Cleaning up the air we breathe:

using statistics to understand the impact of air pollution

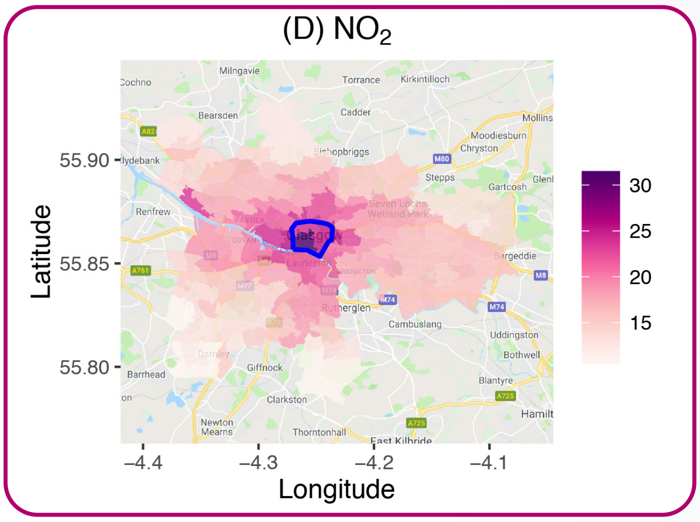

Figure 1: Levels of NO_2 pollution in the different Intermediate Zones within Glasgow. The blue line shows the Glasgow Low Emission Zone boundary where pollution is highest.

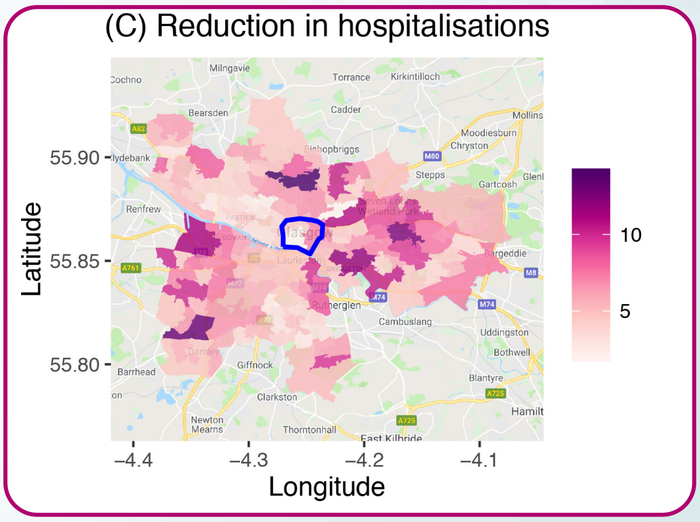

Figure 2: Projected reductions in hospitalisations if NO_2 pollution levels are reduced by 5 microgram per cubic metre in that area, for instance as the result of introducing a local Low Emission Zone. The biggest reductions are found outside the Glasgow Low Emission Zone boundary.

On a global scale air pollution is one of the most important environmental threats to human health. Worldwide an estimated 90% of the world's population is living in places where the pollution exceeds WHO air quality guidelines. In developed countries such as the UK, much of the air pollution is due to road transport so governments have been forced to act to reduce such man-made and preventable sources of pollutants. One response has been to introduce what are known as Low Emission Zones; these restrict entry to parts or sometimes all of a city by the most badly polluting types of vehicle. Low Emission Zones are found all over Europe, and increasingly will be used in the UK with many new Low Emission Zones (LEZs) planned.

In order to decide how best to use LEZs it is important to investigate their impact in terms of reducing pollution and improving public health – if they work well, then they can be rolled out to other areas, whereas if their impact is limited, then other more effective interventions could be prioritised instead. There are many unknowns associated with the introduction of a Low Emission Zone, primarily because we are dealing with a complex area involving a mixture of environmental factors, transport issues and human behaviour, with the potential to cause some unintended consequences. For example, bus operators may transfer older polluting buses to routes outside a LEZ and private car users might choose to avoid the Low Emission Zone, simply displacing their pollution to a different part of the city. Despite these many uncertainties, statisticians have powerful methods at their disposal, which can help unpick many of these problems.

Statisticians at the Universities of Glasgow and Strathclyde have been working alongside public health and environmental scientists to examine the potential impact of the new Glasgow Low Emission Zone. When it comes to air pollution, every city and country is different, not only in geography, but also in terms of demographics, and types of pollution. The statisticians wanted to understand whether the Glasgow Low Emission Zone would have a potential public health impact, using data available in Scotland, rather than assuming that the results would be similar to those from other Low Emission Zones around the world.

They began by examining the link between air pollution and health in Scotland, looking at the most recently available data. No substantial studies had been done using recent data, meaning that it was important to look at the current impact of air pollution, rather than what had been happening historically. The administrative geography of mainland Scotland can be described by 1252 'Intermediate Zones' that have an average of 4000 residents. In each of these zones the statisticians looked at the levels of four different pollutants. Two of these were Nitrogen Oxides: NO_2, NO_x and the others were two different sizes of particulate matter (particles in the air resulting from traffic and other sources): $PM_{2.5}$ and PM_{10}.

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The statisticians then looked at levels of ill health, examining five key measures: *Cardiovascular hospitalisation, Cardiovascular mortality, Respiratory hospitalisation, Respiratory mortality and Total non-accidental mortality.*

There are lots of contributing factors to ill health, including poverty and age. One of the powers of statistics is that it is possible to strip out the influence of these other (confounding) factors, and look at the connection just between the levels of air pollution and the measures of ill health.

The study found that there was a statistically significant link between an increased level of any one of the four pollutants and an increased level of admissions to hospital for a respiratory illness (respiratory hospitalisations). They also found a statistically significant link between increased levels of fine particles ($PM_{2.5}$) and respiratory mortality (deaths from respiratory disease). For example, they estimated that if there was a 5 microgram per cubic metre increase in levels of NO_2, then this would result in an associated increase in admissions for respiratory illness of somewhere between 0.8% and 4.8%. This is compelling evidence that air pollution is adversely associated with the health of the Scottish people and shows that by reducing pollution levels there could be a benefit to public health.

The statisticians then turned their attention to the new Low Emission Zone that was introduced in Glasgow in December 2018. This Low Emission Zone is sited in the busy retail and commercial city centre district where pollution levels are highest but where relatively few people actually live. Even though the highest levels of pollutants are found in these places, only relatively few people live there or stay for long periods; most people pass though them for short periods on their daily commute or shopping trip.

“Air pollution is one of the most important environmental threats to human health.”

One of the major challenges of air pollution studies, is that we do not have reliable monitors for people to wear and people's exact movements across a city are unknown. For instance, an office worker could spend most of the day in a building in a highly polluted street but be working in a tall office block, where they are protected to some degree from the traffic fumes below.

This is again where statistics comes in – the researchers looked at the effect on public health of reducing NO_2 pollution by 5 microgram per cubic metre on the different Intermediate Zones across Glasgow. The results showed that even though the pollution levels were highest in the centrally located Low Emission Zone, reducing pollution there is not expected to lead to a big reduction in admissions to hospital for respiratory illness. On the contrary, reducing levels of pollution in some of the further out zones, may lead to a greater reduction in such hospitalisations. This is certainly food for thought for anyone who is a city planner – it may actually make more sense to introduce a Low Emission Zone in a residential area where the density of residents is greater. However, this would need to be traded off against the fact that pollution levels were probably already lower and so the scope to reduce these is likely to be a lot less. Further statistical work needs to be done in order to look into this problem further, but it does challenge the automatic assumption that Low Emission Zones should be put in the most polluted and most central areas, if one of the aims is to improve health for the maximum number of people.

TECHNICAL SUPPLEMENT

An area with an older resident population or a higher rate of pre-existing poor respiratory health (e.g. lots of cases of chronic obstructive pulmonary disease COPD) is bound to have a higher death rate than an area populated by relatively young fit adults (e.g. students), meaning that death rates can be misleading when they are taken out of context. One of the ways the statisticians took this into account was by using a measure called the Standardised Mortality Ratio (SMR). Firstly they took the actual number of deaths due to respiratory causes (the observed deaths) for each Intermediate Zone. Then they split the population of each IZ according to age and sex, for example there might be 200 men who are in the 60-65 age category. They then looked at national data (for Scotland) to find out how many of those men would be expected to die in the study's two year time frame from respiratory illness. They then summed up all the expected deaths over the different age group categories to arrive at an expected number of deaths. The Standardised Mortality Ratio is then calculated as follows:

$$\text{Standardised Mortality Ratio} = \frac{\text{Observed Number of Deaths}}{\text{Expected Number of Deaths}}$$

If this came out as 1.2, this would mean that the Intermediate Zone had seen 20% more deaths from respiratory illness than would be expected. This is just one of the ways in which the statisticians used the structure of the underlying population. They also looked at poverty and other risk factors when completing their study. This enabled them to see what effect was caused by air pollution, as opposed to the demographics of the population.

Experts

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