Iechyd Cyhoeddus Cymru
Public Health Wales

Making a Difference:

Reducing health risks associated with road traffic air pollution in Wales

2018

Authors and Contributors

This report was written by Charlotte Grey[i], with help and input from Huw Brunt[ii], Sarah Jones[ii], Sumina Azam[i], Jo Charles[iii], Tom Porter[iv], Angela Jones[v], Teri Knight[vi] and Sian Price[vi]. Kelvin Jones[iii] supported the development of the infographic. Mark A Bellis[i], Giri Shankar, Andrew Jones[ii] and Chrissie Pickin[vi] provided advice and guidance for the development of the report.

I Policy, Research and International Development Directorate

ii Public Health Services Directorate

iii North Wales local Public Health Team

iv Cardiff and Vale local Public Health Team

v Cwm Taf local Public Health Team

vi Health and Well-being Directorate

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Policy, Research and International Development Directorate
Floor 5, Public Health Wales NHS Trust
Number 2 Capital Quarter Tyndall Street
Cardiff CF10 4BZ
Tel: +44 (0)29 2022 7744

Executive Summary

This chapter is an extension of Public Health Wales' Making a Difference publication and is intended to be used as a standalone document, and support the work by Public Service Boards and other multiagency partnerships in Wales.

Air pollution from road traffic is a significant national problem. The solutions outlined seek to reduce the emissions from road traffic and thus achieve positive public health impacts through developing a more sustainable economy, thriving society and optimum health and well-being for the present and future generations in Wales.

Exposure to outdoor air pollutants increases the risk of poor health and mortality and in the UK, each year, results in the equivalent of 40,000 early deaths and reduces average life expectancy by 7-8 months. Outdoor air pollution is the largest contributor to the global environmental burden of disease. The air pollutants of greatest public health concern are particulate matter (PM) and nitrogen dioxide (NO_2). In Wales each year, the equivalent of around 1,604 deaths are attributed to $PM_{2.5}$ exposure and 1,108 deaths to NO_2 exposure. Air pollution can disproportionately affect vulnerable population groups e.g. children, older people, those with underlying disease, and those exposed to higher concentrations because of living or commuting in urban or deprived locations. In Wales, the societal cost of air pollution from health service costs and lost work-days is estimated to be **£1 billion each year.**

Road traffic emissions account for two-thirds of air pollution at urban monitoring sites. Road traffic produces PM and NO_2 from engine emissions, tyres and brake wear, re-suspended road dust and chemical reactions in the air. Air pollution from traffic causes a problem both locally and further away, as pollutants are able to travel long distances and spread over wide areas.

The framework in Wales to manage air quality includes both national-level policy measures and local air quality management implementation. Any breaches of National Air Quality Objectives lead to Air Quality Management Areas (AQMA) being declared and air quality action plans being developed to tackle problems. Wales has 41 AQMA where pollution standards for these pollutants are actually or likely breached.

Everyone has a role to play in reducing air pollution from road traffic sources through working collaboratively. Legislation, including the Well-being of Future Generations (Wales) Act 2015 and Public Health (Wales) Act 2017 can be used to embed prevention, sustainability, and health into solutions at national and local levels.

In seeking solutions to the problem of air pollution from road traffic, **a package of interventions to reduce emissions, taking a multi-sectoral approach with action at local, national, and international level, is likely to have the greatest cumulative impact.**

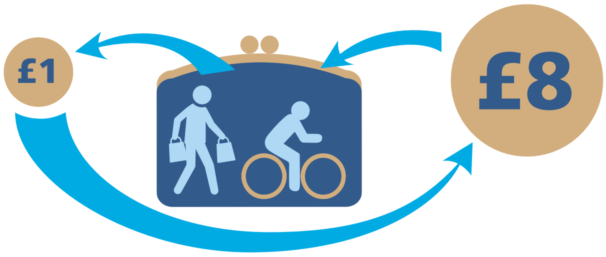
Solutions to reduce our reliance on motorised road transport and promote the use of cleaner vehicles and transport, can be sub-divided into **adaptation** measures and **mitigation** measures. Adaptation includes reducing pollution through policy drivers for change in practice. Mitigation includes strategies to include air pollution in planning decisions, improve health communication, and encourage environmental behaviour change.

The health benefits can be both direct and indirect (from reduced congestion, noise and improved road safety). As combustion engines also produce carbon dioxide (CO_2), a greenhouse gas, the solutions will also have climate change benefits.

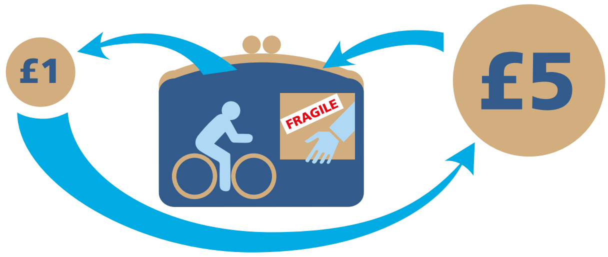
Economic and societal benefits of reducing road traffic emissions include:

Active Travel and Sustainable Transport

- **For shorter journeys** such as trips to shops or schools, **walking** and **cycling** has a return of £8 for £1 invested. For longer journeys use public transport, together with walking and cycling

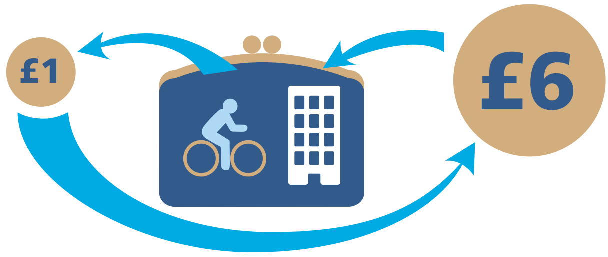


- **Promoting zero emission transport** for the **final mile** of business deliveries returns £5 for every £1 invested



- **Linking places** where people live and work through **walking** and **cycling infrastructure** has a return of £10 for every £1 invested

- **Corporate low emission travel plans** like **cycle to work schemes** return £6 for every £1 invested



Reducing vehicle emissions

Car clubs can help **reduce the number of vehicles** on the road and encourage use of **public** and **active transport**, with £13 returned for £1 invested

Low emission zones in populated areas can return £27 for every £1 invested

Reducing urban speed limits from 30mph to 20mph would reduce PM emissions, crash casualties and fatalities, as well as increase community cohesion

Purpose

This chapter – an extension of Public Health Wales' *Making a Difference* work programme (Public Health Wales NHS Trust (PHW), 2016) – seeks to inform and encourage action to reduce health risks associated with outdoor air pollution exposure. It focuses specifically on air pollution from road traffic sources since this is where available evidence is strongest, and also because the majority of air quality problems in Wales stem from this pollution source.

Like other *Making a Difference* chapters, this work draws on research evidence and expert opinion to guide, support and facilitate action to protect health and reduce inequalities. The actions outlined in this chapter seek to reduce emissions from road traffic and thus achieve positive public health impacts through developing a more sustainable economy, thriving society and optimum health and well-being for the present and future generations in Wales.

Methodology

The methodology used has previously been described in *Making a Difference* (PHW, 2016). Much of the high level evidence used was drawn from a recent report from National Institute for Health and Care Excellence (2017).

Public health context

The outdoor air pollutants of primary public health concern are particulate matter (PM; defined by particles being less than 2.5μm (fine $PM_{2.5}$) or 10μm (PM_{10}) in diameter (Brunt, 2018)) and nitrogen dioxide[1] (NO_2). Other pollutants (sulphur dioxide (SO_2), ozone (O_3), and black carbon) can also harm health (Brunt, 2018; National Institute for Health and Care Excellence (NICE) 2017) but are beyond the scope of this work. Outdoor air pollution is a complex mixture of gases and other pollutants, so health effects may in fact be due to the underlying toxicity of the mixture (WHO Regional Office for Europe, 2013; WHO Regional Office for Europe, 2016).

Air pollution is the largest contributor to the global environmental burden of disease (EBOD) (WHO Regional Office for Europe, 2015), with outdoor air pollution alone causing a significant proportion of attributable mortality (279,000 in Western Europe in 2012, or 44 deaths per 100,000 capita) (WHO Regional Office for Europe, 2015; World Health Organization (WHO), 2012). Public Health Wales estimates that, in Wales, the equivalent of 1,604 deaths can be attributed to $PM_{2.5}$ exposure, and 1,108 deaths to NO_2 exposure, each year (based on 2011/12 data; McCarthy and Brunt, 2018).

A wide range of adverse health effects have been linked to exposure to PM outdoors. There is no evidence of a safe level of exposure to PM, or a threshold below which no adverse health effects occur (WHO Regional Office for Europe, 2013). Short-term exposure can result in eye, nose and throat irritation, asthma symptom exacerbation, and headaches and nausea. Long-term exposure

1 NO_2 and NO (nitric oxide) are often referred to together as NO_x (nitrogen oxides), of which NO_2 is of greatest concern to health.

increases morbidity and mortality risks from heart disease and strokes, respiratory diseases, lung cancer and as well as other harmful health effects (WHO Regional Office for Europe, 2013). Exposure to NO_2 increases morbidity and mortality, particularly at levels that are at or above the current EU limits set by policy (WHO Regional Office for Europe, 2013). Short-term exposure to NO_2 is associated with increased cardiovascular and respiratory morbidity (Brunt, 2018).

Across the UK each year, it is estimated that the equivalent of 29,000 deaths (COMEAP, 2010; Gowers et al., 2014) are attributed to long-term exposure to $PM_{2.5}$ air pollution, and the equivalent of 23,500 deaths (Department for Environment, Food and Rural Affairs (Defra), 2015) are attributed to long-term NO_2 exposure. Given the potential for overlapping health effects of PM and NO_2, it is estimated that the equivalent of 40,000 deaths occur annually in the UK, as a result of exposure to outdoor air pollution (Royal College of Physicians (RCP), 2016). On average, exposure reduces the life expectancy of every person in the UK by 7 to 8 months (Defra, 2007), but vulnerable sub-groups of the population are likely to be disproportionately affected. The societal cost of air pollution (accounting for health service costs and reduced productivity through lost work-days) in the UK stands at around £20 billion every year (RCP, 2016), with an estimated cost of £1 billion every year in Wales (PHW, 2016).

Air pollution from road traffic

This chapter focuses on road traffic emissions as these are a significant source of PM and NO_2 (Brunt, 2018).

Road traffic emissions account for more than 64% of air pollution at urban monitoring sites (NICE, 2017)[2]. NO_x (including NO_2) is produced by combustion processes and are also a precursor for secondary pollutants[3] (PM and O_3). PM from road transport is directly emitted from combustion, tyre and brake wear, re-suspended road dust, and from secondary particles formed by chemical reactions in the air (Brunt, 2018; Organisation for Economic Co-operation and Development (OECD), 2014; WHO Regional Office for Europe 2013). Pollutants not only cause problems locally but, when suspended in air, can travel long distances and over wide geographical areas[4] (Brunt, 2018).

In Wales, 41 Air Quality Management Areas (AQMAs) have been declared by local authorities (as at April 2018). AQMAs are priority areas for intervention because actual or potential breaches of statutory pollutant-specific Air Quality Objectives (AQO) are possible (Welsh Government, 2017). While general air quality in Wales, like the rest of the UK, has improved over past decades, problems persist. Wales' annual mean concentrations of NO_2 and PM_{10} pollutants have gradually fallen from 16 and 14 µg/m^3 respectively in 2007, to 13 and 11 µg/m^3 respectively in 2014), but $PM_{2.5}$ concentrations are increasing (from 8 µg/m^3 in 2007 to 10 µg/m^3 in 2014) (Brunt, 2018).

Transport is known to contribute to 24% of UK greenhouse emissions through production of the carbon dioxide (CO_2) (Department for Business,

2 This is the rationale for focusing this *Making a Difference* update on road traffic. Other sources, such as industrial point sources, are therefore beyond the scope of this work, but evidence will be kept under review to inform subsequent updates.

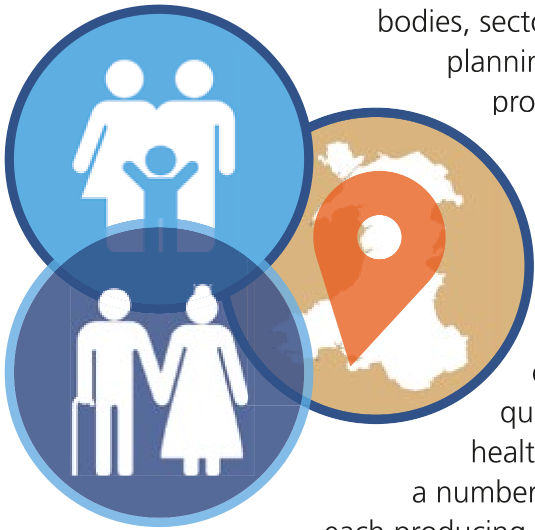
3 Secondary pollutants are formed when primary pollutants interact with each other in the atmosphere, for example NO_x reacting chemically with VOCs (volatile organic compounds) emitted by trees, in the presence of sunlight, to produce ground-level ozone.

4 This is termed 'long range transboundary air pollution'

Energy & Industrial Strategy (BEIS), 2015), so although not considered in this report, solutions to reducing road traffic emissions are also likely to have wider climate change benefits.

Inequalities

Exposure to air pollution, and the consequent health risks and impacts, vary across different population groups. Air pollution combines with other aspects of the social and physical environment to create an inequitable disease burden on more deprived parts of society (WHO Regional Office for Europe 2013). Air pollution can disproportionately affect vulnerable population groups e.g. children, older people, people with underlying chronic disease, as well as those exposed to higher levels because of living or commuting in urban or deprived areas (NICE, 2017; WHO Regional Office for Europe, 2016).



People living in deprived areas may be more exposed to air pollution (Goodman et al., 2011). Analyses of local air pollution, multiple deprivation and health data in Wales has found that air pollution concentrations (notably NO_2) are highest in the most deprived areas (Brunt et al., 2017). This leads to a triple jeopardy, where air pollution, impaired health and deprivation interactions can create disproportionate disease burdens between and within communities, contributing to health inequalities. People living in deprived areas with lower air pollution levels may also be more sensistive to increases in air pollution. In the case of PM_{10} pollution in Wales, compared to 'low' pollution and 'least' deprived areas, those who live in 'low' pollution and 'most' deprived areas have twice the risk of respiratory mortality, with the risk increasing to 2.4 times in 'high' pollution and 'most' deprived areas (Brunt at al., 2017).

Different interventions to reduce air pollution may also widen inequalities, for example, evidence from Scotland suggests that commuters from low income households are less likely to own a bicycle, which can impact accessibility to active transport (Muirie, 2017).

Action to reduce exposure to air pollutants

Air pollution is everybody's business and it is essential for there to be good awareness, collaboration and action across relevant public bodies, sectors and systems e.g. transport, planning, regulation, health, public protection, sustainable development. Members of the public have an important contribution to make too (Brunt, 2018).

Interventions to reduce air pollution from road traffic emissions aim to improve air quality and prevent a range of health conditions and deaths. Taking a number of actions in combination, each producing a small benefit, is likely to act cumulatively to produce significant change (NICE, 2017). Examples from the USA have demonstrated that tackling multiple sources of $PM_{2.5}$, have led to improvement to health outcomes, decreased hospitalisation from asthma and coronary heart disease (CHD), and improved outcomes for vulnerable groups (Ubido and Scott-Samuel, 2015).

Exposure to air pollutants requires action by public authorities at the local, regional, national, and international levels (Brunt, 2018; WHO Regional Office for Europe, 2013). A multi-sectoral approach to prevent and reduce emissions is needed to develop and effectively implement long-term policies and strategies that reduce risks of air pollution to health (WHO Regional Office for Europe, 2013). This approach is supported across Wales through the Well-being of Future Generations (Wales) Act 2015 (National Assembly for Wales, 2015), that includes goals to achieve a healthier Wales, that is more globally responsible and equal, through thinking more about the long-term, looking to prevent problems and taking a more collaborative joined-up approach. The Public Health (Wales) Act 2017 is a vehicle whereby Health Impact Assessments (HIA) could be used to ensure that impacts on health are taken into account in decisions on planning and design.

The existing air quality management framework in Wales[5], set out in national policy has two complementary approaches:

- National-level policy measures seeking to drive large-scale improvements e.g. legislation; emissions standards setting; and fuel, vehicle and other technology developments; and
- Local Air Quality Management (LAQM) regime implementation, where Local Authorities must work with others to assess and manage air pollution in their areas. When actual or likely Air Quality Objectives breaches are identified, Air Quality Management Areas (AQMA) are declared and air quality action plans developed to tackle problems.

The cost effectiveness, or return on investment, of interventions to tackle air pollution is likely to be highly dependent on local settings (NICE, 2017). Interventions to improve air quality are likely to help tackle health inequalities, but may also disproportionately disadvantage these groups if the measures are unaffordable at a personal level, such as being able to afford a lower pollutant emitted vehicle (NICE, 2017). Many of the examples of interventions are from larger conurbations than those found in Wales, so the numbers associated with cost-benefit analysis need to be considered within those caveats.

To assist readers, the following section describes interventions to reduce emission of air pollutants from road traffic, and where there is evidence that the intervention is cost-effective this is detailed. Effective interventions may directly improve health from reduced exposure to pollutants, and increase active travel and use of sustainable modes of transport, or have indirect health co-benefits from reduced congestion, noise and improved road safety. Interventions are divided into adaptation and mitigation measures. Adaptation includes actions to reduce the levels of pollutants being emitted, through policy drivers for change in practice such as regulations and enforcement of Clean Air Zones. Mitigation includes actions to prevent public exposure to pollutants through strategies to consider and reduce air pollution through planning decisions, better health-centered communication, and encouraging environmental behavior change at individual and corporate level.

5 Air Quality Strategy for England, Scotland, Wales and Northern Ireland (supported in part by Part IV of the Environment Act 1995)

Evidence of intervention effectiveness

The implementation of national r**egulatory measures to reduce emissions** from road traffic pollutants has been shown to be effective in urban areas (Chanel et al., 2014). However the impact of a regulatory measure to reduce a single pollutant is difficult to distinguish from other pollutants in the air that may be reducing in the same time period, as air pollution exists as a mixture of gases and other pollutants (Chanel et al., 2014). For example, evidence from the implementation of three European Commission regulations to reduce the sulphur content in liquid fuels of vehicles, for the 20 European cities studied, has suggested that the measures to reduce emissions of sulphur dioxide (SO_2) from road traffic has postponed 2212 deaths per year since 2000, attributable to reductions in SO_2, valued at €192m per year; for London alone the annual monetary benefit was €20.8m. It is plausible that such interventions also reduce PM and NO_2 indirectly.

Clean Air Zones comprise a **package of interventions** that require changes in practice and a joined up multi-sectoral approach (Planning, Environment, and Transport) to reduce air pollution and risks. The main expense would be setting up the initial infrastructure, but once established running costs should fall and possibly be funded through charges and fines. Clean Air Zones deliver substantial benefits across large populations (NICE, 2017). Local factors such as population size and distribution, climate and geography, will affect the extent to which these will benefit areas within Wales compared to cost. The greater the number of interventions involved in the package used to enable the Clean Air Zone, the more expensive the set up costs (NICE, 2017). Clean Air Zones that have cost-benefit data tend to be from larger cities than those found in Wales. Welsh Government plan to consult on a Clean Air Zone Framework for Wales (Defra, 2017), requiring close working across local authorities and other stakeholders to help Wales comply with the **National Air Quality Objectives**[6] (Department for Environment, Food and Rural Affairs (Defra), 2017). Different interventions that may form part of the package of a Clean Air Zone include:

1) Low Emission Zones (LEZ) are systems of local road charging or regulation that encourage individuals and businesses to use cleaner vehicles or more sustainable modes of transport by targeting vehicles emitting high levels of pollutants and not meeting emission standards, such as older engines (Butcher and Ares, 2015). Measures include retrofitting or reprogramming existing vehicle fleets, and encouraging replacing vehicles with cleaner technologies and design. The greatest impact can likely be achieved in major cities with high traffic volumes and populations (Butcher, 2013), thereby limiting the applicability of LEZ to Wales. Evidence from schemes in major cities, suggests LEZ are most cost-effective

6 National Air Quality Objectives – are standards for specific air pollutants as set out in EU Directives and transposed into UK law.

during the initial years, but are likely to remain cost-effective over a longer period if the scheme continues to be updated, with some reduction in cost-benefit as vehicle fleets progressively improve as regulations change (Ballinger et al., 2016). However, it is likely that the high costs involved in setting up a LEZ would mean that cost-benefit would be reduced in smaller conurbations. LEZ can cover entire cities (as is the case in greater London) where a wide range of vehicles using the area are targeted, or LEZ-style initiatives can also exist in smaller cities (as in Brighton, Oxford, Norwich, and Nottingham[7]), where, for example, the focus of the LEZ is on reducing bus emissions (Butcher and Ares, 2015). Currently, there is a lack of cost-effectiveness data from smaller LEZ-style schemes.

Data from the London and Stockholm LEZ show reduction in PM (Butcher and Ares, 2015), and data from Berlin and Cologne show reductions in PM and NO_x, translating into reduced exposure and therefore health risks (Butcher and Ares, 2015). Co-benefits beyond emission reduction include reduced fuel consumption, reduced road traffic crashes, and reduced noise (Ballinger et al., 2016). Projections from the introduction of an ultra-LEZ in London, which will include all vehicles including passenger cars, would have health benefits of £101m from reduced road traffic emissions, although this benefit is likely to decline to £32m by 2025 (Ballinger et al., 2016). Evidence also suggests that measures to upgrade vehicles to conform to LEZ standards would provide a return of between £2 to £2.41 for every £1 spent (Kilbane-Dawle, 2012; Ubido and Scott-Samuel, 2015). One model from Amsterdam (the Netherlands) suggesting a higher benefit in the first year of the LEZ of £27 for every £1 spent (Ballinger et al., 2016). Although a city-wide LEZ is unlikely to be applicable to Wales, innovative LEZ-style schemes to reduce emissions from vehicles that emit high levels of pollutants could be considered, particularly in high traffic-volume areas.

2) Congestion charging zones could contribute to a package of interventions in Clean Air Zones and help improve the flow of traffic, reducing time spent in slow or stationary traffic (NICE, 2017). Monitoring is needed to ensure that congestion charging does not adversely impact on air pollution outside the zone from vehicle diversion, and to ensure that it does not contribute to inequalities by affecting some groups disproportionately (NICE, 2017). Evidence suggests that congestion charging is cost-effective, with co-benefits of reducing road traffic crashes and travel time. In Stockholm, there was a net social benefit (e.g. shorter travel time, reliable travel times) of just under 700mSEK/year (£67m) (of which 500mSEK/year (£48m) was from saving travel time); and in Milan an annual net benefit of €6m (savings from injuries contributed €8.4m and reduction in air pollutants €2m) (Crombie et al., 2016b). In Milan, traffic was reduced by 14.2% nine months after introduction, with increased use of public transport. In Stockholm, reduced emissions are estimated to have saved five life-years per year[8] for Stockholm county as a whole (Ubido and Scott-Samuel, 2015). A congestion charging zone is less applicable to Wales because

7 Population sizes in thousands (Brighton & Hove 289, Oxford 163, Norwich 142, Nottingham 322) compared to Wales' cities (Cardiff 361, Swansea 244, Newport 149, Wrexham 137)

8 The cost-benefit analysis concludes that within the Stockholm county each year of the congestion charge, five lives are saved due to reduced emissions resulting from the charge. It is suggested that this is an underestimate.

of the population size of urban areas, however, adaptations could be considered to discourage congestion in high traffic areas, through for example, using parking-charges as a lever to shift car users towards using park and ride facilities.

3) Smooth driving on motorways and major roads is likely to have a positive benefit on air pollution, using technology such as variable speed limits and average speed technology. Smooth driving, with reduced acceleration from stop-go driving, leads to a reduction of traffic congestion and improvement of traffic flow (NICE, 2017). Evidence from Amsterdam (the Netherlands) suggests that speed restrictions on motorways in urban areas are cost-effective, with co-benefits of reduced fuel consumption, reduced road traffic crashes, and reduced noise, with a benefit of £51 for every £1 spent (Ballinger, 2016). Applicability to Wales will depend on population density, meteorological factors, and long range pollution (i.e. pollutants that are suspended in air that can travel long distances from source(s)), length of motorways in urban areas, and the types of measures and enforcement used. Evidence from Rotterdam (the Netherlands) suggests that a combination of LEZ and speed management zones on motorways have contributed to 85% of those living within 400m of the motorway gaining 0-1 months of life expectancy, and the remaining 15% gaining 1-3 months, depending on distance from the motorway (Ubido and Scott-Samuel, 2015). In Barcelona (Spain), a motorway speed management zone was estimated to decrease mortality rates by about 0.6% and increase life expectancy by 0.15 months (Ubido and Scott-Samuel, 2015). In Wales, there has been implementation of a variable speed limit scheme on the M4 motorway to tackle congestion around the city of Newport (junctions 24-28), and a permanent 50 mph Average Speed Enforcement system in Port Talbot (junctions 40-41) to manage traffic flow and reduce congestion.

4) Reducing speed, acceleration and braking in built up areas. Acceleration and braking contribute to higher emissions of pollutants through increased fuel consumption and tyre and brake wear. Acceleration and deceleration in residential areas characterised by stop-start traffic, can be reduced by introducing **20mph speed limits** (Jones and Brunt, 2017). The impact on air pollution should be taken into account in residential areas that use traffic calming; any interventions should be designed to minimise rapid deceleration and subsequent acceleration. **Road signs that display real time speeds** of vehicles can be used to reduce unnecessary stop-go driving (NICE, 2017). Reducing the speed of traffic in built up areas has the co-benefits of reducing road traffic crashes and supporting a modal shift towards active travel (NICE, 2017). Evidence suggests reducing the speed limit from 30 to 20mph in Wales would save an estimated 6–10 lives and 1200–2000 casualties each year, at a value of prevention of £58m–£94m; with a positive impact from $PM_{2.5}$ reduction of 117 fewer attributable deaths and 1400 fewer years of life lost (Jones and Brunt, 2017).

5) Low/zero emission sustainable travel. Travel using low emission vehicles is likely to have the benefit of reduction of air pollution, if there is high enough uptake of the technologies; however uptake is reliant on adequate infrastructure being in place (NICE, 2017). Although engine emissions from electric vehicles themselves are low, they still emit high levels of non-exhaust PM (Timmers and Achten, 2016). Reductions in engine noise may increase risk to other road users, including pedestrians and cyclists.

Evidence from the USA suggests that **changing the fuel used for fleets** from conventional diesel to emission controlled diesel (ECD), compressed natural gas (CNG), or diesel hybrid vehicles may not be cost-effective compared to other medical and public health interventions (Crombie et al., 2016a). However, a study from Chile estimated that by switching to a compressed natural gas (CNG) public transport system would reduce urban $PM_{2.5}$ emissions by 229t/year, and avoid 36 premature deaths (Ubido and Scott-Samuel, 2015). While the evidence is inconclusive at present, the use of **all-electric vehicles and plug-in hybrid electric vehicles** can deliver co-benefits of reduced noise at speeds under 30mph and no direct air pollution from combustion of fuel when in electric mode, and have particular benefits when in congestion

(Robinson and Nath, 2010). However, these vehicles require infrastructure and charging points to improve uptake. Evidence suggests that uptake of car clubs that allow access to vehicles with newer technologies and reduce the use of older, less efficient vehicles show a benefit of between £13.36-£13.58 for every £1 invested (depending on the vehicles' efficiency), and are a quick win as they can be delivered quickly and easily, with co-benefits for noise reduction (Kilbane-Dawle, 2012). The level of benefit is likely to depend on the size of the fleet, availability of lower-emission vehicles, uptake, and population size - so in Wales the impact on air pollution is likely to be lower, particularly outside urban areas. However, availability of car clubs may also contribute to a modal shift in transport away from reliance on car ownership and towards public and low emission, active transport (Kilbane-Dawle, 2012; Pridmore et al., 2017), and to reducing inequalities through offering low cost alternatives to buying and running a car, in both urban and rural areas (Pridmore et al., 2017; Kay, 2011).

6) Active and sustainable travel.
A combination of measures to increase acceptability, appeal, and safety of active urban travel i.e. cycling and walking over vehicle use, would provide greater health benefits (7332 DALYs from reduction in CO_2 alone) than focusing solely on low emission transport (160 DALYs), with co-benefits of building up social capital and reducing transport poverty (Ubido and Scott-Samuel, 2015). Active travel is a 'best buy' for transport investment and a 'wonder drug' for health, with co-benefits of increasing physical activity, thereby improving physical and mental health, building more connected communities (Muirie, 2017), reducing road traffic crashes and congestion (Department for Transport (DfT), 2011). Active travel is most feasible for shorter journeys, such as commutes to schools, work and local shops, but would have a greater impact if used as part of longer journeys using low or zero-emission sustainable public transport as part of an integrated transport system (Muirie, 2017), enabled by infrastructure investments. The Making a Difference report showed that promoting physical activity through active travel is a 'best buy' that could save the NHS in Wales £0.9 billion over 20 years (PHW, 2016).

Interventions driven by local authorities in the UK that reduce single occupancy cars and increase non-car options, such as bus-use, walking, and cycling, are cost-effective and, based on decongestion alone, demonstrate a benefit of £4.5 for every £1 spent (DfT, 2011). A sustainable transport fund used to finance local authority projects has proved cost-effective, delivering a return of £5 for each £1 invested, with a range of £2 to £8 for each £1 for individual projects, with benefits of reducing congestion and co-benefits to health, journey quality, and safety (DfT, 2011).

Investing in **walking** environments was found to have a return of up to £37 for every £1 invested in well targeted schemes for walking and links to schools (DfT, 2011).

Evidence suggests that the direct economic benefits of **cycling** contributes nearly £3bn a year to the UK economy through bicycle sales, manufacturing, reduced traffic congestion, lower pollution levels, and lower NHS costs (Muirie, 2017). The economic benefit accruing from cycle trips into and out of Glasgow city centre in 2012 (calculated on the basis of reduced mortality) equated to over £4m (Muirie, 2017). Evidence from the Netherlands suggests that in addition to health economic benefits, cycling prevents about 6500 deaths nationally each year, and adds six months on average to life expectancy (Muirie, 2017). The extent of the benefits are likely to be influenced by the extent of the cycle path network, location and background levels of pollution, and time spent at busy junction-interfaces. The costs involved would be negligible if factored in at the planning stages by local authorities. Interventions to increase cycling are cost-effective, with a return of between £2.59 (combinations of physical infrastructure, promotion and smart measures) and £14 (for off-road cycle paths) for each £1 invested. Benefits will increase with time, assuming higher cycling rates can be maintained with less additional investment and are higher for off-road cycle routes (Ballinger et al., 2016; DfT, 2011).

Evidence shows that interventions to **link communities** to areas of economic activity through creation and upgrading of traffic calmed and traffic-free walking and cycling routes is cost effective, and has shown an average return of £10 for each £1 invested, with a range of £3.7 to £32.8 (DfT, 2011). Financial benefits can be seen to accrue as a result of improvements in health when more of the population become physically active through choosing to walk or cycle for all or part of their journey, with a mean return of £5.62 for every £1 invested in the UK (DfT, 2011).

7) Interventions to promote businesses in urban areas to take on Zero Emission Last Mile delivery, where businesses use zero emission transport, such as bicycle couriers, for the last leg of their deliveries, show a benefit of £5.05 for every £1 invested, with co-benefits of reducing congestion and noise pollution (Kilbane-Dawle, 2012). Encouraging businesses to deliver goods using zero emission transport within shorter, urban distances is a model that is applicable to larger towns in Wales, and has been growing, for example, with takeaway food deliveries by bicycle courier.

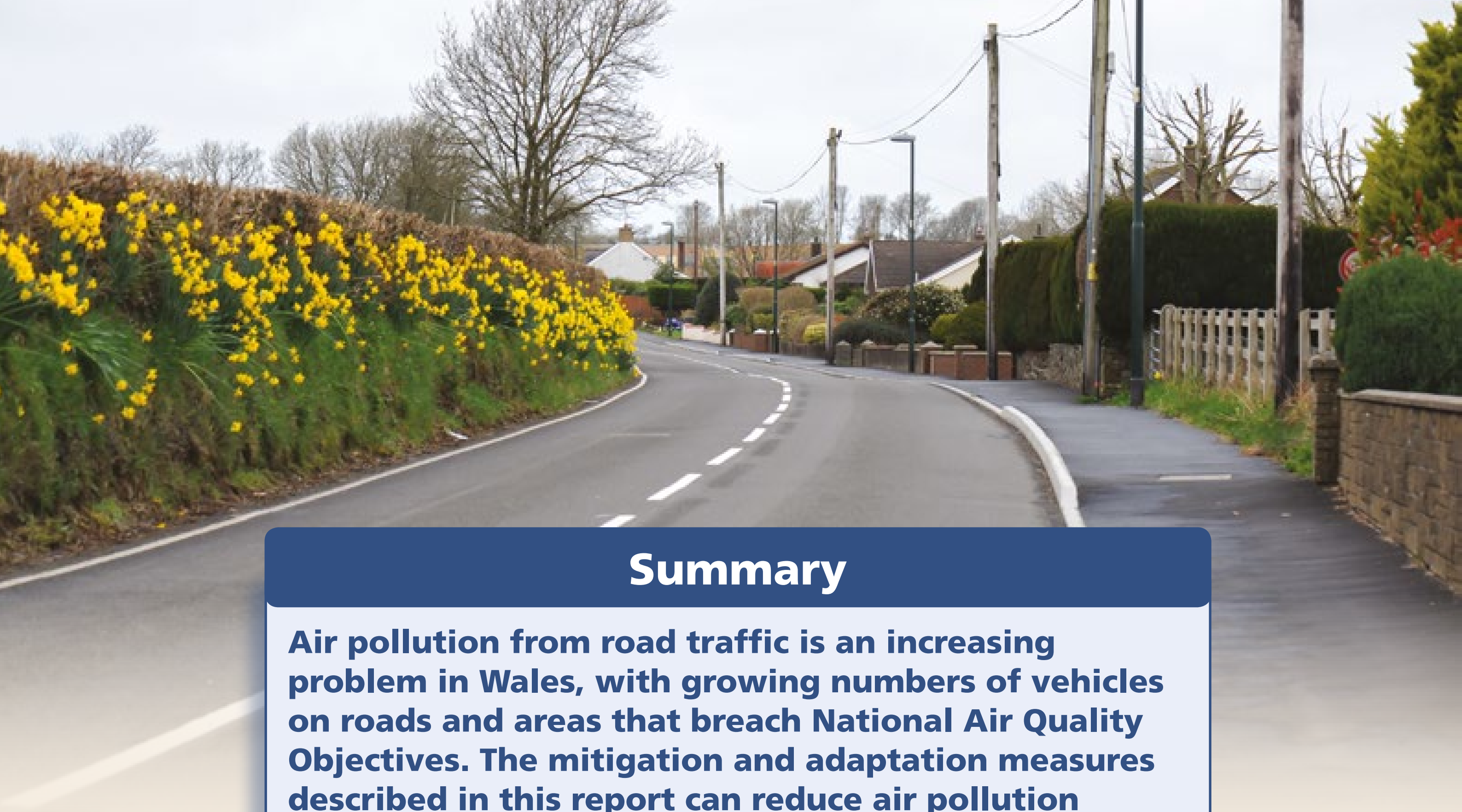
8) Strategic planning at local and regional levels supports a consistent approach to planning and advance consideration of the impact that planning decisions will have on air pollution e.g. avoiding pollution traps by creating 'street canyons' by location of solid barriers, or providing infrastructure for sustainable low- and zero-emission travel. With solid barriers a rebound effect is likely, so that the pollution that would reduce to background levels by 150-200m from the motorway without the barrier will, with the presence of a barrier, reduce in the area 80-100m, but increase again in the area from 100-250m and up to 400m away, with different barriers having different impacts (Ballinger et al., 2016). The impact will depend on local factors and population density. **Solid barriers**, such as noise or visual barriers, located at the side of major roads can affect the dispersal of air pollutants, similarly trees and vegetation may have a similar direct effects, or indirect effects through their contribution to the production of secondary pollutants[3] (NICE, 2017), with co-benefits for noise reduction. Evidence from the USA suggests that for a population living adjacent to a motorway the placement of a solid barrier can lead to a return in the first year of £3 for every £1 spent, with 10 QALYs gained at a cost per QALY of £25,199 (Ballinger et al., 2016). However, this return may be considered insufficient; given the NICE threshold for cost-effectiveness of an intervention is £20,000 per QALY gained. A downside to solid barriers on roads is the potential to increase road traffic crash severity. The value to the economy of preventing a single fatality on the roads is on average £1.8m, and the value of preventing a serious road traffic casualty is £200,421 (DfT, 2016).

9) Good communications can help raise professional and public awareness around air pollution problems and solutions and inform and support individual and population behaviour change to reduce risks, as well as gain public support for interventions (NICE, 2017; NICE, 2007; NICE, 2014; NICE, 2016), with the premise that good communications makes air pollution 'everyone's business'. Special consideration should be given by local authorities and public health teams to working with health professionals to reach out to vulnerable groups who are particularly affected by, or more susceptible to outdoor air pollution exposure (NICE, 2017).

10) Behaviour change can be encouraged through further awareness of why air pollution is a concern, combined with **individual mitigation measures** that can be taken to help reduce emissions from road traffic e.g. by reducing unnecessary engine idling or changing travel habits. For example, campaigns to prevent **vehicle idling** have been shown in the USA to be cost-effective, with a benefit of £44 for every £1 spent (although, this was for an anti-school bus idling campaign, so is less directly applicable to the UK) (Ballinger et al., 2016). Awareness campaigns to encourage drivers to switch off when stationary, particularly when idling for prolonged periods at sensitive locations in city centres such as taxi ranks, loading areas, bus stations and AQMA, already exist as part of local authority Air Quality Action Plans in Wales. This could be extended to statutory **idling enforcement** for cars which has been considered in Oxford (Ballinger et al., 2016). Idling enforcement in taxi ranks delivered by local authorities has been shown to have a return of £4.12 for every £1 invested; where the higher the

compliance, the smaller the rank would need to be to be cost-effective (Kilbane-Dawle, 2012). At 100% compliance, a taxi rank with 49 vehicles would be needed, and at 25% compliance a 200 capacity taxi rank would be cost-effective (Kilbane-Dawle, 2012). In the Welsh context the benefit is likely to be smaller. Evidence suggests that **eco (or efficient) driving training** is likely to be cost-saving for businesses. For example eco-driving training for taxi-drivers driven by local authorities could have a return of £5.75 for every £1 invested in fuel savings, with co-benefits of reducing air pollution and improving road safety (Kilbane-Dawle, 2012).

11) Develop and implement corporate environmental sustainability strategies. This is especially relevant to public bodies and other large organisations in Wales who have a duty to consider and minimise their environmental impact, reduce emissions, and protect public health and well-being (NICE, 2017). **Procurement choices** of vehicles is likely to have an impact on vehicle emissions and could be done when replacing older vehicles; the cost of doing this would depend on the extent of the changes and relative cost of the vehicles (NICE, 2017). **Encouraging behaviour change,** such as fuel efficient driving, is likely to be cost-neutral, where behaviour training costs are off-set by fuel savings from changing driving habits to become more energy efficient, and effectiveness would depend on the views of those receiving the training (NICE, 2017). **Low emission travel plans** could also be used to encourage staff to re-evaluate their commute to work (and travel while at work) and generally encourage a move away from car travel. Interventions such as work-based 'light-touch nudge' behaviour change interventions to increase sustainable travel of employees have been trialled in the UK, including car sharing, encouraging public transport use through personalised commuter plans, and cycling intervention such as an e-bike trialling scheme (Behavioural Insights Team, 2017). These interventions are likely to be more effective if they are more intensive and integrated with other measures intended to help reduce barriers to behaviour change within a larger work-place (Behavioural Insights Team, 2017). For example, cycle to work schemes have shown a return of £6.22 for every £1 invested (Kilbane-Dawle, 2012).



Summary

Air pollution from road traffic is an increasing problem in Wales, with growing numbers of vehicles on roads and areas that breach National Air Quality Objectives. The mitigation and adaptation measures described in this report can reduce air pollution and associated risks for everyone. In addition, it is important to take targeted action in areas with poor air quality and poor health to reduce any air pollution-linked health inequalities.

A range of solutions that reduce our reliance on motorised transport and encourage the use of cleaner vehicles, are shown to be cost effective. It is likely that a collaborative and sustainable approach to implementing a combination of adaptive and mitigative measures will have the greatest impact on improving the health and well-being of current and future generations.

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Providing information, advice and taking action, across sectors, to promote health, prevent disease and reduce health inequalities
Health Protection
Providing information, advice and taking action to protect people from communicable disease and environmental hazards
Microbiology
Providing a network of microbiology services which support diagnosis and management of infectious diseases
Health intelligence
Providing public health data analysis, evidence finding and knowledge management
Screening
Providing screening programmes which assist the early detection, prevention and treatment of disease
Safeguarding
Providing expertise and strategic advice to help safeguard children and vulnerable adults
NHS quality improvement and patient safety
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www.publichealthwales.org

Public Health Wales
Number 2 Capital Quarter
Tyndall Street
Cardiff CF10 4BQ

Tel: 02920 227744

Email: generalenquiries@wales.nhs.uk

@PublichealthW

/PublicHealthWales