WEST SUSSEX

Air Quality Needs Assessment

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Overview

Outdoor air pollution is a major public health issue costing the UK economy £20bn a year and contributing to over 40,000 deaths a year. The nature of air pollution in the UK has changed over the decades. The black smoke and sulphur dioxide which were released into the atmosphere as a result of industrial and domestic coal burning have reduced substantially since the 1950s and the introduction of the first UK Clean Air Act in 1956. With road traffic increasing by a factor of 10 between 1949 and 2012, and total distance walked each year decreasing by 30% between 1995 and 2013[1], there is now increased emphasis on the contribution made by vehicular emissions to air quality.

The Committee on the Medical Effects of Air Pollutants (COMEAP) report on the effect on mortality of air pollution. Its report in 2010 suggested that anthropogenic particulate matter could have an effect on UK mortality of 29,000 extra deaths (in 2008), with a loss of total population life of 340,000 life-years and a loss of life expectancy from birth of approximately six months. Reports in 2015 have also reviewed evidence for a dose-response relationship between ground level ozone and hospital admissions and mortality, and have concluded that there is now sufficient evidence to consider nitrogen dioxide having an independent impact on health.

West Sussex has relatively low levels of air pollution, though there are areas where air quality objectives are exceeded, and action plans to address this have been drawn up by the districts and borough councils. There is also now thought to be no threshold level below which air pollution will have no detrimental effects on health and mortality, and the contribution of anthropogenic particulate matter with a diameter of 2.5 micrometres or less has been quantified.

Addressing outdoor pollution will have co-benefits with

- public health, through an increase in walking and cycling through active travel,
- climate change, through reduction in CO_2 emissions through reduction in combustion of fossil fuel
- environment and biodiversity, through reduction in chemicals harmful to ecosytems
- improved energy efficiency

The aim of this document is to inform the Director of Public Health and the Health and Wellbeing Board about the scale and impact of air quality in West Sussex, and, during its development, to contribute to the West Sussex Air Quality Plan.

[1] Every breath we take: The lifelong impact of air pollution. Royal College of Paediatrics and Child Health 2016

Types and sources of air pollutants

The main types of air pollutants have changed over the past few decades; those considered the most prevalent are outlined below. The Department for Environment Food & Rural Affairs (Defra) has summarised sources and effects of the main components of air pollution[2].

Nitrogen oxides

Oxides of nitrogen are produced by combustion processes in air. Nitrogen oxide (NO) and nitrogen dioxide (NO_2) are together referred to as NO_x. The largest source of emissions of NO_x is from diesel cars and vans (light duty), other significant sources are combustion in industry, heavy duty vehicles, and electricity and heat production.

Particulate matter (PM)

Particulate matter is categorised on the basis of the size of the particles e.g $PM_{2.5}$ has a diameter of less than 2.5 micrometres (µm, one micrometre is one thousandth of a millimetre), PM_{10} has a diameter of 10 µm or less (table 1).

Table 1: Type and size of particulate matter

Particles	Diameter
Nanoparticles/ultrafine particles ($PM_{0.1}$)	<0.1 µm
Fine particles $PM_{2.5}$	2.5 µm or less
PM_{10}	10 µm or less
Coarse particles	2.5-10 µm
Dust	75 µm or less

Particulate matter is particles of matter from a variety of sources, such as engine emissions, tyre and brake wear, quarrying, and construction. Emissions can also come from natural sources, such as sea spray and Saharan dust. PM can be emitted directly into the atmosphere, or can be formed of secondary particles as a result of chemical reactions, where other pollutants such as ammonia, sulphur dioxide, nitrogen oxides, and organic compounds act as precursors.

The largest contributor to anthropogenic PM pollution in the UK is industrial, commercial, and residential combustion. Road transport is also a significant contributor, especially in urban areas. In addition to exhaust emissions, PM pollution can come from tyres, brakes, and road erosion; these particles may contain elements such as transition metals, which are themselves toxic. Even with the cleanest fuel, road transport will never be emission free.

The relative contribution of domestic combusion of wood and coal to PM pollution had been declining, but domestic burning of solid fuel, for example in wood burning stoves, is becoming increasingly popular. This relative contribution depends on location and other sources of pollution, so away from urban pollution hotspots domestic burning of solid fuel has been estimated to contribute 38% of PM pollution, whereas in London approximately 9% of winter PM pollution is estimated to be from wood burning stoves and open fires[3].

[2] Defra: What are the causes of air pollution? https://uk-air.defra.gov.uk/assets/documents/What_are_the_causes_of_Air_Pollution.pdf

[3] The Potential Air Quality Impacts from Biomass Combustion, Air Quality Expert Group, prepared for Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of the Environment in Northern Ireland, 2017

PM_{10} can be breathed into the lungs; $PM_{2.5}$ can be breathed deeper into the lungs, into the alveoli where they can irritate the alveolar wall; $PM_{0.1}$ can pass into the bloodstream.

Ozone

Ozone is not emitted directly from any man-made source, but is produced by chemical reactions between other air pollutants, such as NO_x and volatile organic compounds (VOCs), in the presence of strong sunlight. NO_2 reacts with oxygen to produce ozone and NO. There is an equilibrium reaction where ozone reacts with NO to produce NO_2 and oxygen. This ozone degradation reaction is more likely to occur in urban areas, where there is more NO emitted by road traffic than in rural areas; ozone concentrations are therefore generally higher in rural areas. The presence of VOCs also results in higher levels of ozone, and these compounds react with NO to produce NO_2, therefore there is less NO in the atmosphere to degrade the ozone.

The precursors to ozone formation may have been emitted at distant locations, and formation may take place over several hours or days; ozone levels cannot be managed locally.

Non-methane volatile organic compounds (VOCs)

As mentioned above, the presence of VOCs may result in increased levels of ozone. Most VOCs emissions are from industry; they are also released from solvents in paints and coatings, and from domestic energy production from coal and oil. Natural vegetation such as trees can also be a significant source of atmospheric VOCs. For example, pine trees emit terpenes and deciduous trees emit isoprenes, and all VOCs in the atmosphere can react with other chemical to produce air pollution[4].

Sulphur dioxide

Sulphur dioxide is mainly produced as a result of combustion of sulphur-containing fuels by power stations and refineries. Emissions can be mitigated by switching the fuel from coal to gas, and pollutant capture such as flue gas desulphurisation.

Ammonia

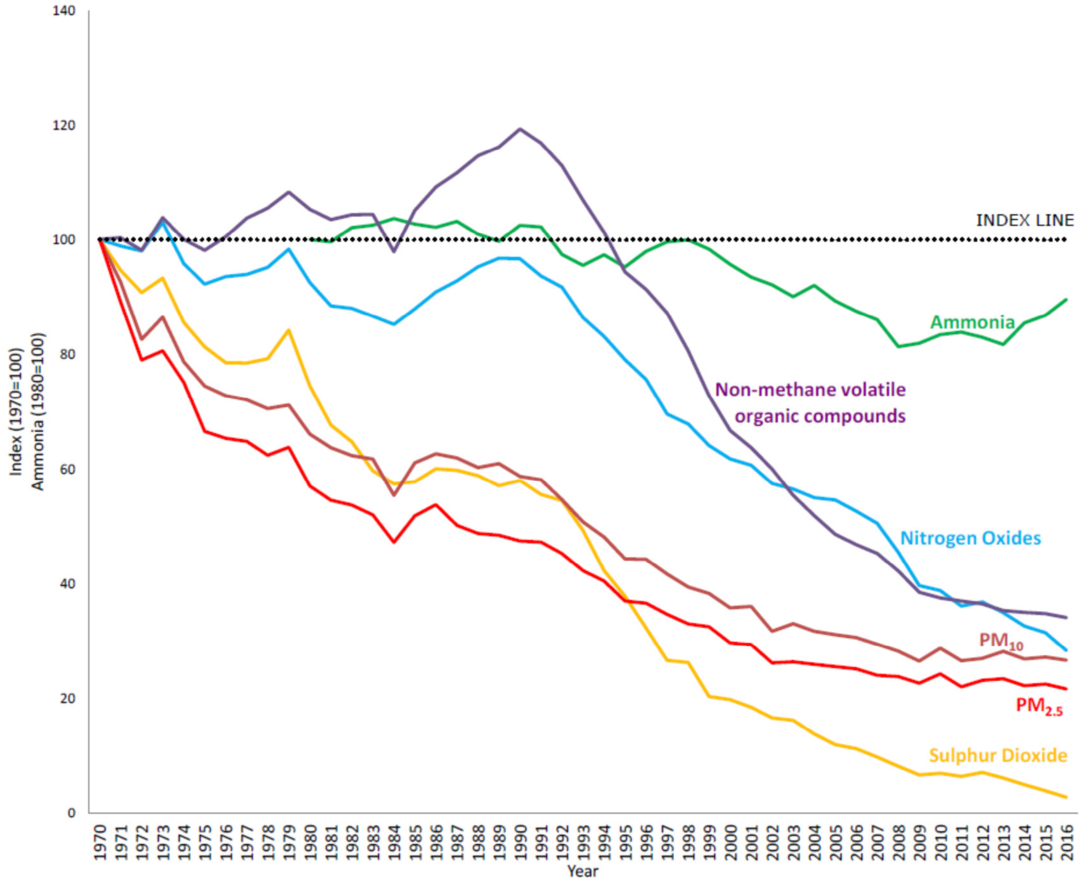
Agriculture, mainly through livestock manure and fertilizers, is the main source of ammonia emissions, with other sources such as transport and waste disposal accounting for a small proportion. Ammonia can produce secondary particulate matter, through chemical reactions in the atmosphere e.g. it reacts with SO_2 to produce ammonium sulphate and with NO_x to produce ammonium nitrate.

Trend in emissions

As shown in figure 1, the concentration of many pollutants has fallen markedly since the 1970s, due in part to changes in the methods of power generation (e.g. away from coal), and to improvements in vehicle technology.

[4] https://earthdata.nasa.gov/user-resources/sensing-our-planet/volatile-trees

Figure 1: Trends in UK sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia and particulate matter (PM_{10}, $PM_{2.5}$) emissions 1970 – 2016



Source: Defra[5]

The index line is a comparator that shows the level of emissions if they had remained constant from the beginning of the time series.

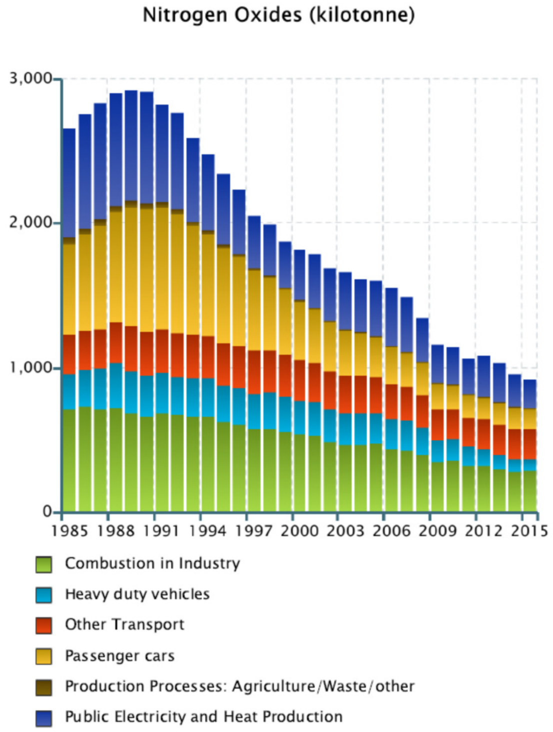
- Emissions of sulphur dioxide in 2016 have fallen by 97 per cent since 1970, to 0.18 million tonnes.
- Emissions of nitrogen oxides in 2016 have fallen by 72 per cent since 1970, to 0.89 million tonnes.
- Emissions of non-methane volatile organic compounds (NMVOCs) in 2016 have fallen by 66 per cent since 1970, to 0.82 million tonnes.
- Emissions of ammonia in 2016 have fallen by 10 per cent since 1980, to 289 thousand tonnes.
- Emissions of PM_{10} in 2016 have fallen by 73 per cent since 1970, to 170 thousand tonnes.
- Emissions of $PM_{2.5}$ in 2016 have fallen by 78 per cent since 1970, to 108 thousand tonnes.

The time series of emissions of nitrogen oxides and particulate matter, by sources of emission, are shown in figures 2 and 3.

[5] Defra Statistical Release: 15 February 2018 Emissions of air pollutants in the UK, 1970 to 2016

Figure 2: Time series of sources of nitrogen oxides emissions, UK, 1987 to 2015

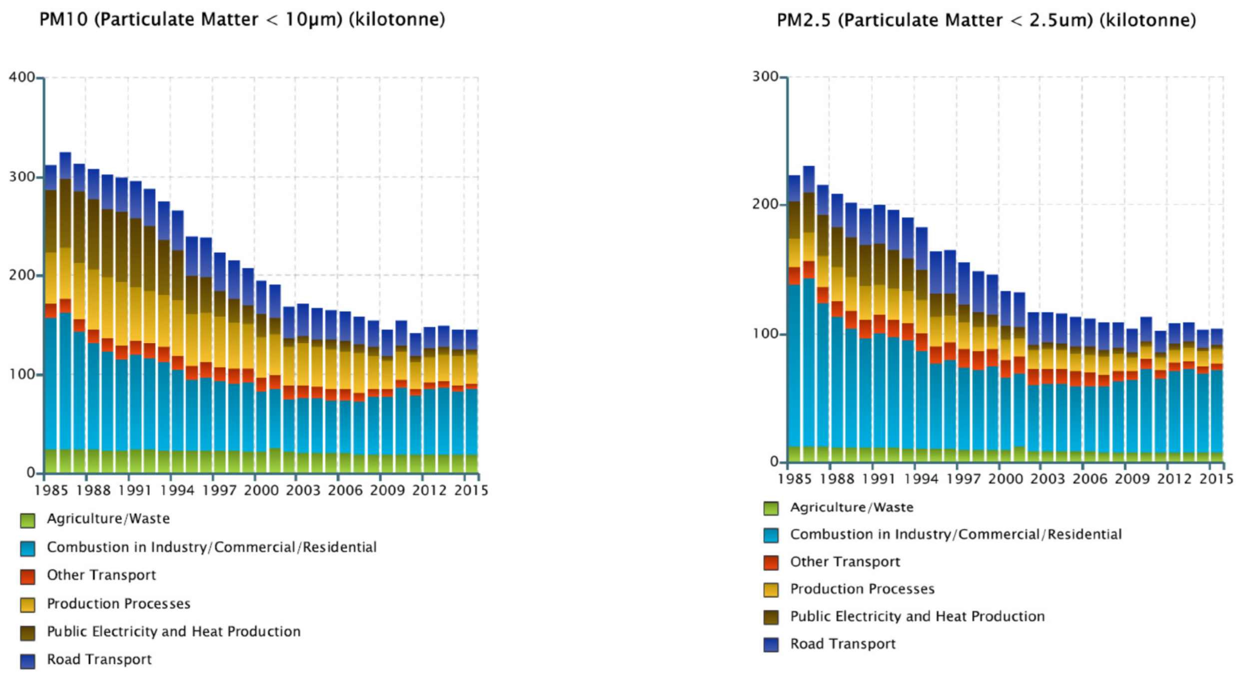
Source: National Atmospheric Emissions Inventory



After a peak in 1989 here have been large decreases in the emission of nitrogen oxides in the UK, with the largest proportional decrease in emissions from passenger cars and heavy duty vehicles.

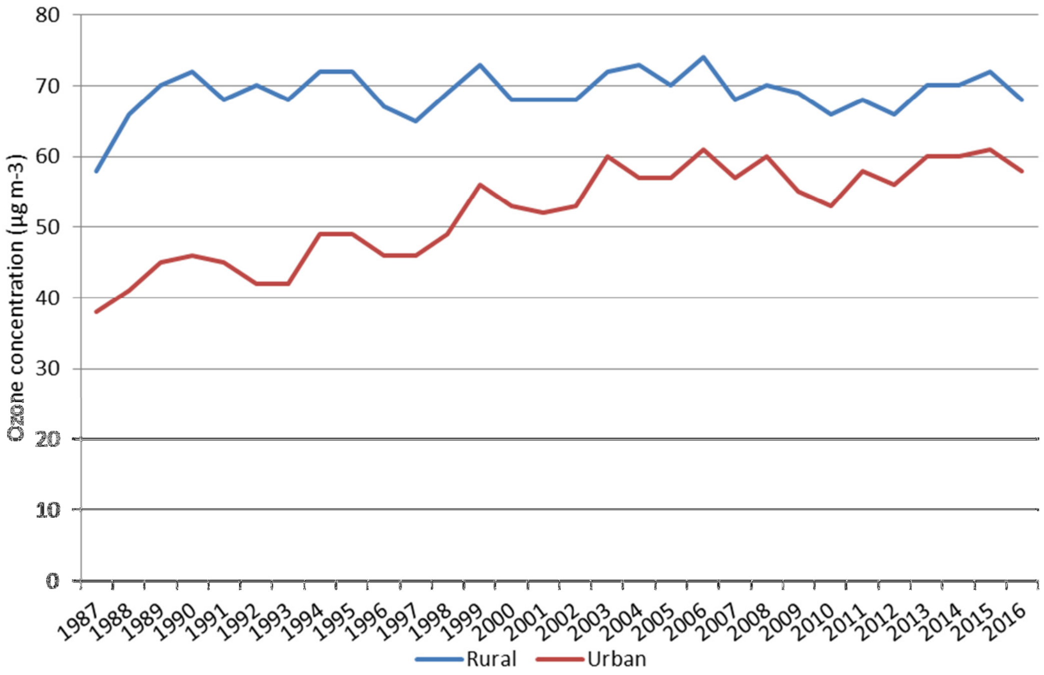
Figure 3: Time series of sources of particulate matter emissions, UK, 1987 to 2015

Source: National Atmospheric Emissions Inventory



Again, emissions of particulate matter has decreased since the 1980s. The largest decrease has been in emissions due to public electricity and heat production, with some reduction in emissions from industrial, commercial, and residential combustion. There has been a small decrease in emissions from road transport. However, despite the emission of precursors decreasing over time, the concentration of ozone has not demonstrated an equivalent decrease (figure 4).

Figure 4: Trends in annual levels of rural and urban ozone in the UK, 1987 to 2016
Source: Defra[6]



As discussed above, precursors to ozone formation may be generated at large distances from the actual ozone pollution, and ozone pollution in England may, in part, be due to precursor generation on the continent.

Factors affecting air pollution

High concentrations of air pollution occur in cities and along roads with traffic-generated pollution making a large contribution. In rural areas, agriculture and upwind industry make the largest contribution. Concentrations of pollutants may be high at the source of pollution but can rapidly dissipate. However, the layout of the environment can affect this dispersal, with tall buildings creating a "canyon" effect which can trap pollution, leading to very high local concentrations. Plants can be used to screen the population from sources of pollution, as pollutants can be deposited on vegetation and so the air can be filtered in this manner, but tall and/or dense foliage can contribute to the canyon effect.

The weather can also affect levels of air pollution. Wind can aid dispersal of pollutants, and concentrations of these can build up on still days. Sunlight can catalyse the reaction between nitrogen dioxide and oxygen, resulting in higher levels of ozone.

[6] Defra Statistical Release, 27 April 2017 Air quality statistics in the UK 1987 to 2016

Monitoring

Most air quality monitoring in West Sussex, by district and borough councils, is of NO_2, using non-automatic (passive) monitoring via diffusion tubes. There is some PM_{10} monitoring, and one rural ozone monitor. The number of stations and types of pollutants measured in each region is shown in table 2. Automatic monitoring sites produce hourly pollutant concentration reports whereas non-automatic measuring sites produce less frequent reports e.g. daily, weekly, or monthly.

Table 2: Number of monitoring sites and type, by responsible local authority, in West Sussex
Source: Annual status reports 2017

District/Borough	Type of monitoring	Number of sites	Total pollutants monitored
Adur	Non-automatic	23	NO_2
	Automatic	0	
Arun	Non-automatic	15	NO_2
	Automatic	0	
Chichester	Non-automatic	11	NO_2
	Automatic	3	NO_2, O_3, PM_{10}
Crawley	Non-automatic	30	NO_2
	Automatic	1	NO_2, PM_{10}
Horsham	Non-automatic	41	NO_2
	Automatic	3	NO_2, PM_{10}
Mid Sussex	Non-automatic	35	NO_2
	Automatic	0	
Worthing	Non-automatic	41	NO_2
	Automatic	1	NO_2

Automatic sites at Storrington and Worthing are linked to the Automatic Urban and Rural Network (AURN)[7]. This is the largest automatic monitoring network, and is the main network used for compliance testing against the Ambient Air Quality Directive. It produces hourly high-resolution information which is communicated to the public via electronic media and web platforms. The site at Storrington measures NO, NO_2, NO_x, (previously it had measured PM_{10} and $PM_{2.5}$ but these have been relocated to other sites within the south east); the site at Worthing measures NO, NO_2, NO_x and, as of 01/03/2018, $PM_{2.5}$.

Defra models annual mean ambient air quality[8]. Maps for West Sussex, from Defra's national Pollution Climate Mapping modelling, are shown in figures 5 to 8, the mean, minimum, and maximum values of nitrogen dioxide, PM_{10} and ozone are shown in table 3.

[7] https://uk-air.defra.gov.uk/networks/network-info?view=aurn
[8] https://uk-air.defra.gov.uk/data/gis-mapping

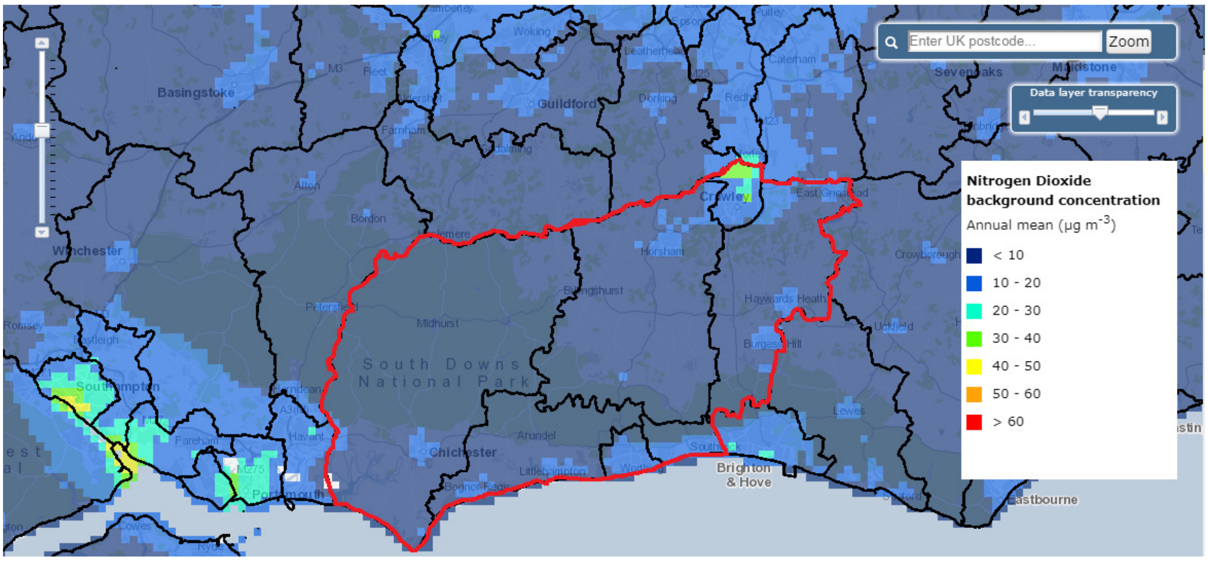
Table 3: Mean, minimum and maximum values of nitrogen dioxide and particulate matter, and number of days where background ozone was greater than 120 μgm^{-3}, 1km x 1km grid within West Sussex, 2015

Source: Defra UK Ambient Air Quality Interactive Maps

	NO_2 Background concentration Annual mean (μg m^{-3})		PM_{10} Background concentration Annual mean (μg m^{-3})		$PM_{2.5}$ Background concentration Annual mean (μg m^{-3})		Ozone background Days greater than 120 μg m^{-3}	
	West Sussex	UK	West Sussex	UK	West Sussex	UK	West Sussex	UK
Min	5.9	1.2	10.0	5.0	6.5	3.0	0.0	0.0
Max	38.8	54	17.1	23.7	11.8	17.2	3.2	7.6
Mean	8.3		12.5		8.1		2.9	

Figure 5: Ambient air quality map, nitrogen dioxide background concentration, annual mean (μgm^{-3}), 2015, West Sussex

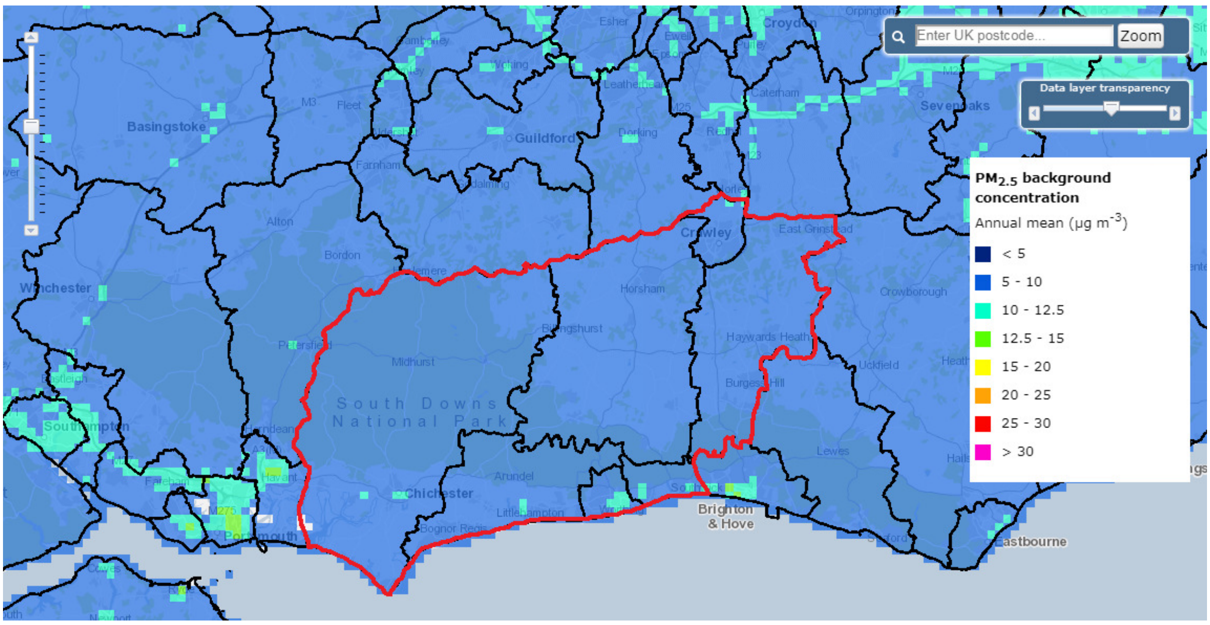
Source: Defra UK Ambient Air Quality Interactive Maps



The higher concentrations of NO_2 are in urban areas, especially in Crawley near to Gatwick Airport.

Figure 6: Ambient air quality map, $PM_{2.5}$ background concentration, annual mean (μgm^{-3}), 2015, West Sussex

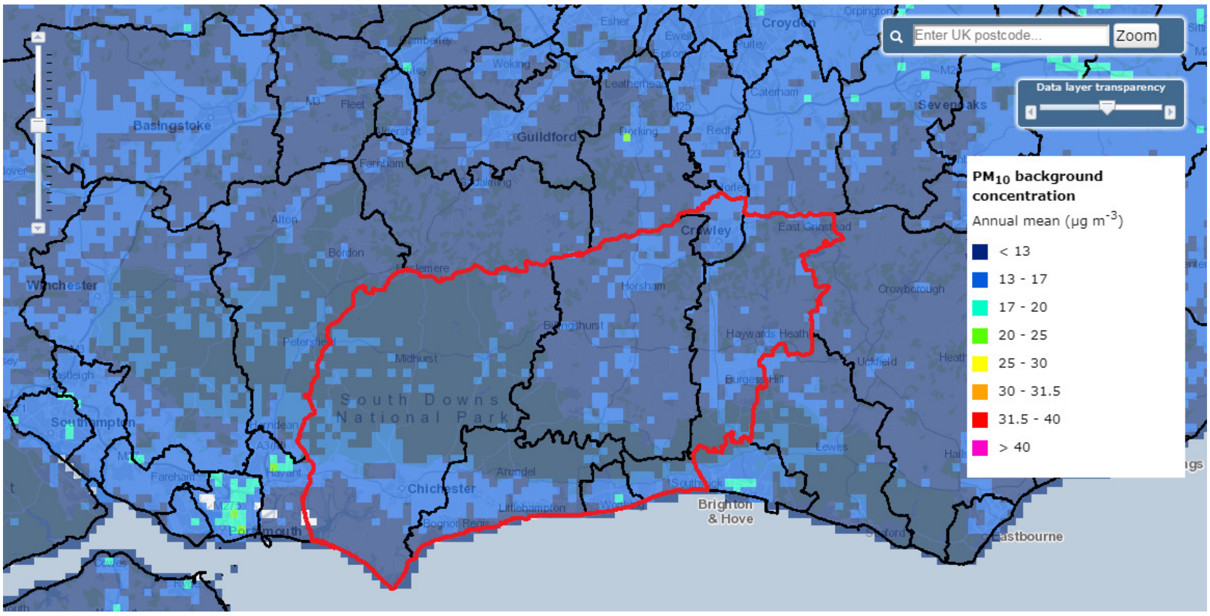
Source: Defra UK Ambient Air Quality Interactive Maps



There are pockets of higher modelled concentration of $PM_{2.5}$ in the urban areas of Adur, Worthing, Littlehampton, and Chichester

Figure 7: Ambient air quality map, PM_{10} background concentration, annual mean (μgm^{-3}), 2015, West Sussex

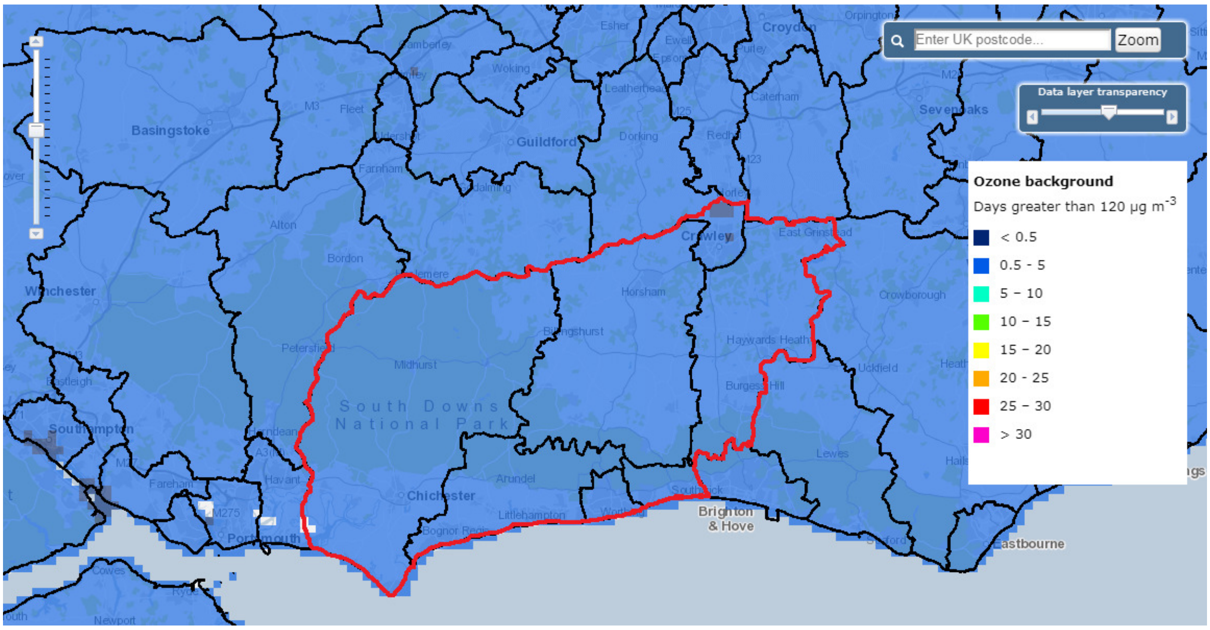
Source: Defra UK Ambient Air Quality Interactive Maps



Higher concentrations of PM_{10} are in the urban areas of West Sussex, and follow the main highways of the A27, A23 and A24.

Figure 8: Ambient air quality map, ozone background, number of days greater than 120 μgm^{-3}, 2015, West Sussex

Source: Defra UK Ambient Air Quality Interactive Maps



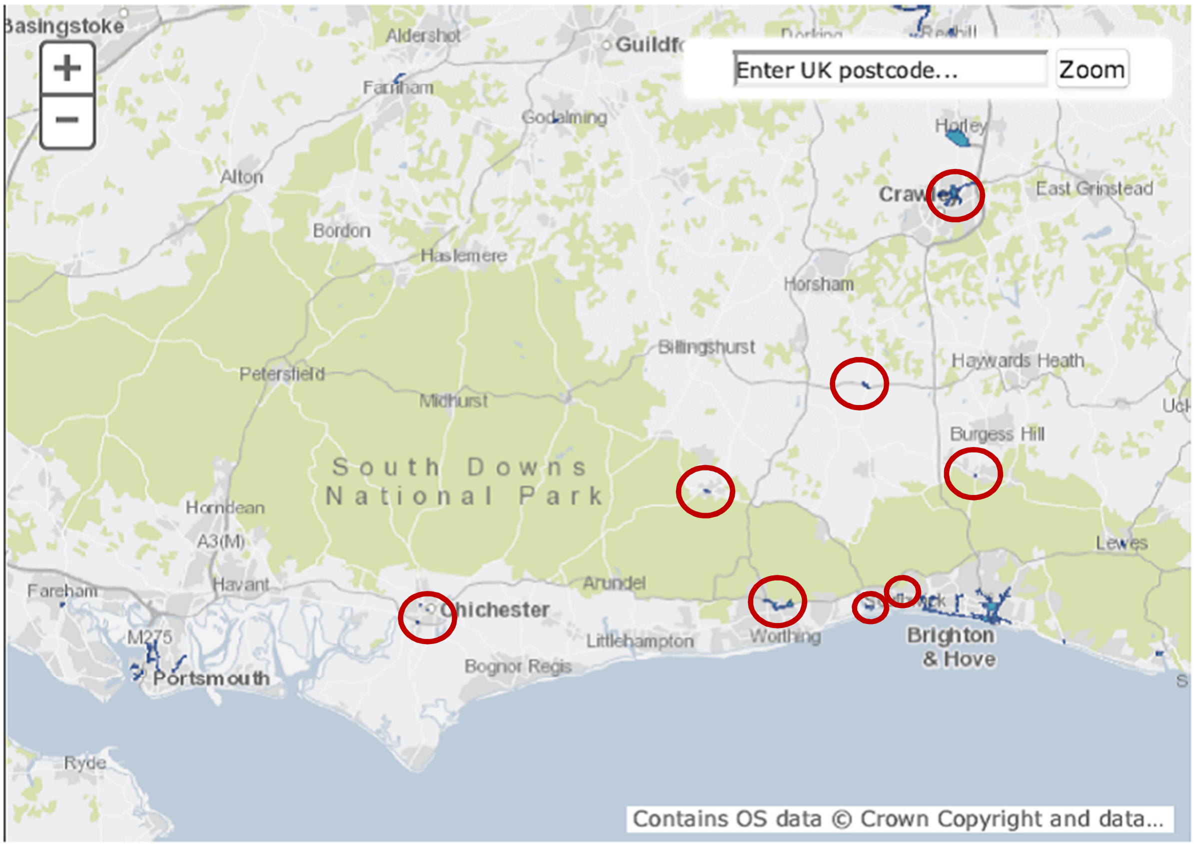
Lower concentrations of modelled ground level ozone are around Crawley, supporting the observation that urban levels of this pollutant are generally lower than rural levels.

Total emissions mapping data for pollutants including PM and NO_x data are available on the National Atmospheric Emissions Inventory website[9]; as ozone is not directly emitted from any source there is no equivalent map for this pollutant.

Local authorities are required to submit an Annual Status Report (ASR) on air quality, in fulfilment of Part IV of the Environment Act 1995 Local Air Quality Management. Where air quality objectives are not being achieved, or likely to be achieved[10], local authorities are required to designate an Air Quality Management Area (AQMA) and to develop an action plan. At present there are 10 AQMAs within West Sussex, shown in figure 9 (three separate AQMAs within the city of Chichester), which relate to localised air pollution on specific roads. They are all for annual exceedance of NO_2, and all cite road transport as the source of pollution. Arun is the only district or borough within West Sussex which has not declared an AQMA.

Figure 9: Location of AQMA boundaries within West Sussex, 2017

Source: Defra AQMAs interactive map



Action plans

The National Institute for Health and Care Excellence (NICE) issued updated guidance on outdoor air quality and health in June 2017[11], and much of the local authorities' action plans on air quality reflect this guidance. Engine emission standards may be improving but increases in volume of road

[9] http://naei.beis.gov.uk/data/gis-mapping

[10] As set out in the Air Quality (England) Regulations 2000

[11] https://www.nice.org.uk/guidance/ng70

vehicles act to counter this improvement. Many measures act to reduce the use and impact of fossil fuel vehicles. Initiatives include promotion of walking and cycling, installation of electric vehicle charging points, promotion of smoother driving through driver education and the co-ordination of traffic lights, routing of road traffic away from residential areas if possible, anti-idling campaigns, and the establishment of car clubs. Plans also include upgrading the local authority vehicle fleet to greener technology, and encouraging public transport providers to do similar. Education and awareness-raising are also promoted to affect public behaviour.

Also included in the NICE guidance is advice around planning and development management; the Ministry of Housing, Communities and Local Government (formerly the Department for Communities and Local Government) has also produced guidance on air quality in planning[12]. The impact of any development on air quality should be considered, and action taken to address increases in causes or effects of air pollution, either long-term or during construction. This could include effects on traffic (congestion, volumes, speed or composition), new sources of air pollution, increased exposure of people to pollution (such as siting housing or work places in areas of poor air quality), or unacceptable impacts during construction.

Sustainable transport is a key focus of the West Sussex Transport Plan 2011-2026[13], and the West Sussex Walking and Cycling Strategy[14] sets out the county council's aims and objectives for walking and cycling with priorities for investment in infrastructure improvements. The West Sussex Air Quality Plan[15] "Breathing Better" has recently been released. Each district and borough council has to prepare a local plan which sets planning policies in a local authority area. A number of policies within local plans specifically reference air quality; these are summarised in the West Sussex Air Quality Plan Appendix 2, and described in full on district and borough council websites.

A whole systems approach will be necessary in the alleviation and mitigation of the detrimental effects of air pollution. No one intervention will be sufficient to improve air quality, rather there will need to be many incremental steps acting in concert or independently to bring about such change. Such actions may be undertaken at all levels, from national legislation to individual choice. Some such actions which may contribute to improved air quality at a national, place, community, and individual level, are summarised in figure 10.

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12 https://www.gov.uk/guidance/air-quality--3
13 https://www.westsussex.gov.uk/media/3042/west_sussex_transport_plan_2011-2026_low_res.pdf
14 https://www.westsussex.gov.uk/media/9584/walking_cycling_strategy.pdf
15 http://www2.westsussex.gov.uk/ds/mis/110718env4a.pdf

Figure 10: Whole systems approach to the alleviation and mitigation of air pollution

National legislation

- Emission control – transport, industry, energy production
- Planning regulations

Place

- Improved/wider pavements
- Filtered permeability*
- Cycle lanes and bike parking
- Segregated cycle routes
- Traffic calming
- Parking management
- Open green spaces
- Safe and attractive environment
- Safe road crossing points
- Electric vehicle charging points
- Public transport infrastructure
- Strategic planning of vegetation
- Low emission zones
- Clean air zones
- Smoke control areas
- Planning for energy efficiency

Community

- Active travel
- Cycle share schemes
- Car clubs
- Cleaner air champions
- Walking and cycling champions
- Health walks
- School walking buses
- Daily mile
- Anti-idling campaigns
- Efficient home energy schemes
- SMS messaging air alerts

Individual

- Exercise referral
- Active travel choice – walking, cycling, public transport
- Green technology transport e.g. electric cars
- Clean burn stoves in place of older stoves and open fires
- Use of smokeless fuels

* allows through-access for walking and cycling, but removes it for motor traffic

Sussex-air

The Sussex Air Quality Partnership (Sussex-air) was established over 10 years ago to support Sussex authorities with their duties under Environment Act 1995 and implementation of the United

Kingdom Air Quality Strategy; West Sussex County Council and the districts and boroughs are represented on this partnership. Areas of interest to the partnership include policy and research into air quality to; understand the sources of pollution, reduce its impacts where possible, inform and protect vulnerable people and to deliver improvements in air quality, working with a regional focus. Sussex-air has produced guidance for local authorities around planned developments, assessing their potential impact on air quality, advice on conducting air quality and mitigation assessment, and planning recommendations[16].

As air quality is not just a local issue, but a regional, European and global issue, Sussex-air works with and provides a link to various local, regional, non-government, government and European bodies. It links to wider issues including Climate Change, Strategic Health Policy, EU and UK air quality developments, regional initiatives, research and government policy.

Health effects

Air pollution can have acute and chronic effects on health, mainly on morbidity and mortality from respiratory and cardiovascular conditions. The World Health Organization co-ordinated the HRAPIE project (Health risks of air pollution in Europe)[17] to provide an evidence base on the health effects of air pollutants As part of this it provided recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. In the UK the Committee on the Medical Effects of Air Pollutants (COMEAP) advises the government on all matters concerning the health effects of air pollutants, and has reviewed the evidence on the relationship between morbidity and mortality, and air pollutants.

The concentration-response coefficient for mortality from all causes in those aged 30 years and over as a result of long-term exposure to $PM_{2.5}$ is reported to be 1.06 (6%) per 10 µg/m^3 change in annual average airborne $PM_{2.5}$ concentration; this relationship is linear with no threshold below which there are no health effects.

COMEAP has also reviewed the available evidence on appropriate concentration-response functions for exposure to ground-level ozone and recommended the following concentration-response coefficients for short-term exposure[18] (table 4). The evidence suggests this relationship is linear with no threshold.

Table 4: Concentration-response coefficients for short-term exposure to ground level ozone
Source: COMEAP

Health endpoint	Concentration-response coefficient: % increase per 10µm/m^3 daily maximum 8-hour running mean ozone (95% CI)
All cause mortality, all ages	0.34% (0.12-0.56%)
Respiratory hospital admissions, all ages	0.75% (0.30-1.20%)
Cardiovascular hospital admissions, all ages	0.11% (-0.06-0.27%)

16 Air quality and emissions mitigation guidance for Sussex, Jan 2014, Sussex Air Quality Partnership
17 http://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health_risks_air_pollution_HRAPIE_project.pdf?ua=1
18 Quantification of Mortality and Hospital Admissions Associated with Groundlevel Ozone A report by the Committee on the Medical Effects of Air Pollutants, 2015

The main short-term effects of ground-level ozone are on respiratory conditions, including shortness of breath, coughing, sore throat, and inflamed airways. It can also cause aggravation of existing disease such as asthma, emphysema, and bronchitis, and can increase the frequency of asthma attacks and cause chronic obstructive pulmonary disease.

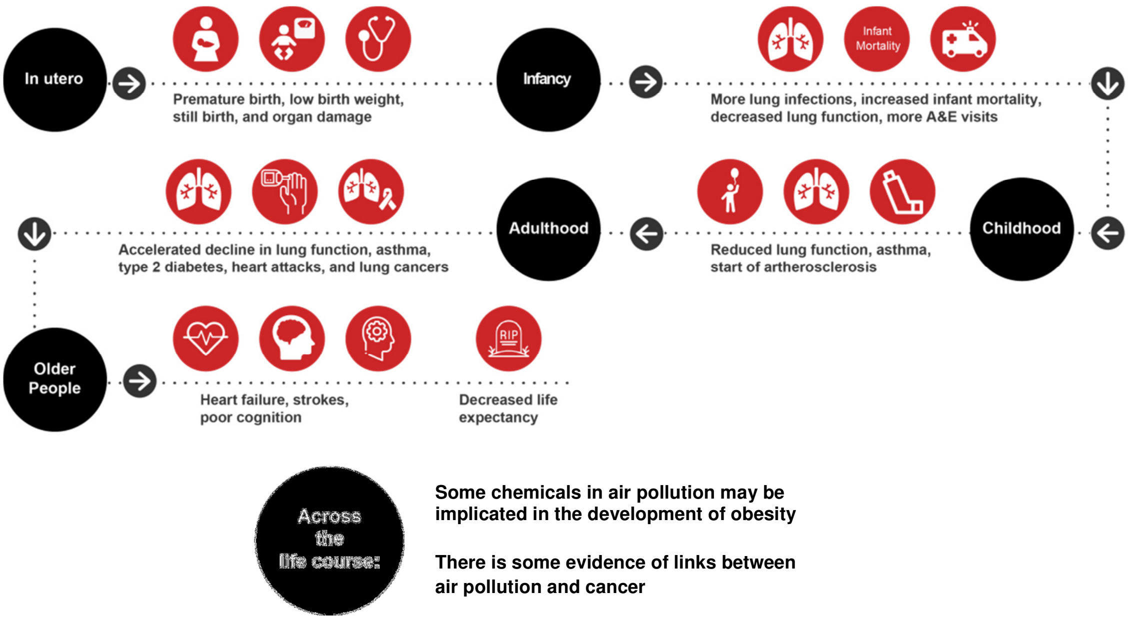
The relationship between NO_2 and health is less clear. Although there is strengthening evidence of an independent effect of NO_2 on health, there is a correlation between PM and NO_2 and so there is likely to be substantial overlap in their effects on mortality[19]. High levels of NO_2 can result in inflammation of the airways, and can enhance the response to allergens in sensitive individuals.

Life course effects of air pollution

The chronic and lifecourse effects of air pollution on health have been summarised in the report by the Royal College of Physicians and the Royal College of Paediatrics and Child Health[20]. An overview of the lifecourse effects of air pollution on health is shown in figure 11.

Figure 11: Life course effects of air pollutants

Source: West Sussex Public Health & Social Research Unit



Before birth

Although smoking in pregnancy is the greatest source of avoidable harm, pollutants in air can also affect the developing foetus. Air pollution affects foetal growth and birth weight, and it has been estimated that more than one fifth of cases of low birth weight at term are due to traffic-related air pollution exposure by pregnant women, this is associated with exposure to particulate matter. Greatest harm occurs with exposure during early pregnancy. Although there is less evidence than for particulate matter, the gaseous pollutants ozone, nitrogen dioxide, and possibly carbon monoxide, have been linked with low birth weight. Low birth weight for gestation is associated with

[19] Interim statement on quantifying the association of long-term average concentration of nitrogen dioxide and mortality COMEAP 2015

[20] Every breath we take: The lifelong impact of air pollution. Royal College of Paediatrics and Child Health 2016

low lung function, chronic obstructive pulmonary disease (COPD), cardiovascular disease and early death in adulthood. Low birthweight is also associated with rapid postnatal growth which is itself linked to obesity, asthma, and low lung function. Poor foetal growth is associated with abnormal development of the kidneys, and with hypertension and kidney disease in adulthood. Air pollution exposure has been associated with premature birth, with the strongest evidence for the effect of ozone and sulphur dioxide, and weaker evidence for exposure to particulate matter, PM_{10} and $PM_{2.5}$.

Air pollution can also affect the development of the foetus, and lead to perturbations in the development of organ systems. These may include the heart, lung, brain, hormonal and immunity systems. These effects may not be immediately apparent but may manifest decades after birth. There is evidence for prenatal exposure to heavy metals such as lead and mercury crossing the placenta and accumulating in the foetus, resulting in adverse effects on the development of the brain and nervous system leading to reduced cognitive function, lower IQ, attention deficit hyperactivity disorder and possible autism spectrum disorder during childhood. It has been suggested that similar effects could be caused by exposure to $PM_{2.5}$ which enter the bloodstream.

Childhood

The risk of death within one year of birth is increased among babies living the areas with high levels of air pollution. Acute exposure to high levels of air pollution results in increased respiratory symptoms, and increased attendances at A&E departments. Air pollution adversely affects the growth of lung function during childhood, up to late teens. This is to some extent reversible if the child moves away from areas of high pollution. There is evidence that NO_2 and PM are associated with new-onset wheeze and asthma from pre-school through to adulthood. Neurocognitive development may also be affected in childhood. Heavy metal exposure in young children impairs cognitive development and lowers IQ, and NO_2 can impair sensory, motor, and psychomotor function. Air pollution has also been implicated in the development of obesity in children, and this is also a risk factor for cardiovascular disease in later life. PM and NO_2 exposure in childhood can increase insulin resistance but it is unclear if this has an effect on the development of diabetes in adulthood.

Adulthood

Exposure to air pollutants in adulthood also has effects on health with marked effects of the respiratory and cardiovascular systems. Lung function naturally declines with age and chronic exposure to air pollution can accelerate this. Onset of asthma in adults is also associated with exposure to PM and NO_2.

Chronic exposure to air pollutants is also associated with the development of cardiovascular disease. Long-term exposure to $PM_{2.5}$ is associated with an increase in markers for atherosclerosis but it is not clear if childhood exposure contributes to this. Once cardiovascular disease is established, spikes in PM air pollution may exacerbate conditions; increased exposure to PM can increase the likelihood of atherosclerotic plaque rupture via inflammatory response in the lung. There is an increase in myocardial infarctions in the hours following exposure to traffic-related air pollution in those with pre-existing cardiovascular disease, and the risk of stroke also increases with increasing $PM_{2.5}$ levels.

Chronic exposure to PM and NO_2 is associated with an increase in type 2 diabetes in adults, and there is evidence of reduced cognitive function in older adults with increased exposure to PM. There may be an interaction between air pollution and other stressors, such as poor diet, tobacco smoking, and exposure to certain drugs.

The International Agency for Research on Cancer (IARC) has classified air pollution as a Group 1 carcinogen (carcinogenic to humans)[21]. Particulate matter was evaluated separately and was also classified as a Group 1 carcinogen. There is sufficient evidence that exposure to outdoor air pollution causes lung cancer; this manifests in adults but, as there is a long latency period, it is possible that exposure to PM in childhood may increase this risk. There is a positive association with an increased risk of bladder cancer.

Mortality attributable to $PM_{2.5}$

The Public Health Outcomes Framework (PHOF) includes an indicator which quantifies the contribution of exposure to $PM_{2.5}$ on mortality. 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. The PHOF indicator is:

- 3.01 - Fraction of all-cause adult mortality attributable to anthropogenic particulate air pollution (measured as fine particulate matter, $PM_{2.5}$).

In 2015 the value of this indicator for West Sussex was 4.2% (compared with 4.7% for both England and the South East). The time course of changes of this indicator between 2010 and 2015 is shown in table 5, and graphically in figure 12.

Table 5: Fraction of all-cause adult mortality attributable to anthropogenic $PM_{2.5}$, West Sussex, South East and England, 2010-2015

Source: PHOF

Year	Fraction of all-cause adult mortality attributable to anthropogenic $PM_{2.5}$		
	West Sussex	South East	England
2010	5.0	5.5	5.6
2011	5.2	5.5	5.4
2012	4.7	5.1	5.1
2013	4.8	5.2	5.3
2014	4.4	4.9	5.1
2015	4.2	4.7	4.7

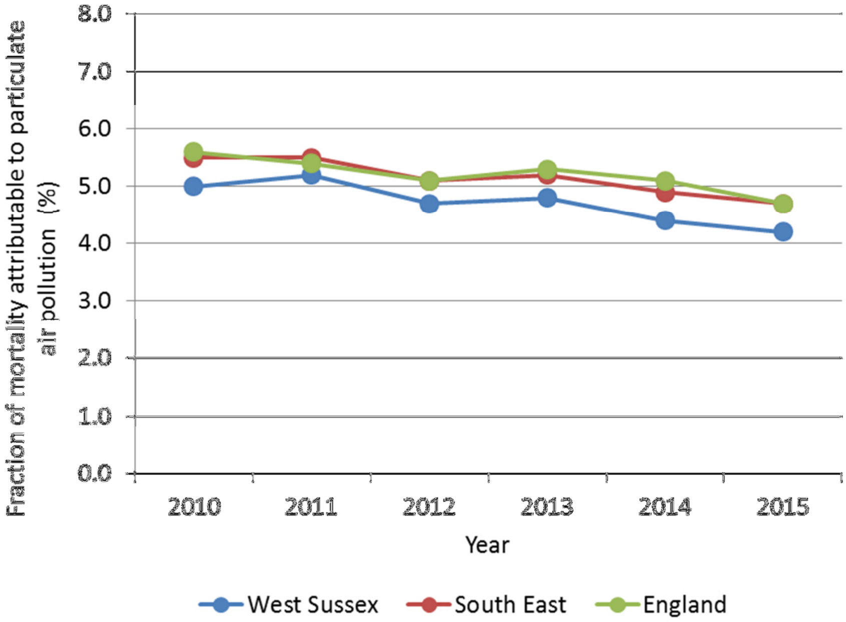
The fraction of all-cause adult mortality attributable to anthropogenic $PM_{2.5}$ decreased between 2010 and 2015 for England, the South East, and for West Sussex. The value of the fraction for West Sussex was below that of England and the South East for all years shown.

The figures for mortality due to air pollution are estimates of mortality attributable to a risk factor. Deaths are not individually attributed to air pollution, but rather it can be thought of as a contributory factor in many deaths from other causes such as respiratory disease and cardiovascular disease.

[21] https://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf

Figure 12: Time course of fraction of all-cause adult mortality attributable to anthropogenic $PM_{2.5}$, West Sussex, South East and England, 2010-2015

Source: PHOF



The indicator, which is expressed as a percentage of the adult mortality in a given year, can be converted into the same statistical units as most of the other mortality indicators in the PHOF, i.e. age standardised (<75 years) premature mortality per 100,000 population per year, the methodology for this is outlined in the briefing for directors of public health produced by Defra and PHE[22]. This conversion allows the local mortality attributed to particulate matter air pollution to be ranked against local mortality due to other sources of disease (table 6).

Table 6: Ranking of PHOF mortality indicators for West Sussex, 2013-15

Source: PHOF

Indicator in PHOF		Mortality rate per 100,000
4.03	Preventable mortality	159.1
	Overall premature deaths*	295.0
4.05ii	Preventable cancer < 75 years old	75.0
4.04ii	Preventable CVD < 75 years old	39.9
4.07ii	Preventable respiratory disease < 75 years old	12.8
	Mortality attributable to PM2.5 <75 years**	**12.4**
4.06ii	Preventable liver disease <75 years old	11.7
4.10	Suicide rate	10.1
4.08	Communicable diseases	9.0

*Source: PHE Healthier Lives

** Calculated from overall premature deaths and fraction of all-cause adult mortality attributable to anthropogenic PM_{25}

The table above illustrates that, in West Sussex, exposure to $PM_{2.5}$ is calculated to be responsible for a higher rate of premature mortality than preventable liver disease, suicide, or communicable diseases.

[22] Air Quality: A Briefing for Directors of Public Health Defra, PHE, March 2017

The fraction of mortality attributable to anthropogenic $PM_{2.5}$ in 2015 for the districts and borough councils within West Sussex is shown in table 7.

Table 7: Fraction of mortality attributable to anthropogenic $PM_{2.5}$ in 2015 for the districts and borough councils within West Sussex, 2015
Source: PHOF

Area	Fraction of mortality attributable to particulate air pollution (%) 2015
Adur	4.6
Arun	4.1
Chichester	4.1
Crawley	4.2
Horsham	4.1
Mid Sussex	4.1
Worthing	4.8
West Sussex	4.2
England	4.7

In 2015 Worthing had the highest fraction of mortality attributable to anthropogenic $PM_{2.5}$, at 4.8%; Arun, Chichester, Horsham and Mid Sussex had a fraction of mortality at 4.1%, which is the lowest value in West Sussex.

airAlert

airAlert[23] is a service, provided by the Sussex Air Quality Partnership, that sends alert messages to vulnerable people in Sussex informing them that poor air quality is predicted in their area. The alerts are sent to home phones via voice message, to mobile phones via text and via email. Evaluation[24] of the service carried out suggested the effect on hospital admissions in response to a pollution alert was small, due to the small number of people who are signed up to the service, but that the majority of people receiving alerts take action such as avoiding polluted areas or carrying asthma medication and that there will be health benefits apart from hospital admission avoidance.

Inequalities

Air pollution is harmful to everyone but some people will be affected more than others. Air quality is one of the measures included in the IMD (indices of multiple deprivation), and contributes to the living environment deprivation domain. Deprived areas often have higher levels of air pollution, due to industry and busy roads. People may be more vulnerable due to their age; the elderly and children are more susceptible to the effects of poor air quality. Long term conditions, such as cardiovascular and respiratory disease, may be exacerbated by air pollution. Obese people are more susceptible to air pollution, and poor air quality has been implicated in the development of obesity.

Quality of housing, healthy diet, and access to green spaces can mitigate the effects of poor air quality, but these factors are less likely to be obtainable for those who live in deprived areas. Stress

[23] http://www.airalert.info/Sussex/Default.aspx
[24] Air pollution alert services evidence development strategy – prediction of possible effectiveness and assessment of intervention study feasibility. King's College London Environmental Research Group, MRC-PHE Centre for Environment and Health 2014

due to unemployment and low income can also adversely influence the effect of air pollution on the body. A diet rich in antioxidant nutrients (vitamins and minerals, from e.g. fruit and vegetables) offers some protection, but is less likely to be accessed by those living in deprived areas.

People are more at risk if they have greater exposure or are more vulnerable to air pollution. If they are more vulnerable they may have a higher risk of an adverse reaction or experience a more severe health outcome for a given exposure. They may experience an adverse health outcome at a lower level of exposure and so would be more likely to experience the level of pollution which would trigger the adverse health outcome.

The Public Health Outcomes Indicator 0.2iii reports inequality in life expectancy at birth. Based on local deprivation deciles life expectancy across the social gradient, from the least to the most deprived, is reported. In West Sussex, for the period 2014-16, males in the most deprived decile had a life expectancy 7.6 years lower than that of those in the least deprived decile; for females this difference was 6.4 years. Individual lifestyle choices, such as smoking, diet, and exercise would be responsible for much of this difference. However, air pollution will affect the entire population of an area, regardless of individual behaviour, and so it is possible that higher levels of air pollution in the more deprived areas are contributing to this social gradient of mortality.

Environmental effects

The detrimental effects of air pollution extend beyond its effect on human health. Sulphur dioxide, nitrogen oxide, and ammonia can cause acidification resulting in damage to soil, vegetation, and buildings. Nitrogen-containing compounds, such as ammonia and nitrogen oxides, deposited in soils or rivers affect the nutrient content of the water and lead to eutrophication, and uncontrolled growth of algae in water courses leads to oxygen depletion and loss of biodiversity. Ozone is a strong oxidising agent and can lead to the damage of urban vegetation and significant reductions in crop yields. Particulate matter, depending on its chemical composition, can result in the soiling of buildings and acidification.

Co-benefits

Many of the interventions to address air pollution have co-benefits with public health. Promotion of active travel to reduce car journeys results in an increase in walking and cycling, with protective effects against obesity, cardiovascular disease, and cancer. In addition to the benefits to physical health, activity is also beneficial to mental health and wellbeing, providing protection against depression and anxiety, and improving self-esteem[25].

NHS Choices details the benefits of regular activity. For adults aged over 18 years, 150 minutes of moderate activity or 75 minutes intense activity per week[26] is recommended. Ideal moderate activity is brisk walking and cycling, which could be incorporated into active travel. It is estimated that people who do regular physical activity have:

- up to a 35% lower risk of coronary heart disease and stroke

[25] https://www.nhs.uk/conditions/stress-anxiety-depression/mental-benefits-of-exercise/
[26] https://www.nhs.uk/Livewell/fitness/Pages/whybeactive.aspx

- up to a 50% lower risk of type 2 diabetes
- up to a 50% lower risk of colon cancer
- up to a 20% lower risk of breast cancer
- a 30% lower risk of early death
- up to an 83% lower risk of osteoarthritis
- up to a 68% lower risk of hip fracture
- a 30% lower risk of falls (among older adults)
- up to a 30% lower risk of depression
- up to a 30% lower risk of dementia

For West Sussex, if all adults were physically active, this would translate to

- 10,000 fewer people on coronary heart disease GP register
- 23,000 fewer people on diabetes GP register
- 20,000 fewer people on depression GP register
- 2,500 fewer people on dementia GP register
- 175 fewer cases of breast cancer per year
- 210 fewer cases of colon cancer per year
- 845 fewer emergency admissions for hip fracture in those aged 65 and over

A reduction in dependence on vehicular road transport presents the opportunity for the development of public spaces where people can walk and cycle in safety. This could result in the provision of attractive and safe communal environments, where people will want to meet and engage, resulting in improved community cohesion and reduced social isolation. The London Healthy Streets approach, discussed below, demonstrates how this may be addressed.

As discussed above, exposure to and response to air pollution is a source of inequality. Addressing the causes of air pollution is likely to have the most benefit in the more deprived areas, and so will therefore also address inequality.

Measures introduced to reduce air pollution with also address the climate change agenda. Reduced combustion in industry, in the domestic setting, and through vehicular transport will reduce the quantity of carbon dioxide released into the atmosphere.

Green infrastructure

The definition of green infrastructure in the National Planning Policy Framework[27] is as follows:

> *A network of multi-functional green space, urban and rural, which is capable of delivering a wide range of environmental and quality of life benefits for local communities.*

As part of urban planning, green infrastructure has the potential to improve air quality and enhance sustainability of urban environments. Streets are less traffic-dominated and more welcoming.

[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/6077/2116950.pdf

One example of green infrastructure in West Sussex is Crawter's Brook, in the Manor Royal area of Crawley, which has been transformed from a neglected remnant field parcel and woodland in a built-up industrialised area. It is now a public park, with picnic area and space for activities, and functions as a wildlife corridor and flood attenuation area.

Crawter's Brook, Manor Royal, Crawley, Photo Allen Scott, Landscape Architect

Resources

KonSULT

KonSULT, http://www.konsult.leeds.ac.uk/ , the Knowledgebase on Sustainable Urban Land use and Transport (Leeds University), addresses difficulties in finding consistent and comprehensive empirical evidence of transport policies, and provides detailed information on individual policy measures. It contains a measure option generator, policy guidebook and decision makers' guidebook

Healthy Streets London

Healthy Streets London is a long-term plan to encourage Londoners to reduce their reliance on driving, by encouraging them to walk and cycle more. It aims to do this by improving local environments with more space for walking and cycling, providing better public spaces where people can interact, prioritising better and more affordable public transport and safer and more appealing routes for walking and cycling, planning new developments so people can walk or cycle to local shops, schools and workplaces, and having good public transport links for longer journeys

A toolkit has been developed[28]; the approach is based on ten indicators

- People choose to walk, cycle and use public transport
- Pedestrians from all walks of life
- Easy to cross
- People feel safe
- Things to see and do
- Places to stop and rest
- People feel relaxed
- Not too noisy
- Clean air
- Shade and shelter

A number of questions has been devised around each indicator to help address what changes could be made to improve the experience of using a street. Although this was toolkit was designed for London, much of it will be applicable to West Sussex.

Recommendations

"Air Quality: A Briefing for Directors of Public Health", published in 2017 by Defra, PHE, and the Local Government Association, is a series of briefings which together constitute a toolkit to aid in the formulation of an appropriate public health response to local air pollution. It identifies three main groups which will be key in tackling air pollution; local decision makers, the public, and elected members. The role of these groups is summarised below.

Engaging with the public

During short-term periods of high air pollution local health messages should be disseminated to the public. Advice can be given on the expected severity of the episode and what actions should be taken by the general population, and those that may be more susceptible due to long term conditions. Such advice may include whether outdoor activities may be continued, and whether those with long-term conditions should take extra precautions around managing their health. In West Sussex, the public should be encouraged to sign up to airAlert, a service provided by the Sussex Air Quality Partnership (Sussex-air) that sends free messages direct to vulnerable people informing them about air pollution levels in their area.

The public should be educated about long-term air pollution exposure. This will include types and sources of pollution, health and other effects, and steps the individual or community can take to reduce production of and/or exposure to pollution. Six principles for public communication about air pollution have been identified

- Explain what air pollution is
- Help people understand how they can protect themselves
- Explain the health impacts
- Make it local – explain it is a problem linked to specific places rather than a general problem of the atmosphere
- Explain how individual can make a difference

[28] https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/healthy-streets

- Demonstrate leadership and empower communities, rather than expecting individuals to change their behaviour

Engaging with partners and local decision makers

Outdoor air quality should be included in the Joint Strategic Needs Assessment. This will ensure the Health & Wellbeing Board is engaged, thereby encouraging partnership working by organisations represented on the board, and providing scrutiny of policies. In addition to local authorities and health organisations, stakeholders will include industry, voluntary sector and community institutions, and the local media.

Engaging with elected members

Local authorities have many powers over areas and policies which could lead to improved air quality. These include traffic and parking management; street design and road layouts; planning, powers to deal with idling engines; public and school transport policies; forbidding the dirtiest vehicles or favouring clean vehicle fuels like petrol, liquid petroleum gas, or compressed natural gas over diesel and bio-diesel; installing electric vehicle charging points; reviewing and enforcing Smoke Control Areas; low or zero emission last mile services; fleet management and car clubs; vehicle and building air conditioning; building energy efficiency and cleaner heat sources. Elected members are in a position to promote such policies. They could also encourage cabinet understanding and scrutiny of council strategies which could have an impact on air quality; in the county these include the West Sussex Plan 2017-22, the West Sussex Transport Plan 2011-26, the West Sussex Walking and Cycling Strategy 2016-26, the Rights of Way Management Plan 2018-28, the Bus Strategy 2018-26 (under development), the Electric Vehicles Policy (under development), and the current review of parking standards relating to car and cycle parking at new developments within the county. Elected members could also encourage the Local Enterprise Partnership (Capital to Coast) to consider mitigation of air pollution alongside economic development.

West Sussex Air Quality Improvement Plan

This document should be read in conjunction with the air quality improvement plan “Breathing Better: partnership approach to improving air quality in West Sussex”, produced by West Sussex County Council. The plan brings together the responsibilities of the county council, the district and borough councils, and Highways England in improving air quality in the county, and outlines the approach and activities being undertaken to tackle the issues of air pollution. Partnership working between these, and wider partners, will be necessary to deliver the plan.

Glossary

AQMA	Air Quality Management Area
ASR	Annual Status Report
AURN	Automatic Urban and Rural Network
COMEAP	Committee on the Medical Effects of Air Pollutants
COPD	Chronic Obstructive Pulmonary Disease
Defra	Department for Environment Food & Rural Affairs
HRAPIE	Health Risks of Air Pollution in Europe
IARC	International Agency for Research on Cancer
KonSULT	Knowledgebase on Sustainable Urban Land use and Transport
LGA	Local Government Association
NAEI	National Atmospheric Emissions Inventory
NICE	National Institute for Health and Care Excellence
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
PHE	Public Health England
PHOF	Public Health Outcomes Framework
PM	Particulate matter
Sussex-air	Sussex Air Quality Partnership
VOCs	Non-methane volatile organic compounds