Air pollution and health in Scotland: A summary of the evidence

Professor Duncan Lee

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Duncan.Lee@glasgow.ac.uk

1. Introduction

- Air pollution has long been known to adversely affect public health in both the developed and developing world.
- A report by the Royal College of Physicians in 2016 estimates that 40,000 premature deaths are attributable to air pollution each year in the United Kingdom.
- Epidemiological studies into the effects of air pollution have been conducted since the 1990s, with one of the first being that conducted by *Schwartz and Marcus (1990)* in London.
- Since 1990 a large number of studies have been conducted, which collectively have investigated the short-term and long-term health impact of air pollution.

Current Scottish context

Air pollution is currently an important policy area in Scotland, with examples including:

- The review of the Cleaner Air for Scotland (CAFS) strategy in 2019.
- The introduction of Low emission zones (LEZs) in the four major cities, with the first in Glasgow beginning a phased implementation in 2019.
- Numerous other air pollution reduction policies being introduced, such as the Avenues project in Glasgow (`https://www.glasgow.gov.uk/avenues`).

Aims of the talk

- Summarise the evidence base on the health impact of air pollution in Scotland.
- Present the results from a recent study conducted in Scotland.

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2. Current evidence base

The health impact of air pollution has been quantified by 3 main study designs.

- Time series studies quantifying short-term effects.
- Spatial areal unit studies quantifying long-term effects.
- Individual-level studies (cohort and population) quantifying long-term effects.

The latter type allow individual-level cause and effect to be established, but are more costly and time consuming to conduct than the first two types.

Scottish evidence - Respiratory disease

- The Scottish evidence is relatively small in terms of the number of studies.
- However, consistent significant associations have been found between air pollution and respiratory ill health using different study designs, including:
    - Prescribing rates in primary care - Lee (2018).
    - Hospital admissions - Huang et al. (2018).
    - Mortality - Beverland et al. (2014).
- These findings broadly agree with the international evidence.

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Scottish evidence - Cardiovascular disease

- No associations have been found between air pollution and cardiovascular ill health using different study designs, including studies by
  - Prescott et al. (1998) - time series design.
  - Willocks et al. (2012) - time series design.
  - Beverland et al. (2014) - individual design.
  - Lee et al. (2018) - spatial design.
- These studies have considered both hospitalisations and mortalities, and have studied a range of pollutants including NO_2, PM_{10}, $PM_{2.5}$ and black smoke.
- These findings broadly disagree with the international evidence, which has found significant associations between air pollution and cardiovascular disease.

Scottish evidence - Other health end points

- **All-cause mortality** - Inconsistent results, some studies found significant associations (e.g. Beverland et al. 2012) while others found no effects (e.g. Carder et al. 2008).
- **Maternal exposure and pregnancy outcomes** - Inconsistent results, some studies found significant associations (e.g. Clemens et al. 2017) with foetal growth, while other studies (e.g. Dibben and Clemens 2015) found no association with low birth weight.
- **Mental health** outcomes have been associated with air pollution in the international literature, but associations have not been greatly studied in Scotland thus far.

3. A recent Scottish study

- One of the most recent studies based in Scotland was conducted using data from the two-year period 2015-16.
- The study has a spatial ecological design, and uses spatial contrasts in disease incidence and air pollution to estimate population-level effects.
- It was conducted by myself jointly with:
  - Prof Chris Robertson - University of Strathclyde.
  - Dr Colin Ramsay - Health Protection Scotland.
  - Dr Colin Gillespie - Scottish Environment Protection Agency.
- It was published as *Estimating the health impact of air pollution in Scotland, and the resulting benefits of reducing concentrations in city centres*, in Spatial and Spatio-temporal Epidemiology, Volume 29, June 2019, P85-96.

Data and study region

- The study region is mainland Scotland in 2015-2016, and we have data for $K = 1250$ Intermediate Zones (IZ).
- We use total counts of the numbers of cases of the following disease outcomes in each IZ over 2015-2016 as the disease measure:
  - Cardiovascular hospitalisations.
  - Cardiovascular mortality.
  - Respiratory hospitalisations.
  - Respiratory mortality.
  - Total non-accidental mortality.

Other data

- Population demography is accounted for using indirect standardisation, which computes an expected number of disease cases in each IZ, based on 5-year age and sex specific population estimates in each IZ.

- Average concentrations of NO_x, NO_2, PM_{10} and $PM_{2.5}$ over 2015-2016 are obtained from DEFRA (Pollution Climate Mapping model) on a $1km^2$ resolution, and are converted to the IZ scale by averaging.

- Covariates include:
  - Domain specific indicators of the Scottish Index of Multiple Deprivation (SIMD) 2015 (access to services, crime, housing, income).
  - Dwellings per hectare as a proxy for urbanicity.

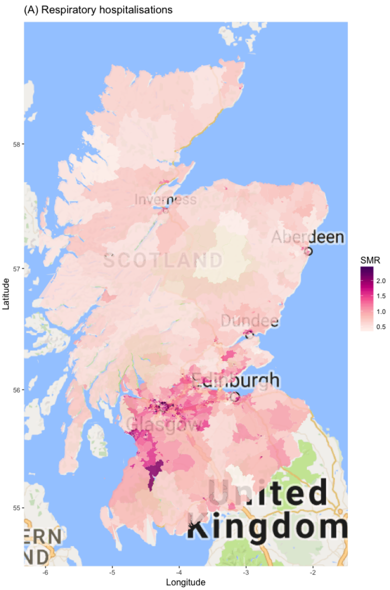
Measuring disease risk

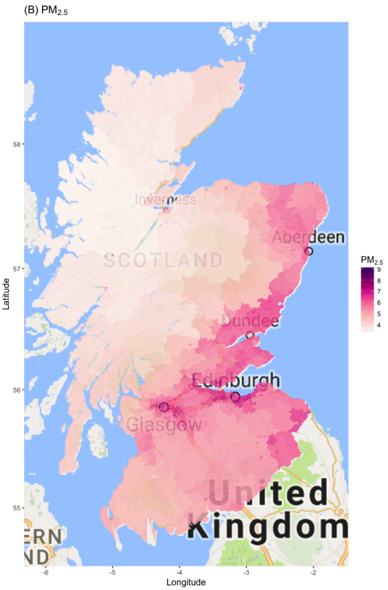
An exploratory measure of disease risk for the population living in each Intermediate Zone is the standardised mortality (or morbidity) ratio (SMR), which is computed as

$$SMR = \frac{\text{Observed number of disease events}}{\text{Expected number of disease events}}.$$

- SMR$=1$ means there are as many deaths as expected.
- SMR>1 means there are more deaths than expected. If SMR=1.2 there are 20% more deaths than expected.
- SMR<1 means there are fewer deaths than expected.

Data maps


(A) Respiratory hospitalisations
58
57
56
55
Latitude
Inverness
Aberdeen
SCOTLAND
Dundee
Edinburgh
Glasgow
United
Kingdom
-6
-5
-4
-3
-2
Longitude
SMR
2.0
1.5
1.0
0.5


(B) $PM_{2.5}$
58
57
56
55
Latitude
Inverness
Aberdeen
SCOTLAND
Dundee
Edinburgh
Glasgow
United
Kingdom
-6
-5
-4
-3
-2
Longitude
$PM_{2.5}$
9
8
7
6
5
4

Modelling

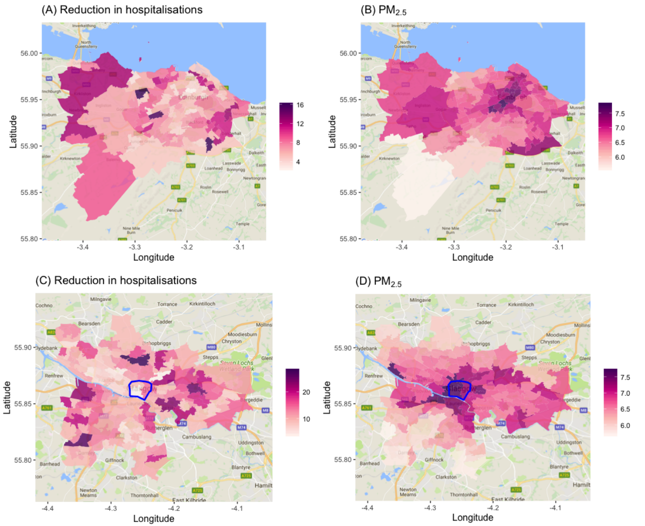
- We considered each disease outcome separately, and only put one pollutant in each model as all pairs of pollutants are highly correlated (between 0.66 and 0.99).
- This led to 20 different models, five disease outcomes and four different pollutants.
- Thus all results are marginal, that is, you cannot add up the estimated pollution effects across multiple diseases or pollutants.
- The results should also not be compared to other study designs (e.g. cohort studies), as the data scales are not comparable.
- The results on the next slide are presented as relative risks, which represent the increased risk of disease if pollution concentrations increased by a fixed amount.

Pollution-disease relative risks

Disease	Pollutant			
	NO_2	**NO_x**	**$PM_{2.5}$**	**PM_{10}**
Cardio h	1.012 (0.994, 1.030)	1.006 (0.995, 1.016)	1.018 (0.997, 1.040)	1.006 (0.995, 1.017)
Cardio m	0.988 (0.970, 1.006)	0.993 (0.982, 1.005)	0.995 (0.994, 1.016)	0.997 (0.987, 1.008)
Resp h	**1.028 (1.008, 1.048)**	**1.014 (1.002, 1.025)**	**1.058 (1.034, 1.083)**	**1.023 (1.011, 1.035)**
Resp m	1.032 (0.997, 1.067)	1.017 (0.996, 1.038)	**1.045 (1.002, 1.090)**	1.014 (0.992, 1.035)
Total m	1.003 (0.986, 1.020)	1.001 (0.990, 1.011)	1.012 (0.992, 1.033)	1.005 (0.995, 1.016)

The results for NO_2 and NO_x relate to a $5\mu gm^{-3}$ increase whilst those for $PM_{2.5}$ and PM_{10} relate to a $1\mu gm^{-3}$ increase.

The potential impact of decreasing $PM_{2.5}$



The estimated impact on the number of hospital admissions if $PM_{2.5}$ had been decreased by $1 \mu g m^{-3}$ in 2015-2016.

4. Conclusions

- Air pollution appears to have a consistent effect on respiratory disease across the Scottish literature, with all studies finding significant associations.
- In contrast, the Scottish studies consistently find no significant associations with cardiovascular disease, which is at odds with the international literature.
- Further work is required to quantify why this discrepancy exists for cardiovascular disease, as well as to investigate the link between air pollution and mental health in Scotland.
- However, the major limitation of all air pollution and health studies is that they assume an individuals exposure is equivalent to the outdoor concentration at their home which is implausible.