviro-dashboard and mobile application.



NTU

Nottingham City Council

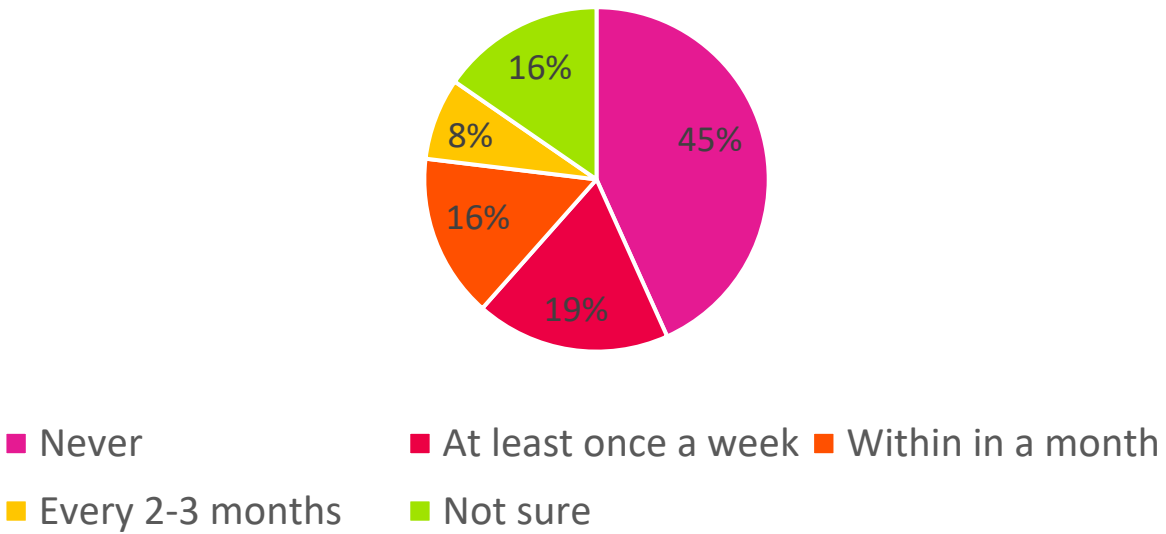
Making it personal – will small / portable sensors transform air pollution management and research?

global action plan

OUR LIVES. OUR PLANET.

Most people are not accessing air pollution conditions data

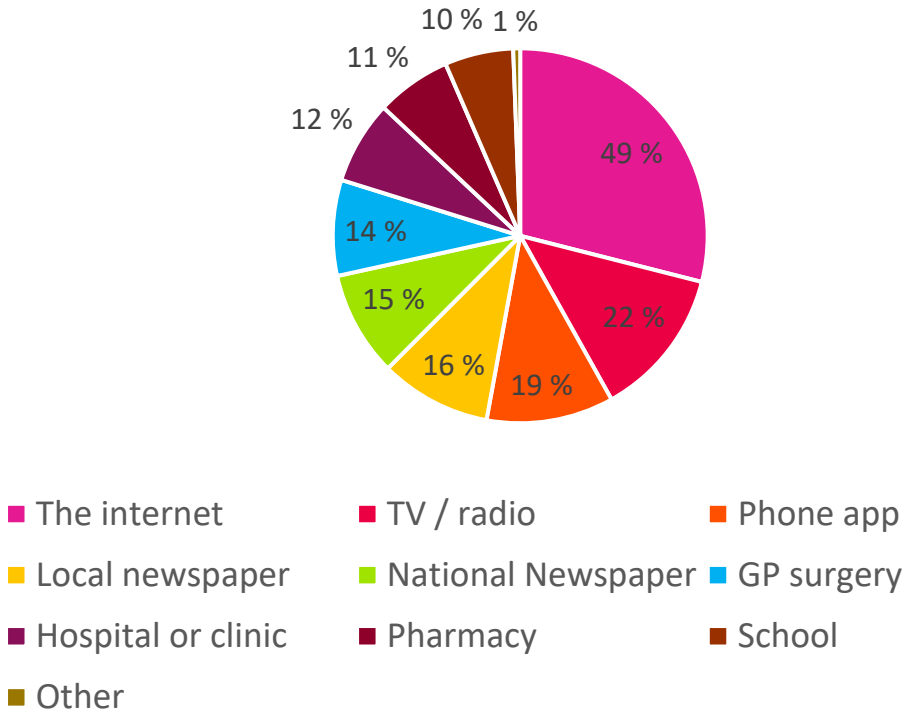
Have you ever accessed information about air pollution conditions (forecasted or real time), and if so, how often do you do this?



Data collected via CAPIT survey June 2021 (n=2,000) in partnership with research at the University of Oxford (Kayla Schulte) (we are in the process of generating a more comprehensive sociodemographic analysis of the data and intend to present these results at upcoming conferences)

The internet is the most common place people access information about air pollution conditions

You said you have accessed information about air pollution conditions.
Where have you accessed this (n=769)



Data collected via Clean Air Public Insights (CAPIT) survey June 2021 (n=2,000) in partnership with research at the University of Oxford (Kayla Schulte) (we are in the process of generating a more comprehensive sociodemographic analysis of the data and intend to present these results at upcoming conferences) https://www.actionforcleanair.org.uk/capit

When people have air pollution conditions information, they act on it

onse to information you received about air pollution conditions

Top three actions

- 25% chose to walk or cycle instead of driving
- 18% used public transport instead of driving
- 18% made efforts to switch off the engine of their vehicle when stationary

Data collected via Clean Air Public Insights (CAPIT) survey June 2021 (n=2,000) in partnership with research at the University of Oxford (Kayla Schulte) (we are in the process of generating a more comprehensive sociodemographic analysis of the data and intend to present these results at upcoming conferences) https://www.actionforcleanair.org.uk/capit

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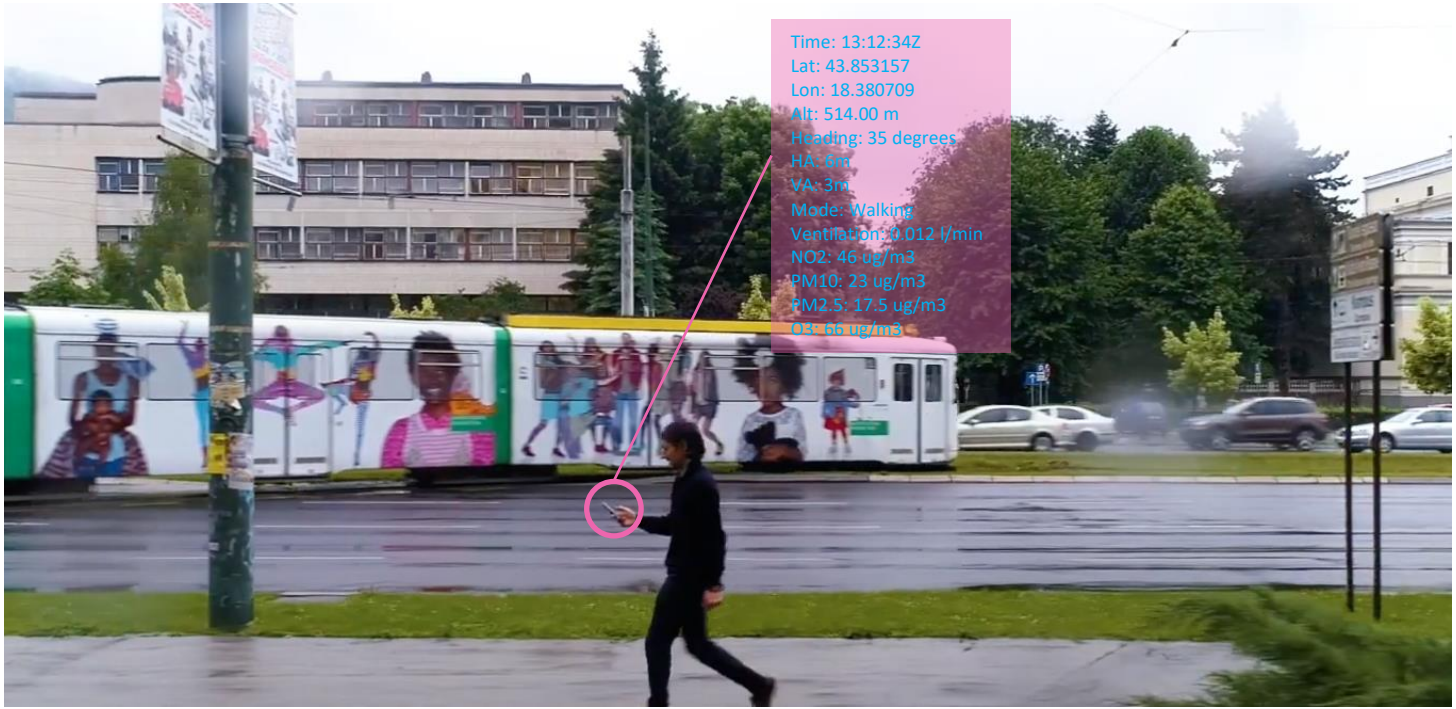
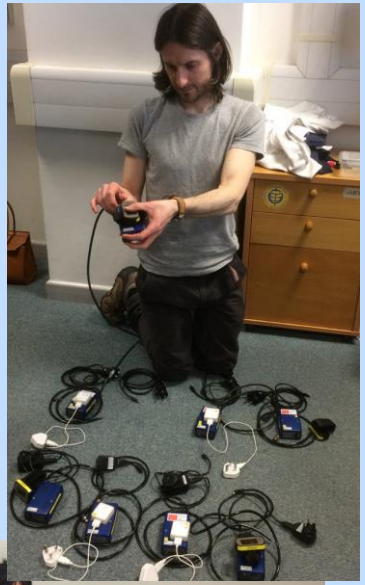
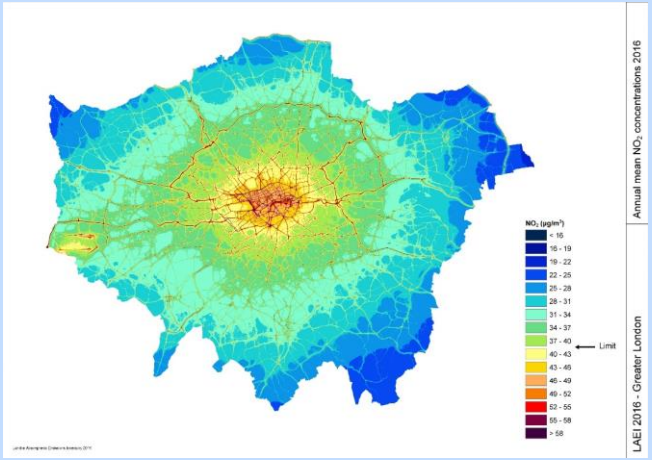


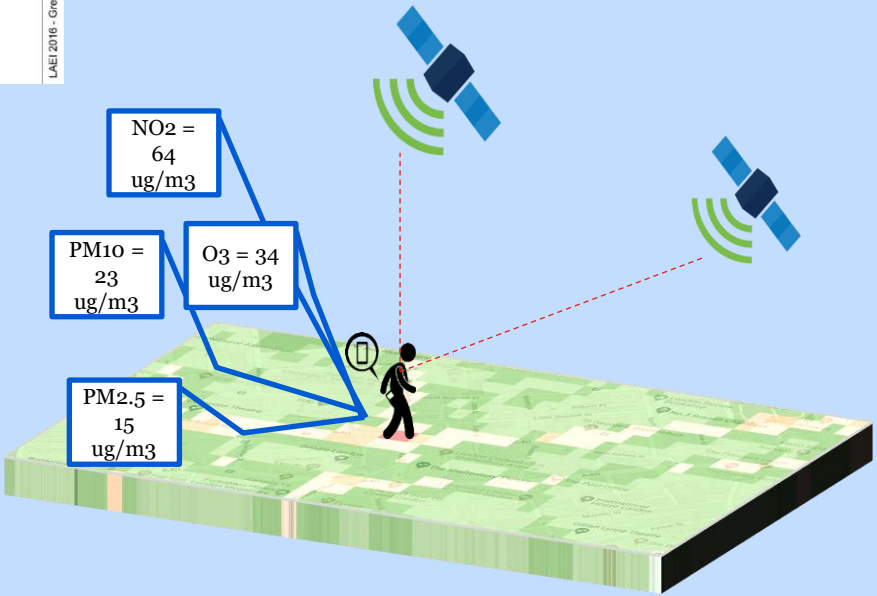
Clean Air Research Futures – Small Sensors





2.5 billion

1.5 billion



CityAir - Widget

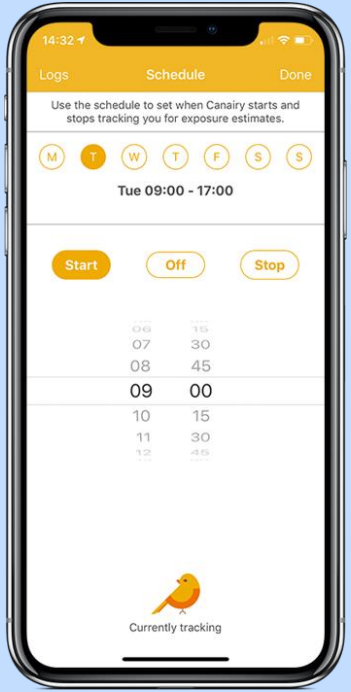
The new CityAir App

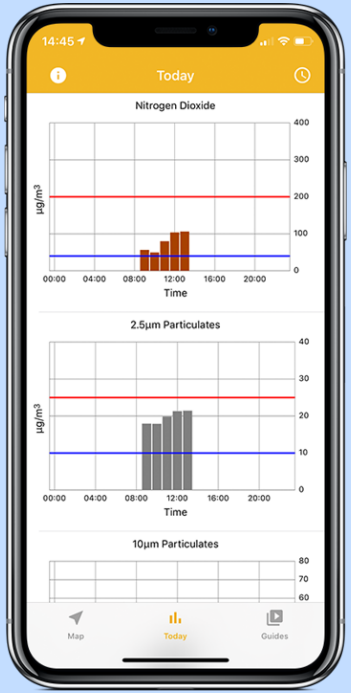
- Low pollution routes
- Alerts & Advice
- News
- And now..

Live Air Quality where you are - right on your home screen

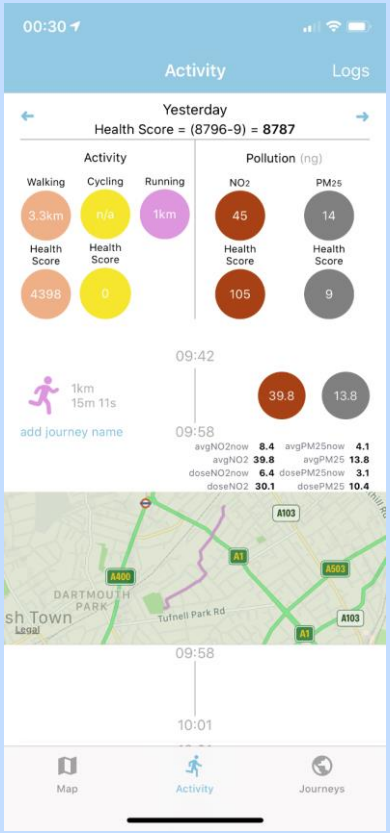
Imperial College London

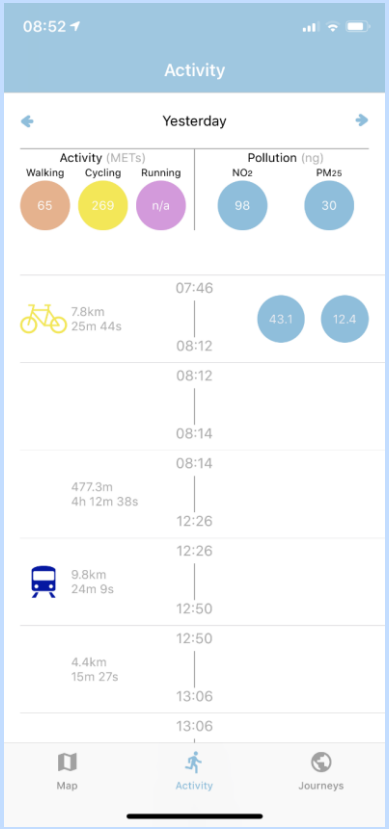
Canairy – outdoor worker exposure





Airwaze – Activity tracking





Nottingham Trent University

Department of Computer Science

Any Questions?