Review of Air Quality and Health in Gloucestershire

Executive Summary

Scope of this review

- This review supports the air quality health and system impact assessment for Gloucestershire. An initial version was shared with participants of the air quality health and system impact assessment workshop held by Gloucestershire County Council in January 2018. This paper is intended to inform the work of its Scrutiny Task Group on Air Pollution and its Impact on Public Health.
- The review focuses on two key pollutants: particulate matter and nitrogen dioxide. These are the two principle pollutants affecting health of the population, and which are amenable to action at the local level.
- The review summarises evidence of the relationship between air quality and health, and the interventions to improve air quality or mitigate its impact on health at the local level. There is also a review of the data on air quality in Gloucestershire, relevant health outcomes, and associated information including levels of active travel.

What do we mean by air quality?

- Air quality is a measure of the degree to which the surrounding air in a given location is pollution free. Sources of pollution can be local or regional. Locally generated pollution relates to the pollution levels produced within a given area. In Gloucestershire sources include industry, transport and agricultural. Regional pollution originates from other areas but can be detected within the given area. This can be seen on a regional, continental or global scale.
- The key pollutants contributing to poor air quality are: particulate matter, nitrogen dioxide, carbon monoxide, carbon dioxide, sulphur dioxide, and low level ozone. While all of these pollutants contribute to poor human health outcomes, the review focuses on particulate matter and nitrogen dioxide as these are most amenable to action at the local level in Gloucestershire.
- Particulate matter describes pollution which is mixture of solid particles and liquid droplets. PM$_{10}$ and PM$_{2.5}$ (particles less than 10 and 2.5 micrometers in diameter respectively) are of most interest as they are fine inhalable particles which can be absorbed into the lung tissue. In Gloucestershire the main local sources are from road use; combustion of fuel, road use and brake dust among other sources.
- Nitrogen Dioxide (NO$_2$) is the most notable of a group of gases referred to as nitrogen oxides (NO$_x$), in terms of its impact on health. The main sources of NO$_2$ are from petrol and diesel road vehicles, and power plants. In Gloucestershire the principle local source of NO$_2$ which the population is exposed to is from road transport.
- There are both national and European directive target levels for specific pollutants. Even after leaving the European Union, these targets are likely to be maintained.
- Poor air quality is the greatest environmental threat to Public’s health in the UK. It has a large impact on health and life expectancy in the UK. It is also has a large cost in terms of health and social care use, and lost productivity.
The relationship between air quality and health

- In the UK, there are approximately 340,000 life years lost, and 40,000 deaths annually from exposure to poor air quality (estimates principally from particulate matter and nitrogen dioxide).
- Exposure to poor air quality results in both acute admissions to healthcare services, and long term health and social care needs.
- Poor air quality is a source of inequality, where those who are most deprived are also the most likely to live in areas with the highest level of exposure. Even though they may not be large contributors of pollutants themselves.
- There is no safe level of exposure to PM₂.₅ or NO₂. Even where air quality meets European Directive limits there is still a negative impact on health outcomes.
- PM₂.₅ (finer particulate pollution) is the most studied form of pollution, and has the strongest evidence base for independent causal effect on poor health outcomes. It has been shown to impact on the development of both pulmonary and cardiovascular diseases, as well as some cancers.
- Short term exposure to PM₂.₅ has a strong relationship to myocardial infarction (heart attack) and myocardial ischemia (restriction of blood to the heart). Studies have also shown increased incidence of arrhythmias (irregular heart beat) and stroke. For longer term exposures, PM₂.₅ has a strong relationship to myocardial infarction, angina, and prevalence of atherosclerosis (build-up of plaque on inside of arteries). There has also been a strong relationship between long term exposure to PM₂.₅ and prevalence of chronic obstructive pulmonary disease.
- There is a strong independent relationship between short term exposure to NO₂ and the prevalence of respiratory conditions, particularly asthma in children, and associated exacerbation of respiratory conditions (strongest in asthmatics). There is also evidence to suggest an impact on cardiovascular disease outcomes, but this is not strong enough to infer causality.
- For longer term exposure to NO₂ there is likely an independent causal effect on respiratory disease. The evidence is also suggestive of a similar relationship to cardiovascular disease, although this is not currently strong enough to support an independent causal relationship.

Air quality and health data in Gloucestershire

- Air quality levels for PM₂.₅ in Gloucestershire are in line with regional averages. Estimated levels are highest in Tewkesbury and Cheltenham, which are both higher than regional averages. Modelled data for PM₁₀ at the lower super output area (LSOA) shows the highest estimated concentrations in Gloucestershire are in the Churchdown and Ashchurch areas of Tewkesbury and the west of Cheltenham.
- Air quality levels for nitrogen dioxide at the LSOA level are within EU directive target levels. The highest estimated concentrations are in North Gloucester, Cheltenham and around Gloucestershire Airport.
- 16 NO₂ monitoring sites across the county exceeded WHO recommendations. 11 of these sites are located in Cheltenham district, 4 were located in Gloucester and 1 is located in Cotswold at the Air Balloon Roundabout.
- There are 8 air quality management areas (where national air quality targets are not being achieved) in Gloucestershire. The majority are located in urban areas or in the case of Cotswold at a major road junction (the Air Balloon junction, Birdlip) due to high vehicle emissions.
People with asthma and other pulmonary conditions such as chronic obstructive pulmonary disease (COPD) are particularly vulnerable to the impact from poor air quality. In Gloucestershire we have 42,000 people recorded as living with asthma, and over 11,000 people known to be living with chronic obstructive pulmonary disease. Poor air quality exacerbates acute episodes as well as long term management, which can lead to higher health and social care use. There is also data which suggests that those who are already reliant on adult social care also have a higher exposure to poor air quality.

Within Gloucestershire there are nine Lower Super Output Areas that exceed the recommended levels for Nitrogen Dioxide, of these 2 are in the most deprived 20% of the country in terms of indices of multiple deprivation. This is higher than expected, and suggests a disproportionate effect on the most deprived.

In Gloucestershire children (who are more vulnerable to the effects of poor air quality) also have higher levels of exposure than other age groups.

Gloucestershire has high rates of car use for travel to work compared to the rest of the UK. Even where journeys to work are less than two kilometres, a much lower proportion are made on foot or by bicycle than in the rest of the UK. Levels vary significantly within the county between rural and urban areas. In Cheltenham over 6% of commuter trips are made by bicycle, compared with the national average of 2%.

**Interventions to improve air quality**

- A review was undertaken by the National Institute for Health and Clinical Excellence to highlight the key interventions amenable to action at the local level to improve air quality and/or to mitigate its impact on health. The focus of the evidence review was on air quality related to road use.

- The principle intervention areas highlighted from the review are: planning (including transport planning); clean air and congestion charging zones; reducing emissions from public sector transport and vehicle fleets; smooth driving and speed reduction; active travel; and awareness raising (health promotion and health education). Table 1 is a summary of the key interventions and the strength of the evidence regarding their effectiveness.

- The most cost-effective interventions were: integration of air quality in local planning decisions; low emission zones (restriction of heaviest polluting vehicles); changing to emission-controlled diesel or compressed natural gas; driver training to address driving style (reduce idling); smoothing traffic flows through speed reductions; and specific interventions to support active travel.

- Promotion of behaviour change to support improved air quality, should focus on: explaining what air pollution is; advice on how people can protect themselves; explanation of the health impacts; keep it local; promote understanding of how individuals can make a difference; and empower communities and promote leadership.

- It is important that action is not limited to air pollution hot spots alone. Air pollutants and their sources are mobile so actions in one area may affect another – it is important not to simply move the problem to another community.
<table>
<thead>
<tr>
<th>Category</th>
<th>Intervention</th>
<th>Effectiveness</th>
<th>Cost-effectiveness</th>
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<tr>
<td>Planning</td>
<td>Include air pollution in local planning</td>
<td>Green</td>
<td>Green</td>
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<td></td>
<td>Road side barriers</td>
<td>Red</td>
<td>Red</td>
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<td></td>
<td>Street vegetation</td>
<td>Yellow</td>
<td>Yellow</td>
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<td></td>
<td>Bypass construction</td>
<td>Red</td>
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<td>Clean air and congestion charging zones</td>
<td>Low emission zones restricting certain classes of vehicle</td>
<td>Yellow</td>
<td>Yellow</td>
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<td></td>
<td>Infrastructure supporting use of zero and low-emission travel (e.g. charging</td>
<td>Green</td>
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<td></td>
<td>points)</td>
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<td>Reducing emissions from public sector transport</td>
<td>Changing to emission-controlled diesel or compressed natural gas</td>
<td>Yellow</td>
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<td>services and vehicle fleets</td>
<td>Driver training to address driving style (reduce idling)</td>
<td>Yellow</td>
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<td>Amending bus routes to reduce stop-starting</td>
<td>Red</td>
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<td>Smooth driving and speed reduction</td>
<td>Individual traffic-calming measures</td>
<td>Red</td>
<td>Red</td>
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<td></td>
<td>Smoothing traffic flows through speed reductions</td>
<td>Green</td>
<td>Green</td>
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<tr>
<td>Active travel</td>
<td>Provide a choice of cycle routes including routes avoiding highly polluted</td>
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<td>roads</td>
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<td></td>
<td>Separate cycle routes from motor traffic and reduce time spent by cyclists</td>
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<td>in areas of high pollution</td>
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<td>Raising public awareness</td>
<td>Providing evidence to the public</td>
<td>Yellow</td>
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<td>Providing information to businesses</td>
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<tr>
<td></td>
<td>Providing information to health professionals</td>
<td>Yellow</td>
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- A red traffic light means this is not an effective/cost-effective intervention.
- An amber traffic light means the evidence is mixed, or that this may be an effective intervention but only in specific local circumstances.
- A green traffic light means that evidence suggests this is an effective/cost-effective intervention.
Multi-stakeholder Workshop on Air Quality and Health

The Air Quality and Health impact assessment workshop was held on the 16th January 2018. The workshop aim was to review the relationship between air quality and health in Gloucestershire, in aid of developing approaches to improve local air quality and its impact on the population’s health. 55 delegates attended from a variety of organisations and professions across Gloucestershire to provide a range of expertise and local knowledge. Attendees included individuals from Active Gloucestershire; NHS Gloucestershire Clinical Commissioning Group; District Councils; Gloucestershire County Council; Gloucestershire wildlife trust; Gloucestershire Local Enterprise Partnership; Public Health England; Highways England; Stagecoach; and University of Gloucestershire.

The workshop was opened by the Chair of the Air Quality Member task group, Jeremy Hilton, and Nigel Riglar, Gloucestershire County Council Commissioning Director for Communities & Infrastructure. Attendees heard from Dr Adrian Davis, an independent consultant on public health and transport, before taking part in group discussion sessions to explore key themes. The event closed with Sarah Scott, Gloucestershire County Council Director of Public Health, summarising key feedback from the discussions.

Workshop participants highlighted key areas for prioritisation in Gloucestershire, including:

- Need for Leadership and Vision
- Importance of partnership and collaboration in moving forward positively
- Clean and accessible public transport
- Strengthening of planning and transport policy
- Need to engage and educate the public on air quality and health in Gloucestershire
- Promotion of walking and cycling as a viable alternative to private cars
- Support for increased use of electric vehicles
- Improvements in monitoring and information sharing of air quality in Gloucestershire
- Public sector and contractors to lead by example in terms of ‘cleaner’ fleets

A summary of the workshop outputs is provided in the section on ‘Multi-stakeholder Workshop on Air Quality and Health’ on page 36.

Recommendations from Air Quality and Health System Impact Assessment

The recommendations from the air quality and health system impact assessment are based on a review of the outputs from the process: evidence of relationship between air quality and health; data and epidemiology review for Gloucestershire; evidence review of intervention to improve air quality and/or mitigate its impact on health; and the outputs from the multi-stakeholder workshop.

Summaries of the sections from the health and system impact assessment were reviewed by a small group of officers from different departments in Gloucestershire County Council to agree key recommendations. The key recommendations respond to the issues and evidence raised in the health and system impact assessment. The following provides a short summary of the recommendations:
Define a Gloucestershire strategy for air quality and health
A strategy on air quality and health should be developed in the next 12 months by public and private bodies in a partnership approach. The County Council should facilitate a system wide approach through community leadership.

Develop a model for partnership and collaboration to develop and oversee the agenda
A model of partnership across private and public bodies needs to be established in the next six months to drive the development and delivery of the agenda, including the Gloucestershire strategy, for air quality and health in Gloucestershire. This group should report into the Gloucestershire Health and Wellbeing Board on strategy development and implementation.

Promote clean and accessible public transport
A review of interventions to accelerate the uptake of cleaner vehicles for public transport and taxis should be carried out, including the role of licensing policies and additional infrastructure requirements. The review group should also review accessibility to public transport and the specification of transport contracts. Recommendations should be made in respect of licensing policies and the specification of council-funded transport services.

Strengthen air quality, health and active transport in planning and transport policies
Planning and transport policies - and their operational use - at a local and county level should be reviewed, and frameworks developed to incorporate consideration of air quality and active travel into larger development proposals and highway schemes.

The Gloucestershire Local Transport Plan review should give greater recognition to the impact of transport on air quality and public health and set more ambitious targets for raising the proportion of trips made by sustainable and active travel.

Engage and educate the public on air quality and health
A campaign should be developed to make the public aware of the issue of air quality and health in Gloucestershire, and the positive actions that they can take to protect themselves and help to improve air quality. The promotion and engagement of the public on air quality and health should be targeted across the life course: schools; children/teenagers; working age adults; the elderly; hard to reach groups.

Promotion of active travel and interventions to facilitate its uptake
A programme of work should be established to promote the uptake of active travel in Gloucestershire. This work should engage the public, businesses, public sector, and schools in actions to improve active travel uptake. It should consider affordable ways of piloting 20mph zones and making changes to promote smoother traffic flow. This programme of work should link with other public health work which is already focusing on behaviour change to improve activity levels. e.g. Gloucestershire Moves.

Support the uptake of electric vehicle use
A group should be set up to explore opportunities to promote uptake of electric vehicles for both business and private use to coincide with investment to improve electric charging infrastructure. The group should also review options to incentivise electric vehicle uptake.
Improve monitoring and information sharing of air quality in Gloucestershire
A sub-group of the strategy group should be established to review deployment of air quality monitoring equipment to help improve understanding of air quality in Gloucestershire. The group should also make recommendations as to how air quality monitoring information can be shared with the general public in Gloucestershire so they can engage and respond to it in a timely way.

Review public sector fleet/contractor fleets to reduce emissions
Local public sector bodies should review their current in-house vehicle fleets and develop fleet replacement plans to make these cleaner. A group of public sector bodies should also review contracting arrangements with providers to understand how these can be used as a tool to reduce emissions from external contractors’ fleets.
Introduction to Air Quality and Health

Introduction

Air quality and health impact assessment
This review provides a summary overview of air quality and health in support of a Gloucestershire health impact assessment. A Health Impact Assessment (HIA) describes a systematic approach to understanding the impacts and opportunities in a project or proposal. This methodology is being used to help direct the development of a Gloucestershire wide approach to air quality and the impacts on the health of our population. The HIA will support:

- exploration of the issue of air quality including its impact on health in Gloucestershire
- review and summary of the evidence base regarding actions that can be taken to improve air quality and reduce its impact on the health of the population of Gloucestershire
- prioritise actions to take forward and to build consensus

The HIA requires a multi-stakeholder approach to ensure solutions are prioritised which will work for Gloucestershire, and to build support for taking a programme of work forward. The end result of the HIA is an evidence based work programme which has wide stakeholder support.

Scope of the review
This review forms part of the HIA. It provides broad background information for participants of the air quality and health workshop. It aims to give participants some basic information on the subject area, and to highlight the relevant evidence base.

The review summarises evidence of the relationship between air quality and health, and the interventions to improve air quality or mitigate its impact on health at the local level. There is also a review of the data on air quality in Gloucestershire, relevant health outcomes, and associated information including levels of active travel.

Whilst there are many types of air pollution, this review focuses on: particulate matter and nitrogen dioxide. These are the two principle pollutants affecting the health of the local population, and which are amenable to action at the local level.

What is Air Quality?
Air quality is a measure of the degree to which the surrounding air in a given location is pollution free from any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. The main sources of poor air quality in the UK are generated from transport, power generation and industrial combustion. The key air pollutants which are contribute to poor air quality are Nitrogen Dioxide ($NO_2$), Particulate Matter ($PM_{2.5}$, $PM_{10}$), Carbon Monoxide (CO), Carbon Dioxide (CO$_2$), Sulphur Dioxide (SO$_2$) and Low Level Ozone (O$_3$). At the local level, in the context of Gloucestershire, the key sources of poor air quality are nitrogen dioxide and particulate matter. These are also the most amenable to action at the local level, stemming principally from transport.

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Particulate matter describes pollution which is a mixture of solid particles and liquid droplets. PM$_{10}$s and PM$_{2.5}$s (particles less than 10 and 2.5 micrometers in diameter respectively) are of most interest as they are fine inhalable particles which can be absorbed into the lung tissue, and for the smallest particles, into the bloodstream. Nitrogen Dioxide (NO$_2$) is the most notable of a group of gases referred to as nitrogen oxides (NO$_x$), in terms of its impact on health. Nitrogen oxide is currently the main pollutant monitored in reference to air quality. Particulate matter is currently not being routinely monitored at the local level, however is considered a fundamental element in poor air quality standards.

**Why is air quality and its impact on health important?**

This review covers in detail the relationship between air quality and health, and also summarises some of the potential impacts at the local level. The World health Organisation has described air quality as the greatest environmental threat facing the public’s health. In the United Kingdom poor air quality has been estimated to be responsible for as many as 40,000 premature deaths$^2$. Additionally, it is estimated that there is a cost in terms of health care use of £16bn. This does not include the cost through lost productivity, which is estimated to be £2.7bn$^3$.

**Policy and guidance**

**Gloucestershire**

Through the Local Air Quality Management Policy Guidance local authorities have a duty to investigate the levels of pollution within their area, with the most obvious method being to directly measure the levels of pollutant. If a monitoring area is likely to, or has breached the European commission air quality standards, the local authority has a legal obligation to declare an Air Quality Management area (AQMA). Local authorities are then required to produce an air quality action plan detailing the measures put in place to reduce pollution.

**National UK**

In 2017, the UK Government released an updated air quality plan/policy with a focus on nitrogen dioxide (NO$_2$) emissions. This highlights where the UK is performing below our EU objectives, and sets out the approach to reduce emission levels in 29 of the 37 town and cities with non-compliant AQMAs to within statutory limits “in the soonest time possible”. Some of the key elements of the strategy include: development of clean air zones (for concentrated efforts); reduction of emissions from the current road transport; acceleration of road vehicle fleet turnover to cleaner vehicles; reduction of emissions from other forms of transport; reduction of industry emissions; and reduction of emissions from buildings and other stationary sources.

**Role of Local Authorities**

Local authorities have a target to reduce local levels of NO$_2$ to comply with the European Commission air quality objectives. Unlike climate change gases NO$_2$ pollution is local. The Local Authority controls several of the levers for improving air quality such as planning and transportation. They also have close partnerships with local stakeholders which are critical to help drive forward local positive actions. In 2017 the UK Government released a national framework with direction for


$^3$ Department for Environment, Food and Rural Affairs (2014), Valuing the Impacts of Air Quality on Productivity, DEFRA
local authorities, and additional financial support, together with national level initiatives aimed at reducing emissions.
Relationship between air quality and health: summary of the evidence

Overview of approach to evidence review

This review summarises evidence of the relationship between air quality and health, with the aim to describe the nature and extent of the impact of poor air quality on the health of people. The review focuses on two areas of air pollution which are particularly relevant to action at the local level, and where the highest related burden of disease is estimated: particulate matter; and nitrogen dioxide. The review draws mainly from other reviews of published evidence on the impacts of these pollutants on human health: The Lancet Commission on Pollution and Health (2017); Royal College of Physicians report: Every breath we take - the lifelong impact of air pollution (2016); DEFRA, PHE, and LGA report: Air quality – a briefing for Directors of Public Health (2017); the Committee on medical effects of air pollutants – statement on the evidence for the effects of nitrogen dioxide on health (2015); and World Health Organisation: Review of evidence on health aspects of air pollution – REVIHAAP (2013). The review also references individual studies to evidence specific points, most of which are contained in the comprehensive reviews listed before.
Impact of poor air quality

Impact of poor air quality on disease and life expectancy

There is a strong and improving evidence base of the impact of poor air quality on health in terms of the burden of disease and associated mortality. Estimates are normally based on the impact of PM$_{2.5}$ (less than 2.5 micrometers in diameter) and/or nitrogen dioxide. The strongest evidence of impact comes from studies regarding PM$_{2.5}$, but evidence reviews are also suggestive of an independent impact from nitrogen dioxide$^{4,5,6}$. The Royal College of Physicians (2016) estimates the combined premature mortality from poor air quality at 40,000 deaths in the UK annually. Other estimates, suggest that there are 29,000 deaths from particulate matter pollution alone, with 340,000 life years lost annually$^{7}$.

There is no safe level of PM$_{2.5}$ or NO$_x$. At all levels of exposure, both short and long term, there is a negative impact on a population’s health and life expectancy$^4$. Air quality meeting the target levels set by the European Union for PM$_{2.5}$ and NO$_x$ will still have a measurable impact on the health outcomes for a population.

There is good evidence for a relationship between short and long term exposure to poor air quality and the development of cardiovascular and pulmonary conditions, as well as some cancers$^{3,4,5,7}$. There is also an emerging evidence base for a relationship between poor air quality (mainly related to PM$_{2.5}$) and the development of conditions of the central nervous system, and childhood developmental outcomes$^{4,5}$.

Poor air quality impact on health and social care

The association between exposure to poor air quality and the development of pulmonary and cardiovascular disease results in reliance on health and social care support much earlier than would otherwise have been needed$^8,^4$. This results in a substantial additional strain on health and social care resources, both in acute response, and providing care for conditions over many years. This results in a substantial resource burden on health and social care services (both publically and privately funded) over many years.

Poor air quality relationship with other health stressors

It is important that poor air quality is not viewed in isolation. It is a stressor on the health of a population, which interacts with other stressors, having a multiplying or co-determinant effect$^7,^4$. It may create susceptibility to disease in some populations, or help to accelerate the impact from other factors. It is also a source of inequality in populations, where those who are the most deprived are also the most likely to live in areas with the highest levels of exposure, and thus endure the worst

outcomes in a society, even though they may not themselves be substantial contributors to poor air quality \(^7,^{9,10}\).

**Particulate matter and health**

**Particulate matter and its impact on health**

PM\(_{2.5}\) is the most studied form of air pollution, and has the strongest evidence base for causality of premature mortality and poor health \(^7,\,^5,\,^6,\,^4\). PM\(_{2.5}\) can be inhaled deep into the lung causing damage to the tissue, and the finest of these particles (PM\(_{0.1}\)) can pass directly into a person’s bloodstream \(^7,\,^5,\,^6,\,^4\), which can have a direct impact on a person’s cardiovascular health. There is strong evidence of an independent link between exposure to PM\(_{2.5}\) and poor cardiovascular and pulmonary health \(^7,\,^5,\,^6,\,^4\), which in turn negatively impacts a person’s length and quality of life.

The health impacts from PM\(_{2.5}\) can be divided into the effects from long term and short term exposure \(^7,\,^4,\,^5,\,^6,\,^{11}\). For short term exposures (ranging from hours to a few weeks), there is a strong relationship to the exacerbation of pre-existing respiratory conditions, particularly for asthma and chronic bronchitis. As a consequence there is a subsequent relationship with use of healthcare resources such as emergency admissions for these conditions. There is also strong relationship between short term exposures and myocardial infarction (heart attack) and myocardial ischemia (restriction of blood to the heart). Again, there is a subsequent relationship with increased healthcare use. Studies have also shown increased incidence of arrhythmias (irregular heart beat) and stroke.

For longer term exposures (months to years) studies have shown an increased risk of coronary events including myocardial infarction and angina\(^{12}\), and a potentially related prevalence of atherosclerosis (build-up of plaque on inside of arteries). There has also been a strong relationship between long term exposure to PM\(_{2.5}\) and prevalence of chronic obstructive pulmonary disease\(^{13}\).

There is an emerging evidence base, which is suggestive of a relationship between long term exposure to PM\(_{2.5}\) and poor childhood development and the development of conditions of the central nervous system such as Parkinson’s disease and Alzheimer’s.\(^4\)

**Particulate matter mechanisms of impact**

There are several mechanisms by which exposure to particulate matter causes poor health. Inhalation of the particles deep into lung tissue, and the damage and deterioration of the tissue has an impact of the development of pulmonary disease. Evidence suggests this occurs through a variety of mechanisms, including inflammatory response and oxidization due to free radical production,


\(^{12}\) Chest pain/pressure, normally due to obstruction or spasm of the coronary arteries

\(^{13}\) Term for a group of conditions which cause long term breathing difficulties. It includes emphysema and chronic bronchitis.
both of which cause damage to the lung tissue\footnote{Xing, Y., Xu, Y., Shin, M. and Lian, Y. (2018). The impact of PM2.5 on the human respiratory system. Journal of Thoracic Disease, [online] (E69–E74). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4740125/}. Much of the cardiovascular disease associated with PM$_{2.5}$ is believed to stem from a build up of plaque in the arteries which leads to narrowing and restriction of blood flow\footnote{The inner lining of the blood vessel whose function helps ensure proper blood flow to and from the heart}. There is a related increase in oxidative stress, endothelial\footnote{United States Environmental Protection Agency. "Integrated Science Assessment for Oxides of Nitrogen – Health Criteria." 2015} dysfunction, and increased propensity for blood to coagulate. These are interrelated consequences which are believed to be the key mechanisms leading to cardiovascular disease.

**Nitrogen dioxide and health**

**Nitrogen dioxide and its impact on health**

There is a growing evidence base for an independent impact from NO$_2$ on the development of poorer health outcomes and life expectancy\footnote{The evidence base is strongest for short term exposures and particularly the respiratory impacts. Short term exposure to NO$_2$ (from less than 1 hour to several days or weeks) shows a strong positive relationship to prevalence of respiratory conditions, particularly asthma in children, and associated exacerbation of respiratory conditions (strongest in asthmatics). There is also evidence of a relationship to prevalence of cardiovascular disease and outcomes, although this is not sufficient to infer causality\footnote{Faustini, A, R Rapp and F Forastiere. "Nitrogen dioxide and mortality: review and meta-analysis of long-term studies." Eur Respir J (2014): 744-753.}.\footnote{Devalia, J, et al. "Effect of nitrogen dioxide on synthesis of inflammatory cytokines expressed by human bronchial epithelial cells in vitro." Am J Respir Cell Mol Biol. (1993): 271–278} COMEAP’s (2015) review of the evidence base concludes that it is reasonable to say that NO$_2$ has an independent impact on health outcomes. A systematic review and meta-analysis suggests that the mortality from long term exposure to NO$_2$ is likely to be on a similar scale to PM$_{2.5}$\footnote{Blomberg, A and et al. "The inflammatory effects of 2 ppm NO2 on the airways of healthy subjects." American Journal of Respiratory and Critical Care Medicine (1997): 418-42}.

Air quality and health data in Gloucestershire

Air quality data for Gloucestershire

Modelled data
DEFRA assesses air quality in the UK through a combination of monitoring and modelling. DEFRA has no monitoring sites in Gloucestershire so relies on modelling data which uses information about local sources of pollution and infrastructure to estimate levels of pollution.

Current WHO Air Quality Guidelines levels for PM2.5 are set at 10 ug m\(^{-3}\). DEFRA estimates that in 2015 the total annual mean PM2.5 concentration in Gloucestershire was below this level at 8.9 ug m\(^{-3}\). Gloucestershire was also below the national average of 9.4 ug m\(^{-3}\) and in line with the regional average of 8.8 ug m\(^{-3}\).

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22 Oxidative stress is caused when antioxidant defenses in the body are not sufficient to counteract the free radicals produced in the body. Free radicals can damage cells.

24 WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, World Health Organisation [http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf](http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf)
The estimates suggest within Gloucestershire levels of PM2.5 are highest in Cheltenham and Tewkesbury where they exceed regional averages.

Figure 2: Population weighted annual mean PM2.5 concentration, Gloucestershire and its districts

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25 Modelled Background Pollution Data, Defra [https://uk-air.defra.gov.uk/data/pcm-data](https://uk-air.defra.gov.uk/data/pcm-data)
26 Ibid.
DEFRA also produces estimates of anthropogenic (originating from human activity) PM2.5, this is because estimates based on total PM$_{2.5}$ might give a misleading impression of the scale of the potential influence of policy interventions. The estimates of anthropogenic PM2.5 suggest that Gloucestershire in line with national averages and similar to the South West.

![Population weighted annual mean anthropogenic PM 2.5 concentration, Gloucestershire and its statistical neighbours, 2015](image)

**Figure 3: Population weighted annual mean anthropogenic PM 2.5 concentration, Gloucestershire and its statistical neighbours**

At district level Cheltenham and Tewkesbury had the highest levels of anthropogenic PM 2.5, with Gloucester also exceeding regional averages.

---

27 Ibid.
Estimates of particulate matter PM10 and nitrogen dioxide are also available for small areas (Lower Super Output Areas\(^29\)). Figure 5 shows that in terms of PM10, levels are estimated to be at their highest in the Churchdown and Ashchurch areas of Tewkesbury and the west of Cheltenham.

\(^{28}\) Ibid.
\(^{29}\) These are small areas based on Census 2011, and contain an average of 1,600 people.
Figure 5: Modelled estimates of Particulate Matter (PM10)\(^{30}\)

Figure 6 shows that in terms of Nitrogen Dioxide, levels are estimated to be at their highest in North Gloucester, Cheltenham and around Gloucestershire Airport. The current WHO Air Quality Guidelines levels for Nitrogen Dioxide are set at 40 ugm-3 meaning all Lower Super Output Areas in Gloucestershire meet recommended levels.

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\(^{30}\) CDRC https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah
Monitoring air quality in Gloucestershire

All Districts and Borough councils measure a background nitrogen dioxide level, which provides a general indicator of pollution levels at particular sites. Within Gloucestershire there are around 170 monitoring sites (in some cases there are multiple monitoring sites in one location). There were 16 sites across the county that exceed the WHO recommendations. The majority of these sites (11 of the 16) were located in Cheltenham district, 4 were located in Gloucester with the remaining site located in Cotswold at the Air Balloon Roundabout.
Air Quality Management Areas

The aim of air quality monitoring is to ensure that national air quality targets are achieved. When a local authority finds areas where the objectives are not likely to be achieved, it must declare an Air Quality Management Area (AQMA) there. This area must be defined geographically however it could be just one or two streets, or it could be much bigger. The local authority must also develop a plan with remedial actions to bring pollution exceedance to within statutory levels.

There are 8 AQMAs across Gloucestershire, where monitoring shows the sites do not meet the EU air quality objective for nitrogen dioxide. The majority of AQMAs are located in major urban areas or in the case of Cotswold at a major road junction (the Air Balloon junction, Birdlip) due to high vehicle emissions.

---

32 Sourced from district councils
Table 1: AQMAs in Gloucestershire

<table>
<thead>
<tr>
<th>Local Authority</th>
<th>AQMA Name</th>
<th>Pollutants</th>
<th>Date Declared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheltenham Borough Council</td>
<td>Cheltenham Whole Borough AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>18/11/2011</td>
</tr>
<tr>
<td>Cotswold District Council</td>
<td>Birdlip AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>08/04/2008</td>
</tr>
<tr>
<td>Cotswold District Council</td>
<td>Thames Street, Lechlade</td>
<td>Nitrogen dioxide NO₂</td>
<td>02/04/2014</td>
</tr>
<tr>
<td>Forest of Dean District Council</td>
<td>Lydney AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>01/07/2010</td>
</tr>
<tr>
<td>Gloucester City Council</td>
<td>Barton Street AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>08/08/2005</td>
</tr>
<tr>
<td>Gloucester City Council</td>
<td>Priory Road AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>08/08/2005</td>
</tr>
<tr>
<td>Gloucester City Council</td>
<td>Painswick Road AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>05/10/2007</td>
</tr>
<tr>
<td>Tewkesbury Borough Council</td>
<td>Tewkesbury Town Centre AQMA</td>
<td>Nitrogen dioxide NO₂</td>
<td>05/12/2008</td>
</tr>
</tbody>
</table>

Air quality and health in Gloucestershire

Exposure to poor air quality contributes to premature mortality. Based on national modelled data applied to Gloucestershire (not adjusted for attributes of Gloucestershire and the local population) exposure to particulate matter air pollution is estimated to contribute (as one of a number of factors) to around 278 deaths a year, representing a annually loss of 2,848 life years. These estimates are based on the research evidence of mortality risk, combined with modelled levels of the background air pollution to which populations are exposed at local authority level.

Table 2: Local mortality burdens associated with particulate air pollution

<table>
<thead>
<tr>
<th>Local Authority</th>
<th>Attributable deaths</th>
<th>Associated life years lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheltenham</td>
<td>55</td>
<td>579</td>
</tr>
<tr>
<td>Cotswold</td>
<td>42</td>
<td>405</td>
</tr>
<tr>
<td>Forest of Dean</td>
<td>37</td>
<td>368</td>
</tr>
<tr>
<td>Gloucester</td>
<td>52</td>
<td>575</td>
</tr>
<tr>
<td>Stroud</td>
<td>53</td>
<td>497</td>
</tr>
<tr>
<td>Tewkesbury</td>
<td>39</td>
<td>424</td>
</tr>
<tr>
<td>Gloucestershire</td>
<td>278</td>
<td>2,848</td>
</tr>
<tr>
<td>England</td>
<td>25,002</td>
<td>264,749</td>
</tr>
</tbody>
</table>

---

33 AQMAs, DEFRA  
34 Ibid.  
35 Attributable deaths- long term exposure to anthropogenic particulate air pollution is estimated to have an effect on mortality risks equivalent to the number of attributable deaths. Air pollution is likely to contribute a small amount to the deaths of a larger number of exposed individuals rather than being solely responsible for the number of deaths equivalent to the calculated figure  
36 Associated life years lost - the years of life lost to the population due to increased mortality risk attributable to long term exposure to particulate air pollution
Table 3 presents a comparison of deaths attributable to some other key risk factors in Gloucestershire. It is important to note that unlike the other indicators that are based on recorded mortality data for specific causes of death, the figures for air pollution are estimates of mortality attributable to a risk factor. Deaths are not individually attributed to air pollution, rather, air pollution is considered to be a contributory factor in many deaths.

Table 3: Ranking of PHOF mortality indicator for Gloucestershire, 2014-16 and 2015 for indicator 3.01

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Mortality rate per 100,000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventable mortality (4.03)</td>
<td>167.5</td>
</tr>
<tr>
<td>Preventable cancer &lt;75 (4.05ii)</td>
<td>68.4</td>
</tr>
<tr>
<td>Preventable CVD &lt;75 (4.04ii)</td>
<td>43.5</td>
</tr>
<tr>
<td>Preventable Respiratory disease &lt;75 (4.07ii)</td>
<td>15.3</td>
</tr>
<tr>
<td>Preventable Liver disease &lt;75 (4.06ii)</td>
<td>13.9</td>
</tr>
<tr>
<td><strong>Mortality attributable to PM$_{2.5}$ &lt;75 (3.01)</strong></td>
<td><strong>13.2</strong></td>
</tr>
<tr>
<td>Suicide rate Persons (4.10)</td>
<td>10.6</td>
</tr>
<tr>
<td>Communicable diseases (4.08)</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Air pollution affects daily quality of life as it can exacerbate lung conditions such as Chronic Obstructive Pulmonary Disease (COPD) and asthma, resulting in increased use of medications and hospital admissions. In 2016/17 reported asthma prevalence in Gloucestershire (from primary care registers through the Quality Outcome Framework (QOF)) was 6.6% of the local population equating to around 42,300 people. Asthma prevalence in Gloucestershire was higher than the national average of 5.9%. In 2012/13 there were 517 hospital admissions for asthma. This equates to a rate of 0.84 per 1,000 population which was lower than the national rate of 1.21 per 1,000 population. Hospital admissions for asthma in people aged less than 19 years was 157.6 per 100,000 in 2015/16 which equates to 212 admissions. The rate is lower than the national average of 198.6.

In 2016 there were estimated to be approximately 11,370 people in Gloucestershire with chronic obstructive pulmonary disease (COPD) (from primary care registers through the Quality Outcome Framework (QOF)), this equates to a prevalence 1.8% in which was lower than the national average of 1.9%. However, the local estimate is likely to be very conservative given the high number of undiagnosed COPD sufferers. Gloucestershire had a lower rate of emergency hospital admissions for COPD (292 per 100,000) than the England average (411 per 100,000) in 2015/16, this equates to 1,121 admissions. At district level Cotswold (180.3 per 100,000), Forest of Dean (253.7 per 100,000)

38 Royal College of Physicians. Every Breath We Take: The Lifelong Impact of Air Pollution.; 2016.
39 GP Practice Profiles, Public Health England
40 Public Health Profiles
41 Ibid.
42 GP Practice Profiles, Public Health England.
and Stroud (226 per 100,000) have better rates of hospital admissions for COPD than Gloucestershire, Cheltenham (348 per 100,000) and Gloucester (254 per 100,000) had worse rates, while Tewkesbury have a similar rate (267 per 100,000).

**Air quality and vulnerable populations in Gloucestershire**

The effects of air pollution are distributed unequally across the population. The more urban and congested areas have higher levels of pollution, as do areas near arterial and trunk roads. This, therefore, impacts on the health of those that live and work next to these areas.

**Deprivation**

Studies have suggested that the most deprived areas bear a disproportionate share of poor air quality. Within Gloucestershire there are 9 Lower Super Output Areas that contain monitoring sites that exceed the target levels for Nitrogen Dioxide, of these 2 are in the most deprived 20% areas. In Gloucestershire Lower Super Output Areas in the most deprived 20% of the country account for 22% of LSOA’s that exceed recommended levels and only 8% of the total LSOAs. This suggests that deprived populations in Gloucestershire bear a disproportionate impact of air pollution.

**Table 4: Deprivation and monitoring sites that exceed the recommended level for Nitrogen Dioxide**

<table>
<thead>
<tr>
<th></th>
<th>LSOAs that have monitoring sites that exceed the recommended levels for Nitrogen Dioxide</th>
<th>Total LSOAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quintile 1 (most deprived 20% of the country)</td>
<td>22.2%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Quintile 2</td>
<td>33.3%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Quintile 3</td>
<td>22.2%</td>
<td>23.9%</td>
</tr>
<tr>
<td>Quintile 4</td>
<td>11.1%</td>
<td>23.9%</td>
</tr>
<tr>
<td>Quintile 5 (least deprived 20% of the country)</td>
<td>11.1%</td>
<td>32.2%</td>
</tr>
</tbody>
</table>

Additionally, the most deprived 20% of LSOAs had higher air pollution levels than the least deprived neighbourhoods, with a difference of 1.4 ugm/3 in terms of nitrogen dioxide.

**Table 5: Estimated Nitrogen Dioxide by deprivation quintile**

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen Dioxide average annual mean (ugm/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quintile 1 (most deprived 20% of the country)</td>
<td>9.6</td>
</tr>
<tr>
<td>Quintile 2</td>
<td>8.7</td>
</tr>
<tr>
<td>Quintile 3</td>
<td>7.7</td>
</tr>
<tr>
<td>Quintile 4</td>
<td>7.6</td>
</tr>
<tr>
<td>Quintile 5 (least deprived 20% of the country)</td>
<td>8.2</td>
</tr>
</tbody>
</table>

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43 Public Health Profiles  
44 Index of Multiple Deprivation 2015, DCLG and data sourced from districts  
45 Index of Multiple Deprivation 2016, DCLG and CDRC [https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah](https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah)
Car ownership
Evidence suggests “communities that have access to fewest cars tend to suffer from the highest levels of air pollution, whereas those in which car ownership is greatest enjoy the cleanest air” and “Those communities that are most polluted and which also emit the least pollution tend to be amongst the poorest in Britain”\textsuperscript{46}. This is linked to the fact that in many places poor housing stock is located close to busy road networks, and occupied by more deprived communities.

Within Gloucestershire there are 65 (17.4\%) Lower Super Output Areas that have lower levels of car ownership than the national average. Of these areas 8 (89\% of all monitoring sites) have monitoring sites that exceed the recommended levels of nitrogen dioxide. The modelled estimates show that in areas where car ownership is lower than national levels, pollution levels (from NO\textsubscript{2}) are higher.

Table 6: Estimated Nitrogen Dioxide by car ownership\textsuperscript{47}

<table>
<thead>
<tr>
<th>Nitrogen Dioxide average annual mean (ugm/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher level of car ownership than nationally</td>
</tr>
<tr>
<td>Lower level of car ownership than nationally</td>
</tr>
</tbody>
</table>

Age
Children tend to be more likely to live in areas where air pollution is high\textsuperscript{48}, and also suffer some of the worst consequences. Table 7 shows levels of nitrogen dioxide are higher in areas in Gloucestershire that have a higher proportion of children (compared to national data), conversely levels of nitrogen dioxide are lower in areas that have a higher proportion of people aged 20+.

Table 7: Estimated Nitrogen Dioxide by age\textsuperscript{49}

<table>
<thead>
<tr>
<th>Nitrogen Dioxide average annual mean (ugm/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher % 0-4 year olds than nationally</td>
</tr>
<tr>
<td>Lower % of 0-4 year olds than nationally</td>
</tr>
<tr>
<td>Higher % 5-19 year olds than nationally</td>
</tr>
<tr>
<td>Lower % of 5-19 year olds than nationally</td>
</tr>
<tr>
<td>Higher % 5-19 year olds than nationally</td>
</tr>
<tr>
<td>Lower % of 5-19 year olds than nationally</td>
</tr>
</tbody>
</table>

\textsuperscript{47} 2011 Census and CDRC https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah
\textsuperscript{48} Fecht, D. et al Associations between air pollution and socioeconomic characteristics, ethnicity and age profile of neighbourhoods in England and the Netherlands. Environmental Pollution, 2015; 198: 201. A summary of the article is available at: http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_26-1-2015-12-17-52
\textsuperscript{49} 2016 Mid year estimates, ONS and CDRC https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah
Pre-existing conditions
People with pre-existing conditions are more susceptible to the health effects of air pollution, particularly pulmonary and cardiovascular disease. Those with long term conditions often require increased levels of support from social care over a much longer period of time than a ‘healthy’ person. Table shows levels of nitrogen dioxide are higher in areas where the rate of adult social care service users is higher than the county average.

Table 8: Estimated Nitrogen Dioxide by Adult Social Care Service Users

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen Dioxide average annual mean (ugm/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher rate of Adult Social Care Service Users than the county average</td>
<td>8.1</td>
</tr>
<tr>
<td>Lower rate of Adult Social Care Service Users than the county average</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Active travel in Gloucestershire

Walking and cycling
Switching journeys from cars to walking, cycling and public transport not only has a large beneficial impact on the individual’s health, but a wider benefit to the population health as there are corresponding decreases in overall air pollution levels. There are also subsequence impacts in term of health improvement from increased activity levels.

Figure 6 shows that in 2011 76% of people travelled to work by car, which was higher than the national average of 66%. The Forest of Dean had the highest proportion of residents travelling to work by car (84%) closely followed by Stroud (83%), conversely Cheltenham had the lowest proportion of residents travelling to work by car at 64%.

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50 GCC Data and Analysis Team and CDRC [https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah](https://data.cdrc.ac.uk/dataset/access-to-healthy-assets-and-hazards-ahah)
Those making short car trips are a prime target area for switching to active travel or public transport\textsuperscript{52}. Figure 7 shows that just over 50% commutes of less than 2km were made by bicycle or foot, while only 2.5% were made using public transport. This is much lower than the national average.

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\textsuperscript{51} 2011 Census, ONS
\textsuperscript{52} www.sustrans.org.uk/sites/default/files/images/files/publications/Short%20journeys%20big%20savings%202011%20AUG.pdf
Figure 7: Travel to work method for journeys less than 2km\textsuperscript{53}

\textsuperscript{53} Ibid.
Air Quality Interventions

This evidence review looks at the interventions to support improvements in air quality or to mitigate its impact on health. The review focuses on measures related to pollution from road traffic. The review uses a number of evidence resources, but draws most heavily on the NICE guidance relating to outdoor air quality and health.

The review of interventions is divided into sub-sections: planning (including transport planning); clean air and congestion charging zones; reducing emissions from public sector transport and vehicle fleets; smooth driving and speed reduction; active travel; and awareness raising (health promotion and health education). Table 9 is a summary of the key interventions and the strength of the evidence regarding their effectiveness and cost-effectiveness.

Table 9: Summary of interventions to improve air quality or mitigate the impact on health

<table>
<thead>
<tr>
<th>Category</th>
<th>Intervention</th>
<th>Effectiveness</th>
<th>Cost-effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Include air pollution in local planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Road side barriers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Street vegetation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bypass construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean air and congestion charging zones</td>
<td>Low emission zones restricting certain classes of vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infrastructure supporting use of zero and low-emission travel (e.g. charging points)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing emissions from public sector transport services and vehicle fleets</td>
<td>Changing to emission-controlled diesel or compressed natural gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Driver training to address driving style (reduce idling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amending bus routes to reduce stop-starting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth driving and speed reduction</td>
<td>Individual traffic-calming measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smoothing traffic flows through speed reductions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active travel</td>
<td>Provide a choice of cycle routes including routes avoiding highly polluted roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Separate cycle routes from motor traffic and reduce time spent by cyclists in areas of high pollution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raising public awareness</td>
<td>Providing evidence to the public</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Providing information to businesses

Providing information to health professionals

A red traffic light means this is not an effective/cost-effective intervention.

An amber traffic light means the evidence is mixed, or that this may be an effective intervention but only in specific local circumstances.

A green traffic light means that evidence suggests this is an effective/cost-effective intervention

Planning
Considering the impact of new buildings, facilities and estates, intervening at the planning stage is significantly more cost-effective than installing solutions retrospectively and so should be strongly considered. There is a good amount of evidence on planning to guide choice of interventions.

Methods of including air pollution in local planning
- Local plan and other strategic planning processes can include zero- and low-emission travel (cycling, walking, providing charge points for electric vehicles in workplaces, supporting car sharing schemes or car clubs)
- Site and design new buildings, facilities and estates to reduce the need for motorised travel
- Minimise exposure of vulnerable groups to air pollution by not siting buildings (including schools, nurseries and care homes) in areas where pollution levels will be high
- Site living accommodation away from road sides
- Avoid street and building configurations that encourage pollution to build up where people spend time (e.g. deep street canyons)

Street vegetation
Including landscape features such as trees and vegetation in open spaces or as “green” walls or roofs where this does not restrict ventilation is effective (evidence from one moderate quality and 2 low quality modelling studies). If vegetation does not interfere with airflow in a street canyon, e.g. green roofs or walls, then this may reduce air pollution. However this may be prohibitively expensive to install, depending on local circumstances. Street trees are unlikely to reduce air pollution in most street designs and could worsen it in some cases (for example if they reduce airflow).

Roadside barriers
This is complex and depends on a range of local factors. Structures such as buildings and other physical barriers will affect distribution of air pollutants (evidence from low quality studies). Solid noise barriers probably reduce air pollution in the immediate lee of the barrier but there are higher levels of pollution at some distance from the barrier. Impact on health will depend on the details of the dispersion of air pollution downwind from a roadside barrier and on where people live or spend time in relation to the barrier. Cost-effectiveness is uncertain due to data quality issues.

Bypass construction
There is only 1 low quality UK study so evidence around improving air quality is insufficient, and bypass construction is extremely expensive and applicable only in specific circumstances.
Benefits of including air quality in planning
- New developments do not exacerbate poor air quality or expose people to high levels of air pollution
- Reduced risk of inadvertent exposure of people to poor air quality from redistribution of pollution
- Appropriate use of trees to encourage deposition of air pollutants will also have benefits in reducing heat stress, providing shade and creating a more attractive environment

Potential harms of including air quality in planning
- Using trees in areas where they do reduce ventilation and so worsen air pollution
- Using barriers in a way that creates poorer air quality

Clean air zones
A Clean Air Zone “defines an area where targeted action is taken to improve air quality and resources are prioritised and coordinated in order to shape the urban environment in a way that delivers improved health benefits and supports economic growth.” There is a reasonable amount of evidence around use of clean air zones with over twenty five studies looking at the various aspects including low-emission zones, congestion charging zones, use of alternative fuels, traffic restrictions, changes to fuel used in public vehicle fleets, and driver training. All studies were of moderate or low quality.

Low-emission zones (LEZs)/Congestion charging
LEZs usually involve restrictions or charges on certain classes of vehicle (congestion charging). There is sufficient evidence (from 4 moderate-quality and 2 low-quality studies) to show reductions in pollution with low-emission zones, particularly with more stringent restrictions on vehicle classes.

While existing low-emission zones have only slightly improved air quality, this is partly due to failure of new technology to reduce individual vehicle emissions under real driving conditions, and partly due to limited scope of existing low-emission zones (classes of vehicles restricted and failure to address overall volume of traffic). Several studies of traffic restrictions suggest that vehicle restrictions or bans have little impact unless they restrict the volume of traffic substantially. It would be important to monitor outside the zone to identify whether traffic is moving elsewhere.

People living in more deprived areas are likely to be exposed to higher levels of air pollution and so could gain more from reductions; however they may be less likely to afford new vehicles and so might be disadvantaged by a charging scheme. This is also a potential impact of interventions designed to encourage low- and zero-emission travel, such as providing parking concessions for electric vehicles.

Main benefits from congestion charging schemes came from changes to traffic flow, travel time savings and reductions in road injuries rather than from air pollution savings.

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Large-scale schemes like city-wide clean air zones (that can include low emission zones) can be expensive to set up but can deliver substantial benefits. They also target a large population so the cost per head of the population is likely to be relatively low. After high set up costs, running costs are likely to be substantially lower and potentially covered by charges or fines. If ongoing income is then used for other activities to reduce air pollution then this is likely to encourage public support. Perceptions of charging schemes may be of income generation rather than reducing air pollution, or that restrictions may damage economic growth and activity and so emphasizing the public health benefit of the schemes would be important.

Evidence from Amsterdam suggested an annual cost of around £2 per head for the low-emission zone. A clean air zone involving a range of interventions (including promoting zero- and low-emission travel) might be more expensive but is likely to have an additive positive effect.

**Support for zero- and low-emission travel (including active travel)**
This may include providing electric charging points; encouraging walking and cycling; and developing integrated public transport networks based on low emission vehicles.

**Fuel-efficient driving initiatives**
These may include “no vehicle idling” areas, and driver training to improve driving style and reduce emissions and fuel consumption. Two low-quality studies from the US looked at anti-idling information campaigns for bus drivers and suggested they would probably be effective at reducing idling time but this is likely to have limited applicability in the UK where there isn’t the same culture of large fleets of school buses. Driver training to improve driving style is addressed in the next section.

**Benefits of clean air zones**
- Discouraging use of the most polluting vehicles by restricting their access to some areas, or by encouraging zero- or low-emission travel, will improve air quality
- Increased levels of physical activity from encouraging active travel
- Reduction in health inequalities by reducing vulnerable groups’ exposure to poor air quality

**Potential harms of clean air zones**
- Approaches covering only limited classes of vehicles or geographical areas may not reduce emissions sufficiently or may move pollution elsewhere
- People who depend on highly polluting vehicles or older vehicles that do not meet current emission standards may not be able to afford to replace them

**Reducing emissions from public sector transport services and vehicle fleets**

*Changing to emission-controlled diesel or compressed natural gas*
Some councils have retrofitted some or all of their vehicles to run on gas fuels (LPG, CNG or biogas) which emit as little as 1/30th of the particulate matter caused by diesel, and are cheaper to run as
fuel costs are less. Four modelling studies (all of low quality) showed potential for considerable improvements in air quality from fuel changes if the penetration of technologies is large enough.

**Driver training**

Several aspects of driving can be improved to reduce emissions including:

- reducing rapid accelerations and decelerations
- correcting gear selection to improve fuel consumption
- switching off engines when parked at roadside
- vehicle maintenance: particularly maintaining correct tyre pressure

There was expert advice given to the NICE committee that fuel consumption could be reduced by around 20-25% by adopting efficient driving techniques, with a realistic long-term reduction of 5-10% however no studies had been found.

Efficient driver training is likely to be cost saving. Training costs are estimated at a one-off cost of £25-£30 per driver with an annual fuel saving of around £96. Views of those receiving training are important in determining the potential for success. Two low quality studies looked at the impact of information and training on driver behaviour and suggested that it may help to reduce fuel consumption and time spent idling.

**Procuring public sector vehicles**

Considering low emissions as criteria in procurement decisions is likely to be an effective and cost-effective intervention. Changes to the vehicle fleet could be done as part of the usual turnover of vehicles. This recommendation was made by the NICE committee on the basis of expert advice.

**Amending bus routes to reduce stop-starting**

Amending bus routes to improve traffic flow and reduce stop-start driving did not have sufficient supporting evidence, and local factors would be particularly significant and this could involve considerable disruption.

**Benefits of reducing emissions from public sector vehicles**

- Increased knowledge about factors associated with fuel economy could result in lower fuel use and improved air quality
- Energy-efficient driving with fewer rapid accelerations and decelerations will improve fuel consumption and reduce wear and tear on vehicles, leading to financial benefits; it would also reduce road danger
- Training public sector staff may have the additional benefit of altering their driving habits outside work and making them a more general societal norm

**Smooth driving and speed reduction**

Interventions include:

- Speed limits and average speed technology on road side

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- 20mph limits without physical measures (to avoid unnecessary accelerations and decelerations) to reduce speeds in urban areas
- Signs that display a driver’s current speed to reduce unnecessary accelerations
- Physical traffic calming measures (e.g. speed bumps, pinch points)

Two studies (one moderate quality, one low) showed that speed limits and enforcement on urban motorways have a small positive effect on PM$_{10}$ and NO$_2$ with emission reduction depending on the impact of speed management on traffic dynamics. **The greater the reduction in congestion, the larger the reduction in emissions.** Where traffic flow is not improved by changes to the speed limit, it is unlikely that air quality would improve.

Economic modelling from Amsterdam suggested that reducing the speed limit from 100kph to 80kph on a section of motorway was highly cost effective at reducing air pollution (for every £1 invested they would expect £51 in economic benefits), depending on existing enforcement infrastructure and whether additional speed cameras are needed.

Evidence around 20mph speed limits in relation to vehicle emissions is complex. Principally 20mph speed limits have been becoming increasingly popular in the UK for their impact on road traffic accidents. A review for the London Borough of Hammersmith and Fulham$^{56}$, found evidence that in Germany when 30kmh zones were introduced in the 1980s, drivers changed gear 12% less often, braked 14% less often and required 12% less fuel. Results on emissions differ according to what is being measured – particulate emission (PM$_{10}$ and PM$_{2.5}$) is likely to be reduced while NO$_2$ and CO$_2$ levels are unlikely to be affected either way by speed reduction. If driving style is smooth, then it seems that 20mph speed limits are not likely to worsen emissions$^{57}$.

However, driving style with greater braking, acceleration, deceleration and gear changes is likely to increase emissions (especially particulate matter). A UK modelling study looked at 9 traffic calming measures including road humps, pinch points, raised junctions, chicanes and mini-roundabouts. While there were uncertainties about the modelling, this and two other low-quality studies did support an increase in emissions associated with individual traffic-calming measures, although these were not seen in area-wide traffic calming measures. Therefore 20mph speed limit zones without traffic calming measures, and aimed at improving traffic flow with smooth driving, seem most likely to provide benefit.

A modelling study suggested substantial benefits are possible from changes to the behaviour of a relatively small number of drivers, using wireless technology to identify optimum speed. Although this is not implementable at the moment, due to a lack of necessary technology in vehicles, a similar effect could be obtained by the expansion of variable speed limit control using signs outside the vehicle.

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Benefits of traffic calming and speed reduction
- Reducing stop-go driving will lower emissions of air pollutants from accelerations and decelerations, lowering exposure of the population to poor air quality
- Reduced speeds in urban areas encourages walking and cycling (as cars travelling at high speeds will discourage these modes of active travel) which would reduce emissions of air pollutants
- Reducing speed will reduce the number and severity of road injuries.

Potential harms of traffic calming and speed reduction
- Individual traffic-calming measures may increase rapid acceleration and deceleration driving and so increase emissions
- On major roads where there are very few (or no) route choices the cost of using average speed cameras is likely to be small. However in areas like residential streets while there are possible benefits, implementation will be much more difficult due to the number of route options. Other measures (such as signs indicating current speed) may be more useful.

Walking and cycling
Supporting active travel (walking and cycling) is potentially a highly effective and cost-effective intervention with multiple knock-on benefits to health.

Interventions which support cycling include:
- Providing a choice of cycle routes including routes avoiding highly polluted roads and, if this is not possible, separating cycle routes from motor traffic and reducing time spent by cyclists in areas of high pollution
- Where roads are busy, consider:
  o Providing as much space as possible between cyclist and motorised vehicles
  o Use dense foliage to screen cyclists from motor vehicles (uncertain evidence, and this also needs to take into account the importance of keeping cyclists visible to reduce risk of collisions and normalize cycling)
  o Reduce time cyclists spend at highly polluted sites, including junctions (as this has been shown to increase exposure to air pollutants)

Dedicated cycle routes have been found to be effective in reducing exposure to air pollution. Six studies from the US, Netherlands, Canada and the UK found exposure to PM$_{2.5}$ was lower on low traffic routes, and air pollution levels were reduced by increasing separation from traffic.

Construction and maintenance of dedicated and separated cycle routes may entail additional costs, but these costs would be lower than constructing and maintaining vehicular roads. In the modelling by NICE, off-road cycle paths were the most cost-effective of all the interventions they looked at. In urban areas where specific paths are likely to be widely used, cost-benefit ratio was 1:14 (indicative costs in first year to total indicative benefits in the first year) with a cost per quality adjusted life year (QALY) gained of £5,075. This assumed that several routes are developed – a single route would cost less but may also be less effective as it would reach less of the population.

Benefits of encouraging active travel
- There is an additive impact with both reducing traffic-related air pollution and increasing physical activity with the resulting health benefits
- Benefits to drivers from reducing congestion as well – one study suggested that exposure to air pollutants for drivers is as high as for cyclists and in fact air quality inside cars may be poorer than that outside
- Perceptions of poor air quality put some people off cycling and so improving air quality will encourage more people to cycle and so further reduce air pollution.

**Potential harms of encouraging active travel**
- Increased collisions as a result of more cyclists if cycle routes are poorly designed

**Raising public awareness**

DEFRA undertook qualitative research with the public to explore their understanding of air pollution in order to improve public communication. They identified six principles:

A. **Explain what air pollution is**: what particulate matter is made of and where it goes
B. **Help people understand how they can protect themselves**: don’t raise public concern unless you can satisfy the desire to do something to reduce their exposure
C. **Explain the health impacts**: focus on what is known for certain about health consequences
D. **Make it local**: talk about it as a problem linked to specific places
E. **Explain how individuals can make a difference**: keep focus on actions people can take rather than long-term solutions
F. **Demonstrate leadership and empower communities**, instead of just expecting individual behaviour change

NICE also suggest considering giving businesses information on how they can reduce road-traffic-related air pollution and improve fuel efficiency, e.g. helping drivers to develop an energy-efficient driving style; schedule deliveries to minimise congestion; encourage employees to cycle to work.

Evidence is uncertain around the effectiveness of providing the public with information on how road-traffic-related air pollution affects their health and how their transport choices (e.g. driving during episodes of high pollution) contribute to this. However, many people do not understand the link between health and road-traffic-related air pollution and do not realize they can help reduce the pollution and their exposure to it through changes in their behaviour. For example there may be a lack of understanding that air pollution can be greater inside a car than outside. Without public understanding, it is difficult to get support for changes needed, and any changes are likely to be unsustainable.

Equally the evidence is uncertain around making businesses aware of the need to reduce air pollution by encouraging active travel, more energy-efficient driving and scheduling deliveries to reduce congestion.

**Benefits of engaging the public**
- Help people, especially most vulnerable, to reduce their exposure especially when levels of pollution are high
- Help people understand how to change their behaviour to reduce emissions and therefore reduce population-level exposure
- Support the development of social networks which can be built on for benefits in other areas

**Potential harms of engaging the public**
- Actions to reduce the amount of polluted air from entering a home (such as closing windows) might increase indoor levels of air pollutants
- Harm from unfounded concerns about the possible health effects of air pollutants
Final thoughts

- Evidence of air quality monitoring will be an important part of most large scale changes – before and after implementation. Currently traffic data for most roads is ad-hoc and low quality.
- There is a risk that intended changes erode over time as drivers become used to the change and readjust their behaviours. Therefore continual monitoring and adjustments to schemes will be needed to ensure positive progressive effects are achieved.
- Many small and highly localized interventions may be required with a cumulative effect.
- Piecemeal, uncoordinated actions to tackle air pollution may make the situation worse, e.g. if different vehicle types are not classed in the same way in all clean air zones, then the overall impact will be diminished.