Outdoor Air Quality and Health

Contents

1. Executive Summary

Air pollution in Greenwich today is bad for our population's health. Levels of Particulate Matter and NO_2 in some parts of Greenwich continue to be high enough to be detrimental to human health – even when they are meeting the legal standards.

Air pollution is fundamentally linked with other determinants of population health: particularly levels of physical activity, aspects of the built environment which can promote physical and mental health, and levels of greenhouse gas emissions. Cleaning up air quality has the potential to deliver strong co-benefits: actions that improve air quality, increase physical activity and reduce emissions will address three of the major public health problems at once.

Exposure to outdoor air pollution has been shown to have a range of both short- and long-term impacts on health, with the larger burden of disease being from longer-term effects of exposure to pollutants. Air pollution is associated with cancer, hospitalisation and respiratory episodes. In the long-term, air pollution can lead to increased rates of mortality and reduced life expectancy.

Inequalities within the population – for example the fact that poorer people are at higher risk of suffering from cardiovascular or respiratory disease – can be exacerbated by poor air. Combined with geographical inequalities in the distribution of pollutants, this means that changes in air pollution levels won't affect everyone in the same way.

Greenwich is undergoing a period of rapid population growth, much of it focused on more polluted parts of the Borough. Additionally, the political importance of air quality, which has been identified as a priority issue, for example, by the London Mayor, is higher than ever. This means that now is a crucial time to deliver bold action which improves air quality while delivering co-benefits – such as active travel and reduced greenhouse gas emissions – that will also improve health.

Greenwich has several assets which can assist us in tackling the health impacts of poor air quality within the Borough, from our green parks and open spaces to our extensive network of air quality monitors. Several strategies and teams – including planning, environmental health, digital services, transportation, public health and other departments – all influence air quality and health in Greenwich.

To get the greatest public health gain, we should align these efforts and focus them on:

- delivering co-benefits for health (such as physical activity)
- for parts of the population that stand to experience the greatest health (such as young people in more deprived areas).

Three key areas of focus for action can lead to benefits for air quality and also co-benefits for health via secondary effects. These are:

- Bold action to encourage a strong modal shift towards **active forms of transport – walking and cycling**. This may include traffic management, car-free days, walking clubs, or initiatives with schools and workplaces.

- **Planning for healthy environments** - such as making new developments walkable, cycle-able and less car-orientated. Embedding approaches such as Healthy Streets into regeneration and development planning, developing a walkable Green Grid and aligning cycling infrastructure across the Borough can all help.

- **Work to reduce health risk among the most vulnerable groups** - young people, older people and those with pre-existing diseases. Potential actions could be running anti-idling measures at schools and hospitals, delivering educational sessions for schools about active travel, and awareness-raising through our Expert Patient Programme.

This JSNA chapter was written by Liam Crosby, Registrar in Public Health and Wellbeing, RBG. The original specification was developed with input from Environmental Health and Transport teams. Inputs to the JSNA included a desk-based literature review; meeting with air quality experts at GLA, TfL, King's College University; attending events about air quality – hosted by the Transport Research Lab, University College London Sustainability Exchange, Transport Research Laboratory.

The current draft has addressed comments received from colleagues in Public Health and Wellbeing, Transportation, Planning, and Environmental Health. The JSNA was presented to the Air Quality Task Force in December 2016.

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2. What Do We Know about Air Quality and Health?

Air Quality is an important environmental determinant of population health. There is increasing scientific consensus around the impacts of air pollutants on mortality (deaths) and morbidity (illnesses). It is possible to estimate the proportion of mortality attributable to pollutants in the air – and this forms an outcome indicator in the Public Health Outcomes Framework (PHOF). Across the UK, one pollutant alone (PM2.5) has been estimated to have an effect equivalent to 40,000 deaths a year.[1] .

The economic cost from the impacts of air pollution in the UK is estimated at between £5 and £17bn every year. This is comparable to the economic cost of obesity and physical inactivity in urban areas (which have been estimated at over £10 billion each).[2]

We know from past experience that improving air quality can contribute to improvements in health: for example reductions in particulate matter (PM) concentrations between 1980 and2000 are estimated to have contributed to 2.7 years extra life expectancy in USA.[3]

But air pollution remains a problem in London, including in Greenwich.[4] Most estimates suggest that in London, bringing air quality in line with EU directive[5] and WHO guidelines[6] could add between two and six months to life expectancy at age 30 .[7,8] Estimates of annual deaths due to air pollution in London are in the thousands; and in Greenwich 6.3% of deaths are estimated to be due to small-particulate matter (PM) pollution alone.

2.1 Policy Context for Improving Air Quality

Key points:

- Some pollutants can travel across geographical boundaries and there are many sources of pollution. Policies and strategies at many levels can therefore affect air quality, from WHO guidelines, the European Directive, and the London Plan, to Greenwich's Air Quality Action Plan.
- Relevant policies within RBG include the Air Quality Action Plan (2016-20); the Local Plan; the Greenwich Smart City strategy; the Local Implementation (Transport) Plan; the Greener Greenwich Strategy; and the Cycling Strategy.
- To get the greatest public health gain, we should align these strategies and focus them on actions that will deliver co-benefits for health (such as physical activity) for parts of the population that stand to experience the greatest health benefits (such as young people in more deprived areas).
- At London level, the recent change of Mayor – who has control of London-wide transport and planning policy – means that policy changes are now being considered which will affect air quality within Greenwich, as improving air quality is a stated priority of Mayor Khan.

Historically some of the most important gains to air quality – and associated reductions in disease and death – have been due to large-scale policy implementation. For example, the Clean Air Act of 1956 for the first time introduced effective regulation on domestic and industrial emissions. Over the next three decades, its implementation played a key part in reducing pollutant levels in the UK.[9]

Given the fact that many pollutants can cross boundaries and that there are many sources of pollution, action at many levels is required. This means that policies at international, national, London and Greenwich level are all significant. Policies in several fields (transport, sustainability, planning) all contribute to improvements in air quality and its impact on local health.

2.1.1. International Policies

World Health Organisation Air Quality Guidelines (2005)
The WHO has produced guideline levels for selected air pollutants (particulates, O_3, NO_2, $S0_2$), based on all published evidence on their health effects. These international guidelines form the basis of the UK and EU legislation.

EU Directive (2008)
The European Union's air quality Directive (2008/50/EC) sets legal standards for a variety of pollutants that are considered harmful to human health and the environment. These standards include both limit values (which are legally binding) and target values (which should be attained where possible without excessive costs).[1] Many of the limits are not required to be met until 2030, which means there could be a substantial lead-time before conformity with the WHO standards is mandatory in Europe.[10] However all countries are required to make a plan setting out how they will meet the standards as soon as possible.

2.1.2 National Policies

The Air Quality Standards Regulations (2010)
These Regulations transpose the EU Directive into UK law. They include legal limits for particulates, O_3, NO_2, and S_2 as well as carbon monoxide, lead and several hydrocarbons. They include criteria for determining how achievement of the limit values should be assessed, and they also include regulations about where monitoring points should be located (near to where the population is likely to be exposed).

National Air Quality Strategy (2007)
The Government's National Air Quality Strategy provides the Government's policy framework for air quality management and assessment in the UK. It sets out how different sectors (industry, transport

[1] These values comprise a concentration value for the pollutant, an averaging period over which it is measured, the date by which the limit values are to be achieved. In some cases there are allowed a number of days when these values are exceeded per year.

and local government) can contribute to achieving the air quality objectives. The government published an Air Quality Plan in 2015, which set out the actions which would be undertaken to meet targets set out in the Air Quality Regulations; however a legal case brought by ClientEarth successfully challenged the Air Quality Plan for not going far enough – as such the government is currently re-writing the Plan.

National Planning Policy Framework (NPPF)
The NPPF sets national policy for planning, with which all Local Plans must comply. The NPPF acknowledges that air quality considerations are relevant in the planning process and states that developers need to take into account local authority Air Quality Management Areas (AQMA), Air Quality Action Plans (AQAPs) and Low Emission Strategies. The NPPF recognises the role that positive planning can play in improving air quality and public health. One of the 12 Core Planning Principles of the NPPF states that planning should: "contribute to conserving and enhancing the natural environment and reducing pollution" by "preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution".

2.1.3 Regional Policy

Given the important contribution that London-level polluters – such as traffic on major Transport for London (TfL) roads – make to air pollution in Greenwich, regional policy is particularly important.

The **London Plan** is the GLA's overall planning document for London, with which all Boroughs' Local Plans must be compliant. One of the six top-level objectives of the London Plan is that "London will become a world leader in improving the environment locally and globally, taking the lead in tackling climate change, reducing pollution, developing a low carbon economy, consuming fewer resources and using them efficiently." The new Mayor of London will set out a new London Plan and the early consultation document *"A City For All Londoners"*, which indicates his overarching approach for the new London Plan, indicates that air quality is likely feature more strongly in the new London Plan.

The GLA also has a **Mayor's Air Quality Strategy (MAQS)** which includes focus on sustainable transport, construction and demolition sites, the planning process, energy efficient buildings and raising public awareness. See section 2.4 for information on the new Mayor's proposed changes to the MAQS.

Finally the **Mayor's Transport Strategy**, a statutory document, sets out the vision for transport at London-wide level, and how TfL will deliver it. This strategy includes, for example, modal share goals that cycling and walking will make up 5% and 25%, respectively, of all journeys by 2031 and that private motorised transport will fall from 43% to 37% over the same period. Again, the *City for All Londoners* consultation document suggests that stronger approach to modal shift and air quality improvement will be present in the new Transport Strategy.[11]

2.1.4 Borough-level Policy

Several policies at Borough-level are important for controlling air quality:

Air Quality Action Plan, 2016-2020

In accordance with the UK **Air Quality Standards Regulations** and because targets included therein had been exceeded in Greenwich, in 2002, the Council designated the entire Borough as an Air Quality Management Area (AQMA) for NO_2 and PM10. An Air Quality Action Plan (AQAP) was then put in place and an updated version for 2016-20 is nearing completion. The AQAP sets out some of the technical details for how to monitor air quality in the Borough, as well as the actions that will be undertaken to improve it. The AQAP prioritises actions to:

- Manage the impact of Growth,
- Support Healthier lifestyles for residents,
- Reduce the impact of traffic,
- Reduce the Council's own emissions.

RB Greenwich produces Annual Status Reports in relation to pollutant trends within the Borough-wide AQMA. These are available on the council website.[12]

Local Plan

The Royal Greenwich Local Plan is the core strategic document for development in the Borough, running up to 2028. The Local Plan includes strategic priorities around improving accessibility, capacity and quality of the public transport network, promoting sustainable travel in the Borough, and ensuring that the necessary physical, social and green infrastructure is provided or existing infrastructure is enhanced to support the planned growth and development. The policy states that "Royal Borough is committed to reducing all types of pollution, including air pollution"; it also includes a specific policy E(c) on Air Pollution.

Growth Strategy

The Council's Growth Strategy brings together the vision for regeneration, planning, property, tourism and transport. This includes the promotion of strategic transport links to promote inward investment, business competiveness and growth with a particular focus on the four master-plan areas.

Greenwich Smart City Strategy

This strategy sets out how RBG seeks to use technological approaches to address challenges facing the Borough – from population growth to traffic management. Several priorities highlighted within the strategy could have air quality and health impacts: for example smarter refuse collection to minimise use of polluting vehicles, or improved use of Building Information Modelling to improve how people can interact with new developments.

Greener Greenwich Strategy

This is the Royal Borough's response to climate change and air pollution. It outlines the council's past achievements and current activity, and explains how it will respond to climate change and reduce emissions in the coming years. It seeks to "encourage a truly borough-wide response, acting to reduce emissions, as well as to manage and adapting to the impacts of such emissions". It is structured around six areas, and most of the air quality-related actions are the same as those included in the AQAP.

Local Implementation Plan (LIP)

The Local Implementation Plans (LIP) sets out how RBG plans to deliver the Mayor's Transport Strategy. An overall aim of Greenwich's LIP is "to Increase sustainable travel capacity", while specific objectives focus on "reducing Greenwich's contribution to climate change and working to improve the Borough's air quality" and "Increase walking, cycling and public transport access". The latest LIP was completed in 2011 and development of a new LIP based on a new Mayor of London's Transport Strategy has begun, for implementation from 2019. In the meantime, there has been an updating of LIP 2, to act as an interim until LIP 3 is in place.

Cycling Strategy

Royal Greenwich's vision for cycling is for 'more cycling, more often, and even more safely'. The cycling strategy sets out the actions which will be taken to achieve this aim. It focuses on supporting infrastructure changes, particularly within new developments, as well as behaviour change to improve road safety and encourage cycling.

2.2. Air Quality in Greenwich

Key points:

- Air quality has improved in Greenwich in recent years, and today levels of pollutants within RBG are meeting all of the national Air Quality Standards (AQS) objectives. However, Even in areas where levels of $PM_{2.5}$ and NO_2 are lower than the AQS thresholds, in some areas these pollutants are at concentrations which can cause harmful effects for human health.
- Levels of nitrogen dioxide (NO_2) remain above the AQS target in many parts of the Borough. Particulate Matter (PM10 and $PM_{2.5}$) levels in Greenwich are currently within the national AQS objective limits. Levels of these key pollutants today are similar to the London average levels.
- Levels of these pollutants continue to be worse along roads and in the North and West of the Borough.
- By far the most significant source of air pollution within Greenwich is road traffic. Brakes and tyres produce much particulate matter, not only exhaust fumes. This means that opportunities to encourage a strong modal shift away from motor vehicles towards active forms of transport are an important way to tackle pollution. Other sources of pollution include energy-generating boilers, and construction sites which can emit large amounts of PM.

2.2.1. Pollutants with Health Impacts

As a result of historic action to improve air quality, many air pollutants (such as SO_2) are now at levels in London where they can no longer cause health impacts.[13] The pollutants whose levels are of concern today are small-particulate matter (microscopic solid or liquid matter which can be categorised by size – e.g. PM_{10} (diameter <10µg) or $PM_{2.5}$, Nitrogen Dioxide (NO_2), and ground-level ozone (O_3).

	Target Levels	
Pollutant	**UK Air Quality Guidelines 2007.**	**WHO Air Quality Guidelines 2005.[14]**
PM_{10}	40 µg/m3 annual mean	20 µg/m3 annual mean
$PM_{2.5}$	25 µg/m3 annual mean	10 µg/m3 annual mean *No safe level identified*.
Nitrogen Oxides (NO_2 and NO)	40 µg/m3 annual mean	40 µg/m3 annual mean
Ozone	100 µg/m3 8-hour mean, fewer than 10 times per year.	100 µg/m3 8-hour mean

Table 1. Taken from Defra (2010)[15] and UK Air Quality Strategy (2007). Note, only selected guidelines have been included, focused on long-term exposure. For example the UK AQG includes additional target for 50 µg/m3 daily mean of PM10 not to be exceeded more than 35 times per year; these daily targets are not presented.

Levels of pollutants within Greenwich are monitored via the most extensive system of Air Quality Monitoring Stations within London:

- PM10 is monitored at 11 automatic monitoring stations.
- NO_2 is monitored across the Borough through a combination of highly accurate continuous (or automatic) monitoring stations and indicative low-cost diffusion tubes.

Levels of PM10 in Greenwich have been decreasing over the past seven years; and in 2010 were below the AQS objective levels at each monitoring stations. However, at several of the stations levels were higher than the WHO recommended levels, and high enough to cause health impacts.[2]

In 2015 the overall levels of NO_2 for all sites monitored by Greenwich's automatic stations show a slight downward trend from previous years, but a significant number still show pollution levels above the level of 40 ug/m3 ,as set in the Air Quality Objectives. The highest level was at the Woolwich flyover station, which reported an average annual concentration of 66 ug/m3. The trends from the NO_2 diffusion tubes is similar.[16]

Data from this monitoring system is used to model modelled pollutant concentrations across the whole Borough. These modelled estimates are then combined with population data on where people live to estimate the average concentration that people are exposed to. The average level of both NO_2 and $PM_{2.5}$ experienced in Greenwich is similar to the overall London average (see Appendix 1).

[2] At Woolwich flyover the average annual concentration was 29 ug/m3, while at Blackheath Hill monitoring station the concentration was 25 ug/m3.[2]

However, these borough-level averages mask large differences within the Borough. Pollutant levels are higher in central London, i.e. towards the North and West of RBG. Pollutant levels tend to drop off rapidly with distance from a pollutant source: so areas close to major roads tend to be more polluted. Maps of modelled pollutant concentration are available in Annex 1.

In 2011 the Greater London Authority (GLA) identified seven Air Quality Focus Areas within RBG, which are outlined in Figure 5 below (represented by yellow area with description in yellow box). These areas have been selected by the GLA as areas where there is the most potential for improvements in air quality within the Capital. They are areas with both a high level of pollutant and high level of human population exposure.[17]

Given the increased level of vulnerability of younger people to the impacts of air pollution, it is useful to map the location of schools in relation to pollutant levels. Figures 3 shows schools in the borough over a map of modelled NO_2 concentrations and the following figure 4 shows these concentrations graphically. As can be seen, several schools are at locations where modelled exposure to NO_2 is very close to the 40 µg/m3 limit. As these are modelled estimates only, there is a certain amount of uncertainty around their levels which means it is possible that these locations actually experience even higher levels.

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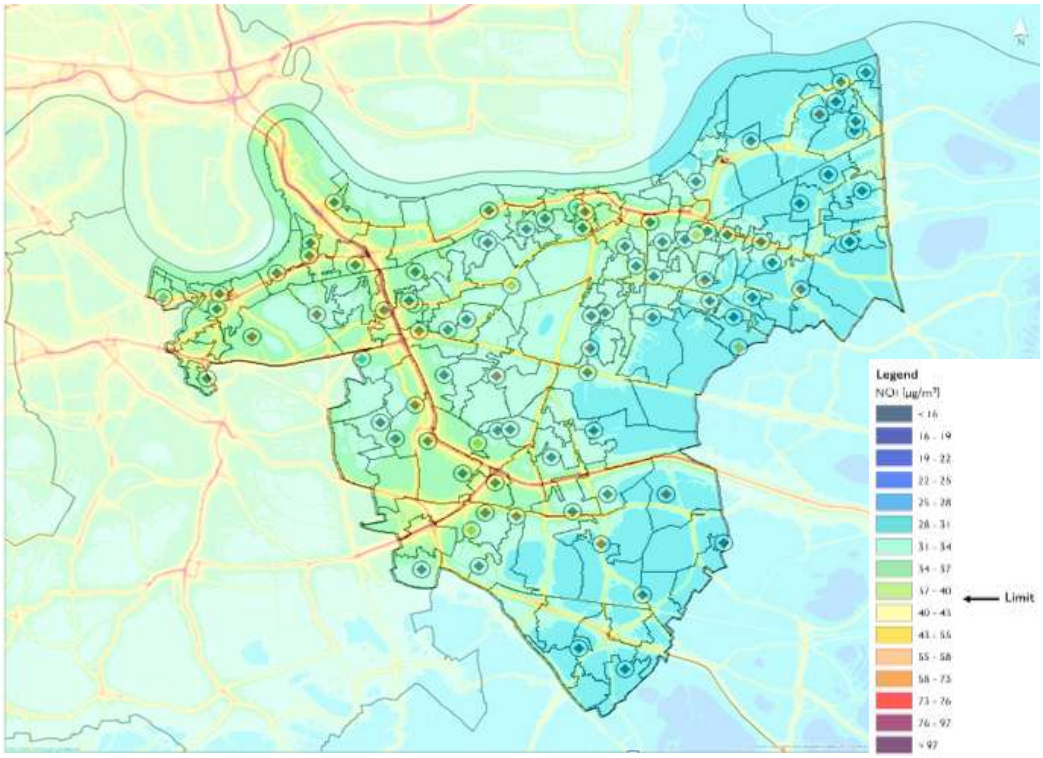


Figure 1: Location of schools in Greenwich compared with air pollution levels. Modelled concentrations of NO2, taken from London Atmospheric Emissions Inventory 2013 modelling, are shown. Schools were mapped using postcodes on MapInfo.

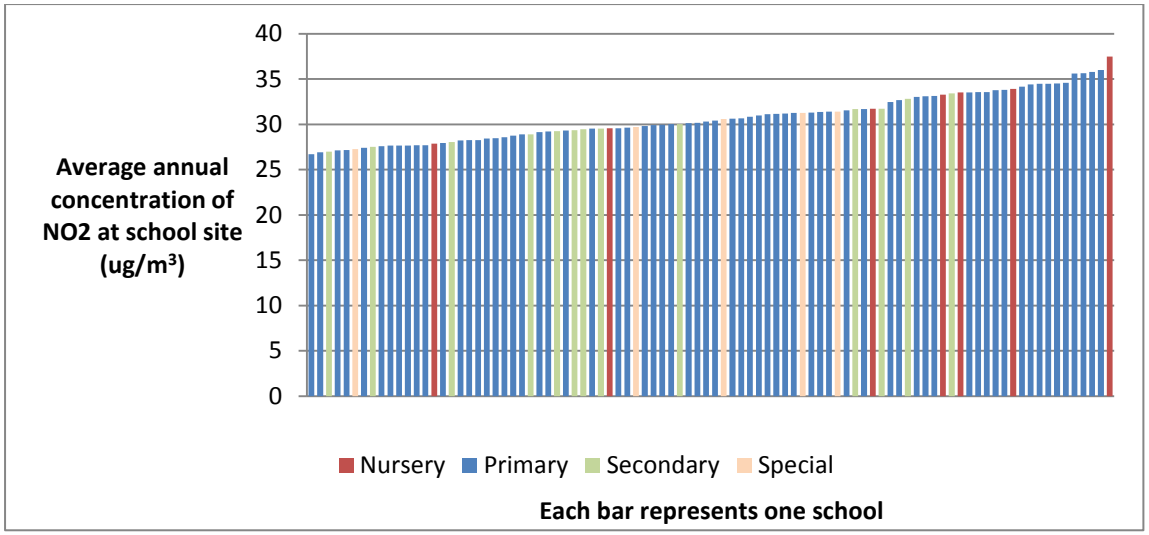


Figure 2: Modelled concentration of NO2 (taken from LAEI 2013 modelled data) at school sites in Greenwich. As can be seen, several schools are close to locations with high levels of NO2; which are close to the recommended threshold of 40 ug/m3. NO2 pollution data to the level of a 20m*20m grid have been modelled by LAEI (2013). School sites were matched to the nearest Northing and Easting coordinates which are nodes on the 20*20 grid, and the level of pollution at that point was imputed.

2.2.2. Sources of Air Pollutants

Within London, the major source of artificial $PM_{2.5}$ and NO_2 is from road traffic; and in particular from large vehicles such as buses, articulated lorries and large vans. Even modern diesel cars produce almost as much air pollution as older cars in urban circulation.[18] Tires and brakes are an important source, particularly of particulate matter. Construction sites can emit much PM via high volumes of dust and emissions from machinery, as can accidental fires and burning of waste. A large proportion (between 40 – 55%) of PM originates outside of London.[19]

Image 5 below shows the estimated major sources of major pollutants at the Air Quality Focus areas within the Borough. As can be seen, traffic is the main source of pollutants at all the locations – though the importance of different types of traffic varies. In Eltham and Greenwich town centre, buses and cars are the main sources, while in Shooters' Hill or Woolwich, HGV emissions are more significant.

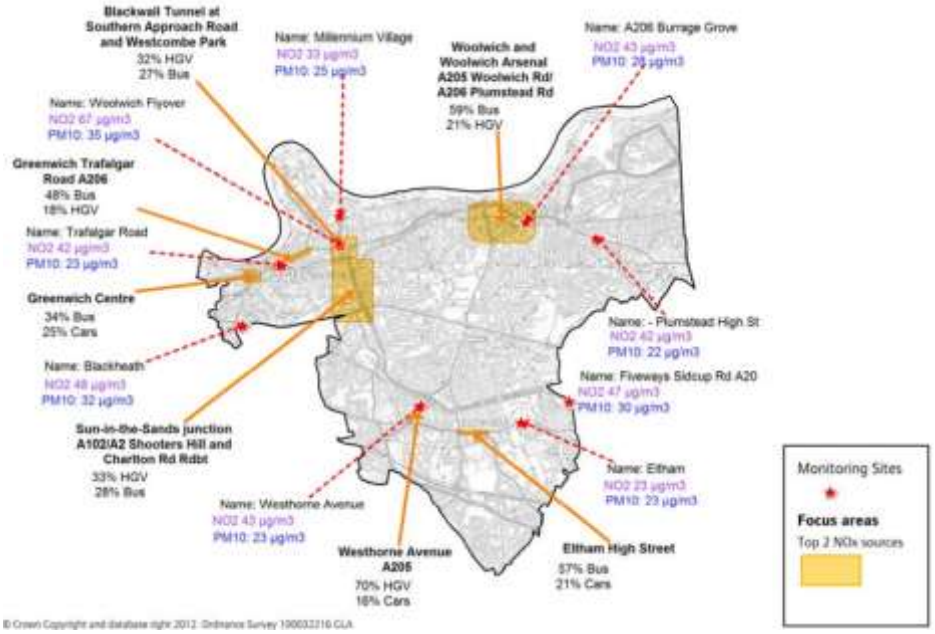


Figure 3: estimated major sources of major pollutants at the 7 air quality focus areas in RBG. Source: GLA (2015)[20]

Please note: since this modelling was undertaken there have been changes to the Air Quality Focus Areas: the Trafalgar Rd focus area has been extended to include Woolwich Rd to the junction with the A102; and news Focus Areas are identified at Plumstead High St and Blackheath Hill.

Much of the air pollution in Greenwich is from sources beyond the control of RBG. In particular, a large proportion of traffic-related pollution comes from roads controlled by Transport for London – especially the A2; A20 and A102, which show as particularly polluted spots on the above maps.

2.3. Air Pollution and Health in Greenwich

Key points:

- Exposure to outdoor air pollution has been shown to have a range of both short and long-term impacts on health, with the larger burden of disease being from longer-term effects of exposure to pollutants. Air pollution is associated with cancer, hospitalisation and respiratory episodes. In the long-term, air pollution can lead to increased rates of mortality and reduced life expectancy.
- While there are epidemiological challenges to understanding precisely which pollutants cause which diseases (see Box), the scientific consensus is that long-term exposure to even low levels of pollutants – low enough to be within the legal thresholds – can have adverse health impacts.
- People who have pre-existing lung or cardio-vascular diseases are likely to be at an increased risk, as are young children and the elderly. Inequalities in vulnerabilities within the population can be exacerbated by poor air
- While short-term exposure to pollutants does increase risk of cardiovascular events, the risk is smaller than the potential benefits of exercise in all except those with pre-existing conditions and vulnerabilities. As such physical activity should be widely promoted.

2.3.1. Morbidity

It is useful to use the "Pyramid" model of population health impacts to conceptualise the impact of air pollution on health: long-term exposure can affect everyone's health, causing mostly imperceptible damaging physiological changes for many people. However for small numbers of people, exposure to air pollution can exacerbate existing health conditions including cardiovascular and respiratory disease.

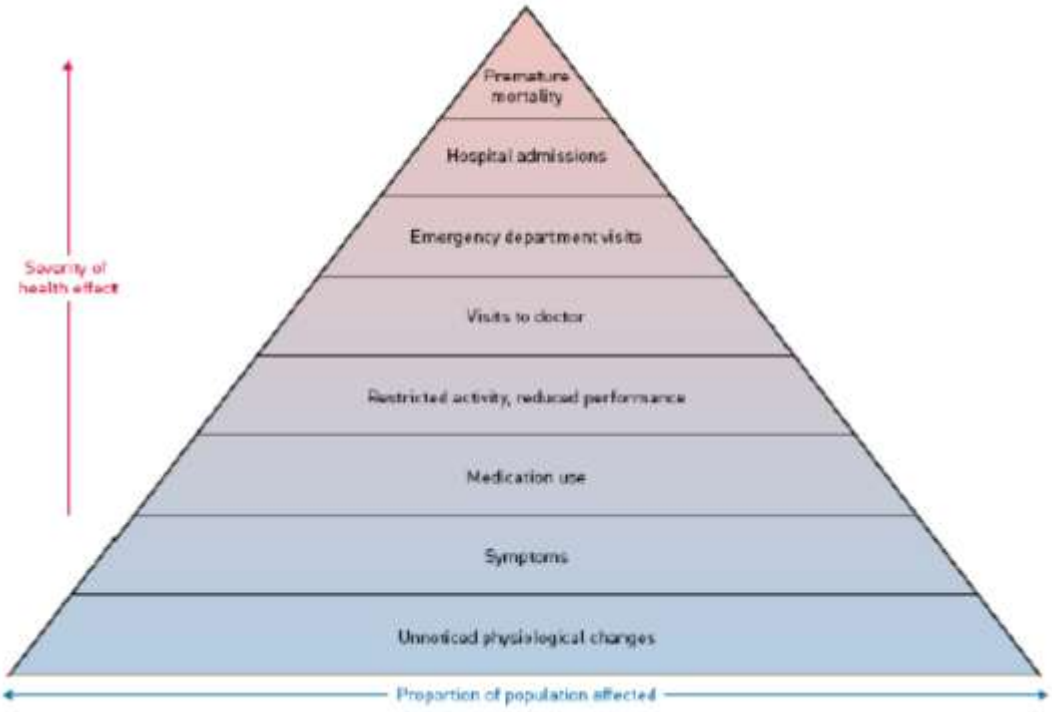


Figure 4: Pyramid model of health impacts (WHO, 2005)

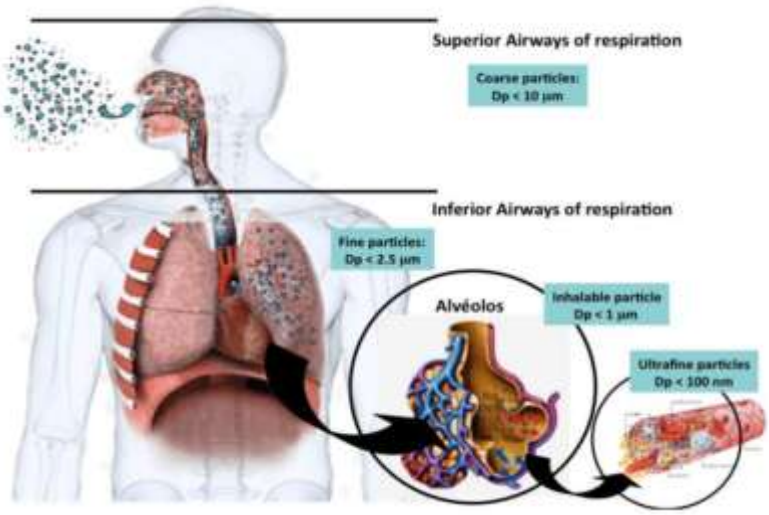


Figure 5: Diagram showing how particulate matter can enter the body.

Short-term Impacts:

Short-term exposure to air pollution can cause several immediate health problems:

- Air pollution can worsen respiratory symptoms in those with **pre-existing lung disease and asthma**.[21] Gaseous pollutants (NO_2, SO_2, O_3), particulate matter ($PM_{2.5}$ and PM_{10}) and traffic-related air pollution have all been implicated. Exposure to elevated concentrations of these pollutants has been linked with a range of respiratory symptoms, including decreases in immune defence leading to increased susceptibility to respiratory infection.[22],[23]
- Air pollution can can also have immediate impacts on **cardiovascular events**: Short-term exposure to traffic-related pollution has been associated with increased risk of **myocardial infarction** for several hours after exposure. One meta-analysis[24] found that admission to hospital or mortality from **stroke** was strongly associated with increased short-term exposures of SO_2, CO, NO_2, $PM_{2.5}$ and PM_{10}.
- **Use of health services** can increase after periods of strong air pollution: PHE's Real Time Surveillance System Team found an increase in GP consultations for respiratory problems immediately following an episode of Saharan air pollution in 2014.[25]

Long-term Impacts:

Long-term exposure to air pollution can also contribute to increased risk of onset of several diseases and health problems, as summarised below:

	Pollutants particularly implicated	Strength of evidence
Cardiovascular disease. There is abundant evidence air pollution, particularly PM, contributes to the risk of cardiovascular disease, including: coronary artery disease, myocardial infarction, heart failure, and stroke.[26]	PM NO_2, O_3	Strong Emerging
Cancer. Long-term exposure to outdoor air pollution, particularly PM, is associated with incidence of and deaths from lung cancer.[27] The International Agency for Research on Cancer (IARC) has classified PM and NO_2 from diesel engines as Group 1 carcinogens.[28]	$PM_{2.5}$.	Strong (adults) Emerging (children)
Reduced lung function. Air pollution has detrimental effects on normal lung function growth in children;[29] while for adults there is emerging evidence that air pollution accelerates decline in lung function.[30],[31]	NO_2, $PM_{2.5}$, PM_{10}	Strong

	Pollutants particularly implicated	Strength of evidence
Respiratory disease. Evidence for air quality's contribution to COPD onset is inconclusive,[32,33] however studies have shown that exposure to air pollution increases risk of progression to "asthma-COPD overlap syndrome" three-fold.[34]	NO_2, $PM_{2.5}$	Emerging (chronic effects)
Low-birth weight. Exposure during pregnancy is linked to low birth weight, which itself is a risk factor for several diseases during adulthood. The evidence is strongest for PM, though NO_2, CO and O_3 have also been linked.[35]	$PM_{2.5}$, PM_{10}. NO_2, CO, O_3	Strong Emerging
Development of asthma. A meta-analysis[36] of 19 studies on the effect of traffic-related air pollution and asthma in children concluded that increased exposure to NO_2 was associated with a higher prevalence (OR 1.05) and incidence (OR 1.12) of childhood asthma.	NO_2 PM	Moderate Weak
Pre-term delivery. Some evidence suggests that the gaseous pollutants SO_2 and O_3 as well as particulates, are associated with pre-term delivery.[37]	SO2, O3.	Emerging
Hypertension. A recent cohort study found long-term exposure to PM2.5 air pollution and high traffic load to be positively associated with incident self-reported hypertension.[38]	$PM_{2.5}$	Emerging
Type II Diabetes. There is moderate evidence that new-onset Type 2 diabetes in adults is associated with exposure $PM_{2.5}$, PM_{10} and nitrogen oxides, thought causality is not clear.[39]	PM, NO_2	Moderate (Adults) Emerging (Children)

Table 2: Summary of diseases associated with poor air quality.

Morbidity in Greenwich.

Table 3 shows the prevalence within RBG of key diseases which have been associated with, or shown to be exacerbated by, air pollution.

As table 3 shows, rates of COPD, cardiovascular disease and lung cancer are all worse in Greenwich compared to elsewhere. As discussed above, poor air quality is associated with each of these diseases. This local picture highlights the importance of tackling air quality's health effects within the Borough.

Table 3 Prevalence of key air quality-related conditions in Greenwich

Condition		Greenwich	London	England
Chronic Obstructive Pulmonary Diseases (COPD)	Estimated prevalence	3.25%		2.91
	Under 74 mortality per 100,000	**45.9**	31.2	32.6
	Emergency hospital admissions	**417**	406	415
Cardiovascular disease	Estimated prevalence	2.1%	2.1%	3.2%
	Mortality per 100,000	**84.7**	78.7	75.7
Asthma	Estimated prevalence per 1000.	8.98	8.86	9.13
	Hospital admissions per 100,000 population	**98.0**	119	121
	Children emergency admissions per 100,000	**232.0**	205.8	219.8
Lung cancer	Registration rate per 100,000	**97.2**	78.5	79.7

Box 1: Local Residents' Perceptions on Air Quality and Health

A consultation exercise relating to the new Air Quality Action Plan was undertaken in September 2016. While many responses to the consultation focussed on a few specific future developments perceived to have detrimental impacts, the consultation also highlighted local residents' perceptions on air quality's health impacts and on potential actions to address them.

Concerns about air pollutant impacts on health

Several residents highlighted concerns around the impacts of pollution on health.

> *"I am extremely concerned that I am living in an area of such high pollution levels which will be affecting my health and well-being."*

> *"Due to the heavy flow of traffic … I rarely manage to open my windows. The black dust that comes in through the windows when open must be a health hazard."*

And impacts on children are a particular concern for local people.

> *"I worry about my health. I worry about my daughter's health"* (local resident during consultation meeting in Greenwich, 22.9.16)

> *"We have a young son who attends primary school in the borough, and I worry about how air pollution is affecting him."*

Support for action to improve health

Many local people supported actions which would tackle negative impacts of air pollution while leading to broader health benefits. For example, residents responding to the survey voiced support **for interventions that would encourage active travel and a modal shift away from cars**:

> *"it is disappointing that Greenwich doesn't have more car free days"*

> *"The borough is well set up in terms of location of population to the schools to allow for an increased uptake in public transport. Actions stating how the council will work with schools and what actions will be focused on should be added to the plan."*

Meanwhile residents are aware that changes to the built environment, particularly the **provision of cycling and walking infrastructure**, could lead to health benefits:

> *"I agree fully with the plans to encourage parents not to drive children to school … but it is difficult to find a route to cycle/walk"*

> *"I am frustrated by not being able to take short cuts because certain areas have been blocked … improvements [to the walkability of the estate] can be made to make people feel safer without making the whole place look so forbidding"*

2.3.2. Mortality

As well as epidemiological evidence that people with higher exposure to air pollutants have increased mortality risk, places that have seen air quality improvements have been shown to experience reductions in mortality. For example following the ban of coal burning in Dublin in 1990, air quality improved and the subsequent three years saw a 6% (95 confidence interval: 4-7%) decrease in all-cause mortality; with the largest decline observed, as expected, for respiratory and cardiovascular (10%) deaths.[40]

While both short-and long-term contributions to mortality can be calculated, it is the longer term impacts--which are associated with increased risk of death widely among the population--contribute a larger overall burden.[41] That is, the effects at the bottom of the above pyramid add up to larger overall impacts on mortality.

To date, the strongest evidence around the strength of the increased mortality risk is for $PM_{2.5}$.[42] WHO has published two major reviews of 2,200 studies concluding that annual $PM_{2.5}$ concentrations are associated with all-cause mortality.[43] DEFRA has estimated that in 2008, artificial $PM_{2.5}$ reduced life expectancy of people in the UK by 6 months.[44]

Estimates of the impact of NO_2 on mortality are less robust but the WHO HRAPIE project has sought to clarify an estimate, and outputs suggest an even greater impact than from particulate matter – though much uncertainty remains. Epidemiological challenges inherent in studying air quality (see Box 2, below) mean there remains uncertainty about the extent to which mortality impacts of different pollutants operate independently of one another,[45] or conversely whether any synergies exist.[46]

An important feature of the epidemiological relationship between PM, NO_2, O3 and other pollutants is that there is a dose-response relationship. That is: greater levels of pollution are associated with higher mortality risk – and this continues even below the cut-off points that are specified in legal documents such as the UK Air Quality Strategy. The implication is that there remains a public health imperative to continue to minimise health impacts even where pollutants do not exceed legal limits.

Box 2: Estimating and Interpreting the Impact of Air Pollution on Health and Mortality

Severe episodes of air pollution can have immediate effects, from aggravating asthma to directly causing a chest infection. However, such immediate effects are relatively rare at levels of pollution witnessed today in Greenwich. The largest health and mortality effects of air pollution are those associated with *sustained exposure to pollutants over a long period of time*.

To estimate the long-term impact of air pollution on health and mortality, we first have to ask: how much does being exposed to pollutants increase a person's risk of disease or death? To answer this question, epidemiologists compare an 'average' group of people who have been exposed to pollutants with an 'average' group of people who haven't. This is quite difficult for air quality. It's not feasible to run a Randomised Controlled Trial for the low-level exposure that builds up over longer periods.

Instead epidemiologists use *cohort* or *cross-sectional* study designs. Both of these are 'non-experimental' – put simply, they seek to use real people in the real world and compare those who have been exposed to those who haven't.

The nature of air pollution makes this quite challenging: people tend to move houses during their lifetimes, and even when living in one place, they spend time at work or at leisure activities at locations which may have very different levels of pollution from their home address.

And that's before you have even begun to figure out how to find an 'average' group of people that haven't been exposed, who are comparable to an 'average' group who have been. For example, studies have found that adults who moved away from major roads had a lower risk of coronary heart disease (CHD) mortality than did those who remained living close to traffic.[47] But how do we know that 'movers' are really the same as 'stayers' in other respects? Maybe healthier people are more likely to choose to move house? For this reason there are large uncertainties from any one study.

However, the Council on the Medical Effects of Air Pollution (COMEAP) has reviewed all existing evidence for the impact of $PM_{2.5}$ on mortality and used them to develop agreed 'concentration response functions' (CRFs), which are agreed coefficients describing how much exposure increases risk of death. WHO's HRAPIE project did the same for NO_2.

We can use these CRFs to calculate the overall burden of mortality 'caused' by air pollution - by applying this effect size to the size of the population at risk and the level of pollution in the air. COMEAP recommends three different measures to be calculated:

- The total number of years of life lost due to air pollution
- The average reduction in life expectancy due to air pollution
- The number of 'deaths brought forward' (bearing in mind that no death is ever totally avoided)

With any of these measures, it is important to remember that they are population level measures, not individual. A measure of 100 'deaths brought forward' does not mean 100 individual people die directly due to air pollution – rather it means that air pollution is *one attributable factor* in the deaths of many more people across the population, and adding these together would give a burden of mortality equivalent to 100 deaths.

For example, in Greenwich:

The '*population weighted average concentration*' of $PM_{2.5}$ is 13.6µg	This is the average level of $PM_{2.5}$ pollution experienced by people in the Borough – the average pollution across areas weighted for the population density of each area.
We can estimate the relative risk for the population as: $RR = 1.06^{(13.6/10)} = 1.082$.	This means that the current level of $PM_{2.5}$ can be said to increase the mortality risk by 8.24% (on average across the Greenwich population), compared to a pollution-free scenario.
The attributable fraction ($AF_{PM2.5}$) is (RR-1)/RR = 7.6%.	This means an estimated 7.6% of mortality in the borough can be attributed to current levels of $PM_{2.5}$.
There were 1584 deaths per year on average, between 2009 and 2011.	Taking a 3-year average can reduce the amount of variability between years.
The number of deaths attributable to $PM_{2.5}$ is $AF_{PM2.5}$ * total deaths = 7.6% * 1584 = 120.	This is an estimation of the mortality burden of Air Pollution across the Greenwich population. In reality it does not mean 120 people have died – rather air quality is *one factor to which a fraction of* many deaths can be attributed.

So far, so good. But several epidemiological challenges remain.

One challenge is deciding what limit should be set as a counterfactual scenario. When we say 'X deaths are attributable to air pollution', we mean 'X deaths are attributable to air pollution *above the ideal / realistically achievable level*'. But deciding on that ideal level is difficult - do you take a legal limit or a minimum? How can you know what the achievable minimum is, especially when some pollutants can drift into an area from elsewhere or even from natural sources? The choice of counterfactual makes a big difference: for example NO_2 can be estimated to be associated with 273 deaths in Greenwich, compared with a NO_2-free scenario; but compared with WHO's recommended realistic-minimum NO_2 of 20 µg, just 90 deaths are attributable.[48]

Another challenge is how to deal with multiple pollutants, which are often very closely correlated – i.e. places with a lot of $PM_{2.5}$ will also have a lot of NO_2. Many epidemiological studies avoid this problem by not seeking to divide the impacts of particular pollutants, instead focusing on overall measures such as 'Near-Roadside Air Pollution'.[49] The close overlap between pollutants also makes it hard to be sure how much mortality is independent of other pollutants: for example there is some suggestive evidence of synergy – i.e. that when pollutants are experienced together, health impacts may be larger.[50] WHO recommends that the mortality due to $PM_{2.5}$ and of NO_2 should be estimated separately and not combined.[51]

Finally a challenge with $PM_{2.5}$ is that this class of pollutants is itself hugely varied. It includes everything from natural Saharan dust to particles from fuel exhaust. While there is some evidence that $PM_{2.5}$ from road traffic sources – which includes broken-up brake pads – is more dangerous than other forms of $PM_{2.5}$, this is not yet fully proven. For now the evidence on 'differential toxicity' of particles is too limited to warrant targeting anything other than overall $PM_{2.5}$.[52]

Mortality in Greenwich Attributable to Air Quality

There are four main sources for estimates of the mortality burden of $PM_{2.5}$, the pollutant with the strongest evidence for mortality effect, at Borough level in London. They are summarised below in table 2. These studies estimate mortality through the three different measures recommended by COMEAP (2010), though each study uses a slightly different methodology, which may affect their results. For example, the King's College report uses data at a higher level of granularity than the PHE (2014) report.

Source	PHOF indicator 3.01 (2013)	King's College report (GLA, 2015)	PHE report (2014)	IOM report (2008)
Estimate for year:	2011	2010	2010	2008
Attributable fraction	6.6%	7.6% (1.3%-14.3%)	7.2%	-
Number of deaths	-	120 (21-226)	119	150 (25-276)
Life Years Lost	-	1659 (293-3111)	1312	-

Table 4 Estimates of the mortality burden attributable to PM2.5 in Greenwich. Note that the main numbers assume a 6% increase in mortality risk per 10µg/m3, while the figures in bracket s are plausibility estimates, based on 1% and 12% increases – as recommended by COMEAP (1998). The PHOF indicator 3.01 is expected to be updated in November 2016.

As Table 4 shows, estimates for the overall burden of mortality attributable to $PM_{2.5}$ in Greenwich show this pollutant contributing a significant amount to the overall mortality in the Borough. For comparison, this compares with England-wide estimates of 6% of mortality in 1998 due to obesity, and 10% due to smoking.[53]

While the different studies in Table 4 are not directly comparable, there appears an indicative trend for studies done more recently tend to estimate lower levels of mortality due to air pollution in Greenwich. This trend is also seen in PHOF data which can be seen in figure 7 below.

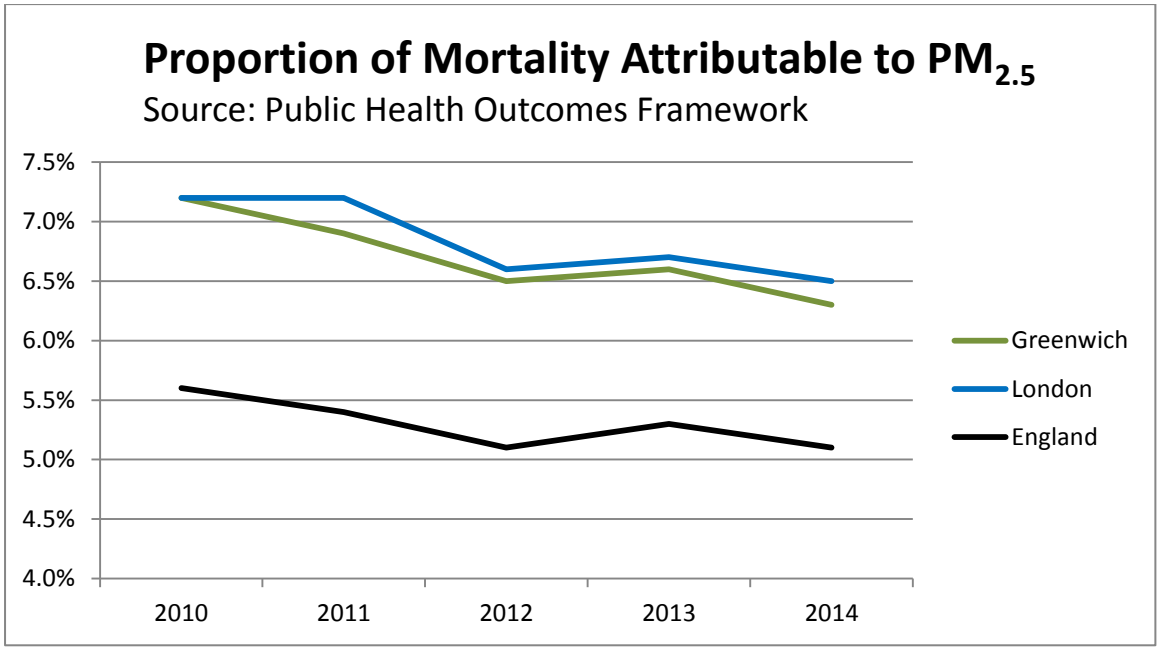


Figure 6

Figure 8 below shows how Greenwich compares with other London Boroughs in terms of the proportion of mortality that can be attributed to poor air quality. Greenwich's proportion is slightly lower than that of London as a whole, and to our neighbouring borough of Lewisham. Unsurprisingly, the ranking of our IMD comparator Boroughs depends on their position within London: Westminster which is in Central London has the second highest proportion of mortality due to air quality, while Enfield which is further from the centre has a lower proportion than Greenwich.

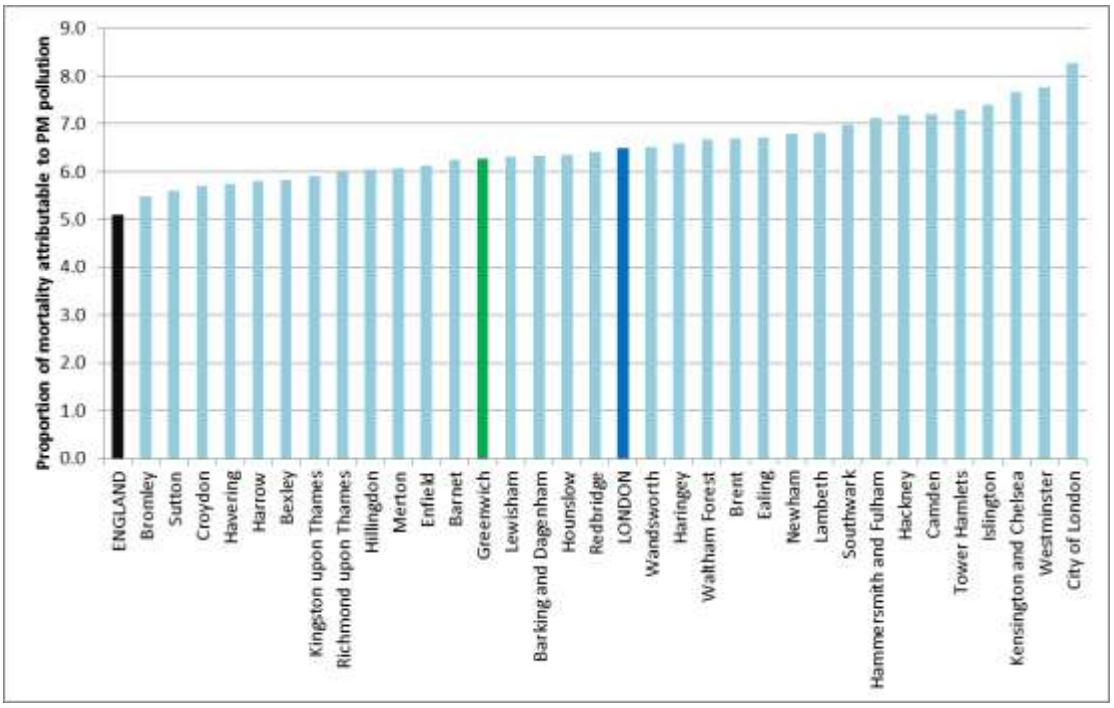


Figure 7

The above estimates are for $PM_{2.5}$ only: they do not estimate the impacts on health of other pollutants. The proportion of mortality that is due to NO_2 can also be estimated, though there is lower epidemiological certainty around the relationship with mortality. These estimates have been used by KCL to estimate the mortality that can be attributed to NO_2, as seen below:

	King's College report (GLA, 2015)
Estimate for year:	2010
Attributable fraction	7.6% (1.3%-14.3%)
Number of deaths.	120 (21-226)
LYY	1659 (293-3111)

Table 5 Estimates of the mortality burden attributable to NO_2 in Greenwich. Note that the main numbers assume a 5.5% increase in mortality risk per 10µg/m3, while the figures in bracket s are 95% confidence intervals, based on 3.1% and 8% increases – as recommended by HRAPIE.

2.3.3. Whose Health Is Most Affected by Air Pollution?

Risk and Protective Factors

Air quality does not impact upon everyone in the same way:

- **Age** is an important effect modifier for the relationship between air pollutants and health: both very young and old people may be more vulnerable to the impacts. Evidence now suggests that there is a significant association between air pollution levels and hospital emergency visits for wheezing and gastro-enteric disorders in children 0–2 years of age.[54] Older people are more likely to have pre-existing respiratory health issues, which places them at greater risk of negative impacts (see below).

- In addition, **life course effects** mean that very young children, whose bodies are still developing, may be vulnerable to negative impacts which can continue throughout their lives.[55] Some evidence suggests that exposure to air pollution during pregnancy or early years can be particularly damaging: studies have found associations between air quality and low birth weight,[56] lung function, development of asthma,[57] and neurological development.[58]

- Studies have shown that people with a range of existing health conditions are more vulnerable to the negative impacts of air pollutants:

    - Patients with **diabetes showed greater decreases in vascular reactivity** in response to four pollutants, compared to patients without diabetes.[59]

    - People with **existing respiratory symptoms** are more likely to suffer during short-term periods of high air pollution. Patients with COPD have a diminished capacity to clear inhaled material from their lungs and may, as a result, incur a higher-than-normal 'dose' at any level of air pollution. In response to elevated levels of pollution, individuals with COPD experience a greater fall in lung function and a higher risk of admission to hospital than healthy persons of the same age.[60]

    - There is evidence that **obesity** is associated with worse impacts from air pollution. Several studies have shown that obese individuals (and/or those with metabolic syndrome) may be at greater risk of cardiovascular events due to PM exposure[99].

- **Level of physical fitness** can affect vulnerability to negative effects of air pollution, as can eating a healthy diet – particularly there is indicative evidence that a diet rich in green and leafy vegetables can protect against the negative impacts of air quality.[61]

- **Geographical risk factors.** The extent to which people are affected by air pollution is very strongly influenced by their proximity to the pollution source.[62] For example, proximity to roads is an important risk factor. People who live within 50 m of a major road have a 63% excess risk of developing high coronary artery calcification compared with those living > 200 m away from a major road (Hoffmann et al. 2007), and many other diseases follow a similar geographical patterning. However, using such geographical patterning to determine individual levels of risk is very complex: for example people may not spend large proportions of their time at home. Air pollution drops off

very quickly as you move away from a major road – so even being at the back of the house is probably less problematic.

2.3.4. Health Inequalities

Poorer people tend to experience many of the above vulnerabilities at once: they may live in polluted places, they are more likely to suffer from diseases like asthma or COPD, and they are more likely to be overweight or not to be able to consume protective healthy diet.[63] For example a study from Wales found *both* that air pollution concentrations were highest in most deprived *and* that the links between air pollution and health were strongest in these areas due to pre-existing vulnerabilities.[64] A general finding is that low-socio-economic groups tend to experience worse effects of air pollution – though this relationship is not straightforward.[65,66]

Air quality can contribute to health inequalities due to both differential **distribution of pollutants** and of **vulnerabilities within the population**:

- As discussed above, many of the risk factors which make people **vulnerable** to air pollution are distributed unequally within the population. Poorer people are more likely to suffer from cardiovascular disease and respiratory conditions for example.

- The geographical **distribution of pollutants** can also contribute to health inequalities. Several studies in the USA, Canada and UK have shown that more deprived communities are more likely to be exposed to higher air pollution.[67,68] At national level in the UK deprived communities tend to be more affected by poor air quality.[69] Within urban settings in the UK the strength of the relationship between deprivation level and air quality is attenuated but remains significant.[70]

Inequalities in the level of pollution experienced by different people are hard to identify. The smallest level of granularity at which socio-economic data are available are Lower Super Output Areas (LSOAs), for which Index of Multiple Deprivation (IMD) data are available. Mapping air pollution at LSOA against the LSOA's level of deprivation does not show any clear trends within Greenwich (see Annex 2). However, LSOAs are quite large in terms of air pollution – i.e. they likely include a range of different pollutant levels, particularly if they border a major road, which may mask inequalities in exposure.

An implication of these inequalities in exposure and vulnerability to air pollutants is that some interventions may not have equitable impacts on health – i.e. they may benefit certain groups may more than others and cleaning up the air may not bring equal benefits to all groups.[71] For example a study in Rome found that richer people benefited more from a low emissions zone as they tended to be living closer to major roads. A recent systematic review of equity impacts of air quality interventions found that while interventions aiming to reduce air pollution had a positive impact on air quality and on mortality rates, the impact on health inequalities was less straightforward and context dependent: in some places the interventions increased inequalities while in others they decreased.

Box 3: Air Quality and Climate Change

Another indirect route by which air quality is linked to health is via its impacts on climate change. Many of the same pollutants which are harmful for our health are also those which contribute to global warming. For

example, the black carbon (soot) component of fine particulate matter makes a significant contribution to climate change.[72]

As the Royal College of Physicians put it:

> *Given that fossil fuel combustion is a major source of both greenhouse gases and local air pollutants, if action is taken to address climate change there could be major improvements in outdoor air quality as a result of decarbonisation of power and transport systems, and improved efficiency of energy use.*[73]

More recently the UK Health Alliance on Climate Change (UKHACC), comprising of eight Royal Colleges along with the BMA, BMJ, Lancet and others have published a report arguing a joined up approach – tackling climate change and health together – so as to "reap enormous benefits, particularly for the most vulnerable people in the UK".[74]

Many actions taken to adapt to climate change can also lead to improvements for air quality. For example provision of improved shade and green spaces, the development of walkable and cyclable neighbourhoods, and improvement to public transport can all improve air quality at the same time as tackling climate change. The co-benefits that result from such actions can have long-term benefits for public health.[75] The UKHACC identifies six key actions including strengthening cross-departmental collaboration; expanding clean air zones; and supporting health professionals to take local action and provide advice to patients.[76]

However not all interventions to address air quality would have co-benefits for reducing greenhouse gas emissions, or vice-versa. For example, the move to encourage diesel cars – intended as a way to reduce GHG emissions – contributed to increases in NO_2 in recent years. Another example is the current proliferation of small commercial plants designed to burn biofuels (for heating industrial estates, for example) which may lead to increased air pollution within built-up areas.[77]

The links between climate change, air quality and health are clearly set out within the Greener Greenwich Strategy.[78]

2.4. Future Trends

Key Points:

- Several current trends have the potential to lead to substantial changes in air quality within RBG, or to changes in the level of population exposure within the Borough.
- Greenwich is expected to experience large population growth over the next decade. This will mostly occur in areas which are already among the most polluted parts of the Borough. As well as posing challenges for the Borough, this growth and the associated development of the built environment offers the potential for meaningful improvements in air quality.
- The air quality impact of developments such as the Silvertown Tunnel or Enderby Wharf Cruise Terminal, and policies such as the Ultra-Low Emissions Zone, is disputed.

2.4.1. Population Change

RB Greenwich is due to experience substantial population growth over the coming years. The London Plan sets out that Greenwich has to provide a minimum of 25,950 homes within the Borough between 2011-2021 and a further 2,595 each year thereafter. The London Plan furthermore sets out where these dwellings are likely to be built, via 'Opportunity Areas' or areas for intensification. [79]

Table 6 below shows the locations where the majority of population growth via new housing is likely to occur, and shows and index of the estimated *current* air quality in the areas. It should be noted that these modelled indices are estimations, and that this table does not consider how the developments or population growth might affect air quality in the areas.

Areas for development were identified from Greenwich's Local Plan *Core Strategy*, and visually matched to LSOAs using Site Allocation documents. The current air quality index for each of these locations is given as an index based on modelled concentrations of four pollutants (nitrogen dioxide, benzene, sulphur dioxide and particulates).

Table 6: Description of Current Modelled Air Quality Status in 'Opportunity Areas' Which Are Expected to See Significant Population Growth

	Description of plan for the area	New housing[3]	Air quality description	LSOA(s)[4]	IMD Air Quality[5]
Greenwich Peninsula	A new District Centre at North Greenwich to serve the residents of around 14,000 new homes on Greenwich Peninsula.	13,000 units	Modelling shows high levels of NO_2 and PM10 concentrations on Greenwich peninsula.	E01001667 E01033733 E01033732	1.547 ● 1.552 ● 1.555 ●
	Creation of a new mixed use urban quarter at Greenwich Peninsula West incorporating new residential units and employment use.	1500 units	Along the eastern edge of the Peninsula West Development Site, the A102 leads towards the Blackwall Tunnel.	E01001667	1.547 ●
Charlton Riverside	Creation of a new mixed use urban quarter at Charlton Riverside	3,500 - 5,000 units	Woolwich Road (A206) has high levels of modelled NO_2 and PM.	E01001709 E01001666	1.422 ● 1.552 ●
Woolwich	Transformation of the Town Centre, with additional trade and usage. Regeneration of Housing Estates	3700 units	Plumstead Road (A206) in Woolwich suffers high levels of modelled NO_2 and PM within the area.	E01033731 E01033736 E01033737	1.351 1.336 1.355
Thamesmead and Abbey Wood	Remodelling of town centre, regeneration of existing housing estates	2000 units	Fairly low levels of pollution compared to borough averages.	E01001578 E01001687 E01033742	1.246 ● 1.334 1.336
Kidbrooke	Redevelopment at Kidbrooke incorporating 4,800 new homes, retail, leisure and community facilities	4,800 units	Junction of A2 with A2213 means high modelled levels of NO_2 and PM.	E01033726	1.446 ●
				Greenwich average	***1.312***

[3] Estimates of numbers of new units are taken from the Local Plan Core Strategy.

[4] The LSOA of each development was estimated by visual inspection of the relevant Site Allocations document which accompanies the Local Plan. Within each area's Site Allocations document, sites whose 'options for future use' included significant residential elements were mapped to the corresponding LSOA.

[5] LSOA-level indices of air pollution were taken from the IMD 2015 sub-domain on air quality. This index is based on modelled levels of four pollutants (nitrogen dioxide, benzene, sulphur dioxide and particulates). ● = LSOA among the most polluted 10% in Greenwich, ● = among the most polluted 10% in Greenwich, ● = better than the average pollution in Greenwich.

There are some limitations to the analysis presented in table 6. For example, this analysis is done at LSOA level and so does not account for differences within LSOAs. Developments which happen within an LSOA which has a main road running through it, but which themselves are located away from main roads (such as at Charlton Riverside) may experience lower levels of pollution than the average within the area. Furthermore this analysis does not take any account of population vulnerabilities, for example the age structure of the new populations which will move to an area. Another limitation is this analysis does not account for ways in which the developments themselves may affect air quality.

Nonetheless table 6 shows that several of the areas which are expected to undergo most new development in Greenwich are in some of the most polluted areas within the Borough. This makes including air quality considerations into planning decisions from the earliest opportunity crucial to addressing air quality's health impacts.

2.4.2. Silvertown Tunnel

A new road tunnel from the Greenwich Peninsula to Silvertown in Newham is planned to be built as one of five new river crossings in East London. Mayor Khan argues that this part of London "urgently needs new river crossings to support housing and business opportunities".[80] The proposed tunnel would be a twin-bore road tunnel, with user charging intended to be used in order to manage congestion and help fund the scheme. Construction is expected to start in 2018/19 for completion in 2022/23.

Transport for London (TfL) has undertaken an Environmental Impact Assessment and a Health Impact Assessment (HIA), which estimate the impacts on health via air quality and other means (such as noise, transport modal shifts, etc) during both the construction and operational phase. The HIA is based on TfL's traffic modelling, and it suggests that there is unlikely to be any negative impacts as a result of the tunnel, estimating that:

- During the construction phase "there is not considered to be an effect on health and wellbeing provided mitigation measures … are put in place."
- During the operational phase, there will no impacts on long-term mortality risk as a result of changes in PM exposure, and changes in mortality as a result of changes in NO_2 exposure may lead to a negligible change in life years lost.[81]

However, this HIS is based on an assumptions included in the forecast traffic flows produced by TfL. These traffic models effectively assume no additional traffic volume will be created as a result of the tunnel, but instead that existing congestion will be reduced. TfL argue that the toll applied for using the tunnel can be varied in order to ensure no change in traffic volumes.

Alternative scenarios based on the impacts of different traffic flows have not been provided by TfL, but it is likely that higher levels of traffic than forecast would lead to more severe impacts. RBG, along with other Councils, has not agreed TfL's traffic forecasts. If the tunnel was to be used to full capacity it would likely have much more significant air quality and health impacts in an area of the Borough which already has poor air quality. Any additional congestion may not only be in the immediate vicinity of the tunnel but may also occur at other hotspots elsewhere in Greenwich.

TFL and the Mayor of London have also committed to some measures that seek to minimise any negative impacts from the tunnel. For example, they have committed that new bus routes using the tunnel will have the latest (Euro VI) class of low-emissions vehicles.

2.4.3. Enderby Wharf Ferry Terminal

Planning permission has been granted for a new cruise ship terminal at Enderby Wharf, in Greenwich Peninsula West. This terminal will host ships up to 230m long, and it is expected that 50 to 60 ships per year will dock at the Wharf. Some local residents have made clear their concern about air quality impacts of the Enderby Wharf terminal, with local groups claiming that the emissions could be comparable to several idling lorries.

RB Greenwich commissioned detailed air dispersion modelling to consider pollutant emissions from cruise liners at Enderby Wharf. This modelling looked at those pollutants with greatest health impacts in Greenwich (NOx, SO_2, PM_{10} and $PM_{2.5}$). The report indicated there were no additional risks to the air quality objective for nitrogen dioxide or any of the other pollutants considered, due to the introduction of cruise ships. The decision not to install a facility for on-shore power supply was made following analysis which showed that 5% of cruise ships worldwide are currently designed in such a way as to allow them to receive such power from the shore.

RB Greenwich has also committed to monitor the impacts of the terminal using existing monitoring system, and an additional air pollution monitoring station will be funded using section 106 money from the scheme.

2.4.4. Toxicity Charge Zone, Ultra Low Emissions Zone

A new Ultra Low Emissions Zone (ULEZ) - an area within which all motor traffic will need to meet exhaust emission standards (ULEZ standards) or pay a daily charge to travel - will be implemented in Central London from 2020 at the latest. The ULEZ vehicle standards will apply 24 hours a day, seven days a week and will be additional to the existing Low Emissions Zone requirements.[82] The new Mayor of London has proposed and consulted on several further charges which would seek to reduce polluting vehicles in the city:

- An emissions surcharge or “t-charge”, which would means additional charges for the oldest, most polluting vehicles to enter into Central London.
- Extending the ULEZ: for heavy vehicles, to become a London-wide ULEZ for heavy vehicles, and for cars and other traffic to extend to the North and South circular roads.

RB Greenwich has lobbied for the extension of the ULEZ to cover all of Greater London. This would ensure that all Greenwich residents benefit from the scheme, and would also avoid any potential negative air quality impacts within the borough arising from polluting vehicles travelling around the South Circular to avoid the charge.

Information on evidence relating to ULEZs on air quality is summarised in the following section on ‘what works’. Studies that have investigated the impacts of Low Emission Zones have not focused on impacts around the edge which may be caused by displacement**.** [83,84]

3. What Do We Know about What Works?

3.1. Synergies and Co-benefits

Key points:

- There is the potential to gain many co-benefits from local action to control air pollution, from improving health to tackling climate change.
- For example, encouraging modal shift away from motorised transport and towards active travel can tackle three of our biggest public health challenges in one go: air quality, climate change and obesity.
- Actions that improve air quality while also contributing to additional co-benefits – such as modal shift or improved healthy environments – will have the greatest public health impact.
- As reductions in the level of pollutants in the air are unlikely to impact on everyone equally, interventions which maximise co-benefits are essential in order to tackle health inequalities.

Interventions which improve air quality can also have other co-benefits, which in turn provide additional causal pathways towards improved health. Examples of co-benefits that can result from interventions to address air quality include:

- **Active travel** such as walking and cycling as a result of modal shift away has the health benefit of increased fitness and helps reduce obesity and many diseases . Promoting active travel can have huge public health benefits – indeed transport is linked to one third of outcomes in the Public Health Outcomes Framework: more than any other wider determinant.[85]
- **Reduced risk of injury** from road traffic.
- **Increased community cohesion and social interactions**: for example due to cleaner air itself making people want to leave the house more, or due to provision of green spaces encouraging community cohesion.
- **Reduced greenhouse gas emissions** which tackles climate change – a key global public health challenge (see box 3)
- **Increased resilience to the impacts of climate change**. For example, reduced risk of flooding as a result of more trees and vegetation.
- **Urban cooling** and a reduction in the urban heat island effect.

In order to deliver these co-benefits, air quality efforts need to work across policy silos, with different teams and programmes working together to deliver actions that will lead to the greatest health benefit.[86]

Thinking about co-benefits can also clarify how different means of reducing air pollutant levels may have different health impacts, even for the same level of pollution reduction. For example, encouraging a move towards electric vehicles won't have as big a health impact as promoting walking and cycling through urban redesign, as the latter not only reduces air pollution but also improves physical activity levels.[87] Some efforts to reduce air quality have the potential for larger health benefits than would be expected as a result of the air quality improvement alone.[88]

However, actions to improve air quality do not always go hand-in-hand with other benefits. Awareness of the way in which these interventions interact with other health determinants can be important for avoiding interventions which may have negative impacts. For example, persuading people to avoid all outdoor physical activity may reduce levels of exposure: however there is clear evidence that at current levels of pollutants witnessed in Greenwich the benefits of physical activity outweigh the pollution risks, except for groups with existing vulnerabilities (such as COPD sufferers).

3.2. What Is the Evidence for Interventions at Local Level?

Key Points:

- Many actions across a range of functions - including planning, transport, environmental health, public health and education services - can assist in reducing the negative health consequences of air pollution. Aligning and coordinating efforts across these services will likely have the largest impacts.
- Public health benefits are most likely to arise from those actions which maximise co-benefits: for example through promoting active travel.
- The National Institute of Health and Care Excellence (NICE) has recently published a review of road traffic interventions which should be considered by Local Authorities when deciding upon actions to reduce air pollution.

This section reviews interventions which may improve air quality. Some of these are applicable at Borough level, while others would require cooperation across Boroughs or to be implemented at regional or national level. Interventions at national policy level, at community level, or at individual level all have the potential to address the health impacts arising from air quality.

The complexity of causal pathways between air quality and health means the evidence for what works best *from a public health perspective* is limited. For example, while many studies have looked at the impact of traffic free days on air quality, few have followed this up to see the resultant impacts on health.[89] NICE considers it appropriate to use changes in pollutant levels – $PM_{2.5}$ or NO_x – as proxy for health impacts where the latter are not available within the evidence base.[90]

Similarly, some actions – such as 20mph zoning – may have equivocal evidence around air quality changes but stronger evidence for impacts on road safety or modal shift. Given the strength of evidence around active travel and health, any interventions which successfully improve active travel area are likely to lead to substantial public health gains.

Box 4: Impacts, Inequalities and Integrated Approach

Impacts vary across different interventions. Co-benefits can mean not all air quality interventions have the same health impact. Sometimes it is assumed that any reduction will lead to health improvements of equal size: this is not always the case.[91] For example, it has been shown that reducing air quality via replacing cars

with lower-emitting versions would have much lower health impact than encouraging active transport which would have significant co-benefits via increase in physical activity.[92]

Inequalities must be considered. Interventions may affect different socio-economic groups differently and thus affect health inequalities. Reductions in air pollution do not always benefit the whole population equally. For example in Rome, higher socio-economic status communities benefited more from the Low Emissions Zone, largely because these groups were more likely to be living close to busy roads in that city.[93] A systematic review of equity within air quality interventions has found that the distribution of health gains from air quality interventions differed from one place to another.[94] This makes it important to actively consider health inequalities when implementing air quality interventions.

Integrated approaches can maximise health benefits. Tackling the health impacts of air pollution can be considered as a 'wicked' problem - i.e. one which requires many different coordinated actions in order to make progress. NICE recommends that a number of actions to reduce traffic-related pollution are undertaken together, "as multiple interventions, each producing a small benefit, are likely to act cumulatively to produce significant change." [95]

A good example of an integrated approach is Copenhagen, which implemented the CPH 2025 Climate Plan in 2009.[96] This 'holistic plan' has four specific focus areas; energy consumption, energy production, green mobility and city administration initiatives. Integrated operational management of public transport has significantly improved mobility and decreased congestion. Altogether this has resulted in 63% of the city's population biking to work or school every day. Reductions in the use of cars have resulted in CO2 emissions dropping by 83% in the city.

This section summarizes some of the actions identified within the published literature.

NICE has recently published a guideline for Local Authorities around traffic-related air pollution and its links to health. This guideline specifies actions that should be taken to reduce traffic-related pollution in particular. [97] Other sources of information on effective interventions include a 2012 review for the Royal Borough of Kensington and Chelsea which recommended 14 cost-effective actions to be taken.[98]

3.2.1. Built Environment, Regeneration and Transport Planning

The layout and built structure of a city can have substantial impacts on air quality. The built environment can influence:

- **Emissions of pollutants**. Encouraging design that encourage modal shift towards cycling and walking may reduce emission levels.
- **Diffusion of pollutants**. Building design can affect wind flow within the 'urban canopy layer' which can limit the transport of pollutants out of the city.[99]
- **Exposure to pollutants**: for example by determining where new housing or facilities are located relative to pollutant sources such as major roads. The California Senate Bill 352 created a

requirement in that state to determine whether a school site within 500 feet of a traffic corridor would create a health hazard from exposure to high levels of criteria pollutants.[100]

Planning for Healthy Environments

NICE recommends LAs should take air quality issues for the built environment into account through the Local Plan or Supplementary Planning Guidance, and should assess site plans from an air quality perspective: for example creating new buildings away from roads and designing developments so as to minimise the need for motorised journeys.

Incorporating health impacts of air pollution into land-use decisions could offer an important avenue for health improvements.[101] Section 2.4 above shows how many 'opportunity areas' in Greenwich – areas which will experience the largest population growth – are in parts of the Borough which are already polluted. This highlights the importance of planning decisions in order to minimise negative health impacts.

Wherever possible new developments should be built away from major roads and opportunities for maximising walkability and public transport infrastructure should be taken within new developments. The rapid 'drop-off' of pollutant levels with distance from roads means even within developments, locating buildings away from the road may reduce levels of exposure. Building away from roads can lead to important co-benefits too: for example increasing levels of play.[102]

A full consideration of interventions around urban design is beyond the scope of this paper, but useful guides have been produced elsewhere.[103]

Infrastructure for Zero-Emission Travel: Walking and Cycling

Infrastructure for active transport is an important factor that can contribute to modal shift and reduction in pollution levels. [104] Clear evidence exists about the features of streets and neighbourhoods which encourage people to walk – this has been set out in the "Healthy Streets" approach adopted by the Mayor of London.[105] Improving walkable connectivity of neighbourhoods has been shown to increase walking rates. TfL has developed several tools – such as 'walkability maps' which can be made available to Borough teams in order to progress.

A review of cycling infrastructure schemes in the UK has found strong evidence for an increase in cycling in such areas.[106] Infrastructure development of the 7 existing cycle networks in London – harmonising them together and providing additional signage – could lead to substantial reductions in emissions (250 tonnes of NOx per annum).[107]

NICE recommends creating infrastructure for walking and cycling in line with NICE guidance on the issue, as a cost-effective means of improving air quality.[108] They also recommend that where possible, cycle routes should be sited away from major roads, and junction design should minimise the time that cyclists spend at polluted sites (where this does not have a detrimental effect for other road users).

Improving public transport infrastructure – such as providing priority bus lanes – is a proven way to encourage modal shift and active transport. Walking to public transport provides opportunity for physical

activity and is an easy way to build the latter into daily life. That said, there is an evidence gap around the particular air quality impacts of bus priority lanes. [109]

Infrastructure for Low- Emission Travel: Electric Vehicles

EVs are not completely pollution-free (as particulates are produced by brakes and tyres), and their promotion does not contribute to co-benefits as does active transport. However, by supporting a move away from ICE vehicles, EVs can help to reduce traffic emissions.

Over the next several years, a number of major global car manufacturers will be mass producing fully electric vehicles aimed at widespread adoption. Tesla has sold over 100,000 Model S vehicles globally, and the company plans to sell 500,000 vehicles per year of their forthcoming Model 3 at a far more affordable price by 2020. Many more manufacturers are currently in the late stages of product development, aiming to capture a significant proportion of the rapidly growing market.

Currently, a lack of charging stations and 'range anxiety' represents a barrier to the uptake of electric cars, though some councils are leading the way on offering charging points and free parking for these cars (Westminster has 145 charging points).[110] Other boroughs are reviewing Parking Strategy to identify financial incentives to encourage the use of EVs.[111]

Green Spaces, Green Screens

Evidence around green infrastructure for health is mixed, and the impacts depend on many factors, including the openness of the space, species used, and the prevalent ventilation. As such, decisions about using green infrastructure should be undertaken on a case by case basis.

A recent review found that green spaces of any size can lead to air quality improvements. Among the 46 identified studies on green space and air pollution, 92 per cent reported pollution mitigating effects. [112]

Several types of green spaces or 'green screens' have been posited to reduce air pollution:

- **Trees**. Planting of trees is the most-studied form of greenery in terms of reduction in air pollutant levels. Much of this evidence shows trees to have a high ability to reduce gaseous pollutant levels at local sites and across cities.[113] There is conflicting evidence: one study found that trees along the kerbside resulted in more than a 50 per cent reduction in measured PM10 levels inside the houses.[114] However, in some cases trees may reduce wind speeds and trap pollutants within 'air pollution hotspots'.[115] NICE recommends that trees can be considered as means of reducing air pollution in open spaces.
- **Green screens and green roofs.** These involve growing vegetation on rooftops, walls or other screens. A full review undertaken in 2011 found that air pollution removal through the intensive application of green roofs is comparable to mitigation effects of urban forests.[116] As well as air pollution reductions, green screens can have some important other benefits – eg noise reduction, aesthetics, etc.[117]

Green screens close to schools were funded by Mayor's Air Quality Fund in several boroughs. Kensington and Chelsea put a green screen in place in a primary school on the Westway, with the intention of reducing exposure; and a report will be produced shortly by Kings College.[118]
The high cost of planting green screens means that they are not cost-effective ways to reduce air pollution, at least across large areas;[119] however NICE recommends they can be incorporated into new buildings where appropriate.

- **Small parks.** These have also been shown to be effective at reducing a range of pollutant levels.[120]

Emissions from Buildings

Buildings account for a substantial proportion of NO_2 emissions and the current Mayoral Air Quality Strategy identifies a target 693t/yr NOx reduction in emissions from buildings. Three actions would be required to achieve such a reduction in pollution from buildings: (1) replacement of old commercial and domestic boilers with new ultra-low NOx models; (2) improving the fabric energy efficiency of buildings; (3) using planning processes to ensure new developments are air pollution neutral or better.[121]

The Mayor of London's "Air Quality Neutral" standards are set out in Supplementary Planning Guidance and can assist in reducing air quality impacts of new buildings.[122] These are implemented within major developments in Greenwich, as Planning Officers consult Environmental Health and attach any recommended conditions.

3.2.2. Traffic Management, Enforcement and Financial Incentives and Disincentives

In addition to changes to the traffic infrastructure as discussed above, schemes that involve some form of 'road rationing' can seek to improve air quality. Several cities pursue such scheme:[123] some have declared an intention to go completely or partially car-free, while others have plans such as car free days, restricting parking places, and congestion or low-emission zones.[124] Oslo in Norway is planning to permanently ban all cars from the centre, while Madrid is looking for a modal shift from driving to walking by banning cars from certain areas.

Evidence of the impact of road rationing on air pollution levels is varied. Airparis, which measures city pollution levels, showed that levels of nitrogen dioxide dropped by up to 40% in parts of Paris on Sunday 27 September 2015, when cars were banned.[125] NO_2 levels in Leeds dropped by 20% on the day of the Tour de France Grand Départ when cars were banned from the city centre.[126] However, a systematic review did not find clear consensus on the impacts of 'high occupancy vehicle' lanes, and suggested that in fact promoting HOV lanes as a travel control measure may be misguided.[127] In Mexico City, the 'Hoy No Circula' scheme (by which cars were banned from the roads for one day in the week depending on their license plate number) eventually caused a lot more cars on the roads – as drivers bought multiple cars in order to get around the scheme – and has been estimated to have raised pollution levels by 13%

Stronger evidence exists for the impacts of road rationing schemes on modal shift[128] – although even here there is at times contradictory effects. This shows the importance of an integrated approach – actions such as providing good public transport or better cycling infrastructure alongside traffic restriction can help to lead to the largest benefits.

Congestion Charging or Low Emission Zones

There is mixed evidence about the impact of Low Emission Zones or Congestion Charging Zones on pollutant levels.

London's Low Emission Zone, which was implemented in 2008, appears to have had a positive impact on air quality. Ambient PM concentrations dropped by 2.46–3.07% within the LEZ, compared to just over 1% for areas just outside the zone. However, no discernible differences have been seen for NO_X concentrations.[129] Evidence from Holland also suggests Low-Emissions Zones may have only limited benefit in terms of reducing NO_2 levels but contribute to a significant reduction in for $PM_{2.5}$.[130] In Rome, emissions zoning had a positive impact on health, reducing NO_2 and PM_{10} significantly, and leading to a decrease in mortality equivalent to 921 years of life gained per 100,000 population.[131]

London's Congestion Charging Zone (CCZ) was introduced in 2003. Modelling of the air quality impacts of the CCZ, based on measured changes to traffic flow, suggested modest reductions in PM10 and NO2 and consequent modest improvements in health amounting to a total of 1888 life years gained across London as a result of the scheme. [132] However, analyses based on measured levels of pollutants within compared to without the CCZ area showed no impact on PM_{10} levels, and in fact a small increase in NO_2 levels – although this analysis was limited by the fact that there was only one roadside monitor within the CCZ area.[133] A study of the Milan CCZ similarly found no evidence of reduction in $PM_{2.5}$, however they did see a reduction in Black Carbon levels – a related indicator which is known to have health impacts.

One potential reason for this apparent lack of effect could be the increase in diesel cars which happened at the same time as the congestion charge was introduced. Furthermore, as PM has many non-traffic components it may be impacted in a limited way by changes to traffic make-up.

In addition to the London Low Emission Zone currently in place by the GLA (or an ULEZ replacement), local boroughs can choose to apply their own central Low Emission Zone(s). This could focus on buses and taxis (as HGVs are covered by the London-wide LEZ, and cars and LGVs do not produce large amounts of pollution), for example requiring certain filters or exhaust designs in order to operate.[134]

Car-Free Days

Car free days are a version of road rationing that can be readily applied at local level. These days first gained popularity in Bogotá, Colombia in the 1970s, when the government developed an initiative to close city streets to motorized traffic every Sunday. This scheme – named *Ciclovía* – worked to encourage cyclists and pedestrians to use the road space. Several hundred thousand people regularly take part in the scheme, and its popularity has led it to be replicated elsewhere, with adaptations.

Some studies have found strong air quality reductions on car-free days: up to 40% reduction in NO_2 levels have been observed,[135] but such effects are not seen everywhere.[136] However there is evidence that, combined with other infrastructure investments, car-free days can increase modal shift towards active transport, which leads to public health benefits. For example, in Bolgna, Lubeck and Aachen, car-free days in the city centre have been associated with reductions in car use of 60%, 40-80% and 36%, respectively.[137] A recent literature review found that the savings accrued via the health benefits of increased in physical activity during car-free days was enough to justify the staging of such events. It also found additional benefits including increases in social cohesion and economic benefits to local businesses (as a result of increased footfall).[138]

NICE recommends consideration of car-free days, particularly as a way to raise public awareness of the health risks of inactivity and of air pollution. [139]

Initiatives to Reduce Idling

Idling traffic produces unnecessary air pollution and it has been shown that turning the engine off reduces levels of particulates both near to and even within the vehicle.[140] TfL estimates that 59% of drivers parking or loading at the side of the road in central London leave their engines idling unnecessarily.[141]

Studies from the USA have shown that no-idling campaigns outside schools can in some circumstances lead to reductions in levels of particulates within the school building.[142],[143] However as this evidence comes from schools in USA where school buses are more common, its relevance to the UK context is not certain. As the evidence around anti-idling enforcement is indicative but uncertain, NICE recommends Local Authorities consider bylaws and other action to support 'no vehicle idling' areas - particularly where vulnerable groups congregate (eg at schools and hospitals).

Certain myths around idling – such as that it is more efficient to leave the engine running rather than stopping and starting – remain, despite new vehicles' manufacturers advising to the contrary.[144] Last year five inner-London boroughs organised a #noidling campaign as part of Clean Air Action Fortnight. For two days in March, 50 volunteers engaged with more than 600 drivers, asking them to turn off their engines.[145] No-idling zones have also been implemented outside major hospitals where vulnerable groups are likely to be present: for example, Great Ormond Street Hospital implemented such a zone using funds from the 2015 Mayoral Air Quality Fund.[146]

Speed Limits

Speed limits can be another local tool available for encouraging a reduction in road traffic volume and encouraging a move towards non-motorised traffic. Evidence about impacts air quality and physical activity is not strong, however evidence around road safety is stronger and a recent systematic review of 20mph zones found that most studies found a significant impact on traffic volume.[147] Several Local Authorities have implemented 20mph zones, and the 2015 Mayors' Air Quality Fund financed some 20mph schemes within London Boroughs.[148]

The important consideration around speed limits is that their implementation does not increase rapid accelerations or decelerations which are known to be detrimental for air quality. NICE recommends that 20mph zones are implemented in areas characterised by stop-go traffic (as this is likely to promote smoother driving). NICE also recommends that here physical measures such as humps and bumps are needed to reduce speed, they should be designed to minimise sharp decelerations and consequent accelerations.

3.2.3. Reducing Emissions from Transport Services and Fleet

Fleet. Upgrades to the Local Authority's fleet offers an opportunity for reducing air pollution. Vertical roof exhausts on buses have cut pollutant levels at breathing height by 90% in USA, while upgrade of bus engines to Euro VI standards, and fitting diesel particulate filters on Euro III taxis can all improve pollution too.[149]

Technological fixes within our fleet can also help to reduce emissions by promoting healthier driving styles. NICE suggests consideration of measures such as ensuring vehicles display real-time fuel consumption rates, or telematics to provide next-day information about driving style.

Fleet recognition schemes. Local Authorities can also promote the ECO Stars Fleet Recognition Scheme,[150] and indeed Greenwich's fleet has achieved ECO Stars level 3. This is a voluntary scheme that provides recognition, guidance and advice on operational best practice to operators of goods vehicles, buses and coaches. The scheme is aimed primarily to help fleet operators work in the most efficient way and the ultimate aim is to reduce fuel consumption which naturally leads to fewer vehicle emissions, thus less impact on air quality, and has the added benefit of making cost savings.

Driver training on fuel-efficient driving. As well as running an efficient fleet, provision of driver training can improve air quality. Acceleration and decelerations can cause increases in the quantity of pollutants produced by vehicles. NICE recommends that local authorities introduce fuel-efficient driving as part of any test carried out when appointing or re-appraising staff who drive as part of their work. They also recommend Local Authorities consider providing training for staff drivers to reduce their vehicle emissions.

3.2.4. Initiatives Aimed Providing Information, Advice, Education or Developing Skills

Business and Work-Based Programmes to Encourage Active Transport

Public information campaigns about active travel, delivered within workplaces, have been shown to be effective at encouraging modal shift and therefore reducing the amount of motorised transport. For example, analysis of the ''Walk in to Work Out'' scheme in Glasgow found significant increase in the amount of time that people spent walking to work,[151] while the Walk to Work Day in Australia has been shown to decrease the proportion of trips made by car.[152] Evaluations of the direct impacts of such interventions on air quality have not been undertaken.

CityAir, a programme within the City of London, sought to work with businesses to encourage walking by foot rather than short-distance taxi rides. Face-to-face meetings were held with facilities, energy, sustainability, operations and communications managers in 100 businesses. These were encouraged to provide maps and eliminate refunds for short-distance taxi fares; the result was a significant reduction in taxi use, which is likely to have resulted in a reduction in air quality (although the latter was not measured).[153] The benefits of a scheme such as this rely on the presence of large firms with many employees taking short-distance car or taxi journeys.

Work with Schools

Given young people's particular vulnerabilities to health effects of air pollution, working with schools could be a good opportunity for improving health outcomes. Working with schools to encourage active forms of travel to school – for example through physical activity promotion, delivering cycling lessons or cycling proficiency training, encouraging provision of bike racks, and providing walking routes to school can help to create modal shift which will have health benefits. The Mayors Air Quality Fund in Finsbury Park funded Apprentices to go into schools and deliver physical activity training. Four schools and local businesses were engaged to encourage walking which led to measurable impacts.[154] Such initiatives could be built into RBG's existing work undertaken with schools.

Car Clubs

Expanding car clubs, which can raise revenue, reduce car use and pollution, could have a positive impact for air pollution and health. A recent modelling study has found that total emissions of urban routes corridor can be reduced up to 35–36% for the urban route with an average vehicle occupancy of 1.70 passengers/vehicle compared to with 1.50 passengers / vehicle. 55% of car owners who joined car clubs in the UK reduced the cars they own by at least one and the annual mileage of Londoner's households decreases by over 2,300km on average when a householder joins a car club.[155] Additionally, car club cars tend to be more efficient than privately-owned vehicles.[156]

Car clubs can be promoted by Local Authorities using a Traffic Management Order in accordance with Section 6 of the Road Traffic Regulations Act 1984 and the Local Authorities Traffic Orders (Procedure) (England & Wales) Regulations 1996. [157]

3.2.5. Advice and Warnings for the Public and People at Particular Risk

Providing Information for Those Particularly at Risk

As identified in this JSNA, certain groups – including people suffering from cardiovascular or respiratory disease – are at increased risks of negative impacts from air pollution. As such, targeted information to these groups which enables them to minimise exposure, particularly during periods of high pollution, can minimise negative health impacts.

As such NICE recommends that healthcare professionals raise awareness of poor outdoor air quality and advise high risk groups on how to minimise their exposure and its impact. For people with particular vulnerabilities, this could include advice to:

- Avoid or reduce strenuous activity outside, especially in highly polluted locations such as busy streets, and particularly if experiencing symptoms such as sore eyes, a cough or sore throat.
- Use an asthma reliever inhaler more often, as necessary.
- Close external doors and windows facing a busy street at times when traffic is heavy or congested to help stop highly polluted air getting in.

Providing the Public with Information around the Risks of Air Quality

Communicating the health effects of air pollution with the public is important for several reasons. Not only do the public state that they want to be involved, also they can play a critical role in realising opportunities for health improvement, whether by reducing their personal exposure to air pollution, reducing their personal contribution to air pollution, or supporting and advocating actions to tackle air pollution locally.[158]

NICE recommends LAs provide the public with information on how:

- health is affected by exposure to air pollutants
- travel choices contribute to pollution and exposure to levels of local pollution
- engine 'idling' affects air quality in the vehicle as well as outside
- to minimise exposure by altering travel habits or routes (this includes restricting time spent with an engine 'idling', particularly near schools).

Additionally, NICE has produced guidance regarding the means by which public behaviour change communications should be produced.[159] Research by Defra found six important principles to be followed when undertaking public communications about air pollution:

1. Use information about **what particulate matter** is made of and **where it goes** to get the broader topic of air pollution onto the agenda – not statistics about health consequences.
2. Don't raise public concern about air pollution unless you can at the same time **satisfy people's desire to do something to reduce their exposure**. Focus on **what is known for certain** about the health consequences of air pollution.
3. Talk about air pollution as a **problem linked to specific places** – and not as a general problem of the atmosphere.
4. Keep the focus of communications on **practical improvements** – not long-term solutions.
5. **Demonstrate leadership and empower communities**, instead of just expecting individuals to change their behaviour.

It is important that any communications for the broad public continue to emphasise the benefits of active travel and physical activity which, for the majority of people, outweigh the risks posed by exposure to air pollution. While exercising does increase respiration and therefore increase exposure to pollutants,[160] there is no evidence that increased exercise in levels of pollutants experienced within London would have any negative impact for people without particular vulnerabilities.[161] In fact models have shown that the health

protection offered by exercise far outweighs the negative impacts, at even the highest levels seen in London.[162]

Assisting the Public to Modify Activity Time, Level or Location:

Several systems exist to increase awareness on air quality levels and to assist people at high risk of negative impacts to modify their activity. Examples include:

- *AirTEXT*, a text alert service which advises subscribers when pollutant levels increase (a scheme which RBG participates in),
- the *CleanSpace* app, which includes a micro-CO monitor and summarises pollution exposure during the user's journey,[163]
- methods to help people reduce their exposure such as Walkit.com.[164]

In spite of these schemes' popularity, there is a lack of strong evidence as to their impact on population exposure.[165] A recent study found that an AirAlert service (similar to AirText) led to a four-fold increase in emergency admissions, and an increase in emergency attendances at hospital.[166]

3.2.6. Reducing Baseline Risk of Cardiovascular and Respiratory Disease

Given that people with respiratory or cardiovascular disease are more vulnerable to negative impacts of air pollution, interventions which reduce risk of those diseases can also lessen the morbidity burden of pollution. Interventions which work towards smoking cessation, obesity reduction, hypertension management, or reduction in COPD can all be useful.

A full discussion of means to reduce CVD and respiratory disease is set out elsewhere in the JSNA and is not repeated here [167]

4. What Do We Know about Local Actions?

Key Points:

- Greenwich has several assets which can assist us in tackling the health impacts of poor air quality within the Borough, from our green parks and open spaces to our extensive network of air quality monitors.
- Several strategies and teams – including planning, digital services, transportation, public health and other departments – all influence air quality and health in Greenwich.
- To get the greatest public health gain, we should align these efforts and focus them on delivering co-benefits for health (such as physical activity) for parts of the population that stand to experience the greatest health (such as young people in more deprived areas).

Regulatory actions taken in recent years, such as the Air Quality Standards Regulations 2010 and imposition of the Low Emissions Zone,[168] have contributed to an improvement of air quality, including in Greenwich.

RBG actions have historically led the way in air quality improvements, and have resulted in the Borough being one of just four local authorities to be awarded air quality Beacon status.

4.1. Assets

Greenwich has several assets which can assist us in tackling the health impacts of poor air quality within the Borough. Actions to improve air quality should seek to align the contributions of each of these assets, and ensure they focus on the approaches and populations that will deliver the greatest public health benefit.

Physical Assets

- **Green and open spaces.** Greenwich has a number of **green flag parks** which can help to diffuse pollutants while providing a haven for local residents. The World Heritage Site of Maritime Greenwich offers extensive open space apart from major roads. Other open spaces include areas in the South East London Green Chain as well as many smaller green spaces.
- **Growth areas.** As noted above, five of the London Plan's growth areas lie in Greenwich, and a further one lies on the Borough boundary. While this presents challenges for air quality, the extensive amount of planning and developing in and around those areas also offers key opportunity to build clean and healthy neighbourhoods.
- **Cycle networks.** Greenwich has made progress in extending and improving cycle routes across the Borough, as well as linking them together to form a network that is useful for a range of cyclists.
- We have the most **extensive monitoring system** of any Borough in London, meaning that we can accurately see trends in air quality in near-real time and can use that information to evaluate interventions.
- The **River Thames** runs along the edge of Greenwich. This offers opportunities for transport of people and goods which may, if clean transport is used, alleviate pressure on local roads.

Experience and Recognition

- Greenwich has a long history of leading the way in improving air quality. Many actions developed here – such as Low Emission Areas which originated on the peninsula have gone on to be implemented widely beyond Greenwich.
- Our **Air Quality Beacon status** recognises the excellent work done to date to improve air quality within the Borough. Greenwich has been awarded **Cleaner Air borough status** by the GLA to recognise our leadership in improving air quality. Awards such as these give us the credentials to take bold leading action to improve the air locally.

4.2. Key Actions Currently Being Delivered

Several actions currently undertaken in RBG will affect air quality and its impact on health. In order to maximise the health benefits, these programmes of work should focus on those areas and populations where pollutant exposure has the largest impacts, and should emphasise approaches and actions which will deliver co-benefits for health wherever possible.

Strategic Alignment

As noted in section 2.1.4 above, several Borough-level strategies – such as the Local Plan – include explicit objectives to improve air quality in Greenwich. Others like the Greenwich Smart City strategy will directly affect air quality and health via their impacts on local infrastructure and the built environment. Others still, such as the Health and Wellbeing Strategy which includes a focus on childhood obesity, may not affect air quality levels but can improve health outcomes by reducing vulnerability to exposure.

These different strategies are being delivered by different teams across RBG; these teams are represented in the Air Quality Task Force which plays a co-ordinating role. In order to ensure the greatest health benefits the strategies should align, complement each other and focus on those parts of the population that stand to experience the greatest health gain. Some current good-practice examples of such alignment include:

- The obesity action plan which sits under the Health and Wellbeing Board currently includes actions seeking to improve walkability of neighbourhoods, thus overlapping with planning strategies locally.
- The draft Air Quality Action Plan mentions anti-idling actions which are focused at schools and can be aligned with Public Health and Wellbeing team's school-focused work.
- The Greener Greenwich strategy clearly specifies the expected co-benefits of each of its actions, including which ones are likely to deliver benefits for 'wellbeing'.

Air Quality Action Plan

Most actions specifically focused on monitoring and addressing air quality within the Borough are set out within our Air Quality Action Plan (AQAP), a new version of which has recently been consulted upon.[169] Progress on actions outlined in the AQAP is monitored by the Air Quality Task Force and reported on annually.

Some key actions occurring within Greenwich include:

Low Emissions Neighbourhood

Greenwich has been awarded funding to deliver a 'Low Emissions Neighbourhood' focused on improving air quality in the Greenwich West and Peninsula wards – some of the most polluted areas of the Borough. Many of the proposed actions have the potential to improve air quality while leading to substantial co-benefits: for example car-free days and incentives to improve walking and cycling.

Horizon 2020

The Royal Borough is a partner in a recently successful bid under the European Commission Horizon2020 call for Smart Cities & Communities. The programme commenced in January 2016, and will last five years to

December 2020. One key pillar of the programme concerns promoting sustainable urban mobility – including through the provision of smart parking meters and other technological advances to reduce unnecessary motorised journeys.

ECO Stars

Through our ECO Stars scheme we are working with local commercial fleet operators in a new scheme that will improve air quality on local roads. The ECO Stars scheme encourages and supports operators of HGVs, vans, buses and coaches to run their fleets more efficiently. Greenwich Fleet Services, DHL (Nisa) and the University of Greenwich were all present at the launch event early in 2016, and since that time we have been working with local hospitals and other fleet operators to roll out the scheme.

Work with Schools

RBG's Public Health and Wellbeing team work with local schools to improve health-related behaviour; including to promote active travel to school. Similarly RBG's transport team is currently working on outreach to schools to raise awareness of air pollution and how reducing idling and increasing active travel can reduce levels of pollutants.

Community Street Audits

We work with local communities to undertake Community Street Audits – these are a way to evaluate the quality of streets and spaces from the viewpoint of the people who use them, rather than those who manage them. They allow a small group of local residents, traders, councillors and officers to assess a route on foot, produce a detailed report with recommendations, and thus feed into the planning process.

Expert Patient Programme (EPP)
Our Expert Patient Programme supports people living with - or caring for someone with - a long-term condition. Some of the conditions that our EPP participants have included are those which increase susceptibility to the impacts of air pollution. Our EPP therefore offers a good avenue of contact, enabling us to provide information around air quality and the health impacts to those who could benefit the most.

4.3. Key Planned Actions

The main actions currently planned around air quality are included in the Air Quality Action Plan (AQAP) for the Borough. The previous AQAP, published in 2002, led to some concrete actions such as Low Emissions Areas for major developments; a lorry ban in Greenwich town centre; and improvements to the refuse collections fleet.

The updated 2016 AQAP will set out the actions that RBG is taking to improve air quality within its boundary; these actions are aligned with the Greener Greenwich Strategy. The main priorities included in the pre-consultation draft plan are:

1. Manage the impact of future growth in the borough, for example by ensuring that new developments are air quality neutral where possible, and that they are designed so as to encourage walking and cycling where possible.

2. Support healthier lifestyles for residents, for example by encouraging physical activity, making new developments car free or car-capped, and ensuring that outdoor spaces are protected from pollution sources.
3. Reduce the impact of traffic on air quality and congestion, for example by supporting national or regional schemes that seek to ensure cleaner vehicles, or by lobbying TFL for extension of the ULEZ to cover the entire Borough.
4. Reduce our own impact on air quality; for example through improvements to our fleet, to the energy efficiency of our buildings and by progressing our Travel Plan to encourage more modal shift towards non-motorised means of transport.

5. What Additional Actions Could Bring Further Public Health Benefit?

Many stakeholders from many teams have a role to play in improving air quality and minimising the health impacts within Greenwich. This JSNA seeks to ensure that all stakeholders are aware of the important health benefits that can arise from their work. Continued coordination between teams – through forums such as the Air Quality Task Force, Walking and Cycling Strategy Group, Obesity prevention delivery group, Low Emissions Zone groups and others can ensure that diverse actions lead to the maximum benefit.

The local Air Quality Action Plan sets out agreed actions for several teams to undertake in order to improve air quality in the Borough.

In order to maximise public health benefit, actions to tackle air quality should (a) ensure they deliver co-benefits for health and (b) focus on those parts of the population that stand to experience the greatest health gains.

Three areas of action in particular could lead strong public health benefit. These areas for action link with other priorities of the Greenwich Health and Well Being Strategy – particularly around tackling childhood obesity and improving mental health and wellbeing.

1. **Bold Action to Encourage a Strong Modal Shift Towards Active Forms of Transport – Walking and Cycling**

   Encouraging modal shift can address three public health issues – poor air quality, physical inactivity and climate change – at the same time. Potential actions may include

   - Continued improvement of the built environment so as to promote walking, cycling and public transport (see also below).
   - Traffic management such as road charging, car-free days, car free roads or areas.
   - Continuing to deliver walking clubs and expanding them to cover larger parts of the population.
   - Initiatives with schools and workplaces, to encourage active transport to work.
   - Utilising Health Economic Assessment to set out the health benefits of transport schemes.[170]

Learnings from innovative schemes including the Low Enterprise Neighbourhoods and Horizon2020 initiatives should be rolled out across the Borough where appropriate. An integrated approach with interventions around infrastructure, traffic management, and educational initiatives coming together is likely to have largest impact.

2. **Planning for Healthy Environments**

   The rapid development which is set to happen within Greenwich offers an opportunity to make new developments walkable, cycle-able and less car-orientated. Potential actions to achieve this include:

   - Implementing whole-area reviews of walkability of development areas. These could be built into planning processes.
   - Using the 'Healthy Streets' approach set out by the Mayor of London to inform the design of new streets. This approach seeks implement design features to ensure that streets are attractive to walk along for all people – of all ages and abilities.
   - Developing a plan for a walkable Green Grid for Greenwich, building on London-wide Supplementary Planning Guidance.[171] Maximising walkability and connected green space within developments.
   - Minimising car parking spaces in new developments.
   - Utilising Health Economic Assessment to assess the health benefits of developments.[172]
   - Incorporating assessment of air quality issues into Community Street Audits.
   - Continuing to work with transport planners to align cycling infrastructure across the Borough, as set out in the Greenwich Cycling Strategy.

   Opportunities such as the National Clean Air Action Day in March 2017[173] can be used to raise awareness of the importance of these actions.

3. **Work to Reduce Health Risk Among the Most Vulnerable Groups**

   Young people, older people and those with pre-existing diseases are more vulnerable to health impacts of air quality. Efforts to minimize pollutant levels where these groups are can therefore lead to important health benefits. Potential actions could include:

   - running anti-idling measures at schools and hospitals,
   - delivering educational sessions for schools about active travel,
   - awareness raising through our Expert Patient Programme and other healthcare professionals.

Annex 1: Population Exposure in Greenwich Compared to Other London Boroughs.

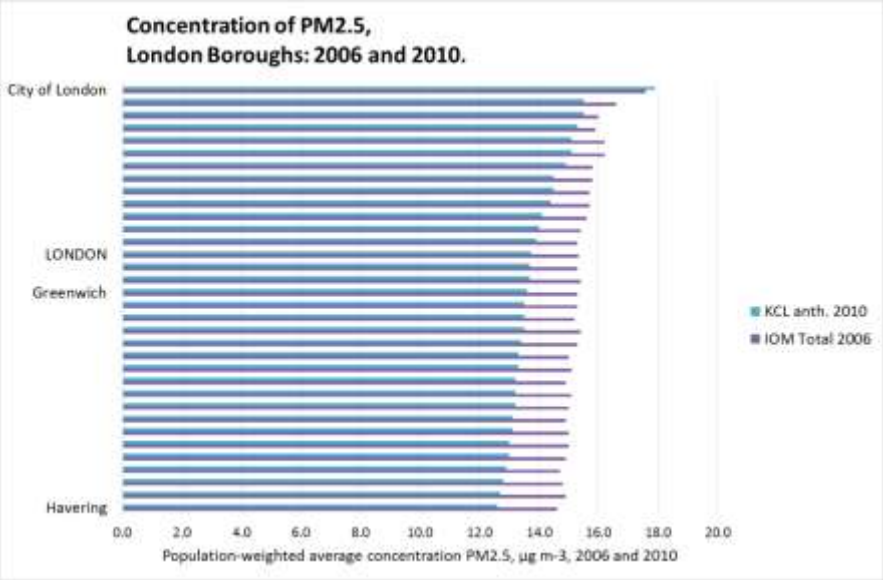


Figure 8: population average weighed concentration for $PM_{2.5}$ by Borough. Source: KCL report for GLA, May 2015.[174]

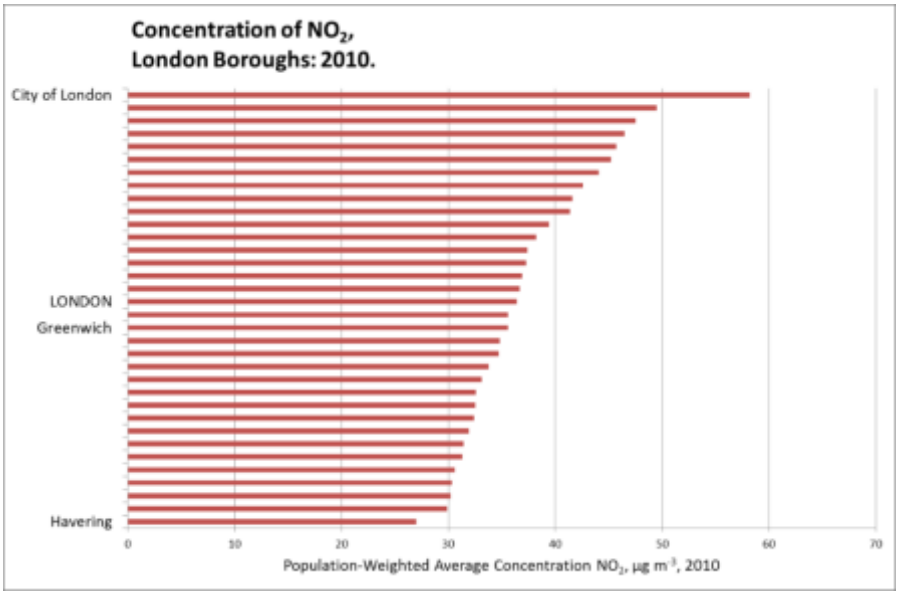
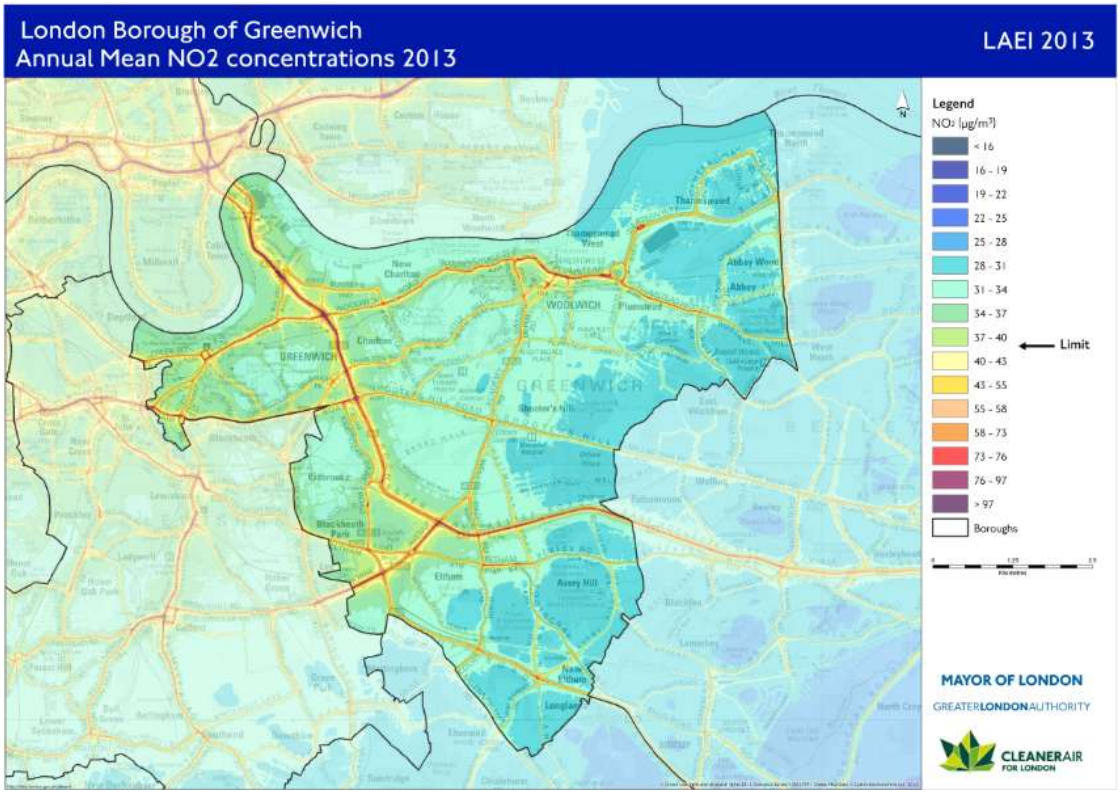
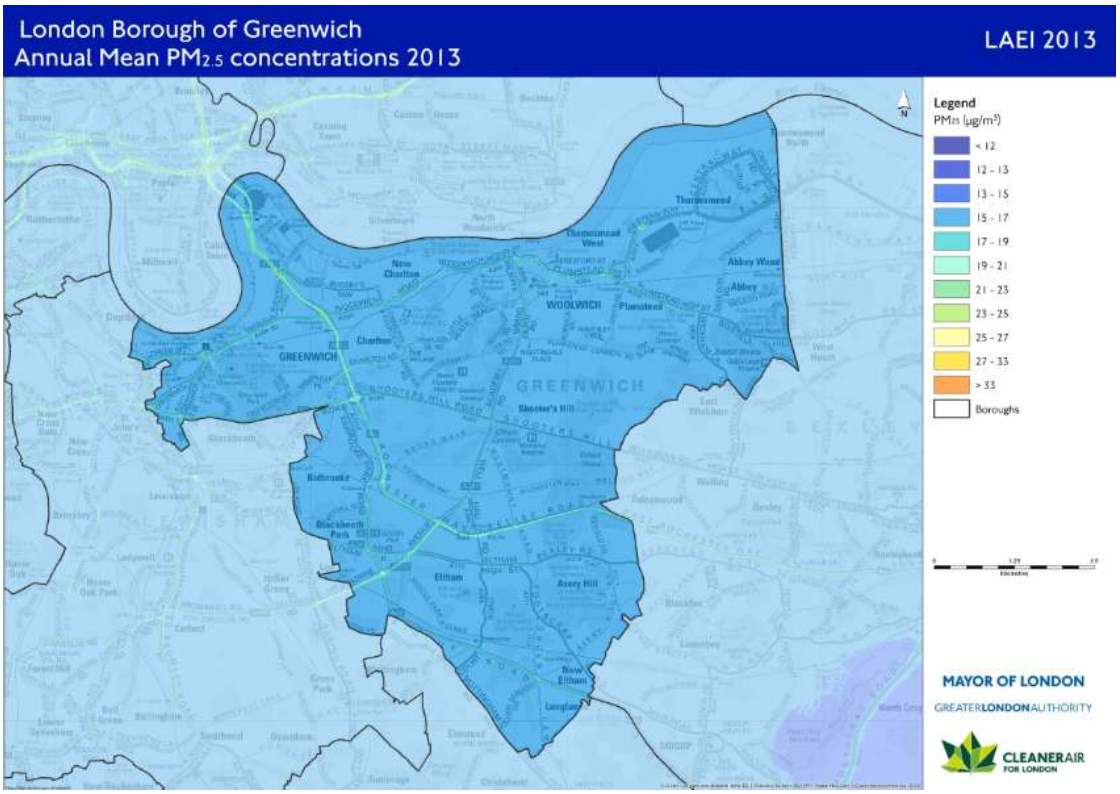


Figure 9: population average weighed concentration for NO_2 by Borough. Source: KCL report for GLA, May 2015.[175]

Annex 2: Maps of Pollutant Levels Modelled Using 2013 Data.





Annex 3: Inequalities in Air Pollution by LSOA-level Deprivation.

This analysis sought to estimate the relationship between air pollution and area-level deprivation within Greenwich.

Data:

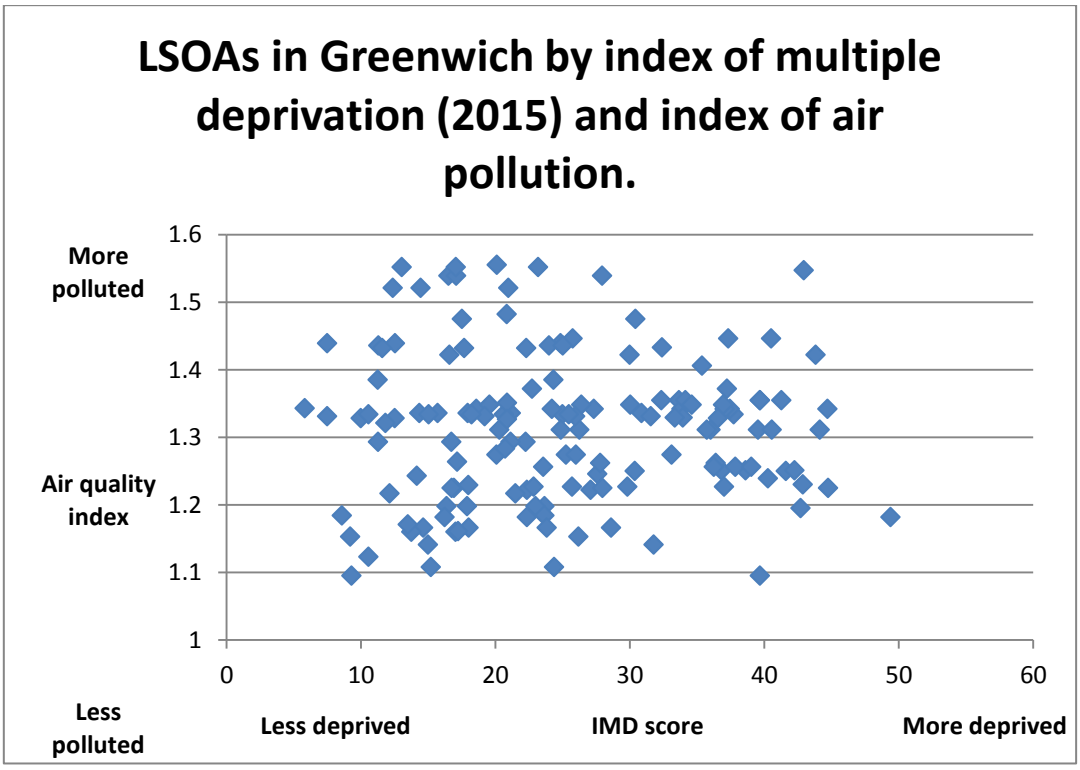
- Estimation of Air Quality was taken from a LSOA-level index of air quality. This index is based on the relative prevalence of four pollutants (PM, NO2, CO, Benzene) compared to the English average. Higher index scores mean higher levels of pollution. Scores higher than 1.0 indicate higher than the English Average – as can be seen below, every LSOA in Greenwich has a higher score than the English average (which is not surprising given our urban setting.
- Data on level of deprivation is taken from the 2015 Index of Multiple Deprivation.

Both of these indices are available at the geographical level of 'Lower Super Output Area' (LSOA).

Findings

As the chart below shows, no clear relationship is found when these two indicators are plotted together, at LSOA level in Greenwich.

There are many possible reasons for this and it is important to note that this analysis does not necessarily mean that more deprived households in Greenwich are not more exposed to air pollution. LSOAs are likely to be geographically too large to form meaningful units of analysis. These LSOAs cover areas with widely differing levels of air quality – particularly as areas close to roads suffer much higher levels. So it may be that deprived households are more (or less) likely to be exposed to worse pollution at that scale – and the data that are available (at LSOA level) are not able to pinpoint such trends.



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