Public Health England

Protecting and improving the nation's health

Estimation of costs to the NHS and social care due to the health impacts of air pollution: summary report

About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. We do this through world-leading science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. We are an executive agency of the Department of Health and Social Care, and a distinct delivery organisation with operational autonomy. We provide government, local government, the NHS, Parliament, industry and the public with evidence-based professional, scientific and delivery expertise and support.

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Glossary of terms and abbreviations

Attributable cases	Estimated from a specified risk factor. In this case, all of the cases quantified are due to the air pollutant.
Baseline	This refers to the 'steady state' of the risk factor assuming no change from current exposure levels. However, changes in the population (for example, ageing occur).
COMEAP	Committee on the Medical Effects of Air Pollutants.
Dose - response	Or exposure response. Describes the change in health effect on an individual caused by differing levels of exposure to a stressor (in this case an air pollutant) after a certain exposure time.
$\mu g/m^3$	Microgramme per metres cubed. Microgramme is a unit of mass equal to one millionth (1×10^{-6}) of a gram.
Incidence	The occurrence of new cases of the disease – not to be confused with prevalence.
NO_2	Nitrogen dioxide is a noxious gas. It is a local, primary traffic pollutant and a biologically relevant indicator of exposure to traffic-related air pollution with known health effects.
PHE	Public Health England.
$PM_{2.5}$	Fine particulate matter. It is an urban background pollutant which often disperses over a large area. PM consists of finely divided solids or liquids such as dust, fly ash, soot, smoke, aerosols, fumes, mists, and condensing vapours that can be suspended in the air.
Prevalence	This is the total number of cases of a disease in a particular population. This indicates how widespread the disease is.
Simulation	The imitation of a real-world process or system over time, in this case the simulation of a virtual country population.

Background

Air pollution is the leading environmental cause of early death - contributing to the equivalent of 5% of all deaths globally (1). Long-term exposure to particulate air pollution is estimated to have an effect equivalent to 29,000 deaths a year in the UK (2). In addition, it is now thought that long-term exposure to nitrogen dioxide (NO_2) is also having an impact on mortality but this has yet to be quantified by the Committee on the Medical Effects of Air Pollutants (COMEAP). Air pollution is also responsible for a substantial amount of morbidity, causing short and long term health effects (3-9), as well as a significant contributor to health inequalites (10).

Tackling air pollution will improve both the enivironment and public health. In the new National Institute for Health and Care Excellence (NICE)/PHE air pollution guidance, local authorites are urged to consider a range of effective interventions that encourage movement to low or zero emmission areas.

Main objective

Knowing the local impact of air pollution on health and related health care costs over time is important for future policy and resource planning and to target mitigation measures and public health campaigns.

The UK Health Forum and Imperial College London, in collaboration with, and funded by Public Health England, carried out a modelling study to quantify the potential costs to the NHS and social care system due to the health impacts of fine particulate matter ($PM_{2.5}$) and NO_2 and to develop a tool for use by local authorities to quantify number of expected disease cases and costs in their local area. The team were led by an expert advisory panel which included representatives from COMEAP, NICE, and DEFRA.

Key results

Total healthcare cost of air pollution in England	
The total NHS and social care cost due to $PM_{2.5}$ and NO_2 combined[1] in 2017 was estimated to be £42.88 million (based on data where there is more robust evidence for an association), increasing to £157 million when diseases are included where there is currently less robust or emerging evidence for an association.	
Between 2017 and 2025, the total cost to the NHS and social care of air pollution for where there is more robust evidence for an association, is estimated to be £1.60 billion for $PM_{2.5}$ and NO_2 combined increasing to £5.56 billion if we include other diseases for which there is currently less robust evidence for an association	
Particulate Matter ($PM_{2.5}$)[2]	**Nitrogen dioxide (NO_2)[3]**
In England, the total cost due to $PM_{2.5}$ to the NHS and social care in 2017 is estimated to be £41.2million, rising to £76.1million when diseases are included where there is less robust evidence for an association.	In England, the total cost due to NO_2 to the NHS and social care in 2017 is estimated to be £1.7million, rising to £81.1million when diseases are included where there is less robust evidence for an association.
In England, the total cost due to $PM_{2.5}$ to the NHS and social care is estimated to be £1.5billion by 2025, and £5.1billion by 2035. This increases to £2.8billion and £9.4billion respectively when diseases with less robust evidence are included.	In England, the total cost due to NO_2 to the NHS and social care is estimated to be £60.8million by 2025, and £230million by 2035. This increases to £2.7billion and £9.2billion respectively when diseases with less robust evidence are included.
The highest cost burden in England due to $PM_{2.5}$ was for secondary care (£1.4billion and £4.5billion by 2025 and 2035 respectively).	The highest cost burden due to NO_2 was for social care (£1.2billion and £3.8billion by 2025 and 2035 respectively).
When all diseases are included (those with more robust and less robust evidence of an association….	
In England, an estimated 1,327,424 new	In England, an estimated 1,140,018 new

[1] Dose-response estimates for NO_2 and the morbidity outcomes were adjusted and reduced by 60% to take account of effects associated with PM ,based on COMEAP recommendations for mortality

[2] The diseases included were: STRONGER evidence of an association: Coronary Heart Disease (CHD), Childhood asthma, Stroke, Lung Cancer; LESS STRONG evidence of an association: Chronic Obstructive Pulmonary Disease (COPD), Diabetes, Low birth weight

[3] The diseases included were: STRONGER evidence of an association: Childhood Asthma; LESS STRONG evidence of an association: Asthma (adults), Diabetes, Lung Cancer, Low birth weight, and dementia. The exposure-response relationships were adjusted to take account of the joint impact of $PM_{2.5}$.

cases of disease are predicted to be attributable to $PM_{2.5}$ air pollution levels by 2035 if current air pollution levels persist.	cases of disease are predicted to be attributable to NO_2 by 2035 if current air pollution levels persist.
Estimates of attributable cases due to $PM_{2.5}$ exposure for Lambeth, an area with high exposure (3242 new cases of disease per 100,000 population by 2035) were far higher than those for South Lakeland (861 new cases of disease per 100,000 population by 2035), an area with low exposure4.	Estimates for attributable cases due to NO_2 exposure for Lambeth (3331 new cases of disease per 100,000 population by 2035) were far higher than those for South Lakeland (1013 new cases of disease per 100,000 population by 2035).
	Reaching EU standards would result in more cases avoided in Lambeth where NO_2 exposure is higher than in South Lakeland where exposure is much lower.

A tool has been developed for use by local authorities to test the impact of changes in $PM_{2.5}$ and NO_2 on future prevalence of air-pollution related diseases and related health and social care costs. This can be downloaded here:
https://fingertips.phe.org.uk/documents/PHE_Air_Pollution_Setup.exe

What does this study add?

This is the first time the healthcare costs of air pollution have been estimated in England. The tool provides estimates on the prevalence of disease and related NHS and social care costs due to air pollution. These are important and useful statistics that will highlight the burden of air pollution to the health care system and quantify the health and related NHS and social care cost savings under different scenarios as compared to a ‘do nothing’ scenario.

The impacts of air pollution and the action required to address it are highly relevant to local government priorities: health, housing, transport, education, local economies, greenspace and quality of life. Local authorities have long had specific legal air quality powers to tackle air pollution locally where there is evidence from either the local or national assessment regimes that it exceeds legal limits. For example, there are currently 28 local authorities in England that are required to draw up local plans to bring forward compliance with legal limits on NO_2. Until now, there has been no simple way for local authorities to estimate the potential savings to the public purse from taking local

[4] Lambeth and South Lakeland were included as case studies to show the health impacts in a highly polluted area (Lambeth) compared with a much less polluted area (South Lakeland).

action on nitrogen dioxide, or from other harmful emissions including $PM_{2.5}$ from domestic chimneys and industrial sources. Alongside these specific obligations, strategic decisions on transport, planning and public health taken by local government all contribute to the quality of the air that people breathe in local communities. Many air quality problems, such as concentrations of NO_2at the roadside, can be tackled most effectively at the local level and local authorities have to be able to set out a strong rationale for using public money on these initiatives. This tool may help local authorities make a more fully developed economic and financial case for reducing emissions.

The Government will publish a new draft Clean Air Strategy for consultation in spring 2018 and a final strategy by the end of the year. This strategy will set out the range of actions the Government will take in the coming years to tackle emissions of 5 key pollutants from a wide range of sources. There will be a need to continually improve our understanding of the important health, environmental and economic consequences of air pollution in order to deliver an ambitious programme of actions. This new research and resource for local authorities is an important step in transforming how we assess public health impacts in order to inform decisions at local level to improve air quality and the health of people living in affected areas.

What is $PM_{2.5}$ and NO_2?

PM stands for 'particulate matter', and 2.5 refers to the size of the particulate – in this case it's 2.5 micrometres or less in diameter. It is an urban pollutant which often disperses over a large area. PM consists of finely divided solids or liquids such as dust, fly ash, soot, smoke, aerosols, fumes, mists, and condensing vapours that can be suspended in the air. $PM_{2.5}$ is produced by combustion in for example, industry, motor vehicles (particularly from diesel engines and vehicle tyres and brakes), and wood burning solid fuel stoves.

NO_2 stands for nitrogen dioxide, and millions of tons of this toxic gas are produced each year. It is a local, primary traffic pollutant and a biologically relevant indicator of exposure to air pollution with known health effects. NO_2 is introduced to the environment largely from vehicle traffic, but also from manufacturing and construction, butane and kerosene heaters and stoves, and cigarette smoke.

How do they affect our health?

$PM_{2.5}$ is particularly harmful since the small particles can easily and quickly penetrate deep into the lungs where they can cause damage to the tissue. Exposure to $PM_{2.5}$ has been linked to a range of health outcomes including asthma, respiratory disease, coronary heart disease, stroke, and lung cancer, with emerging evidence showing impacts on diabetes and low birth weight.

Inhalation of NO_2 affects our health by diffusing into the cells which line the respiratory tract and reacting with antioxidant and lipid molecules. These reactions can drive health effects such as tightening of the airways in the lungs (causing wheezing, coughing, shortness of breath), inflammation, and a reduced immune response. NO_2 has been associated with causing asthma, and lung cancer, with emerging evidence showing impacts on type 2 diabetes, low birth weight and dementia. NO_2 can also exacerbate existing conditions, especially asthma.

Methods used for this study

This study uses a dynamic microsimulation model to predict the future health and economic impact of air pollutants $PM_{2.5}$ and NO_2 to the year 2035. This microsimulation examines data on air pollution exposure by age and sex, making use of disease and population data collected from the literature and on publically available databases. The microsimulation method is an advanced method for modelling chronic diseases because of its capacity to simulate entire populations at an individual level over a life time. The flow diagram below highlights the main steps and assumptions for the model. Note that only dose-response relationships were available for adults, with the exception of asthma where dose-response functions were available.

Analyses for England and 2 case studies: Lambeth (inner city London) and South Lakeland (Cumbria), to represent 2 extremes in air pollutant concentrations have been carried out using the microsimulation model (Part 1). A spin-off tool has been developed for the analyses of all local authorities (Part 2 below). This tool uses a less complex method to the microsimulation as described below.

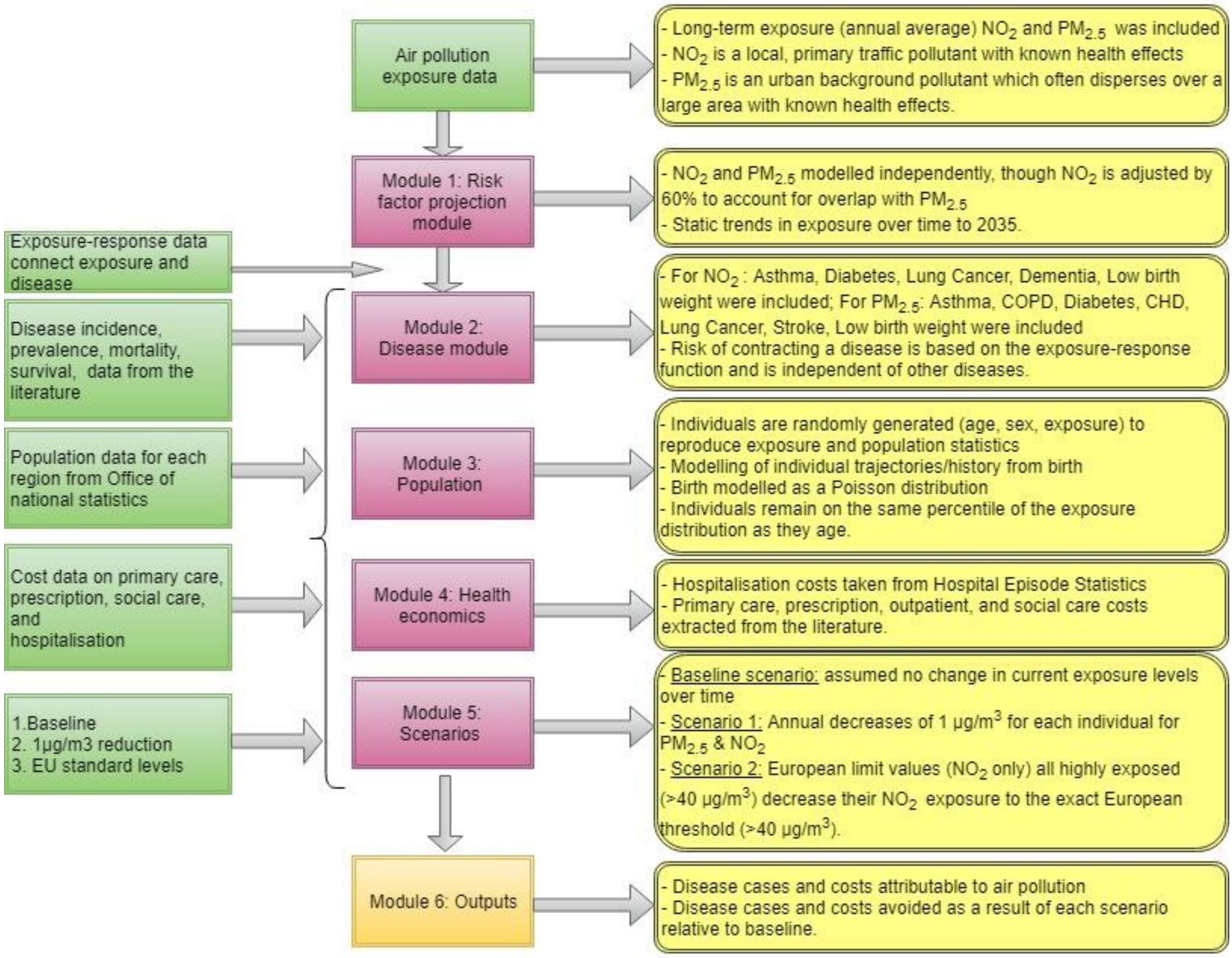

Diagram 1. Flow diagram of model data inputs, assumptions, and outputs.

Table 1 describes the data sources that were included in the model.

Table 1. Data sources included in the model

Parameter	Data source
Population data	Office for National Statistics (ONS) 2015 mid-year estimates
Exposure data	High-resolution maps of $PM_{2.5}$ (100 x 100m resolution) and NO_2 (200m x 200m resolution), originally developed for epidemiological studies in the UK and Europe. Air pollution estimates were assigned to each postcode in England. Exposure categories correspond to dividing the exposures across all postcodes in England into three equal parts (i.e. tertiles)
Exposure-response coefficients	Literature review
New disease cases (incidence), prevalence, mortality, survival data	Literature review, ONS
Cost data	Literature review, Hospital Episode Statistics data and tariffs. Costs include primary care, secondary care, medication use, social care, and a total of these costs.

Part 1: Modelling scenarios

Individuals in a specified region (for example, England, Lambeth, South Lakeland) are simulated in the model. Each individual is exposed to a certain level of pollution as determined by the input data. This gives them a certain chance of getting a disease.

The analyses run were as follows for England, Lambeth, and South Lakeland separately:

1. $PM_{2.5}$ model

- A no-change baseline scenario where exposure stays at current levels over time
- A scenario where $PM_{2.5}$ concentrations are reduced by 1 µg/m^3 in one year, 2017
- A scenario which reduces every individual's exposure to background levels, in order to compute the total attributable number of new disease cases caused by $PM_{2.5}$ pollution.

2. NO_2 model

- A no-change baseline scenario where exposure stays at current levels over time
- A scenario where NO_2 concentrations are reduced by 1 µg/m^3 in one year, 2017
- A scenario where EU standards for NO_2 (40 µg/m^3 per year) are met for all individuals
- A scenario which reduces every individual's exposure to zero, in order to compute the total attributable number of new disease cases caused by NO_2 pollution.

Part 2: The tool

A freely available user friendly tool has been developed which has the ability to run similar analyses to the microsimulation. The tool can quantify the potential costs to the NHS and social care due to the health impacts of $PM_{2.5}$ and NO_2 in England and separately for each local authority. The tool is freely available for download: https://fingertips.phe.org.uk/documents/PHE_Air_Pollution_Setup.exe

The tool is pre-populated with demographic information from the Office for National Statistics (ONS) for England and each local authority, and exposure data for England and each local authority. NHS and social care cost data are included for England and used as a default setting for each local authority. The user can update the population, exposure and cost inputs. Costs included in the tool are primary care, secondary care, medication use, social care, and a total of these costs.

The tool focusses on outdoor air pollution and has the ability to test different ‘what if’ scenarios for the reduction of air pollution, such as a given reduction in the levels of air pollution on the future impact of health and related cost. This scenario allows the user to assess the impact on health and related costs if air pollution for a given percentage of people who are exposed to high and medium levels of air pollution is shifted to low levels of air pollution. The outputs include the number of disease prevalence cases and costs avoided due to a given scenario relative to a baseline (‘no change’) scenario.

Limitations

Results from the microsimulation modelling are limited by the availability of data and the assumptions used. We assumed that individuals remain on the same percentile of exposure as they age. Such that if they start in a high exposure area, they stay there relative to others in the population. We also assumed static trends in exposure over time since we cannot be sure of how changes in policy (and meteorological changes) might alter trends.

Due to time constraints and data availability, it was not possible to take account of other factors such as deprivation. Research has shown that deprived sub-populations are more susceptible to the negative health effects of air pollution and that deprived sub-population are, at the same time, more likely to be exposed to higher air pollution levels (11). Due to data limitations, we assumed that the total population has the same likelihood of contracting an air pollution related disease.

We used the most recent data that were available for each disease. However, some of these statistics were from before 2015, the start year of the simulation. We therefore assumed that these health statistics were valid for this year. Publishing data on new cases of disease and mortality data by age and sex for each disease would improve the estimates outputs from the model.

In the tool, we did not include low birth weight and dementia where evidence for a relationship with air pollution is just emerging or less clear.

Most of the cost data were extracted from the literature and suffers from the usual limitiatons using this approach: each source adopts a different methodology, uses different sources of data, and makes different assumptions. Therefore, they are not fully comparable, although their different magnitudes are reliable estimates of the cost burdens.

What other work is being done to help local authorites tackle the problem of air pollution and related ill health?

PHE has a responsibility to provide systematic support to local authorities working on local air quality plans. It also has a role in working with Directors of Public Health to ensure that action taken to reduce air pollution also takes into account co-benefits such as increased physical activity, climate change mitigation and reducing health inequalities.

NICE/PHE issued guidance (June 2017) to local authorities on interventions they might consider to reduce traffic-related air pollution. In addition, the Government launched a national plan (July 2017) on reducing kerbside levels of NO_2 in which they have asked PHE to support non-compliant local authorities. PHE will work with the Association of Directors of Public Health, Local Government Association, UK Health Forum, Local PHE centres and Local Authorities to support the implementation of the new NICE/PHE guidance.

PHE has also been commissioned by the Department of Health and Social Care to conduct an air quality review of the evidence for effective interventions, which will significantly reduce harm from air pollution stratified by their health and economic impacts. This will build on the NICE/PHE guidance covering industry, planning/structural, vehicle and fuel design, agriculture and behavioural interventions. The findings will feed in to the Defra's Clean Air Strategy. The recommendations will be focused on practical interventions available to local authorities, appreciating and making explicit the limits of the evidence available.

Future work

The tool can be developed in a number of different ways:

1. Inclusion of multiple interacting pollutants within the same tool.
2. Utilise the tool for the Defra commissioned PHE review of air pollution which requires an economic analysis.
3. Development of a tool that measure 'short-term' effects of air pollution.
4. Include measures of deprivation in the tool.
5. Include a series of interventions within the tool.

References

1. World Health Organization. Global Health Observatory data 2017. Available from: http://www.who.int/gho/phe/outdoor_air_pollution/burden/en/.
2. Committee on the Medical effects of air pollutants. Mortality effects of long term exposure to particulate air pollution in the UK (2009). https://www.gov.uk/government/publications/comeap-mortality-effects-of-long-term-exposure-to-particulate-air-pollution-in-the-uk
3. Royal College of Physicians. Every breath we take: The lifelong impact of air pollution. 2016. https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution
4. Mills IC, Atkinson RW, Kang S, Walton H, Anderson HR. Quantitative systematic review of the associations between short-term exposure to nitrogen dioxide and mortality and hospital admissions. BMJ Open. 2015;5(5).
5. Janke K, Propper C, Henderson J. Do current levels of air pollution kill? The impact of air pollution on population mortality in England. Health Economics. 2009;18(9):1031-55.
6. Beatty TK, Shimshack JP. School buses, diesel emissions, and respiratory health. J Health Econ. 2011;30(5):987-99.
7. Kaufman JD, Adar SD, Barr RG, Budoff M, Burke GL, Curl CL, et al. Association between air pollution and coronary artery calcification within six metropolitan areas in the USA (the Multi-Ethnic Study of Atherosclerosis and Air Pollution): a longitudinal cohort study. The Lancet.388(10045):696-704.
8. Hoek G, Krishnan RM, Beelen R, Peters A, Ostro B, Brunekreef B, et al. Long-term air pollution exposure and cardio- respiratory mortality: a review. Environmental Health. 2013;12(1):1-16.
9. Currie J. Pollution and Infant Health. Child Dev Perspect. 2013;7(4):237-42.
10. Wang L, Zhong B, Vardoulakis S, Zhang F, Pilot E, Li Y, et al. Air Quality Strategies on Public Health and Health Equity in Europe-A Systematic Review. Int J Environ Res Public Health. 2016;13(12).
11. Pye S, King K, Sturman J. Air Quality and Social Deprivation in the UK: an environmental inequalities analysis 2006.