Modelling the epidemiological and economic impacts of air pollution reduction in the English metropolitan borough of Sandwell

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Background

- Air pollution is a major public health concern with a high burden of disease.

- Air pollution is a driver of various non-communicable diseases (NCDs), including, but not limited to: asthma, stroke, coronary heart disease and lung cancer.

- Understanding the extent and magnitude of air pollution’s impact on long-term health is important for future National Health Service (NHS) budget allocation, priority setting, and policy planning.

- The project demonstrated a proof of concept in Sandwell, UK enabling local authorities to:
  - plan community priorities by calculating short- and long-term health benefits of Disease Prevention;
  - and to digitally ‘nudge’ behaviour change at locations where air emissions present significant health risk
Sandwell

• Sandwell is a metropolitan borough in the West Midlands, bordering Birmingham, one of the UK’s largest cities.

• It sees significant traffic via the M5, a major road which connects Bristol (in the South) to the West Midlands.
Microsimulation model aims

• The specific aims of this component of the project, using a validated microsimulation model [1], are as follows:
  
  • Generate a model of the health and economic consequences of air pollution specific to Sandwell Metropolitan borough (utilising local population and pollution sensor data).
  
  • Use the model to test the health and economic benefits of a hypothetical air pollution reduction scenario, driven by a combination of policy and behavioural change.
    • Impacts will be assessed over a 10-year timespan (2023-2033).
    • The hypothetical scenario assumes a gradual drop in air pollution exposure across the population over the span of 5 years (2023-27 inclusive).

Overview of the microsimulation and its components

Distribution Program

Risk Factor Data (PM$_{2.5}$ & NO$_2$)

Population Data

Disease Data (Asthma, CHD, COPD, lung cancer, stroke, T2D)

Health Economic Data

Intervention Scenarios

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Microsimulation program

Output Data (disease incidence/prevalence, NHS costs, QoL, life years)

Input datasets

Software programmes

Output datasets

[2]: Pineda, E. et al. 2018, Obesity facts, 11(5)
[3]: HL publications can be found here: https://www.healthlumen.com/track-record/
Epidemiological module of the HealthLumen microsimulation $^{1,2,3}$ for one person

Generate 1 person
- Age
- Sex
- Disease status

Advance year and update age

Person dies or reaches the end of simulation

Update disease and treatment status

Update risk factor levels (NO$_2$ / PM$_{2.5}$ exposure)

Baseline scenario (remains the same)

Intervention (decrease if 2023-2027)

[2]: Pineda, E. et al. 2018, Obesity facts, 11(5)
[3]: HL publications can be found here: https://www.healthlumen.com/track-record/
Methods: risk factors (PM$_{2.5}$ and NO$_2$)

- Risk factor data (PM$_{2.5}$ and NO$_2$) were collected from sensor data from across Sandwell (supplied by Earthsense).
- For this study, we use data from 2019.
  - 2020 onwards was excluded to discount any changes in air pollution due to covid-19 and associated policies. We assume that current pollutant exposure matches pre-pandemic levels.
  - In our baseline scenario, we conservatively assume that air pollution / exposure remains static over the course of the microsimulation (2023-2033).
- PM$_{2.5}$ / NO$_2$ sensor data were mapped onto individual-level exposure based on the following assumptions [1]:
  - We assume that PM$_{2.5}$ / NO$_2$ exposure data aligns with residence (i.e. do not account for transport within or in/out of Sandwell).
  - Age/sex distribution of PM$_{2.5}$ / NO$_2$ exposure was inferred by mapping ward-level PM$_{2.5}$ / NO$_2$ levels (mean and SD) to census data.
  - We assume a normal distribution of PM$_{2.5}$ / NO$_2$ exposure within age/sex categories.

Modelled diseases

- The following diseases were modelled based on the evidence supporting their link to air pollution (PM$_{2.5}$ and NO$_2$):

<table>
<thead>
<tr>
<th>PM$_{2.5}$</th>
<th>NO$_2$ [6]</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Asthma (childhood) [1, 2, 3]</td>
<td>- Asthma (childhood and adult) [1, 2, 7]</td>
</tr>
<tr>
<td>- CHD [1, 2, 3]</td>
<td>- Lung cancer [7]</td>
</tr>
<tr>
<td>- COPD [4]</td>
<td>- Type 2 diabetes [1, 2, 7]</td>
</tr>
<tr>
<td>- Lung cancer [5]</td>
<td></td>
</tr>
<tr>
<td>- Stroke [1, 2, 3]</td>
<td></td>
</tr>
<tr>
<td>- Type 2 diabetes [1, 2]</td>
<td></td>
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</tbody>
</table>

Assumptions: costs and quality of life

- Total costs were calculated by applying the annual cost per case to all prevalent cases of each disease modelled. I.e.:
  - \( \text{Annual cost of disease} = \text{Annual cost per case} \times \text{disease prevalence} \)
- Quality of life (QoL) was estimated using a multiplicative method:
  - By default, QoL is assumed to be 1.
  - If an individual has a disease, their QoL is multiplied by that disease’s utility weight (repeat for all diseases).
  - E.g. if a person has both asthma and CHD, their QoL would be \( 1 \times 0.722 \times 0.61 = 0.44042 \)
  - If a person dies, their QoL becomes 0.
  - Quality-adjusted life years (QALYs) are the sum of all individuals’ QoL scores across one or more years.
Intervention assumptions

• Intervention is based on evidence from:

**Font & Fuller (2016) Did policies to abate atmospheric emissions from traffic have a positive effect in London? Eviron. Pollution.**

• This study evaluated the impact of environmental policies on concentrations of pollutants (NO2, PM2.5 etc.) in London.
  
  • Compares two time points: 2005-9 and 2010-4.
  
  • Environmental policies include investment into catalytic diesel particulate filters and hybrid / low-emission buses, implementation of a Low Emission Zone, and other local schemes.

• The paper reports % drops for several clusters of sites within London.
  
  • For Sandwell, we selected sites showing similar levels of road traffic to Sandwell.

**Selected intervention parameters:**

- **NO2**
  
  3.41% annual decrease
  
  2023-27 (inclusive)

- **PM2.5**
  
  20.83% annual decrease
  
  2023-27 (inclusive)
PM2.5: The intervention is predicted to result in 4016 fewer new cases of disease by 2033.
NO2: The intervention is predicted to result in 143 fewer new cases of disease by 2033.

Asthma and type 2 diabetes comprise a large portion of disease avoided.
PM2.5: By 2033, the modelled intervention is projected to save the NHS around £36.6M in disease costs

CHD and COPD comprise the majority of disease costs avoided.
NO2: By 2033, the modelled intervention is projected to save the NHS around £0.6M in disease costs
PM2.5: By 2033, the intervention is predicted to result in 5,351 additional quality-adjusted life years (QALYs)
NO2: By 2033, the intervention is predicted to result in 253 additional quality-adjusted life years (QALYs)
Strengths and limitations

**Strengths**

- The **microsimulation is a robust tool** for modelling population-level interventions in detail because it models every individual many years into the future. Individuals are randomly generated with relevant characteristics (age, sex, exposure) to produce detailed intervention outcomes.

- Inputs are based on **high-quality data**, including robust literature searches, local demographic data and high-resolution air quality monitoring data.

- Given the right data, this **approach can be applied to other UK regions**, or regions in other countries.

**Limitations**

- Microsimulation doesn’t account for **spatial and temporal variation in pollutants**. Microsimulation models exposure distributions by age, sex and year. Does not account for daily variations in pollutants, nor variation in pollutant at e.g. road level.

- Relies on **real-world evidence from another UK region**. An intervention applied in Sandwell may not be wholly reflective of one applied in London. Interventions should be tailored to local circumstances.

- Challenges **projecting air pollution into the future**, e.g. natural variation in PM2.5 and unexpected factors e.g. COVID-19.

- Other factors such as **socio-economic status** outside of project scope. Deprived sub-populations are more susceptible to the negative health effects of air pollution and at the same time are more likely to be exposed to higher air pollution levels.
Main key messages

Reduced air pollution exposure in Sandwell due to policy and behavioural change has the potential to prevent thousands of cases of diseases, save millions of pounds worth of costs to the local healthcare system, and improve the quality of life of the local population.

For example, as a result of a policy/behaviour change scenario in which we assume a decline in PM$_{2.5}$/NO$_2$ over five years [2023-27 inclusive], we showed that the cumulative annual reductions of PM$_{2.5}$ and NO$_2$ exposures by 20.83% and 3.41% (2023-27) respectively, would result in:

- Over **4,100** fewer new (cumulative incident) cases of diseases
- Over **5,500** additional quality-adjusted life years (QALYs)
- **£37M** healthcare costs avoided due to reduction in the disease burden
- Over **800** additional years of working life

Reduced air pollution exposure in Sandwell due to policy and behavioural change has the potential to prevent thousands of cases of diseases, save millions of pounds worth of costs to the local healthcare system, and improve the quality of life of the local population.
THANK YOU