



Health Impacts of Air Pollution in Bristol

February 2017



Experts in air quality
management & assessment

Document Control

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Executive Summary

In March 2014 Bristol City Council published a report setting out the health impacts of air pollution in the City of Bristol. The report set out the extent to which deaths in Bristol could be attributable to exposure to fine particulate matter. It concluded that:

“... an additional 188 deaths of Bristol residents (over the age of 30) were attributable to air pollution in 2010 (range 65-328), with 24 of these attributable to local road traffic emissions. This compares to an average of 9 people killed each year in road traffic collisions on roads in the City of Bristol.”

Since then, there has been growing evidence that further deaths in the City of Bristol could be attributable to air pollution, through exposure to the gas nitrogen dioxide. The Committee on the Medical Effects of Air Pollutants has provided a means of calculating the deaths attributable to nitrogen dioxide, as well as the combined number of deaths attributable to both nitrogen dioxide and fine particulate matter.

Bristol City Council has commissioned Air Quality Consultants to update its previous work to include the effects of exposure to nitrogen dioxide on deaths attributable to air pollution in the City of Bristol.

The new results show that around 300 deaths each year in the City of Bristol can be attributed to exposure to both nitrogen dioxide and fine particulate matter. This represents about 8.5% of deaths in the City of Bristol being attributable to air pollution.

The proportions of deaths attributable to air pollution vary across the City in relation to pollutant concentrations, from around 7% in some wards to around 10% in others. Concentrations are highest in the centre of the city and therefore so are deaths attributable to air pollution. Road traffic is the dominant local source of emissions contributing to the deaths.

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1 Introduction

- 1.1 In March 2014 Bristol City Council published a report setting out the health impacts of air pollution in the City of Bristol. It concluded that:

“... an additional 188 deaths of Bristol residents (over the age of 30) were attributable to air pollution in 2010 (range 65-328), with 24 of these attributable to local road traffic emissions. This compares to an average of 9 people killed each year in road traffic collisions on roads in the City of Bristol.”

- 1.2 This conclusion was reached on the basis of exposure to fine particulate matter, represented by PM_{2.5} (particulate matter with an aerodynamic diameter of less than 2.5 microns). There has been growing evidence over recent years that the pollutant nitrogen dioxide is also contributing to deaths. The Committee on the Medical Effects of Air Pollutants (COMEAP) has provided a means of calculating the deaths attributable to nitrogen dioxide, as well as the combined number of deaths attributable to both nitrogen dioxide and fine particulate matter (COMEAP, 2015).
- 1.3 Bristol City Council has commissioned Air Quality Consultants Ltd. to update its previous work to include the effects of exposure to nitrogen dioxide on deaths attributable to air pollution in the City of Bristol. At the same time, the calculation of deaths attributable to PM_{2.5} has been updated to take account of more recent data on PM_{2.5} concentrations. As before, the deaths attributable to air pollution have been determined for the wards across the City on the basis of the distribution of pollutant concentrations. The new base year for the analysis has been 2013.

2 Context

Air Quality

- 2.1 The Air Quality Strategy published by the Department for Environment, Food, and Rural Affairs (Defra) has a primary objective to ensure that all citizens have access to outdoor air without significant risk to their health, where this is economically and technically feasible (Defra, 2007a). The document provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The Strategy describes the Local Air Quality Management (LAQM) regime that has been established, whereby every authority has to carry out regular reviews and assessments of air quality in its area to identify whether the objectives have been, or will be, achieved at relevant locations, by the applicable date. If this is not the case, the authority must declare an Air Quality Management Area (AQMA), and prepare an action plan which identifies appropriate measures that will be introduced in pursuit of the objectives. Through this process, Bristol City Council has identified the need to declare parts of the City an AQMA for exceedences of the annual mean and hourly nitrogen dioxide objectives, and on a precautionary basis for PM₁₀ (Bristol City Council, 2015).
- 2.2 The 2007 Strategy also introduces a new approach for controlling exposure to particulate matter that recognises that there is no threshold for the effects, i.e. there is no safe level for exposure. This approach, which is applied to PM_{2.5}, is to require a reduction in average exposure across urban areas, rather than at hotspots. This should produce a greater reduction in health effects of air pollution than the current focus on hotspots.

Public Health Framework

- 2.3 Proposals for a new approach to public health were set out in the White Paper, "Healthy Lives, Healthy People" (HM Government, 2010) and subsequently within the Health and Social Care Act 2012 (HM Government, 2012). Changes came into force on 1st April 2013, which included a new executive agency, Public Health England, with local authorities taking the lead for improving public health. Directors of Public Health are responsible for exercising the local authorities new public health functions and they lead on driving health improvement locally. In addition, Health and Wellbeing Boards have been established to increase the influence of local people. The Public Health Outcomes Framework set out key indicators of public health, which range from the wider determinants of public health through to those which are aimed at reducing premature deaths. There is one indicator for air quality, which is based on the fraction of deaths attributable to particulate air pollution.

Air Quality in Bristol

- 2.4 Bristol operates a number of monitoring sites, with six real time analysers for nitrogen dioxide and an extensive network of passive samplers (diffusion tubes), also for nitrogen dioxide. Defra operates an urban background site in Bristol, which monitors nitrogen dioxide, PM₁₀ and PM_{2.5}. Bristol complies with all of the objectives for all the regulated pollutants other than those for nitrogen dioxide, for which an Air Quality Management Area (AQMA) has been declared. The AQMA also covers PM₁₀, which was included on a precautionary basis. Currently there is no evidence that there are exceedences of the PM₁₀ objectives at locations with relevant exposure. Figure 1 shows the boundary of the AQMA, superimposed on the wards within the Bristol City boundary.

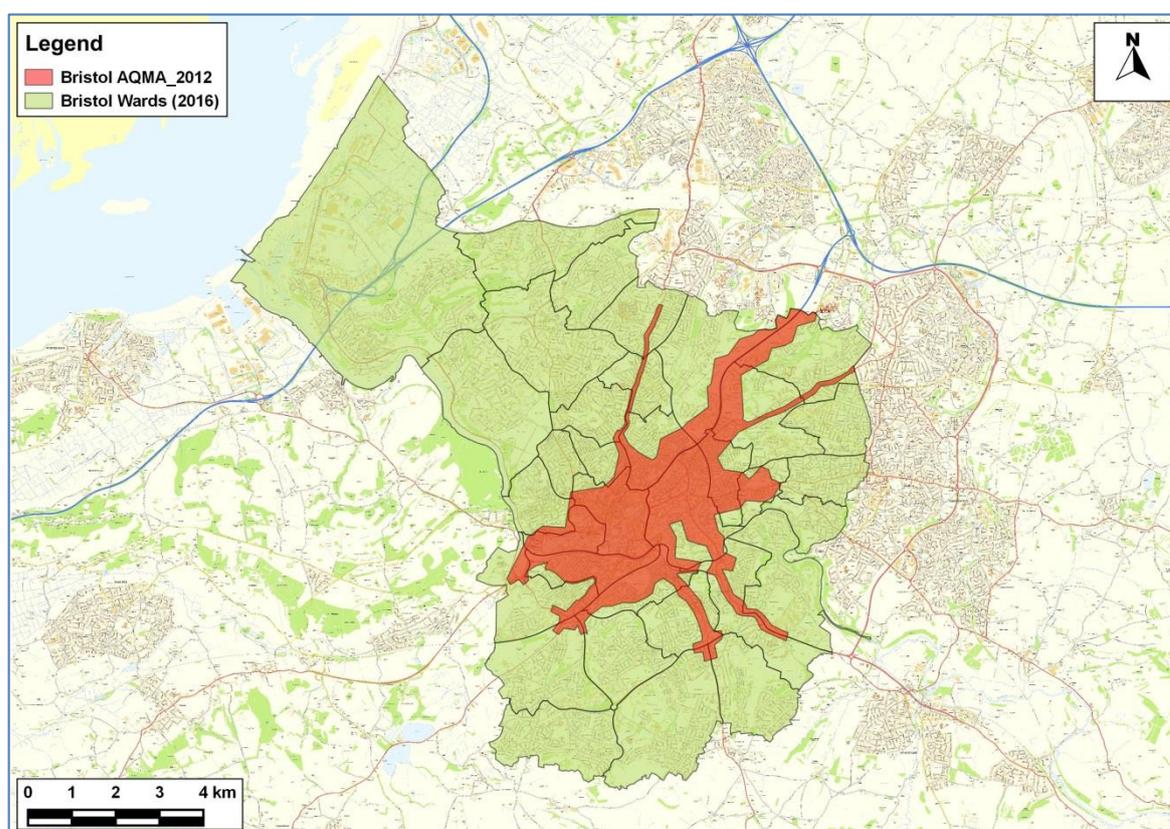


Figure 1: City of Bristol Boundary, Ward Boundaries and Air Quality Management Area

- 2.5 Background concentrations of PM_{2.5} and nitrogen dioxide across Bristol are shown in Figure 2 and Figure 3. These maps have been derived from the national 1x1 km maps of background concentrations made available by Defra. The maps for 2013 are presented, as this is the year for which they were calibrated against monitoring data. Maps for more recent years are available, but these have been extrapolated from 2013, and are thus considered less reliable.

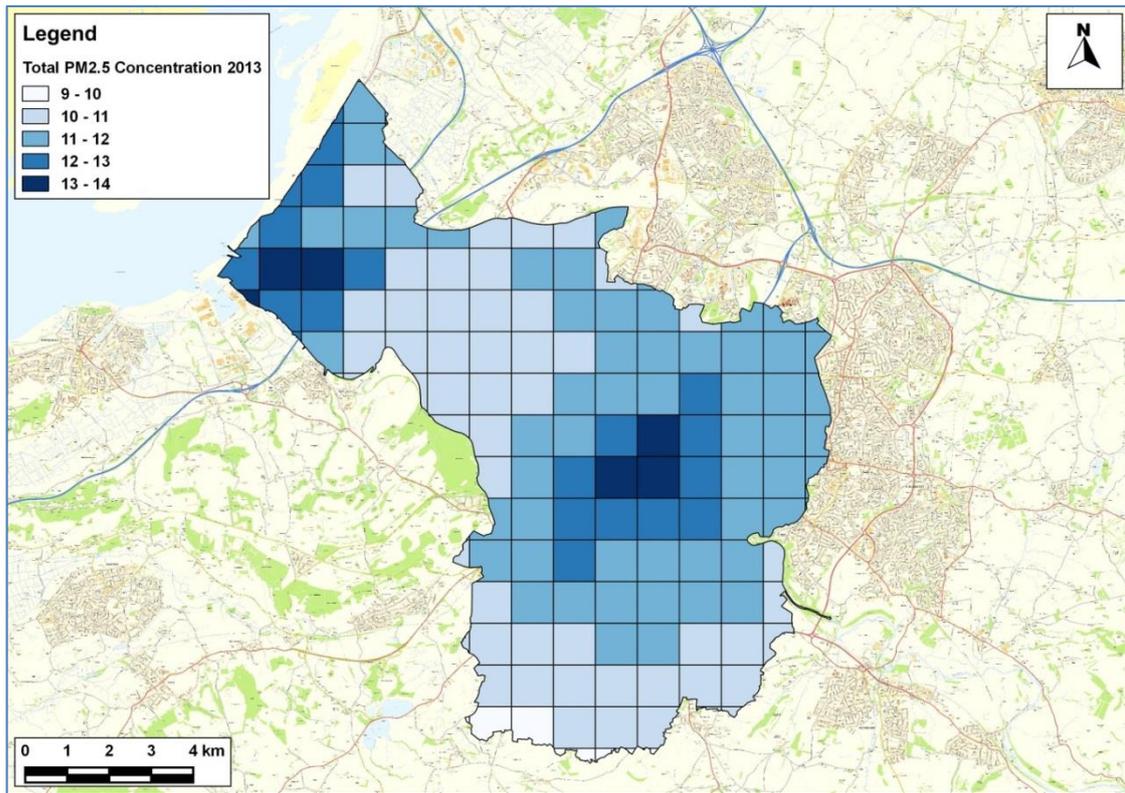


Figure 2: Background PM_{2.5} Concentrations 2013 ($\mu\text{g}/\text{m}^3$)

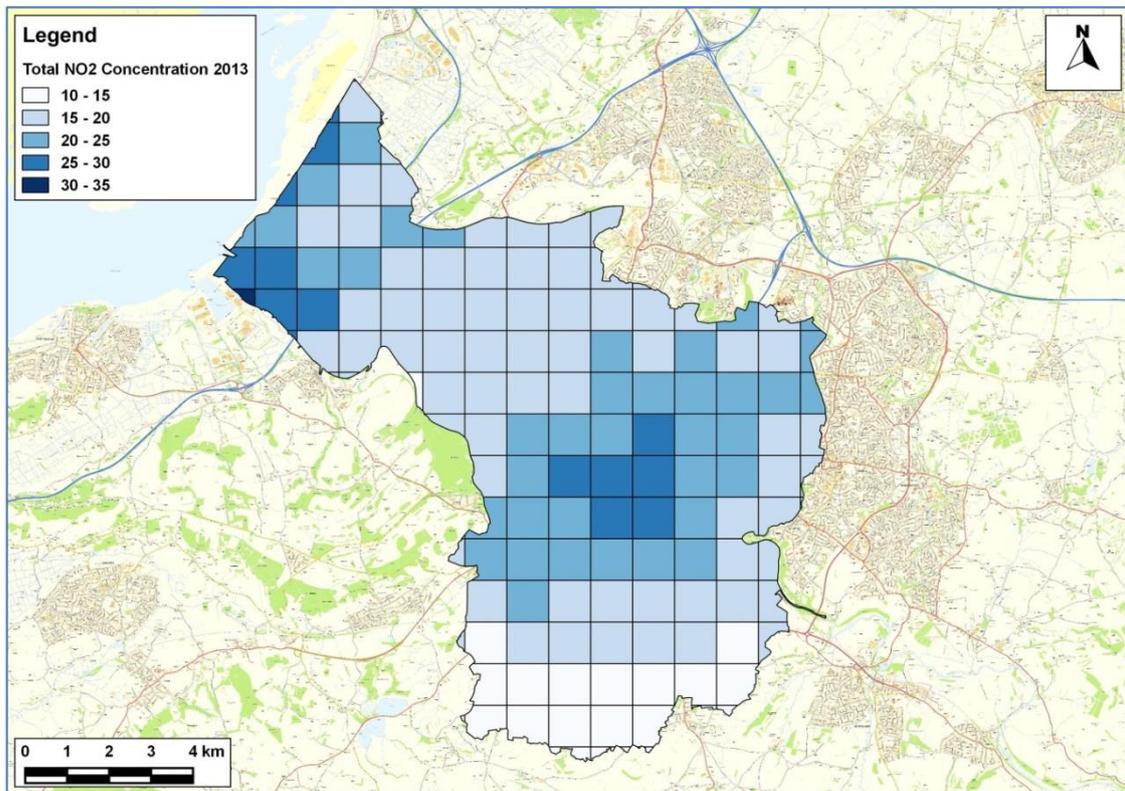


Figure 3: Background Nitrogen Dioxide Concentrations 2013 ($\mu\text{g}/\text{m}^3$)

Sources of Air Pollution

PM_{2.5}

- 2.6 Particles, both as PM₁₀ and PM_{2.5}, have many different sources, both natural and anthropogenic. These can be primary, with the particles emitted directly into the atmosphere, or secondary, with particles formed from precursor gases through atmospheric reactions. Sources of primary particles include road vehicles, industrial sources and power stations, domestic heating and shipping. Natural sources of particles include sea salt. The formation of secondary particles happens relatively slowly (hours to days), thus secondary PM_{2.5} is found well downwind of the sources of emission of the precursor gases. The management of exposure to particles is particularly challenging, given the wide variety of sources.
- 2.7 Within the City of Bristol, the population weighted total PM_{2.5} concentration is 11.45 µg/m³. Of this, the majority (81%) is anthropogenic, with 50% of the anthropogenic fraction being secondary PM_{2.5} and 23% regional primary. This leaves 27% of the anthropogenic fraction being effectively from local sources, which can be considered to be potentially locally controllable. Just under half of this locally controllable PM_{2.5} is associated with local road traffic.

Nitrogen Dioxide

- 2.8 Nitrogen dioxide concentrations are determined by emissions of nitrogen oxides¹, mainly from combustion processes. Road transport and the electricity supply industry are the main sources in the UK as a whole. Within Air Quality Management Areas (i.e. where nitrogen dioxide objectives are not being achieved), road transport is the main contributor.
- 2.9 Within the City of Bristol, the population weighted total nitrogen dioxide concentration is 20.06 µg/m³. All of this is treated as being anthropogenic. Of this, around 74% are effectively from local sources, which can be considered to be potentially locally controllable. Over half (59%) of this locally controllable nitrogen dioxide is associated with local road traffic.

¹ The term nitrogen oxides (NOx) covers both nitrogen dioxide (NO₂) and nitric oxide (NO). Once emitted there are chemical reactions that transform some of the nitric oxide to nitrogen dioxide. The proportion of NO₂ within NOx is thus variable, tending to increase with distance from the emission source.

3 Contribution of Air Pollution to Deaths

Particulate Matter

- 3.1 The earliest understanding of the role of air pollution in contributing to deaths focussed on particulate matter. The Committee on the Medical Effects of Air Pollution (COMEAP) has worked on quantifying the size of the health impacts of air pollution over many years. Its first report, issued in 1998, was limited to quantifying the effects of short-term exposure to particles, sulphur dioxide and ozone on deaths and hospital admissions. More recently it has quantified the effects of long-term exposure, derived by collating the results of several large epidemiological studies (using a meta-analysis of the results of the different studies) (COMEAP, 2009). The 2009 report focusses on particulate matter, represented as $PM_{2.5}$, as this is the pollutant that was most strongly associated with the increased risks of deaths. A subsequent report in 2010 quantified the overall number of deaths in the UK arising from exposure to $PM_{2.5}$ (COMEAP, 2010b).
- 3.2 Public Health England (PHE) used the national quantification work carried out by COMEAP to prepare a health outcomes indicator for application at the local level (PHE, 2014a). This indicator formed part of the *Public Health Outcomes Framework for England 2013-2016*, launched by the Department of Health in January 2012². More specifically, indicator 3.01 set out the 'Fraction of Mortality Attributable to Particulate Air Pollution' and was based on background anthropogenic $PM_{2.5}$ concentrations³. The values of the indicator for each individual local authority for 2010 and 2011 are provided as part of the Public Health Outcomes Framework Data Tool (PHE, 2014a). The indicator has not been updated since its original publication.
- 3.3 A recent PHE report describes how to estimate local mortality burdens associated with particulate matter (PHE, 2014b). This methodology has been applied to this assessment.

Nitrogen Dioxide

- 3.4 In the last few years epidemiological studies have provided evidence that nitrogen dioxide is having an independent effect on deaths. COMEAP has been, and still is, reviewing the evidence to provide its best advice on quantifying the number of deaths attributable to nitrogen dioxide. It has produced an interim advice note on this quantification and also how to combine the deaths attributable to particulate matter with those due to nitrogen dioxide (COMEAP, 2015).
- 3.5 The Greater London Authority has also addressed the combined impact of nitrogen dioxide and particulate matter in a report produced in July 2015 (Walton, Dajnak, Beevers, Williams, Watkiss, &

² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216159/dh_132362.pdf

³ Concentrations of anthropogenic, rather than total, $PM_{2.5}$ are used as the basis for this indicator, as burden estimates based on total $PM_{2.5}$ might give a misleading impression of the scale of the potential influence of policy interventions (Department for Health, 2014).

Hunt, 2015). The authors used a different, higher, risk coefficient than that recommended by COMEAP. The assessment presented here uses the more conservative COMEAP risk coefficient, as used by the Government.

Quantification of Deaths Attributable to Air Pollution

- 3.6 The epidemiological studies have been used to provide risk coefficients for deaths attributable to particulate matter and nitrogen dioxide. The values used in this study are presented in Table 1. They are the officially-recognised risk coefficients used by the UK Government to quantify deaths due to PM_{2.5} and nitrogen dioxide.

Table 1: Quantified Risk Coefficients for Exposure to Different Pollutants

Pollutant	Exposure	Health Endpoint ^a	Risk Coefficient per 10 µg/m ³ ^b	
			Value to use	range
Fine Particles (PM_{2.5})	Annual	Deaths (all causes)	6%	1% - 12%
Nitrogen Dioxide	Annual	Deaths (all causes)	2.5%	1% - 4%

^a Based on deaths for those over the age of 30 years.

^b Risk coefficients taken from (COMEAP, 2015) and (PHE, 2014b)

- 3.7 The calculations that follow use what is termed as the Relative Risk (RR). The Relative Risk is normally defined for a 10 µg/m³ concentration increment (RR₍₁₀₎) is given as 1 + the risk coefficient per 10 µg/m³, with the risk coefficient expressed as an absolute value rather than a percentage. In other words for PM_{2.5} the equation is:

$$RR_{(10)PM_{2.5}} \text{ is } 1 + 0.06 = 1.06 \text{ (range 1.01 to 1.12)}$$

while for nitrogen dioxide the equation is:

$$RR_{(10)NO_2} \text{ for nitrogen dioxide is } 1 + 0.025 = 1.025 \text{ (range 1.01 to 1.04).}$$

4 Quantification of Deaths Attributable to Air Pollution in Bristol

4.1 The quantification carried out is based on a well established methodology set out in the PHE document 'Estimating Local Mortality Burdens Associated with Particulate Air Pollution' (PHE, 2014b)).

4.2 The calculations are based on applying the fractions of deaths attributable to air pollution (the Attributable Fraction (AF)) to the total all-cause deaths for people over 25 years of age in Bristol⁴:

$$\text{Deaths attributable to pollutant P} = \text{AF}_P \times \text{All-cause deaths}$$

4.3 The all-cause deaths for the City of Bristol have been provided by the Public Health Intelligence Unit of Bristol City Council. There were 3,487 deaths for the year 2013⁵.

4.4 The Attributable Fraction (AF) values have been derived from the Bristol specific Relative Risk ($RR_{(B)}$) values for the two pollutants nitrogen dioxide $RR_{(B)NO_2}$ and $PM_{2.5}$ $RR_{(B)PM_{2.5}}$ together with the population weighted concentrations of the pollutants:

$$\text{AF} = (RR_B - 1)/RR_B$$

4.5 The RR_B values have been derived from the published $RR_{(10)}$ values for a $10 \mu\text{g}/\text{m}^3$ change in concentration (see para 3.7) using the population weighted concentrations for nitrogen dioxide and $PM_{2.5}$ for the City of Bristol ($C_{(B)}$):

$$RR_{(B)} = RR_{(10)}^{(C_{(B)}) / 10}$$

4.6 The $RR_{(10)}$ values used in this assessment are those used by the UK Government (see Table 1).

4.7 The population-weighted concentrations for Bristol ($C_{(B)NO_2}$ and $C_{(B)PM_{2.5}}$) have been derived from the national maps of pollutant concentrations for 2013. These maps are available on a 1x1 km grid square basis. These concentrations have then been applied to the populations within the Output Areas (from the Office for National Statistics census data for 2011). The populations in these areas have been assigned the concentration of grid square or squares in which they lie, with the assignment of the population to a grid square concentration on the basis of area. The population-concentration values have also been assigned to wards (using the recently redefined ward boundaries). The basis of the derivation of the population-weighted concentrations is illustrated in Figure 4. In this figure, the output area is shown in red, while the ward boundary is shown in blue.

⁴ Strictly, the AF should be applied to the total all-cause mortality for people over 30 years of age (as this is how the published RR values have been derived), but this statistic is not available in the UK. PHE recognises this to be the case and says that it will only make a small difference (section 2.2.2. in (PHE, 2014b)).

⁵ This year has been used to be consistent with the year for which the AF values have been derived.

The populations in sub areas (a) to (d) are derive by an area weighted apportioning of the population in the output area. Populations (a) and (b) are assigned concentration (1) while populations (c) and (d) are assigned concentration (2). Ward A is assigned the populations (a) and (d) with their respective concentrations, while Ward B is assigned the populations (b) and (c) with their respective concentrations. These calculations are repeated for the whole of the area within the City of Bristol boundary.

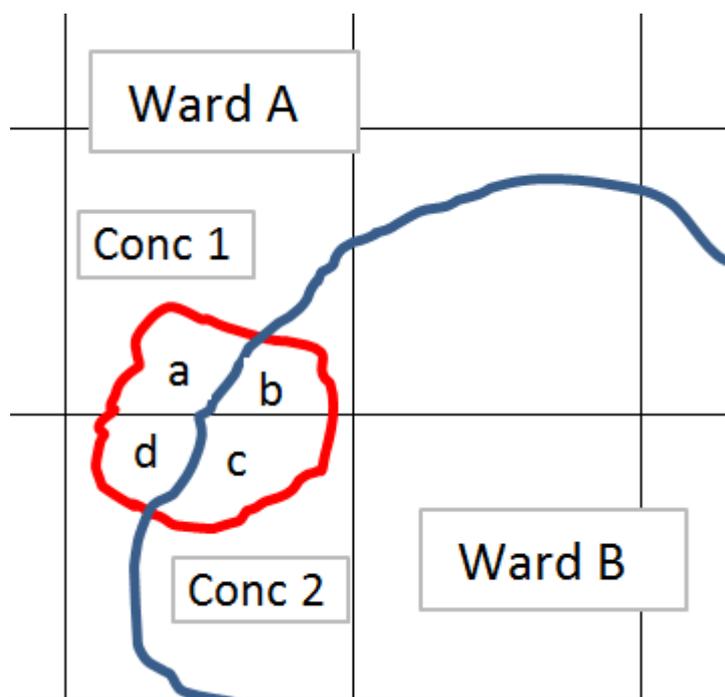


Figure 4: Derivation of Population Weighted Concentrations (see text).

Deaths Attributable to Nitrogen Dioxide

4.8 The calculation of the deaths related to nitrogen dioxide in 2013 is based on the following steps:

The $RR_{(10)}$ value for nitrogen dioxide is 1.025 (see Table 1).

The population weighted concentration ($C_{(B)}$) of nitrogen dioxide for the City of Bristol is $20.06 \mu\text{g}/\text{m}^3$.

The $RR_{(B)NO_2}$ value for Bristol is thus:

$$RR_{(B)NO_2} = RR_{(10)}^{(C_{(B)} / 10)} = 1.025^{(20.06/10)} = 1.05078$$

The AF for nitrogen dioxide is thus:

$$AF = (RR_{(B)NO_2} - 1) / RR_{(B)NO_2} = (1.0578 - 1) / 1.0578 = 0.04833$$

The deaths attributable to nitrogen dioxide are thus:

$$\text{Deaths attributable to NO}_2 = \text{AF} \times \text{All-cause deaths} = 0.04833 \times 3487 = 169.$$

Deaths Attributable to PM_{2.5}

4.9 The calculation of the deaths related to nitrogen dioxide in 2013 is based on the following steps:

The RR₍₁₀₎ value for PM_{2.5} is 1.06 (see Table 1).

The population weighted concentration (C_B) of anthropogenic PM_{2.5} for the City of Bristol is 9.291 µg/m³, derived by subtracting the non-anthropogenic concentration of 2.1572 µg/m³ from the total PM_{2.5}, the latter value being taken from the local authority data sheet made available on the Defra website at: <http://uk-air.defra.gov.uk/datastore/pcm/popwmpm252013byUKlocalauthority.csv>.

The RR_{(B)PM2.5} value for Bristol is thus:

$$\text{RR}_{(B)PM2.5} = \text{RR}_{(10)}^{(C(B) / 10)} = 1.025^{(9.291 / 10)} = 1.0556$$

The AF for nitrogen dioxide is thus:

$$\text{AF} = (\text{RR}_{(B)PM2.5} - 1) / \text{RR}_{(B)PM2.5} = (1.0556 - 1) / 1.0556 = 0.05270$$

The deaths attributable to nitrogen dioxide are thus:

$$\text{Deaths attributable to PM}_{2.5} = \text{AF} \times \text{All-cause deaths} = 0.05270 \times 3487 = 184.$$

Combined Deaths Attributable to Nitrogen Dioxide and PM_{2.5}

4.10 COMEAP recognises that there is a potential for double counting if the individual values for PM_{2.5} and nitrogen dioxide are simply added together. It advises that the risk coefficient for nitrogen dioxide is reduced by 33%, i.e. RR₍₁₀₎ becomes 1.0167. The revised calculation of additional deaths attributable to nitrogen dioxide therefore becomes 114, which is added to 184 deaths from PM_{2.5} to give total combined deaths of 297 (based on unrounded numbers). This represents 8.53% of deaths in the City of Bristol being attributable to the combined effect of exposure to nitrogen dioxide and PM_{2.5}.

Spatial Distribution of the Health Effects of Air Pollutants Across Bristol

4.11 The distributions of the fraction of deaths attributable to PM_{2.5} and nitrogen dioxide across Bristol have been derived for each of the wards following the methodology described above. For each ward a population-weighted concentration has been derived (see para 4.6) and used to produce an AF for that ward (see para 4.8).

Uncertainties

4.12 There are various uncertainties that affect the calculated deaths, which are summarised below.

Uncertainties in the Concentrations

- 4.13 The concentrations used are all based on national modelling, which will give rise to greater uncertainty when applied at a local level.
- 4.14 The concentrations used are background values for a 1x1km grid square. These background values will reflect the contributions from traffic and other sources within the grid square, but do not take account of the fact that concentrations will be higher for people living close to busy road. This will have led to an underestimate of the population weighted concentrations and hence the calculated number of deaths.

Uncertainty in Deaths

- 4.15 The main uncertainty relates to risk coefficients. Wide confidence intervals are cited for both pollutants; in the case of PM_{2.5}: 6% with a range of 1 to 12% (PHE, 2014b); in the case of nitrogen dioxide: 2.5% with a range of 1% to 4% (COMEAP, 2015). Applying these ranges gives the following results for attributable deaths in 2013 in the City of Bristol:

PM_{2.5} alone: 32 – 348 deaths

NO₂ alone: 69 – 264 deaths

Combined PM_{2.5} and NO₂: 101 – 612 deaths

- 4.16 There are additional uncertainties in any assessment of PM_{2.5} effects at concentrations below around 5-10 µg/m³, as the epidemiological studies generally do not include concentrations below these levels. The assumption made is that impacts are linearly related to concentrations down to zero, i.e. with no threshold.
- 4.17 There is uncertainty around the appropriate risk coefficients for nitrogen dioxide, and in particular whether it is appropriate to assume no threshold, i.e. effects continue down to zero. The study carried out by the GLA for London (Walton, Dajnak, Beevers, Williams, Watkiss, & Hunt, 2015) included a sensitivity test with a cut-off of 20 µg/m³, below which no effects were assumed. However the same study used a higher risk coefficient of 5.5%, as compared with the value used in this study. The calculations for the City of Bristol have been based on the more recent interim advice from COMEAP (2015), which recommends no cut-off should be used, but with a lower risk coefficient of 2.5%.
- 4.18 The distribution of the AF values across the wards makes no allowance for the different age structures and sensitivities of the populations in these wards.

5 Health Effects of Air Pollution in Bristol

- 5.1 Annual mean of population-weighted anthropogenic PM_{2.5} concentrations are shown in Figure 5, for the wards across the City of Bristol, with population adjusted nitrogen dioxide concentrations shown in Figure 6.
- 5.2 The exposure to both PM_{2.5} and nitrogen dioxide in the City of Bristol is greatest in the city centre.

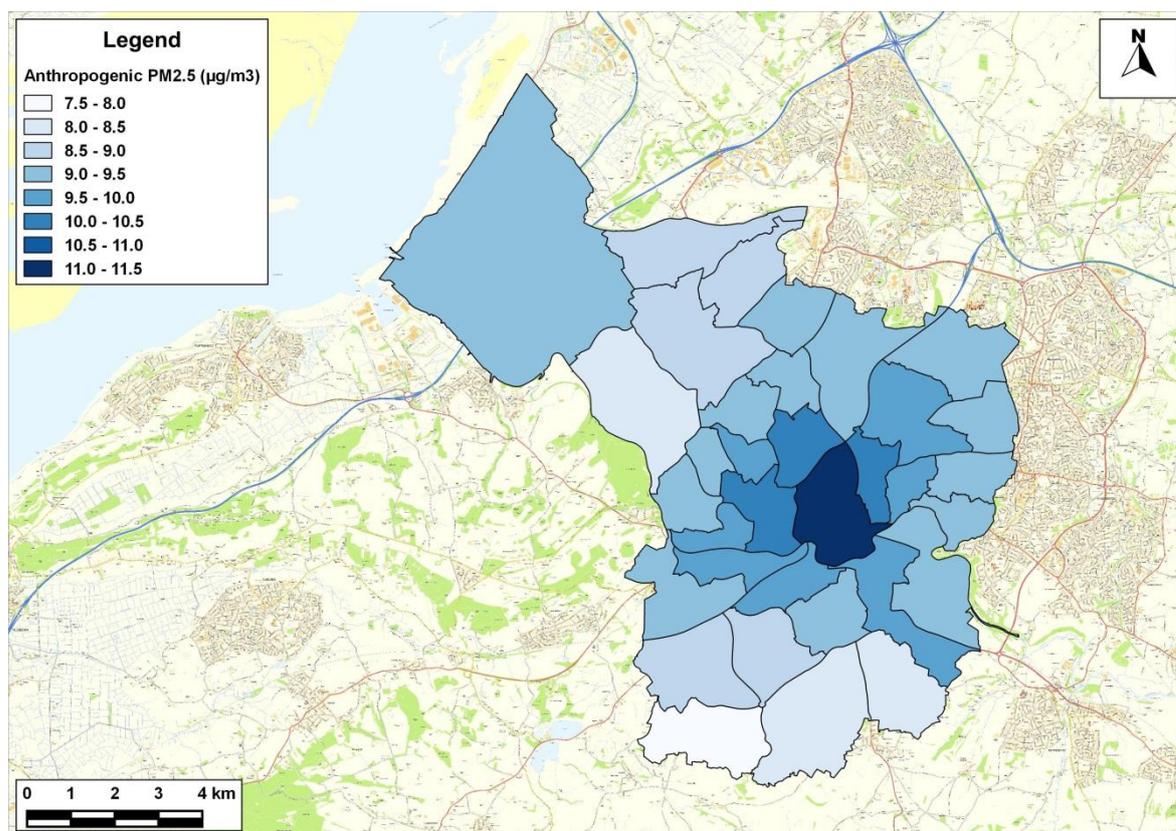


Figure 5: Population-Weighted Anthropogenic PM_{2.5} Concentrations in City of Bristol Wards, 2013 (µg/m³)

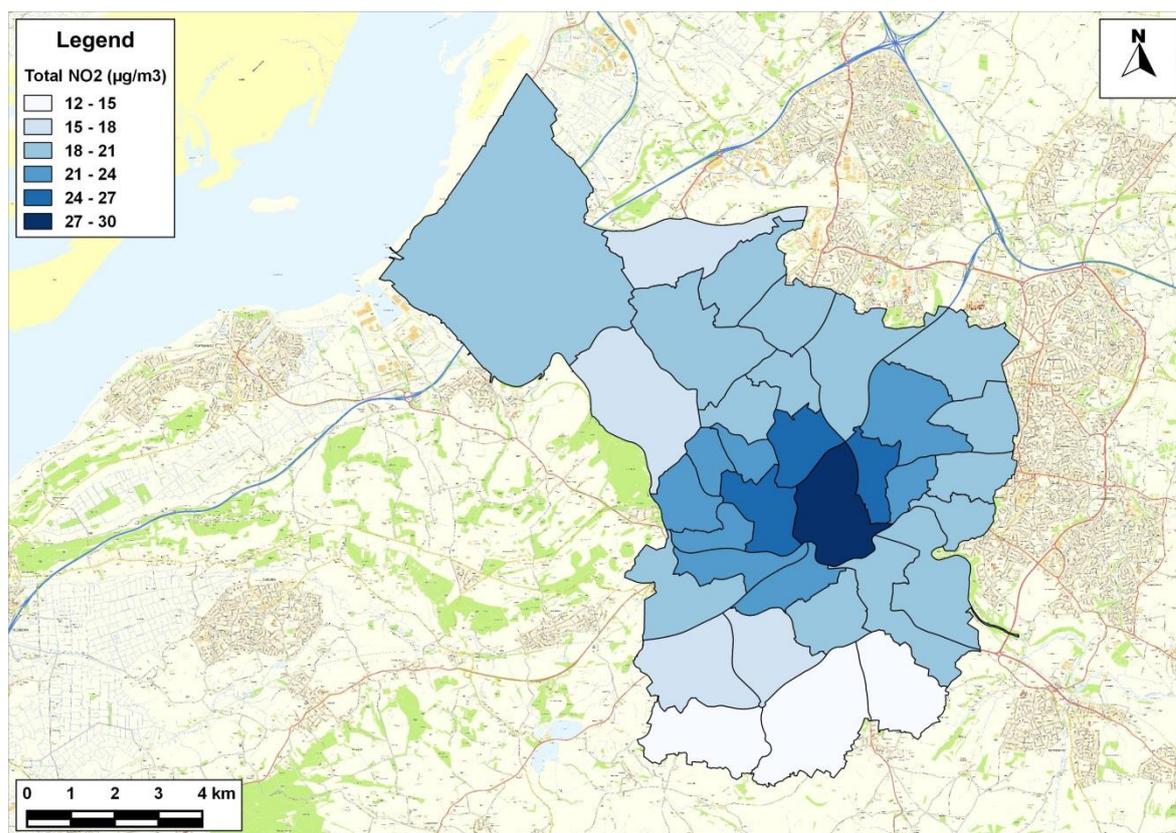


Figure 6: Population-Weighted Total Nitrogen Dioxide Concentrations in City of Bristol Wards, 2013 (µg/m³)

Health Effects

Total Deaths

- 5.3 The total number of deaths attributable to air pollution in Bristol for 2013 is 297 (range 101 to 612). This represents 8.5% of deaths (range 2.9% to 17.6%)
- 5.4 These values can be compared with 12 people killed in road traffic collisions in the City of Bristol in 2013⁶.

Spatial distribution of deaths attributable to air pollution across Bristol

- 5.5 **Figure 7** shows the average Attributable Fraction per ward for PM_{2.5} (i.e. the proportion of the local deaths attributable to exposure to air pollution). **Figure 8** shows the Attributable Fraction for nitrogen dioxide on a ward-by-ward basis. The actual numbers for each ward are included in Appendix A1.

⁶ Obtained from 'Reported Road Casualties in Great Britain: 2013 Annual Report'. They relate to number of deaths on roads within the City of Bristol, not directly to Bristol residents.

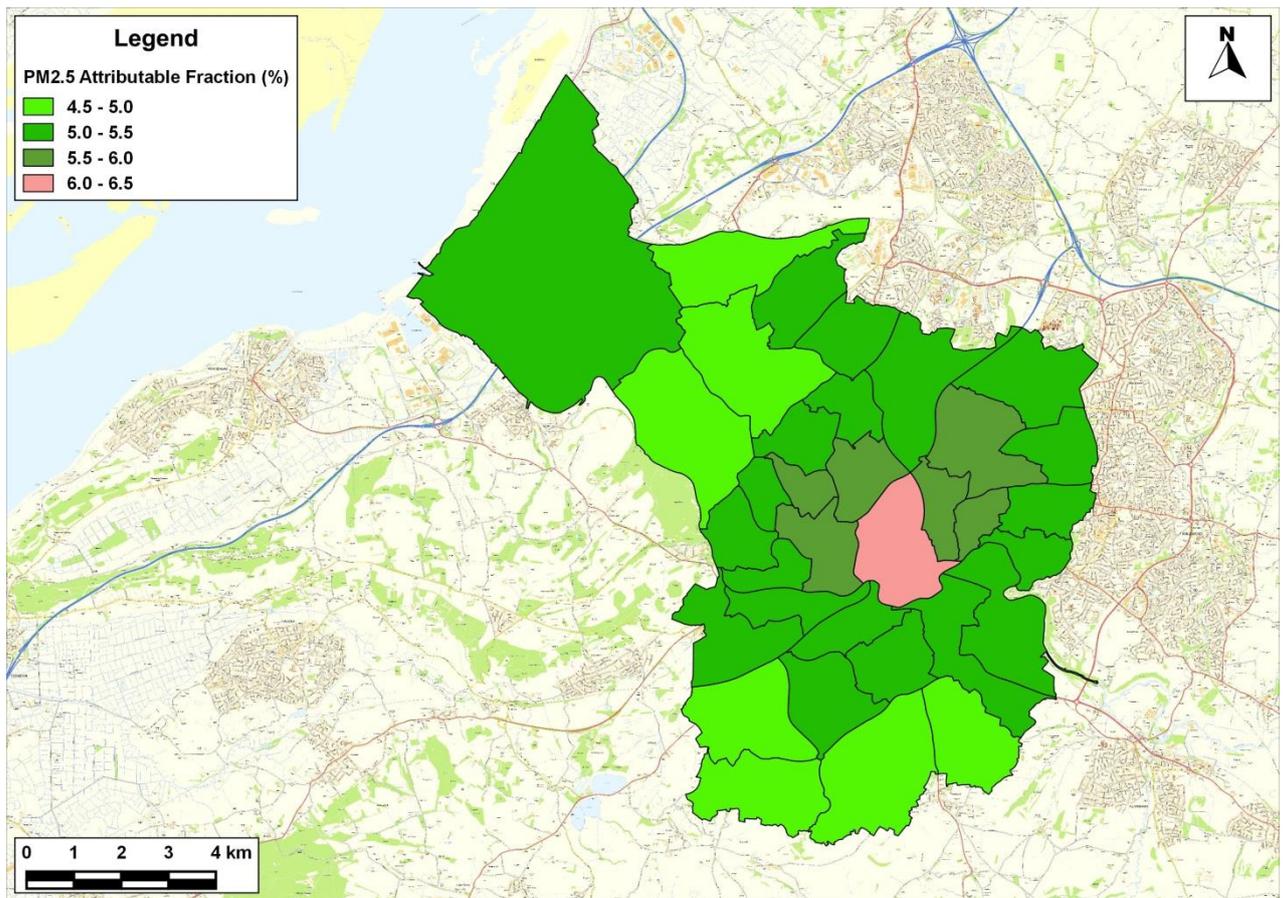


Figure 7: Fraction of Deaths (%) Attributable to Anthropogenic PM_{2.5} in City of Bristol Wards in 2013.

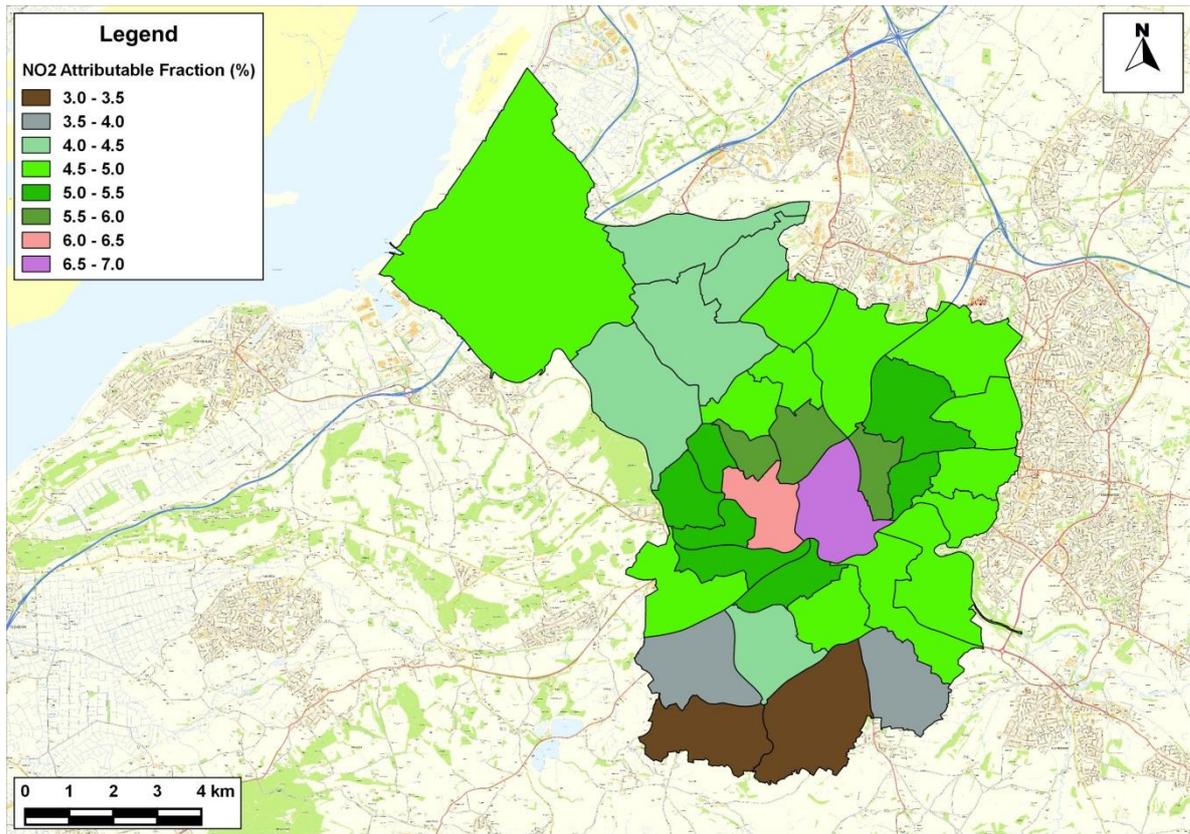


Figure 8: Fraction of Deaths (%) Attributable to Nitrogen Dioxide in City of Bristol Wards in 2013

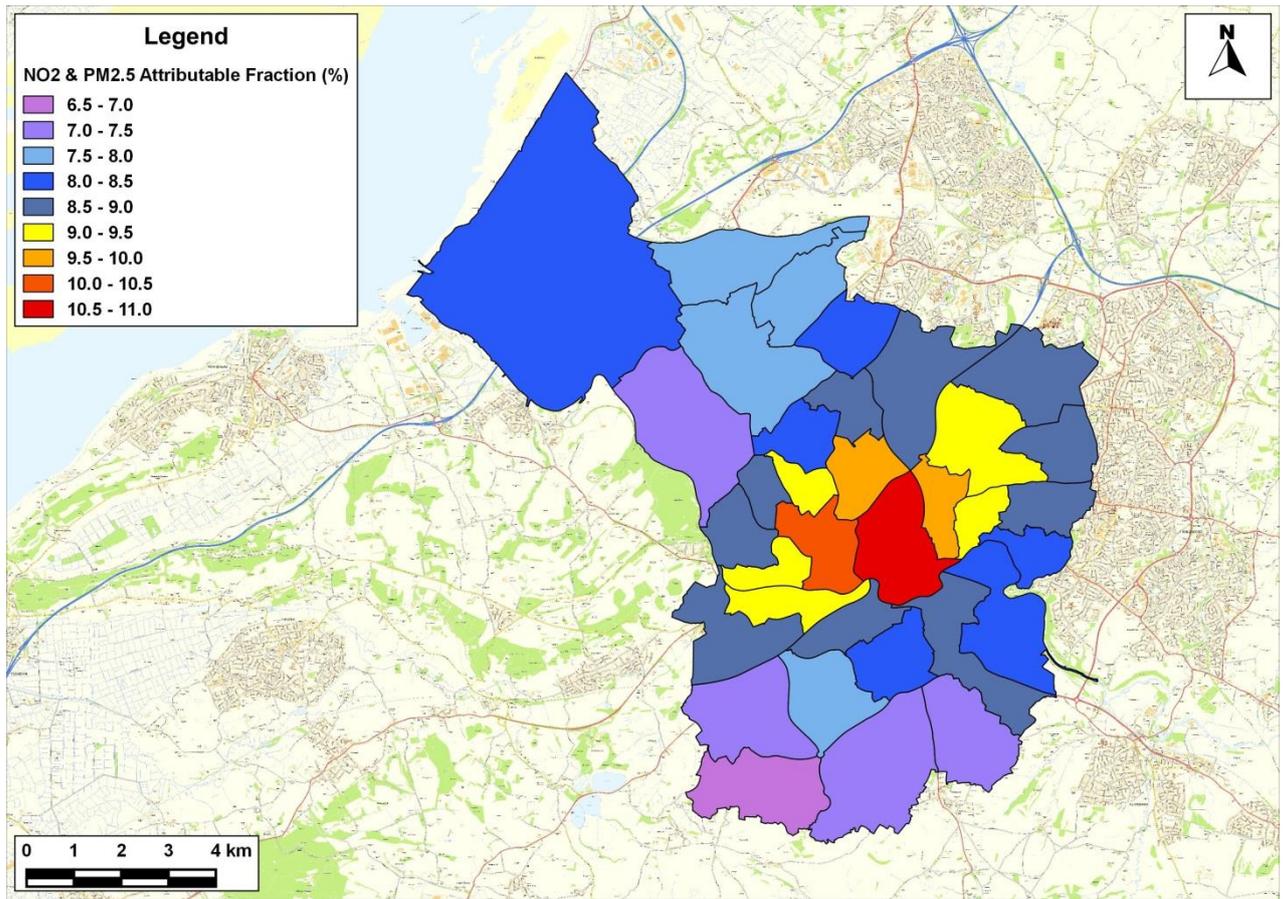


Figure 9: Fraction of Deaths (%) Attributable to Both PM_{2.5} and Nitrogen Dioxide in City of Bristol Wards in 2013

6 Discussion and Conclusions

- 6.1 The central estimate of deaths attributable to air pollution in the City of Bristol is an additional **297 (in adults over the age of 25)** in 2013. This value can be compared to 12 people killed in traffic collisions in 2013 within the City of Bristol.
- 6.2 The greatest excess of deaths attributable to air pollution occurs in central Bristol, rising to 10% of all deaths in some wards. Road traffic is the dominant local source of emissions contributing to the deaths.

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8 Glossary

AF	Attributable Fraction
Annual Mean	Average concentration of a pollutant measured over a year.
Anthropogenic	Originating from human activity
AQMA	Air Quality Management Area. Area defined where air quality objectives are not likely to be achieved.
Asthma	Common chronic inflammatory disease of the airways characterised by symptoms such as wheezing, coughing, chest tightness and shortness of breath
Cardiovascular Disease	A class of diseases that involve the heart or blood vessels (arteries, capillaries and veins)
Confidence Interval	A range of values so defined that there is a specified probability that the value of a parameter lies within it
COMEAP	Committee on the Medical Effects of Air Pollution. An advisory committee of independent experts that provides advice to Government Departments and Agencies on all matters concerning the potential toxicity and effects on health of air pollutants.
Defra	Department for Environment, Food and Rural Affairs
Epidemiology	The branch of medicine which deals with the incidence, distribution, and possible control of diseases and other factors relating to health
Exceedence	A period of time when the concentration of a pollutant is greater than the appropriate air quality objective. This applies to specified locations with relevant exposure
LAQM	Local Air Quality Management
µg/m³	Microgrammes per cubic metre
NO₂	Nitrogen dioxide
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides
PHE	Public Health England

PM₁₀	Small airborne particles, more specifically particulate matter less than 10 micrometres in aerodynamic diameter
PM_{2.5}	Small airborne particles, more specifically particulate matter less than 2.5 micrometres in aerodynamic diameter
Risk Coefficient	The relative risk expressed as a percentage change per a given change in concentration
RR	Relative Risk
Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal

9 Appendices

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A1 Attributable Fraction of Deaths by Ward

A1.1 Table A1.1 sets out the fraction of deaths attributable to air pollution (specifically PM_{2.5} and nitrogen dioxide) in Bristol Wards in 2013. The attributable fraction (AF) takes account of the population weighted average concentration of anthropogenic PM_{2.5} or total nitrogen dioxide in each ward in 2013. The number of deaths per ward has not been calculated, as this will be dependent on the death rate in each ward, which will be influenced by factors such as age structure of the population, deprivation and other social factors, which cannot be quantified. The number would also depend on the total population in each ward, and it would be misleading to imply one ward had more deaths due to air pollution just because it had a larger population.

Table A1.1: Attributable Fraction of Deaths in the City of Bristol in 2013 due to Air Pollution, by Ward (based on new ward boundaries) for PM_{2.5} and Nitrogen Dioxide Alone and In-combination

Ward	Population	Attributable Fraction % PM _{2.5}	Attributable Fraction % Nitrogen Dioxide	Attributable Fraction % Combined
Avonmouth & Lawrence Weston Ward	20,757	5.17%	4.76%	8.38%
Stoke Bishop Ward	11,827	4.72%	4.03%	7.44%
Henbury & Brentry Ward	11,903	4.93%	4.21%	7.77%
Bishopsworth Ward	11,152	4.84%	3.80%	7.40%
Hartcliffe & Withywood Ward	18,340	4.53%	3.17%	6.66%
Frome Vale Ward	12,756	5.32%	4.83%	8.58%
Horfield Ward	12,592	5.13%	4.62%	8.25%
Hengrove & Whitchurch Park Ward	17,255	4.75%	3.46%	7.08%
Clifton Ward	13,261	5.30%	5.14%	8.77%
Clifton Down Ward	10,903	5.34%	5.29%	8.91%
Eastville Ward	13,948	5.52%	5.27%	9.08%
Hillfields Ward	12,612	5.38%	4.93%	8.71%
Stockwood Ward	11,806	4.76%	3.52%	7.13%
Bedminster Ward	12,087	5.32%	4.98%	8.68%
Southville Ward	11,914	5.47%	5.30%	9.05%
Filwood Ward	13,519	5.07%	4.27%	7.95%
Windmill Hill Ward	13,059	5.44%	5.23%	8.98%
Knowle Ward	13,402	5.24%	4.60%	8.34%
Westbury-on-Trym & Henleaze Ward	19,511	4.91%	4.39%	7.87%
Southmead Ward	12,670	5.02%	4.41%	8.00%
Redland Ward	12,966	5.15%	4.83%	8.41%

Ward	Population	Attributable Fraction % PM _{2.5}	Attributable Fraction % Nitrogen Dioxide	Attributable Fraction % Combined
Bishopston & Ashley Down Ward	12,431	5.25%	4.97%	8.61%
Cotham Ward	11,580	5.52%	5.55%	9.27%
Ashley Ward	18,239	5.81%	6.00%	9.86%
Lawrence Hill Ward	17,914	6.22%	6.70%	10.76%
Lockleaze Ward	12,618	5.30%	4.94%	8.64%
Easton Ward	13,954	5.88%	5.85%	9.84%
Brislington West Ward	10,930	5.40%	4.78%	8.63%
Hotwells & Harbourside Ward	4,979	5.49%	5.46%	9.18%
Central Ward	15,009	5.90%	6.38%	10.21%
St George West Ward	6,372	5.63%	5.31%	9.21%
Brislington East Ward	11,678	5.26%	4.55%	8.33%
St George Troopers Hill Ward	5,863	5.22%	4.52%	8.28%
St George Central Ward	12,667	5.36%	4.79%	8.59%
TOTAL	442,474	5.27%	4.83%	8.53%

A2 Professional Experience of the Consultants

Prof. Duncan Laxen, BSc (Hons) MSc PhD MIEEnvSc FIAQM

Prof Laxen is the Managing Director of Air Quality Consultants, a company which he founded in 1993. He has over forty years' experience in environmental sciences and has been a member of Defra's Air Quality Expert Group and the Department of Health's Committee on the Medical Effects of Air Pollution. He has been involved in major studies of air quality, including nitrogen dioxide, lead, dust, acid rain, PM₁₀, PM_{2.5} and ozone and was responsible for setting up the UK's urban air quality monitoring network. Prof Laxen has been responsible for appraisals of all local authorities' air quality Review & Assessment reports and for providing guidance and support to local authorities carrying out their local air quality management duties. He has carried out air quality assessments for power stations; road schemes; ports; airports; railways; mineral and landfill sites; and residential/commercial developments. He has also been involved in numerous investigations into industrial emissions; ambient air quality; indoor air quality; nuisance dust and transport emissions. Prof Laxen has prepared specialist reviews on air quality topics and contributed to the development of air quality management in the UK. He has been an expert witness at numerous Public Inquiries, published over 70 scientific papers and given numerous presentations at conferences. He is a Fellow of the Institute of Air Quality Management.

Stephen Moorcroft, BSc (Hons) MSc DIC MIEEnvSc MIAQM CEnv

Mr Moorcroft is a Director of Air Quality Consultants, and has worked for the company since 2004. He has over thirty-five years' postgraduate experience in environmental sciences. Prior to joining Air Quality Consultants, he was the Managing Director of Casella Stanger, with responsibility for a business employing over 100 staff and a turnover of £12 million. He also acted as the Business Director for Air Quality services, with direct responsibility for a number of major Government projects. He has considerable project management experience associated with Environmental Assessments in relation to a variety of development projects, including power stations, incinerators, road developments and airports, with particular experience related to air quality assessment, monitoring and analysis. He has contributed to the development of air quality management in the UK, and has been closely involved with the LAQM process since its inception. He has given expert evidence to numerous public inquiries, and is frequently invited to present to conferences and seminars. He is a Member of the Institute of Air Quality Management.

Dr Clare Beattie, BSc (Hons) MSc PhD CSci MIEEnvSc MIAQM

Dr Beattie is a Principal Consultant with AQC, with more than fifteen years' relevant experience. She has been involved in air quality management and assessment, and policy

formulation in both an academic and consultancy environment. She has prepared air quality review and assessment reports, strategies and action plans for local authorities and has developed guidance documents on air quality management on behalf of central government, local government and NGOs. Dr Beattie has appraised local authority air quality assessments on behalf of the UK governments, and provided support to the Review and Assessment helpdesk. She has also provided support to the integration of air quality considerations into Local Transport Plans and planning policy processes. She has carried out numerous assessments for new residential and commercial developments, including the negotiation of mitigation measures where relevant. She has carried out BREEAM assessments covering air quality for new developments. Clare has worked closely with Defra and has recently managed the Defra Air Quality Grant Appraisal contract over a 4-year period. She is a Member of the Institute of Air Quality Management and is a Chartered Scientist.

Ricky Gellatly, BSc (Hons) AMIEnvSc MIAQM

Mr Gellatly is a Senior Consultant with AQC with over five years' relevant experience. He has undertaken air quality assessments for a wide range of projects, assessing many different pollution sources using both qualitative and quantitative methodologies, with most assessments having included dispersion modelling (using a variety of models). He has assessed road schemes, airports, energy from waste facilities, anaerobic digesters, poultry farms, urban extensions, rail freight interchanges, energy centres, waste handling sites, sewage works and shopping and sports centres, amongst others. He also has experience in ambient air quality monitoring, the analysis and interpretation of air quality monitoring data, the monitoring and assessment of nuisance odours and the monitoring and assessment of construction dust.

Flo Kirk-Lloyd, BSc (Hons) AMIEnvSc AMIAQM

Ms Kirk-Lloyd was a Consultant with AQC and has four years' experience of air quality modelling, monitoring and assessment. She has completed numerous air quality assessments for development projects and for local authority review and assessment reports, using a range of quantitative and qualitative assessment techniques, including use of the ADMS-Roads and ADMS-5 dispersion models. Ms Kirk-Lloyd has also been involved in the analysis and interpretation of air quality data.