The TRAFFIC STUDY

EEHI Webinar
February 17th 2016

Frank Kelly
King’s College London
**LWEC Environmental Exposure & Health Initiative**

£7M programme with funding provided by NERC/MRC/ESRC/DoH/Defra

<table>
<thead>
<tr>
<th>PI</th>
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<tr>
<td>Kelly</td>
<td>Traffic Pollution and Health in London</td>
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<tr>
<td>Wilkinson</td>
<td>Air pollution and weather-related health impacts: methodological study based on spatio-temporally disaggregated multi-pollutant models (AWESOME)</td>
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<td>Ayres</td>
<td>From Airborne exposures to Biological Effects (FABLE): the impact of nano-particles on health</td>
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<td>Saul</td>
<td>CLOUD TO COAST C2C: Integrated modelling of the fate and transport of faecal organisms</td>
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• Wide and expanding range of health effects
Risk of coronary artery calcification and distance to heavy traffic

Hoffman, 2007
The Questions: Health Effects of Traffic Pollution (HEI 2010)

• Wide and expanding range of health effects

• Sources and components
The Questions: Health Effects of Traffic Pollution (HEI 2010)

• Wide and expanding range of health effects

• Sources and components

• Population exposure
The Questions:
Health Effects of Traffic Pollution (HEI 2010)

• Wide and expanding range of health effects

• Sources and components

• Population exposure

• Exposure-response relationships
Why London?

- Severe traffic pollution (> WHO limits for PM$_{2.5}$ and NO$_2$)
- Variability in population exposure
- Traffic interventions (CCS, LEZ)
- High density monitoring network
- Extensive traffic data (including NPR)
- Fine spatial scale models (20x20m)
- Daily analysis of PM chemical composition
- Availability of a health outcomes from cradle to grave
- Multidisciplinary consortium of experienced investigators
Traffic Pollution and Health in London:

NERC/MRC  2011-2014

King’s College  –   Frank Kelly, Ross Anderson, Sean Beevers, Gary Fuller, Martin Williams

Imperial College – Mireille Toledano, Marta Blangiardo, John Gulliver, 

St George’s UOL – Richard Atkinson, Derek Cook, Peter Whincup

LSH&TM – Cathryn Tonne, Paul Wilkinson

Other collaborators:

Margaret Bell, Ben Armstrong, David Green, Anna Hansell, Paul Elliott
# Organisation of Research Programme

## Management Team
Kelly/Anderson

## Advisory Board
Reps from: Defra, GLA, Tfl, PHE

## POLICY RELEVANCE (lead: Williams)

<table>
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<tr>
<th>Work package 1</th>
<th>Work package 2</th>
<th>Work package 3</th>
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<tr>
<td>Daily PM OP measures &amp; analysis of AQ metrics in a time-series study</td>
<td>Modelling population exposure to traffic pollution</td>
<td>Chronic exposure health studies</td>
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<tr>
<td>(Atkinson/Fuller/Mudway)</td>
<td>(Beevers/Gulliver)</td>
<td>(Anderson/Cook/Toledano/Tonne/Whincup/Wilkinson)</td>
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## VULNERABILITY (lead: Tonne)

## Core facilities

<table>
<thead>
<tr>
<th>Air quality and noise science</th>
<th>SAHSU</th>
<th>Statistics</th>
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<tr>
<td>(Ashmore/Bell Derwent/Green)</td>
<td>(Toledano/Hansell/ Elliott)</td>
<td>(Armstrong/Atkinson Blangiardo/Cook/ Richardson)</td>
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WP1: PM Oxidative Potential and Utilisation of ClearfLo data

1. Oxidative potential and metal composition
   (2yrs 24hr samples from urban background site)

2. Time-series analysis of ClearfLo data to investigate relative toxicity of PM metrics against daily deaths and hospital admissions.
Traffic emissions toxicology
- what we still don’t fully understand

- Are all particles equally active and where does the toxicity reside?
- To what extent are tail pipe-derived particles responsible for the health effects observed?
PM at roadside has higher oxidative potential

November 2004 - March 2006

Glutathione (μM)

PM$_{10}$ Sampling sites

More active

Less active

Box plots showing glutathione levels at various PM$_{10}$ sampling sites.
Traffic emissions toxicology
- what we still don’t fully understand

• Are all particles equally active and where does the toxicity reside?

• To what extent are tail pipe-derived particles responsible for the health effects observed?
Nonexhaust Traffic Particles

Harrison et al, EST, 2012
Traffic exposure metric continues to be a limitation

- \( \text{PM}_{2.5} \)
- NO2
- EC (also referred to as BC, BS, or soot)
- CO
- Ultrafine PM
- Benzene
- Noise
Pollution data available from the ClearfLo project for 2011 & 2012 (NK)

- **Gases:** NO2, SO2, O3, CO
- **PM mass:** PM10/2.5/2.5-10 – traffic (exhaust and non exhaust)
- **PM physical:** volatility, SMPS size bins, APS size bins, surface area
- **Carbon:** EC, black carbon (fossil, wood, London); Primary & secondary OC (total, London, long range) & OC (wood)
- **Ions:** NO3, SO4, Cl, NH4, Na, Ca, K, Ma (Also rural & urban NO3 and London NO3)
- **Metals:** Al, Ba, Cu, Fe, Mn, Mo, Ni, Pb, Cr, Sr, V, Sb, Zn
Time-series analysis of daily traffic derived AP data against daily deaths and hospital admissions
Short term exposure and health outcomes


We assembled a database of > 100 daily, measured and modelled pollutant concentrations characterising air pollution in London between 2011 and 2012.

We selected, a priori, markers of traffic pollution: oxides of nitrogen (general traffic); elemental and black carbon (EC/BC) (diesel exhaust); carbon monoxide (petrol exhaust); copper (tyre), zinc (brake) and aluminium (mineral dust).

Poisson regression accounting for seasonality and meteorology was used to estimate the percentage change in risk of death associated with an interquartile increment of each pollutant.

Associations were generally small with confidence intervals that spanned 0% and tended to be negative for cardiovascular mortality and positive for respiratory mortality.

The strongest positive associations were for EC and BC adjusted for particle mass and respiratory mortality, 2.66% (95% confidence interval: 0.11, 5.28) and 2.72% (0.09, 5.42) per 0.8 and 1.0 μg/m³, respectively.

These associations were robust to adjustment for other traffic metrics and regional pollutants, suggesting a degree of specificity with respiratory mortality and diesel exhaust containing EC/BC.
WP2: Modelling population exposure to traffic pollution

1. Develop a model of population exposure to air pollutants from traffic

2. Develop a model of population exposure to noise from traffic

3. Develop a hybrid-exposure model for population exposure to traffic pollution
Modelled traffic AP exposure

<table>
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<th>PM</th>
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<td>PM10 Total</td>
<td></td>
</tr>
<tr>
<td>PM10 Exhaust</td>
<td></td>
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<tr>
<td>PM10 Non Ex</td>
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<tr>
<td>PM2.5 Total</td>
<td></td>
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<tr>
<td>PM2.5 Exhaust</td>
<td></td>
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<tr>
<td>PM2.5 Non ex</td>
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<tr>
<td>PM Coarse</td>
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<tr>
<th>Gases</th>
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<tr>
<td>NO</td>
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<tr>
<td>NO2</td>
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<tr>
<td>NOx</td>
<td></td>
</tr>
<tr>
<td>O3</td>
<td></td>
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<tr>
<td>Ox</td>
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20x20m resolution

2003-2010

Annual and monthly

Address

Postcode
  PC address point
  PC average
  PC centroid
WP2: Modelling population exposure to traffic pollution

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Modelled traffic noise exposure
Publications using the new noise model for London


- 1.03 million (12%) people are exposed to daytime road traffic noise levels ≥ 65 dB(A)
- 1.63 million (19%) people are exposed to night-time road traffic noise levels ≥ 55 dB(A)
- differences in noise levels between 2010 and 2003 were on average relatively small:
WP3: Epidemiological Studies of Health Effects of Long-term Exposure to Traffic Pollution

1. Early markers and risk factors for vascular disease, markers of chronic inflammation and lung function in primary school children

2. Primary care records: incidence and exacerbation of cardiovascular and respiratory conditions

3. Mortality, hospital admissions, survival after admission for acute coronary syndrome

4. Adverse birth outcomes – low birthweight, preterm birth
WP3: Approaches in common

- Link with modelled exposure at fine spatial scale through address (or postcode)
- Use of spatial-temporal analyses to address potential spatial confounding
- Evaluation of effects of changes in air quality
- Coordination of analyses
- Objective of developing exposure response relationships that fit with exposure modelling for impact analysis and scenario evaluation
TRAFFIC: Exposure Metrics for Chronic Exposure Studies

• Metrics
  – Dispersion model 20x20m: PM and gases
  – Traffic proximity: distance and vehicle density
  – Noise: road, rail, air

• Spatial resolution
  – Address point level: 6 digit, interpolated from 20m points
  – Postcode level (~14 households): PC address centroid
  – Census Output Area (~300 population)
  – Lower Layer Super Output Level (~1500 population)

• Temporal resolution
  – Annual 2003-2010
  – Monthly 2003-2010

• Confounding factors and indicators of vulnerability
  – Socio-economic status
    • Index of multiple deprivation/ Carstairs
  – Ethnicity
  – Proxy for smoking (Lung Cancer mortality)
Epidemiological Studies of Health Effects of Long-term Exposure to Traffic Pollution in London

1. **Adverse birth outcomes** – low birthweight, preterm birth using routine data on births, birthweight and gestation age and (ONS, HES)

2. **Cross-sectional study of Early markers and risk factors for vascular disease, markers of chronic inflammation and lung function** in primary school children using Child Heart and Health Study in England (CHASE)

3. **Primary care records**: incidence and exacerbation of cardiovascular and respiratory conditions using Clinical Practice Research Datalink (CPRD)

4. **Mortality (ONS), hospital admissions (HES), Myocardial Ischaemia National Audit Project (MINAP)**

17/02/2016
CHASE: negative but non significant association
Meta-Analysis: 10ug/m^3 increase in NO_2 associated with a 8ml lower FEV_1

Epidemiological Studies of Health Effects of Long-term Exposure to Traffic Pollution in London

1. **Adverse birth outcomes** – low birthweight, preterm birth using routine data on births, birthweight and gestation age and (ONS, HES)

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4. **Mortality** (ONS), **hospital admissions** (HES), **Myocardial Ischaemia National Audit Project** (MINAP)

211,016 adults aged 40-79 years registered in 75 GP practices between 2005-2011. First occurrence of CHD, MI, stroke, heart failure, hypertension, atrial fibrillation, COPD and pneumonia were identified from medical and hospital records.

• The incidence of heart failure, and to a lesser extent pneumonia, was associated with higher levels of traffic-related air pollution. However for most diseases we found no consistent evidence of associations with air pollution, traffic proximity or noise levels.
• Differences in modelled near and far roadside levels for air pollution from traffic were eclipsed by larger differences between practice areas.

‘While acknowledging that residential models of exposure only give an incomplete picture of cumulative exposure, our results fail to support the hypothesis that living near roads with heavy traffic and/or living in an inner city is associated with serious health effects within Greater London’.
Epidemiological Studies of Health Effects of Long-term Exposure to Traffic Pollution in London

1. **Adverse birth outcomes** – low birthweight, preterm birth using routine data on births, birthweight and gestational age and (ONS, HES)

2. **Cross-sectional study of Early markers and risk factors for vascular disease, markers of chronic inflammation and lung function** in primary school children using Child Heart and Health Study in England (CHASE)

3. **Primary care records**: incidence and exacerbation of cardiovascular and respiratory conditions using Clinical Practice Research Datalink (CPRD)

4. **Mortality** (ONS), **hospital admissions** (HES), **Myocardial Ischaemia National Audit Project** (MINAP)

17/02/2016
Publications considering the long term effects of traffic pollution in London


Publications considering the long term effects of traffic pollution in London


• Long-term exposure to road traffic noise was associated with small increased risks of all-cause mortality and cardiovascular mortality and morbidity in the general population, particularly for stroke in the elderly.


• Overall, there was only weak evidence of positive associations with mortality.


• These data support a relationship of primary traffic and regional/urban background air pollution with poor prognosis among MI survivors.


• An increased risk was observed among those living in areas with the highest socioeconomic deprivation.
Deviation from original proposal

• Link with modelled exposure at fine spatial scale through address (or postcode)
  – OK

• Use of spatial-temporal analyses to address potential spatial confounding
  – Not feasible – insufficient change 2003-2010
  – Spatial analysis presented some problems, depending on nature of health data. HES and mortality required aggregation to LSOA level (~1500 pop).

• Evaluation of effects of changes in air quality
  – Not feasible – lack of sufficient signal and poorly estimated health effects – if any.

• Objective of developing exposure response relationships that fit with exposure modelling for impact analysis and scenario evaluation
  – Few associations identified for air pollution
  – Some potential for quantification of noise effects.
WP2: Modelling population exposure to traffic pollution

1. Develop a model of population exposure to air pollutants from traffic

2. Develop a model of population exposure to noise from traffic

3. Develop a hybrid-exposure model for population exposure to traffic pollution
An Improved understanding of exposure is required

The quality of the exposure data has been regarded as the Achilles heel of environmental epidemiology

Perera & Weinstein, *J Chronic Dis* 1982
Static and Hybrid approaches to exposure assessment
Hybrid exposure model

CMAQ-urban air quality model

Micro-environmental modelling: in-vehicle (bus, car, train, tube), cycle, walk, indoors (I/O exchange - J Taylor (UCL))

\[
\frac{dc_{in}}{dt} = \lambda_{win}(c_{out} - c_{in}) - n\lambda_{HVAC}c_{in} - V_g\left(\frac{A}{V}\right)c_{in} + \frac{Q}{V}
\]

London Travel Demand Survey: Trips by transport mode: Sex, age, gender and socio-economic status

Oyster card data

Detailed human exposure

J Taylor et al., 2014. The modifying effect of the building envelope on population exposure to PM2.5 from outdoor sources. Indoor Air.
doi:10.1111/ina.12116
Exposure measurements


*Note that these are mostly 'black iron' particles on the Tube, not black carbon
Geographic dose to NO$_x$ (top) and PM$_{2.5}$ (bottom)
# Cast of collaborators in TRAFFIC

## LSHTM
- Jaana Halonen
- Cathryn Tonne
- Paul Wilkinson

## Imperial
- Anna Hansell
- John Gulliver
- David Morley
- Rebecca Ghosh,
- Marta Blangiardo
- Daniela Fecht
- Mirelle Toledano
- Danielle Vienneau

## King’s
- Sean Beevers
- David Dajnak
- Gary Fuller
- David Green
- Ian Mudway
- Frank Kelly
- Richard Atkinson
- Ross Anderson
- Evangelia Samoli
- Derek Cook
- Ian Carey
- Peter Wincup
Thank you for your attention!