Liverpool
Public Health
Observatory

# Rapid Evidence Review Series:

## Local interventions to tackle outdoor air pollution with demonstrable impacts on health and health service use

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**LPHO Report Series, number 101**
**Rapid Evidence Review Series, number 4**
***Produced on behalf of the Merseyside Directors of Public Health***

**January 2015**

PROVIDING INTELLIGENCE FOR THE PUBLIC HEALTH

# Rapid Evidence Review Series

## Local interventions to tackle outdoor air pollution with demonstrable impacts on health and health service use

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# Summary

## 1. Background

Liverpool Public Health Observatory (LPHO) was commissioned by the Merseyside Directors of Public Health, through the Cheshire & Merseyside Public Health Intelligence Network, to produce this rapid evidence review. This review presents the evidence on the effectiveness of local interventions to tackle outdoor air pollution, involving demonstrable impacts on health and health service use. A summary of World Health Organisation (WHO) and European air quality guidelines and thresholds was also included. A rapid literature search of academic databases was conducted to examine research evidence from 1994 to 2014. As this is a rapid evidence review, not a full systematic review, the results should be regarded as provisional appraisals.

The review excluded studies that demonstrate associations between air pollution and health, but do not evaluate interventions. This is because the association between air pollution and health has been well documented, with for example the estimated burden of particulate air pollution in the UK in 2008 equivalent to nearly 29,000 deaths (Defra, undated).

## 2. Results

### *2.1 Guidelines*

The main body of the review gives details of current air quality guidelines. A recent WHO report recommended modifications to European Union law, as the EU's Ambient Air Quality Directive current limit value for particulate matter (PM) is presently twice as high as the 2005 WHO Air Quality Guidelines (AQGs) (WHO, 2013).

Particulate matter ($PM_{2.5}$) is the pollutant which has the biggest impact on public health and on which the Public Health Outcomes Framework indicator is based. In 2013, DEFRA undertook a consultation prior to a Review of Local Air Quality Management in England, with a toolkit for local authorities due to be released during 2015. Defra and Public Health England note that typical measures to reduce emissions from local sources include traffic management, the encouragement of uptake of cleaner vehicles, and increased use of public transport along with more sustainable transport methods such as walking and cycling. Local authorities could also consider other measures to improve air quality, such as implementing low emission strategies, including industrial emission controls and the use of smokeless fuels during industrial and domestic combustion (Defra, undated; PHE, 2014a). No evidence for the health benefits of these suggested interventions was presented.

### *2.2 Evidence*

There is a wealth of literature on the health effects of air pollution. There are relatively few studies examining the association between interventions to reduce pollution and health impacts, especially relating to local interventions. It is not always possible to carry out such evaluations experimentally, due to practical difficulties in controlling variables and the size of intervention effects. As a result, health benefit modelling has been developed.

*Cumulative interventions*: A study by Lobdell et al (2011) looked at the modelled impact of cumulative air pollution reduction programmes and found that interventions to reduce PM concentrations are likely to lead to relatively modest reductions over time. Assessment of intervention effects is therefore best carried out targeting small areas of dense population and where pollution concentrations are highest (Lobdell et al 2011; Fann et al 2011; Gibb, 2011). For example in small areas within New Haven (US) having the greatest $PM_{2.5}$ reductions, numbers of CHD and asthma hospitalisations decreased significantly as the reduction in $PM_{2.5}$ increased (Lobdell et al, 2011).

*Active travel and low carbon driving:* A study by Woodcock et al (2009) modelled different scenarios and their health effects in London. They found that a reduction in carbon dioxide emissions through an increase in active travel and less use of motor vehicles had larger health benefits per million population (7332 disability-adjusted life-years [DALYs]) than from the increased use of lower-emission motor vehicles (160 DALYs). This is even after allowing for the increase in road accidents and breathing in air pollution due to active travel, mainly involving cycling and walking (Milner et al, 2012; de Nazelle et al, 2011).

Policies to increase the acceptability, appeal, and safety of active urban travel, and discourage travel in private motor vehicles would provide larger health benefits than would policies that focus solely on lower-emission motor vehicles (Woodcock et al, 2009; PHE, 2014). There are co-benefits that result from pedestrian and cycling-friendly neighbourhood designs, for example such schemes can help to build social capital and limit transport poverty (Giles-Corti et al, 2010).

*Low emission zones (LEZ) and speed management:* So far, it remains unclear what improvements in pollution levels and health can be attributed to the London LEZ, which was established in 2008 as the world's largest LEZ (Ellison et al, 2013; Kendall, 2011). A modelled study of German LEZs suggested that health benefits of roughly 2 billion dollars have come at a cost of 1 billion dollars for upgrading the fleet of vehicles (Wolff, 2014).

*Speed management zones:* Keuken et al (2012) found that speed management and to a lesser extent, a low emission zone, are effective in reducing the health effects of road traffic emissions. In Barcelona, a motorway speed management zone was estimated to decrease mortality rates by around 0.6% and increase life expectancy by 0.15 months. The authors claim that the number of deaths in the Metropolitan area could be reduced by 40 per year as a result of the strategy (Baldasano et al, 2010).

*Congestion charging:* In Stockholm, a study based on observed rather than modelled data found that congestion charging resulted in reduced emissions estimated to save five life-years per year (Eliasson, 2009).

*Natural gas*: A modelled study in Chile estimated that switching to a compressed natural gas (CNG) public transportation system would reduce urban $PM_{2.5}$ emissions by 229t/year, leading to 36 avoided premature mortalities (Mena-Carrasco et al, 2012).

*Electricity:* Markandya et al (2009) reported on the modelled health benefits of clean methods of electricity production from fossil fuels.

*Nationwide programmes:* There are several examples of the health effects of national interventions. In China for example, a variety of national initiatives, including the Blue Sky programme introduced in the 1990s, have led to improvements in urban air quality (Zhang et al, 2005). Zhang et al modelled the health effects of these improvements, which included a 50% reduction in prevalence rates of bronchitis amongst schoolchildren.

## 3. Discussion

Although the evidence on effectiveness is limited, it is important that recommended local air pollution interventions are implemented. All proposals for interventions should include an evaluation component. To be effective, schemes will require multi-sector collaboration.

**Key Findings**

- EU air pollution thresholds are currently much higher than those recommended by WHO
- Relatively few studies were found that were directly relevant to this review. Those studies that do exist almost all use modelling techniques
- Interventions and assessment of intervention effects are best carried out targeting small areas of dense population and high pollution concentrations
- Policies to increase active travel and reduce vehicle use would provide larger health benefits than policies with a sole focus on lower-emission vehicles
- Co-benefits of active travel include increased social capital and reduced transport poverty
- Speed management zones and to a lesser extent low emission zones (LEZs) are effective in reducing the health effects of traffic emissions
- Congestion charging and the use of compressed natural gas (CNG) in public transport both result in significant health benefits
- It is important that local air pollution interventions are implemented, despite the limited evidence base on their effectiveness
- All local proposals for interventions should include an evaluation component. Nitrogen dioxide levels and health effects should be considered in addition to particulate matter
- Multi-sector collaboration is required

# 1. Background

Liverpool Public Health Observatory (LPHO) was commissioned by the Merseyside Directors of Public Health, through the Cheshire & Merseyside Public Health Intelligence Network, to produce this rapid evidence review. It is the fourth in a series of LPHO reviews, with previous reviews covering the topics of loneliness interventions, the cost effectiveness of monitored dosage systems and suicide prevention training. This review presents the evidence on the effectiveness of local interventions to tackle outdoor air pollution, involving demonstrable impacts on health and health service use.

The rapid evidence review was requested by Sefton Borough Council and will inform collaborative work between council departments (Public Health, Environmental Services) and with Public Health England. The review will inform Sefton Borough Council work relating to Air Quality Management Areas (AQMAs) and port development. It will be shared with partners across Merseyside to inform similar work being undertaken.

Rapid evidence reviews are used to summarise the available research within the constraints of a certain timescale, typically less than three months and in this case, three weeks. They differ from full systematic reviews due to these time constraints and therefore there are limitations on the extent and depth of the literature search. They are as comprehensive as possible, yet some compromises are made in terms of identifying all available literature. They are particularly useful to policy makers who need to make decisions quickly but should be viewed as provisional appraisals (CRD, 2009).

## Air pollution and health effects

The brief for this rapid review was to focus on an evaluation of interventions. It excluded studies that demonstrate associations between air pollution and health, but don't evaluate interventions. This is because the association between air pollution and health has been well documented, as summarised briefly here.

For example, a recent World Health Organisation(WHO) scientific report found that long-term exposure to fine dust particles ($PM_{2.5}$), can trigger atherosclerosis, adverse birth outcomes and childhood respiratory diseases (WHO, 2013). The European Commission estimates that as many as 460,000 Europeans die prematurely each year because of poor air quality, with some health groups saying the toll is even higher (EurActiv, 2013). Estimates of the number of deaths in UK local authorities that can be attributed to long term exposure to particle air pollution have been published by Public Health England (PHE, 2014).

Air quality is recognised as the UK's second biggest public health concern after smoking, with the Environmental Audit Commission estimating it annually costs the nation £20bn and can cut life expectancy by years (Henderson, 2012). A Defra briefing paper summarised the health impacts of poor air quality in the UK as follows:

- The burden of particulate air pollution in the UK in 2008 was estimated to be equivalent to nearly 29,000 deaths at typical ages and an associated loss of population life of 340,000 life years lost.

- It has been estimated that removing all fine particulate air pollution would have a bigger impact on life expectancy in England and Wales than eliminating passive smoking or road traffic accidents.
- The economic cost from the impacts of air pollution in the UK is estimated at £9-19 billion every year. This is comparable to the economic cost of obesity (over £10 billion).

*(Defra, undated)*

Particulate matter ($PM_{2.5}$) is the pollutant which has the biggest impact on public health, increasing the age-specific mortality risk, particularly from cardiovascular causes (Defra, undated). The Defra briefing paper noted that exposure to high levels of PM (e.g. during short-term pollution episodes) can also exacerbate lung and heart conditions, significantly affecting quality of life, and increase deaths and hospital admissions. Children, the elderly and those with pre-existing respiratory and cardiovascular disease, are known to be more susceptible to the health impacts from air pollution (Defra, undated).

Box 1 lists the main sources of air pollution.

**Box 1**
**Outdoor air pollution**

Example sources of exposure and exposure pathways:

*Inhalation of toxic gases and particles from vehicle and industrial emissions, or naturally occurring sources such as volcanic emission or forest fires.*

Examples of chemicals:

*Sulphur dioxide, nitrogen oxides, ozone, suspended particulate matter (see Box 2 for types), lead, benzene, dioxins and dioxins-like compounds.*

*Pruss-Ustin et al, 2011*

## Methods

The researcher based the search strategy as closely as feasible in the permitted timescale to the CRD guidance for undertaking rapid evidence reviews (CRD, 2009).

**Identification of studies**
The following electronic databases were searched, initially from 1994-2014: Scopus and the NIHR Centre for Reviews and Dissemination database (CRD database). The CRD database was the first to be searched, as this includes all the main systematic reviews relevant to public health and also includes Cochrane reviews. The Atmospheric Environment Journal was not searched separately, as this journal is included in the Scopus database.

The researcher developed a research strategy incorporating synonyms and spelling variants, based on key papers and how they had been indexed, and were adapted to each database. Reference lists were visually scanned from relevant articles meeting the inclusion criteria.

**Inclusion and exclusion criteria**
The brief for this rapid review was to summarise the evidence from 1994 onwards on outdoor air pollution interventions that demonstrated health effects. This would include behaviour change, transport, other non-clinical interventions and site specific interventions or those that can be implemented at local authority level. The focus was on particulate matter

(PM), ozone ($O_3$) and nitrogen dioxide ($NO_2$). The brief excluded studies that demonstrate associations between air pollution and health, but do not evaluate interventions.

Primary outcome measures to be considered were A&E admissions, GP consultations, prescribing and hospital admissions. Secondary outcome measures were exacerbations of respiratory conditions and condition specific episodes.

WHO and European air quality guidelines and thresholds were to be included.

The review looked for evidence of the effectiveness of interventions in papers published since 1994, up to 1st September 2014. Key search terms for the review included combinations of the following: air; health; pollution; intervention; outdoor; low emission; LEZ; congestion charge; sustainable travel; low carbon; and air quality management + benefit.

Initially, searches were made for key words in the title plus abstract fields. If this produced too many articles for the particular search term, then the search for that term was limited to the title only and then to more recent time periods.

**Data abstraction**

Data was not systematically extracted, as would be expected from a full systematic review. The researcher grouped the data into themes of active travel, low emission zones, etc.

# 2. Results

## 2.1 Guidelines and local and national action

### WHO and European air quality guidelines and thresholds

The WHO air quality guidelines relate to four common air pollutants: particulate matter (PM), ozone ($O_3$), nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$) (WHO, 2005). The WHO noted that for air pollutants not considered in this document, the conclusions presented in the WHO Air quality guidelines for Europe remain in effect (WHO, 2000).

The European Commission has a set of Air Quality Standards, last updated October 2014, which includes a table of standards for each pollutant (EC, 2014).

Modifications to European Union law are recommended in a recent WHO report, as the EU's Ambient Air Quality Directive current limit value for PM is presently twice as high as the 2005 WHO Air Quality Guidelines (AQGs) (WHO, 2013) (see Box 2). The report also recommends a new AQG for nitrogen dioxide ($NO_2$), a toxic gas produced by vehicle engines. The development of AQGs for long-term average ozone ($O_3$) concentrations is another recommendation (WHO, 2013; EurActiv, 2013).

Kurmi and Ayres (2007) note that the present suggestion being debated in Europe about a change in AQS to a $PM_{2.5}$-based standard will, if taken up at the proposed levels, represent effectively a slackening of control for current member states. They comment that while this may still prove challenging for new member states, continuing downward pressure on levels of air pollution is essential if the benefits already seen from improving air quality are maintained.

> **Box 2**
>
> **Comparison of WHO and EU air pollution thresholds**
> *for humans, measured as micrograms per cubic metre:*
>
> • Ozone ($O_3$): WHO per 8-hour period, 100; EU, 120
>
> • Larger particular matter, or $PM_{10}$ (smoke, dirt and dust form coarse particles): WHO annually, 20; EU, 40.
>
> • Fine particulate matter, or $PM_{2.5}$ (metals and toxic exhaust from smelting, vehicles, power plants and refuse burning forming fine particles): WHO annually, 10; EU (as of 2015), 25.
>
> • Sulphur dioxide ($SO_2$): WHO daily, 20; EU, 125.
>
> • Carbon monoxide (CO): WHO and EU, 10 for an 8-hour period.
>
> *EurActiv, 2013*

## Local action

Public Health England has recognised that the increase in mortality risk associated with long-term exposure to particulate air pollution is one of the most important, and best-characterised, effects of air pollution on health (PHE, 2014). The UK Public Health Outcomes Framework (PHOF), Domain 3 relates to health protection, featuring a range of indicators including 'the fraction of mortality attributable to air pollution' (DH, 2013). The indicator is based on particulate matter ($PM_{2.5}$). The baseline data for the indicator have been calculated for each upper tier local authority in England based on modelled concentrations of fine particulate air pollution ($PM_{2.5}$) in 2010. Estimates of the percentage of mortality attributable to long term exposure to particulate air pollution in local authority areas range from around 4% in rural areas to over 8% in cities (Defra, undated).

In 2013, DEFRA undertook a consultation prior to a Review of Local Air Quality Management in England, with a toolkit for local authorities due to be released during 2015. They note that it is important that local authorities focus their actions on what is needed to reduce the public health impacts of poor air quality rather than to continue their current focus on local assessment and reporting. https://consult.defra.gov.uk/communications/https-consult-defra-gov-uk-laqm_review

Similarly, Public Health England emphasised the need for local actions to reduce $PM_{2.5}$ emissions and exposure to air pollution. These should take place alongside continued action at national and international levels, to ensure significant reductions in air pollution (PHE, 2014a).

Road vehicles are an important source of $PM_{2.5}$ and in some places, industrial emissions can also be important. Defra and Public Health England note that typical measures to reduce emissions from local sources include traffic management, the encouragement of uptake of cleaner vehicles, and increased use of public transport along with more sustainable transport methods such as walking and cycling (Defra, undated; PHE, 2014a).

Local authorities could also consider other measures to improve air quality, such as implementing low emission strategies, including industrial emission controls and the use of smokeless fuels during industrial and domestic combustion (Defra, undated; PHE, 2014a). The appropriate design of green spaces was also mentioned by Public Health England. A list of suggested actions from WHO is presented in Box 3.

The following links on the Defra website aim to provide UK local authorities with guidance, examples of good practice and the exchange of other relevant information in the field of local air quality management:

- Smarter choices aim to influence travel choice, encourage public transport, cycling, walking and also by providing the right information to enable travel choice (e.g. through travel planning, personalised travel planning, travel awareness campaigns, car clubs and car sharing and teleworking).
- Sustainable travel guides
- Car sharing and car clubs
- Travel plans
- Buses
- Freight
- Taxis
- Development planning
- Urban traffic management
- Vehicle parking
- Low Emission Zones
- Raising awareness - education

*http://laqm.defra.gov.uk/action-planning/measures/measures.html*

**Box 3**
**WHO: Suggested actions to tackle air pollution**

- **for industry:** clean technologies that reduce industrial smokestack emissions; improved management of urban and agricultural waste, including capture of methane gas emitted from waste sites as an alternative to incineration (for use as biogas);
- **for transport:** shifting to clean modes of power generation; prioritising rapid urban transit, walking and cycling networks in cities as well as rail interurban freight and passenger travel; shifting to cleaner heavy duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulphur content;
- **for urban planning:** improving the energy efficiency of buildings and making cities more compact, and thus energy efficient;
- **for power generation:** increased use of low-emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower); co-generation of heat and power; and distributed energy generation (e.g. mini-grids and rooftop solar power generation);
- **for municipal and agricultural waste management:** strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing; as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low cost alternatives to the open incineration of solid waste. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

*(WHO, 2014)*

Neither the Public Health England report (PHE, 2014) WHO (2014) or Defra (undated) presented any evidence for the health benefits of these suggested interventions.

## 2.2 Evidence for local interventions with demonstrable impacts on health and health service use.

The association between air pollution and poor health has been well documented (see above p.4). Clancy et al (2002) point out that despite these findings, it cannot be presumed that interventions leading to a reduction in air pollution would lead to health improvements.

There are relatively few studies examining this association, especially relating to local interventions.

*Use of modelling:* Health benefit modelling has been developed to assess the health impacts due to changes in air quality caused by the application of air pollution control strategies. It is not always possible to carry out such evaluation experimentally, due to practical difficulties in controlling variables. Also, Lobdell et al (2011) pointed out that in analysis at a local rather than national level, substantial reductions in air pollution (e.g.60% for NOx) are needed to detect health impacts of environmental actions using traditional epidemiological study designs. Lobdell et al (2011) and Sonawane et al (2012) discuss the feasibility of modelling for air pollution reduction health impacts and describe the range of techniques available.

## Cumulative interventions

***New Haven:*** The study by Lobdell et al (2011) looked at the impact that cumulative air pollution reduction programmes may have on health within a small geographic area, New Haven, US. These included national and regional initiatives that resulted in large reductions in ambient nitrogen oxides ($NO_x$)[1] in the area. Local initiatives included a number of voluntary air pollution reduction activities, such as use of ultra-low-sulphur diesel fuel and school bus retrofits. The New Haven area also adopted more stringent vehicle emission standards earlier than did other parts of the United States and had faster fleet turnover. The analysis was of cumulative impacts – the health impacts of individual initiatives were not considered.

Results of the study by Lobdell et al (2011) suggest that projected decreases in NOx may result in statistically significant improvements in health outcomes, including all-cause mortality, asthma prevalence in children and adults, and cardiovascular and respiratory hospitalisations. For other pollutants including PM with more modest reductions, it was not possible to undertake traditional modelling of local effects, but an experiment with small area analysis produced promising results. In small areas within New Haven having the greatest $PM_{2.5}$ reductions (i.e. $PM_{2.5}$ reductions of >4 µg/$m^3$, 2001-2010), numbers of CHD and asthma hospitalisations decreased significantly as the reduction in $PM_{2.5}$ increased.

The New Haven study has been used as a basis for discussions with the local authority on what can be done to reduce impacts from port operations and mitigate exposures at city schools located near busy roads (Lobdell et al, 2011).

***Detroit:*** Similarly, Fann et al (2011) used a targeted approach. Their modelled study on $PM_{2.5}$ control targeted local sources in areas of high population density in Detroit, US, and demonstrated improved outcomes for the susceptible and vulnerable. They found that this approach provided greater health benefits, and also reduced health inequalities, when compared to the more traditional approach. Conventional approaches to air pollution management focus on compliance of single pollutants at designated monitoring stations, while the new approach would focus on reducing multiple exposures in highly populated areas as well (Gibb, 2011). The authors combined information regarding population density,

*[1] $NO_x$ refers to NO and $NO_2$ (nitric oxide and nitrogen dioxide).*

baseline health status, air quality exposure, and socioeconomic status to construct a profile of individuals who were at greatest risk of air pollution impacts, so that air quality management policies could, as far as possible, target emission controls to affect these populations (Fann et al, 2011). It was estimated that this approach would result in 130 avoided deaths in 2020 and 16 avoided asthma hospitalisations. This was compared to the status quo of 71 avoided deaths and 6.8 avoided asthma hospitalisations with the conventional approach to air pollution management.

## Active travel and low carbon driving

The main strategies for decarbonising the transport sector are:

- switching to renewable fuel sources (electric cars, fuel cells)
- increased use of lower emission motor vehicles
- reducing car travel by reducing the need for car journeys, increasing public transport provisions, or encouraging active transport (walking and cycling).

*(Milner et al, 2012. Woodcock et al, 2009)*

Milner et al (2012) noted that based on WHO guidelines, it would be expected that fuel switching would reduce emissions of toxic pollutants, improving air quality, with population wide benefits, mainly to cardio-respiratory health.

A study by Woodcock et al (2009) modelled different scenarios and their health effects in London and Delhi, as illustrated in Table 1. They found that a reduction in carbon dioxide emissions through an increase in active travel and less use of motor vehicles had larger health benefits per million population (7,332 disability-adjusted life-years [DALYs] in London, and 12,516 in Delhi in 1 year) than from the increased use of lower-emission motor vehicles (160 DALYs in London, and 1696 in Delhi). This is even after allowing for the increase in road accidents and breathing in air pollution due to active travel, mainly involving cycling and walking (Milner et al, 2012; de Nazelle et al, 2011).

However, in Woodcock's study, the combination of active travel and lower-emission motor vehicles would give the largest benefits (7,439 DALYs in London, 12,995 in Delhi), notably from a reduction in the number of years of life lost from ischaemic heart disease (10–19% in London, 11–25% in Delhi). Woodcock et al conclude that although uncertainties remain, climate change mitigation in transport should benefit public health substantially. Policies to increase the acceptability, appeal, and safety of active urban travel, and discourage travel in private motor vehicles would provide larger health benefits than would policies that focus solely on lower-emission motor vehicles (Woodcock et al, 2009; PHE, 2014).

Giles-Corti et al found that policies promoting the use of both energy-efficient motor vehicles and increased active transportation would almost double the impact on greenhouse gas emissions. The authors noted the co-benefits for health, with increased physical activity leading to a reduced disease burden (Giles-Corti et al, 2010).

**Table 1 Anticipated environmental and public health impacts of different land transportation strategies to reduce greenhouse gas emissions in London**
*(taken from Giles-Corti et al, 2010, adapted from Woodcock et al 2009)*

| Estimates | Business as usual: 2030 projection | Lower carbon emission motor vehicles alone | Increased active transportation alone | Both lower carbon emission motor vehicles and increased active transportation |
|---|---|---|---|---|
| Change in transport $CO_2$ from 1990 (%) | 4↑ | 35↓ | 38↓ | 60↓ |
| Per person tonnes transport $CO_2$ emissions | 1.17 | 0.73 | 0.69 | 0.45 |
| Air pollution (particulate matter with aerodynamic diameter of ≤2.5 μm) concentrations (μg/m$^3$) | 8.2 | 7.8 | 7.7 | 7.4 |
| **Health effects (per million population) in 1 year compared with business as usual** | | | | |
| Premature deaths | | 17 | 530 | 541 |
| Years of life lost | | 160 | 5188 | 5295 |
| Disability-adjusted life years | | 160 | 7332 | 7439 |

There are other co-benefits that result from pedestrian and cycling-friendly neighbourhood designs, which Giles-Corti et al (2010) note can facilitate incidental contacts between neighbours and appear to foster social capital. The provision of walkable neighbourhoods, with frequent accessible public transport is also an important strategy to limit 'transport poverty' (e.g. households without access to public transport).

Giles-Corti et al (2010) quoted a study reported in a book by the New Zealand Centre for Sustainable Cities (Woodward et al, 2010). Woodward modelled the impact on the health budget of a 5% increase in bicycle trips of less than 7 km. After accounting for additional costs associated with cycling injuries and fatalities, it was estimated that the annual net health savings amounted to $200 million, or around 1.6% of NZ's annual health budget.

A modelled study by Rojas et al (2012) estimated the health benefits of a 40% reduction in car trips, shifted to cycling and public transport in Barcelona. The deaths avoided in the general population in Barcelona City would be 76.15 annually. This is made up of 10.03 deaths avoided due to a 0.64% reduction in exposure to $PM_{2.5}$. A further 66.12 deaths were avoided due to the shift from car trips to cycling. The latter is a net figure, with the health benefits of cycling outweighing the increased exposure to pollution and risk of injury. For the travellers who shift modes, there would be 1.15 additional deaths from air pollution, 0.17 additional deaths from road traffic fatality and 67.46 deaths avoided from physical activity. If half of the replaced car trips were shifted to public transport rather than cycling, there would be fewer deaths avoided annually (43.76 deaths). The authors conclude that interventions to reduce car use and increase cycling and public transport use in metropolitan areas can produce health benefits for travellers and the general population. A secondary outcome is the reduction of emissions.

## Low Emission Zones

In the UK, London has taken a strong lead on improving air quality with the implementation of its Low Emission Zone (LEZ) which is designed to discourage the most polluting vehicles from operating in the capital (Henderson et al, 2012). In LEZ areas, vehicle access is allowed only to vehicles that emit low levels of $PM_{10}$. The London LEZ was established in

2008 as the world's largest low emission zone, with the anticipation that it would provide a unique opportunity to estimate the health effects of a stepwise reduction in vehicle emissions on air quality and health (Kelly et al, 2011). A set of baseline air quality data was produced and the feasibility of evaluating the health effects using electronic primary care records was assessed (Kelly et al, 2011). However, it has been reported that so far, it remains unclear how successful the zone has been and what improvements in pollution levels can be attributed to the LEZ (Ellison et al, 2013; Kendall, 2011).

In 2014, a modelled study using German datasets assessed the effect of air LEZs on air pollution (Wolff, 2014). Their calculations suggest that health benefits of roughly 2 billion dollars have come at a cost of 1 billion dollars for upgrading the fleet of vehicles. They calculated the changes in health benefits using epidemiological estimates measuring the effect of $PM_{10}$ on long-term mortality in a previous study by Medina et al in 2004.

Another German study by Cyrys et al (2014) used alternative PM metrics to evaluate LEZ effects, namely black smoke or elemental carbon, rather than $PM_{10}$. They noted that using these measures, the effects of LEZs are likely to be considerably more significant to human health than was first anticipated, although no evidence for health effects was presented.

## Speed management zones

In Holland, Keuken et al (2012) undertook a modelling study which estimated the health effects of low emission zones and speed management zones. Modelled improvements in elemental carbon (EC) concentrations were translated into life years gained. In the speed management zone on a motorway in the city of Rotterdam, 85% of those living within 400m of the motorway gained 0-1 months of life expectancy and another 15% gained 1-3 months, depending on their distance from the motorway. EC concentrations were also used to evaluate a low emission zone in Amsterdam, specifically for those living along inner-urban roads with intense traffic levels. There was a population weighted average gain of 0.2 months in life expectancy, with a maximum potential gain of 2.9 months. The authors concluded that speed management and to a lesser extent, a low emission zone, are effective in reducing the health effects of road traffic emissions.

In Barcelona, a model was developed that measured the health effects of the speed management zones of 80km per hour on motorways that were introduced in the city in 2008 (Baldasano et al, 2010). The most positive effects of the management strategy were observed for CO, NOx and $PM_{2.5}$, with daily improvements in air quality reaching 10–15%. Levels of NOx were reduced by 5–8% on average and for particulate matter the reduction was around 3%. This reduction was calculated to decrease mortality rates by around 0.6% and increase life expectancy by 0.15 months. The authors also claim that the number of deaths in the Metropolitan area could be reduced by 40 per year as a result of the strategy.

## Congestion charging

In Stockholm City, the decline in traffic as a consequence of congestion charging has been estimated to reduce the emissions of greenhouse gases from traffic by 2.7% (42.5 ktons) (Eliasson, 2009). Other emissions are estimated to have decreased between 1.4% and 2.8%

in the county. In the densely populated city centre, the decrease is estimated to be between 10% and 14%. Health effects are based on observed, rather than modelled data. The reduced emissions are **estimated to save five life-years per year** (for Stockholm County as a whole). Eliasson notes that this is likely to be an underestimate (no more details were given).

## Natural gas use in transport

A modelled study estimated changes in fine particle pollution exposure, health benefits, and economic valuation for an emission reduction strategy based on increasing the use of compressed natural gas (CNG) in Santiago, Chile (Mena-Carrasco et al, 2012). It was estimated that switching to a CNG public transportation system would reduce urban $PM_{2.5}$ emissions by 229t/year. Annual $PM_{2.5}$ would be reduced by 0.33µg/m 3 and up to 2µg/m 3 during winter months. These ambient pollution reductions would be estimated to lead to 36 avoided premature mortalities per year. The intervention is thought by the authors to be a cost-effective way of reducing air pollution, as it targets a high-emitting pollution source.

## Low carbon electricity production

Milner et al (2012) noted there have been multiple studies on the potential health effects of switching from fossil fuels to low carbon alternatives. For example, Markandya et al (2009) reported on the modelled health benefits of clean methods of electricity production from fossil fuels. According to Milner et al (2012), the largest health effects are through reductions in ambient air pollution and also change in occupational injuries relating to the fuel cycle.

## Vehicle scrappage schemes

No studies on the health effects of vehicle scrappage schemes were found. Van Wee et al, (2011) found that emission effects of such schemes are modest and occur only in the short term and concluded that the cost-effectiveness of scrapping schemes is often quite poor.

## National policy interventions

At a national level, Clancy et al (2002) noted that great improvements in air quality in Dublin after the introduction of domestic coal-burning regulations offered an opportunity to assess the effects of reduced particulate air pollution on death rates in the general population. In 1991, the sale of coal in Dublin was banned resulting in more than a 70% reduction in ambient particle levels and a significant improvement in respiratory mortality over the ensuing three years, as summarised in Table 1 (Clancy et al, 2002; Kurmi and Ayres, 2007). The authors allowed for the effects of influenza outbreaks, population change and changes in temperature.

At the time, Clancy et al (2002) noted that the only other known study of effects of air pollution interventions on deaths was that by Pope et al (1992), who recorded that breathable particulate ($PM_{10}$) pollution concentration in Utah Valley during a 13-month strike at a local steel mill dropped by about 15 µg/m, and total deaths were reduced by 3.2%. This was not explored further as the study was carried out before the 1994 scope of this review.

After German re-unification, rates of bronchitis in children fell in old East Germany in line with reductions in sulphur dioxide and smoke (Heinrich et al, 2000). The closure of chemical and power plants and the replacement of brown coal by gas used for domestic heating contributed to these reductions. Kurmi and Ayres (2007) conclude that there is no doubt that legislation aimed at improving ambient air quality will improve health.

There have been studies in the US, China and Japan demonstrating the health benefits of nationwide air pollution programmes, but these studies do not always give details of the actual interventions. This is because they are usually modelled studies, predicting the health effects of hypothetical air pollution scenarios (e.g. Bae and Park, 2009).

Pope et al (2009) noted that air pollution in the US decreased from the late 1970s to the early 2000s. They found an association between reductions in air pollution in this period and changes in life expectancy, with adjustment for changes in socioeconomic and demographic variables and the prevalence of cigarette smoking. A decrease of 10 µg per cubic metre in the concentration of fine particulate matter was associated with an estimated increase in mean (±SE) life expectancy of 0.61±0.20 year (P=0.004) (Pope et al, 2009).

Wong et al (2004) noted that children are significantly affected by the health benefits of improved air quality. They modelled the health effects in children of reductions in pollution resulting from the US Clean Air Act 1990 (CAA). Interventions included restrictions on fossil fuel-fired power plants and the introduction of low $NO_2$ burner technologies in coal fired utility boilers. Reductions in air pollution predicted to occur by 2010 because of CAA regulations were estimated to produce the following health impacts:

- Reductions in $PM_{10}$ would lead to a median of 160 (45-270) fewer cases of post-neonatal mortality (from 1 month to 1 year of birth).
- Reductions in criteria air pollutants[2] would result in a total of 10,000 (4000 - 20,000) averted asthma hospitalisations and 40,000 (10,000 - 70,000) fewer emergency department visits in children aged 1 - 16 years.
- Approximately 20 million (10 - 20) fewer school absences were estimated in children aged 6 - 11, and 10,000 (-20,000 - 70,000) averted cases of low birth weight infants.

The authors provide costings of these benefits. They suggest that some end points might be more appropriately measured over longer periods of time to reflect lifelong benefits (e.g. health and productivity gains resulting from reductions in low birth weight infants).

In Tokyo, nitrogen dioxide ($NO_2$) control policies included regulating emissions for example by introducing air pollution control equipment in industries (Voorhees et al, 2000). Voorhees

[2] *Criteria pollutants:* particulate matter (PM), ozone, carbon monoxide, sulphur dioxide, nitrogen dioxide, and lead (Wong et al, 2004).

et al used modelling techniques to calculate the health benefits of the resulting reductions in $NO_2$ emissions, including:

- avoided medical costs in adults led to savings of $6.08 billion per year;
- lower respiratory illness in children, saving $775 million per year,
- avoided costs of lost wages of $6.33 billion per year,
- the best net benefits to costs ratio was 6:1.

Potential biases, were considered and adequately accounted for, as described in the CRD review of the study[3] (Voorhees et al, 2000).

A variety of national initiatives in China, including the Blue Sky programme introduced in the 1990s, have led to improvements in urban air quality (Zhang et al, 2005). The programme has included the following interventions:

- promotion of the use of cleaner energy in all sectors (industrial, commercial, and residential);
- coal-fired boilers have been upgraded or eliminated;
- testing and standards of motor vehicle emissions have been tightened, including the introduction of city buses powered with liquefied natural gas (LNG) and replacing high emission taxicabs with newer models with lower emissions;
- the strengthening of the enforcement of compliance with emission standards by industry;
- enhanced management of construction projects in order to reduce dust generation and suspension.

Improvements to air quality in China, as described by Zhang et al (2005), include a reduction in outdoor concentrations of total suspended particles (TSP) by 58 µg/m3 or 16.5 % from 1993-1994 to 1999-2000. $PM_{10}$ levels were reduced by 32 µg/m3 or 21 % from 1995-1996 to 2002-2003. Using modelling techniques, Zhang et al translated these changes into the following morbidity prevalence changes:

- overall reductions in TSP and $PM_{10}$ concentrations led to approximately 30% and 50% reductions in school children's prevalence rates of persistent phlegm and bronchitis, respectively,
- and approximately a 30% reduction in female adults' prevalence rates of wheeze and persistent phlegm.
- In male adults, the TSP reduction generated the largest morbidity prevalence reductions, up to 50% for bronchitis, among all the pollutants.

There are more examples of the health effects of national interventions, for example a study in Hong Kong looked at cardiorespiratory and all-cause mortality after restrictions on the sulphur content of fuel (Hedley et al, 2002).

There are interventions that reduce exposure to air pollution, rather than reducing the pollution itself. In 2007, a schools intervention in California introduced a system of warning

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*[3] CRD = NIHR Centre for Reviews and Dissemination. CRD database (NHS National Institute for Health Research, Centre for Reviews and Dissemination, University of York).* *http://www.crd.york.ac.uk/CRDWeb/AboutPage.asp*

flags for high levels of pollution, and adjusted the number of outdoor school activities accordingly. There are no outcomes data available in the literature so far, but the authors state that the programme has the potential to improve students' quality of life and reduce asthma triggers (Shendell et al, 2007).

# 3. Discussion

There is a wealth of literature on the health effects of air pollution. There are relatively few studies examining the association between interventions to reduce pollution and health impacts, especially relating to local interventions. It is not always possible to carry out such evaluations experimentally, due to practical difficulties in controlling variables and the size of intervention effects. As a result, health benefit modelling has been developed. Almost all the studies found for this review used modelling techniques.

Although the evidence on effectiveness is limited, it is important that recommended local air pollution interventions are implemented. All proposals for interventions should include an evaluation component.

In December 2014, Sefton obtained Defra AQ grant funding to look at alternative fuels and natural gas refuelling infrastructure facilities in Liverpool City Region (LCR). If implemented, the LCR scheme could help to address emissions from the significant rise in the numbers of HGVs predicted due to port expansion. This could have clear health benefits, as suggested by the study in Santiago, Chile, which estimated reduced emissions and health benefits from switching to a compressed natural gas transportation system (Mena-Carrasco et al, 2012). It will be important to evaluate the health effects of the LCR scheme.

The focus of the majority of the available evidence presented here is on particulate matter (PM) concentrations, which are recognised as having the biggest impact on public health. However in Sefton with regards to air quality objective (AQO) exceedances, nitrogen dioxide is currently the pollutant that is exceeded in 4 of the 5 Air Quality Management Areas (AQMAs) (all Sefton AQMAs are currently within limits for PM). Local evaluations of initiatives across LCR should therefore consider emission reductions and health effects appropriate to local concerns, which in Sefton would include nitrogen dioxide levels as well as particulate matter.

Multi-sector collaboration is required. Although health or environment authorities will undertake risk assessments, action in energy and transport sectors and industry is required in order to modify health impacts and exposure to air pollution (Pruss-Ustin et al, 2011).

**Key Findings**

- EU air pollution thresholds are currently much higher than those recommended by WHO
- Relatively few studies were found that were directly relevant to this review. Those studies that do exist almost all use modelling techniques
- Interventions and assessment of intervention effects are best carried out targeting small areas of dense population and high pollution concentrations
- Policies to increase active travel and reduce vehicle use would provide larger health benefits than policies with a sole focus on lower-emission vehicles
- Co-benefits of active travel include increased social capital and reduced transport poverty
- Speed management zones and to a lesser extent low emission zones (LEZs) are effective in reducing the health effects of traffic emissions
- Congestion charging and the use of compressed natural gas (CNG) in public transport both result in significant health benefits
- It is important that local air pollution interventions are implemented, despite the limited evidence base on their effectiveness.
- All local proposals for interventions should include an evaluation component. Nitrogen dioxide levels and health effects should be considered in addition to particulate matter
- Multi-sector collaboration is required

# References


Bae, H. J., & Park, J. (2009). Health benefits of improving air quality in the rapidly aging korean society. *Science of the Total Environment*, 407(23), 5971-5977.

Baldasano, J. M., Gonçalves, M., Soret, A., & Jiménez-Guerrero, P. (2010). Air pollution impacts of speed limitation measures in large cities: The need for improving traffic data in a metropolitan area. *Atmospheric Environment*, 44(25), 2997-3006.

Clancy, L., Goodman, P., Sinclair, H., & Dockery, D. W. (2002). Effect of air-pollution control on death rates in dublin, ireland: An intervention study. *Lancet*, 360(9341), 1210.

CRD (2009) *Systematic reviews. CRD's guidance for undertaking reviews in health care*. NHS Centre for Reviews and Dissemination. York: CRD University of York. http://www.york.ac.uk/inst/crd/pdf/Systematic_Reviews.pdf

Cyrys, J., Peters, A., Soentgen, J., & Wichmann, H. -. (2014). Low emission zones reduce PM10 mass concentrations and diesel soot in german cities. *Journal of the Air and Waste Management Association,* 64(4), 481-487.

Defra (undated) *Air Quality: Public health Impacts and Local Actions*. Department for Environment, Food and Rural Affairs (Defra) briefing paper, accessed 10/10/14. http://laqm.defra.gov.uk/documents/air_quality_note_v7a-%283%29

de Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., et al. (2011). Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. *Environment International*, 37(4), 766-777.

DH (2013) *Improving outcomes and supporting transparency. Public Health Outcomes Framework* 2013 to 2016. Department of Health. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263658/2901502_PHOF_Improving_Outcomes_PT1A_v1_1.pdf

EC (2014) *Air Quality Standards*. European Commission (last updated 30/10/14) http://ec.europa.eu/environment/air/quality/standards.htm

Eliasson, J. (2009). A cost-benefit analysis of the stockholm congestion charging system. Transportation Research Part A: *Policy and Practice*, 43(4), 468-480.

Ellison, R. B., Greaves, S. P., & Hensher, D. A. (2013). Five years of london's low emission zone: Effects on vehicle fleet composition and air quality. Transportation Research Part D: Transport and Environment, 23, 25-33.

EurActiv (2013) http://www.euractiv.com/sustainability/urges-tougher-eu-air-pollution-l-news-517503

Fann, N., Roman, H. A., Fulcher, C. M., Gentile, M. A., Hubbell, B. J., Wesson, K., et al. (2011). Maximizing health benefits and minimizing inequality: Incorporating local-scale data in the design and evaluation of air quality policies. *Risk Analysis*, 31(6), 908-922.

Gibb S (2011) *Targeting of Air Pollution Policies Could Double Health Improvements and Reduce Inequalities.* Society for Risk Analysis Press Release. http://www.sra.org/sites/default/files/pdf/press-release/SRA_Air_Pollution_Management_June_2011_Final.pdf

Giles-Corti B, Foster S, Shilton T, Falconer R (2010) The co-benefits for health of investing in active transportation. *New South Wales Public Health Bulletin*; 21: 122–127.

Heinrich, J., Hoelscher, B., & Wichmann, H. E. (2000). Decline of ambient air pollution and respiratory symptoms in children. *American Journal of Respiratory and Critical Care Medicine*, 161(6), 1930-1936.

Hedley AJ, Wong CM, Thach TQ, Ma S, Lam TH, Anderson HR (2002) Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study. *Lancet*; 360:1646-1652

Henderson, K. (2012). A targeted approach to tackling air quality. *Traffic Engineering and Control,* 53(8), 284-285.

Kelly, F., Armstrong, B., Atkinson, R., Anderson, H. R., Barratt, B., Beevers, S., et al. (2011). *The london low emission zone baseline study*. Research Report (Health Effects Institute), (163), 3-79.

Kendall, M (2011) Proceedings Of The Air And Waste Management Association's Annual Conference And Exhibition, *AWMA* Volume: 3 (2011-01-01) p. 2205-2209. ISSN: 1052-6102

Keuken, M. P., Jonkers, S., Zandveld, P., Voogt, M., & Elshout van den, S. (2012). Elemental carbon as an indicator for evaluating the impact of traffic measures on air quality and health. *Atmospheric Environment*, 61, 1-8.

Kurmi, O. P., & Ayres, J. G. (2007). The non-occupational environment and the lung: Opportunities for intervention. *Chronic Respiratory Disease*, 4(4), 227-236.

Lobdell, D. T., Isakov, V., Baxter, L., Touma, J. S., Smuts, M. B., & Özkaynak, H. (2011). Feasibility of assessing public health impacts of air pollution reduction programs on a local scale: New haven case study. *Environmental Health Perspectives*, 119(4), 487-493.

Markandya, A., Armstrong, B. G., Hales, S., Chiabai, A., Criqui, P., Mima, S., et al. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: Low-carbon electricity generation. *The Lancet*, 374(9706), 2006-2015.

Medina S, Plasencia A, Ballester F, Mucke HG and Schwartz J (2004) 'Apheis: public health impact of PM10 in 19 European cities', *Journal of Epidemiology and Community Health*, vol. 58(10), pp. 831–6

Mena-Carrasco, M., Oliva, E., Saide, P., Spak, S. N., de la Maza, C., Osses, M., et al. (2012). Estimating the health benefits from natural gas use in transport and heating in santiago, chile. *Science of the Total Environment*, 429, 257-265.

Milner, J., Davies, M., & Wilkinson, P. (2012). Urban energy, carbon management (low carbon cities) and co-benefits for human health. *Current Opinion in Environmental Sustainability*, 4(4), 398-404.

PHE (2014) *Estimating local mortality burdens associated with particulate air pollution*. Public Health England. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution

PHE (2014a) *Estimating local mortality burdens associated with particulate air pollution. Press Release*. Public Health England. https://www.gov.uk/government/news/estimates-of-mortality-in-local-authority-areas-associated-with-air-pollution

Pope III, C. A., Schwartz, J., & Ransom, M. R. (1992). Daily mortality and PM10 pollution in utah valley. *Archives of Environmental Health*, 47(3), 211-217.

Pope, C. A., Ezzati, M., & Dockery, D. W. (2009). Fine-particulate air pollution and life expectancy in the united states. *N Engl J Med*, 360(4), 376-386.

Pruss-Ustun, A., Vickers, C., Haefliger, P., & Bertollini, R. (2011). Knowns and unknowns on burden of disease due to chemicals: A systematic review

Rojas-Rueda, D., de Nazelle, A., Teixidó, O., & Nieuwenhuijsen, M. J. (2012). Replacing car trips by increasing bike and public transport in the greater barcelona metropolitan area: A health impact assessment study. *Environment International*, 49, 100-109.

Shendell, D. G., Rawling, M. -., Foster, C., Bohlke, A., Edwards, B., Rico, S. A., et al. (2007). The outdoor air quality flag program in central california: A school-based educational intervention to potentially help reduce children's exposure to environmental asthma triggers. *Journal of Environmental Health*, 70(3), 28-31.

Sonawane, N. V., Patil, R. S., & Sethi, V. (2012). Health benefit modelling and optimization of vehicular pollution control strategies. *Atmospheric Environment*, 60, 193-201.

Van Wee, B., De Jong, G., & Nijland, H. (2011). Accelerating car scrappage: A review of research into the environmental impacts. *Transport Reviews*, 31(5), 549-569.

Voorhees, A. S., Araki, S., Sakai, R., & Sato, H. (2000). An ex post cost-benefit analysis of the nitrogen dioxide air pollution control program in tokyo. *Journal of the Air & Waste Management Association*, 50(3), 391-410.

WHO (2000) http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf?ua=1

WHO (2005) *Air Quality Guidelines, global update*, 2005. http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf?ua=1

WHO (2013) *Review of evidence on health aspects of air pollution*. WHO Regional Office for Europe http://www.euro.who.int/__data/assets/pdf_file/0020/182432/e96762-final.pdf?ua=1

WHO (2014) *Ambient (outdoor) air quality and health*. World Health Organisation Factsheet No.313, March 2014. http://www.who.int/mediacentre/factsheets/fs313/en/

Wolff, H. (2014). Keep your clunker in the suburb: Low-emission zones and adoption of green vehicles. *Economic Journal*, 124(578), F481-F512.

Woodward A, Lindsay G (2010) Changing modes of travel in New Zealand cities. In: Howden-Chapman P, Stuart K, Chapman R, editors. *Sizing up the city – Urban form and transport in New Zealand. Wellington*: New Zealand Centre for Sustainable Cities centred at University of Otago.

Wong E Y, Gohlke J, Griffith W C, Farrow S, Faustman E M (2004) Assessing the health benefits of air pollution reduction for children. *Environmental Health Perspectives*; 112(2): 226-232

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., et al. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: *Urban land transport*. The Lancet, 374(9705), 1930.

Zhang, J., Hu, W., Wei, F., Wu, G., Cheng, W., & Chapman, R. S. (2005). Long-term changes in air pollution and health implications in four chinese cities. *Energy for Sustainable Development*, 9(3), 67-76.

## Acknowledgements

Thanks to those who contributed to or supported this review, including the late Gary Mahoney, Principal Environmental Protection Officer, Sefton Council,

Rob Marrs, Senior Technical Officer, Sefton Council AQ Team,

Dr Alex G Stewart, Consultant in Health Protection, Cheshire & Merseyside Public Health England,

Emma Dean, Team Leader - Public Health Intelligence, Sefton Council

Neal Fann, Health and Environmental Impacts Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency

Steve Gibb, Society for Risk Analysis (SRA), US

Chris Williamson, Lead Public Health Epidemiologist, Liverpool City Council,

Linda Turner, Consultant in Public Health, Sefton BC.

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