ENHANCING LOCAL AIR QUALITY MANAGEMENT IN WALES TO MAXIMISE PUBLIC HEALTH AWARENESS, INTEGRATION, COLLABORATION AND IMPACT

HUW BRUNT

A thesis submitted in partial fulfilment of the requirements of the University of the West of England, Bristol for the degree of Doctor of Philosophy

Faculty of Environment and Technology,
University of the West of England, Bristol

April 2018

Word count: 88,979

ABSTRACT

Air pollution is a significant public health concern. The UK Local Air Quality Management (LAQM) regime mandates collaborative action to reduce air pollution to protect health. Despite having this aim, LAQM is disconnected from broader public health policy and practice. Several LAQM 'structure' and 'process' limitations have likely contributed to this unsatisfactory situation and LAQM's failure to deliver effective 'outcomes'. Two main shortfalls are to blame: prescribed risk assessment and management processes that are too narrow in public health scope, and a poor recognition of the valuable contribution that public health bodies and specialists could and should make to support LAQM.

With Wales selected as the research study area, this research explored LAQM shortfalls through complementary research strands, framed by a mixed-methods approach and a convergent parallel study design. The first of these research strands – an ecological study – linked air pollution, deprivation and health data to assess associations and determine the merits of broadening the public health scope of LAQM. The second – a Delphi study – formed expert consensus on the role of public health in LAQM, and defined the value added by, and opportunities, barriers and solutions to, increasing public health awareness, integration and collaboration in LAQM. Research outcomes were subsequently mixed, validated and evolved to develop a suite of drivers (and linked recommended enabling actions) to support new public health-driven ways of working in LAQM in Wales.

The ecological study found that interactions between air pollution and socio-economic stressors modified and compounded associations with important health outcomes. Thus, there is merit in considering air pollution problems and solutions in the context of broader public health priorities. Further, aligning risk reduction actions with principles of proportionate universalism could achieve greater health gain.

Through the Delphi study, experts agreed that public health bodies and specialists could and should do more to support LAQM, and proposed enhanced ways of working around assessing risks, integrating LAQM action with the 'day job' (and *vice versa*), appraising and interpreting evidence, and undertaking research and evaluation. These, together with a better application of

core public health skills such as authoritative communications, policy development advocacy, and change leadership, could add value to LAQM.

Integrating, validating and evolving this evidence – the latter achieved through a workshop and case study interviews with experts – informed proposals for new public health-driven ways of working in LAQM in Wales. These are underpinned by the primary drivers of risk assessment and management approaches of broader public health scope, stronger public health support, and full integration of LAQM with wider public health policy and practice.

In conclusion, this research makes a compelling case for LAQM enhancement through better public health awareness, integration and collaboration. While evidence-based drivers for change can help guide LAQM evolution, stakeholders must still commit to enable and achieve them. The positive impacts resulting from fully connected LAQM and public health policy and practice have the potential to ripple way beyond the LAQM arena to help tackle wider linked public health and wellbeing priorities.

ACKNOWLEDGEMENTS

I would like to thank all members of my PhD supervisory team - Prof James Longhurst, Prof Gabriel Scally, Dr Jo Barnes, and especially Prof Enda Hayes (Director of Studies) - for their guidance, advice and support. Also, to Dr Tim Chatterton and Prof Jimi Irwin for their help at various stages of the research.

I would also like to thank my colleagues at Public Health Wales, particularly my former and current line managers – Dr Marion Lyons and Dr Giri Shankar, respectively - for giving me the advice, space and support to help me complete this research project. Special thanks to Dr Sarah Jones for her support too.

I must also give thanks to all members of the Delphi panel for their co-operation and expert contribution throughout.

Finally, thanks to my wife Katy, daughters Olivia and Georgia, and parents Peter and Hilary, for their continued help, motivation and patience.

CONTENTS

LIST OF ABBREVIATIONS

AQAP	Air Quality Action Plan
AQMA	Air Quality Management Area
AQO	Air Quality Objective
ASR	Annual Status Report
CI	Confidence Interval
EASR	European Age Standardised Rate
EU	European Union
ICD-10	International Classification of Diseases (tenth version)
IQR	Inter-quartile range
LAQM	Local Air Quality Management
LSOA	Lower-layer Super Output Area
MSOA	Middle-layer Super Output Area
NHS	National Health Service
NO_2	Nitrogen dioxide
PM_{10}	Particulate matter (less than 10µm in diameter)
$PM_{2.5}$	Particulate matter (less than 2.5µm in diameter)
PSB	Public Services Board
RR	Rate Ratio
UK	United Kingdom
UWE	University of the West of England
WFG Act	Wellbeing of Future Generations (Wales) Act

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

Chapter overview

This thesis presents an overview of research carried out to explore and address a recognised disconnect between Local Air Quality Management (LAQM) and public health policy and practice. This first Chapter introduces key aspects of the research to help set the scene. It offers background context, a definition of the problem under investigation, and specifies research aim (and sub-aims), objectives and boundaries. The Chapter also introduces the research approach methodology and methods used. It closes by providing a brief summary of the contents of each thesis chapter.

1.1 Air pollution and health – scoping problems and managing risks

Exposure to outdoor air pollution is the most significant environmental determinant of health (World Health Organization, 2015; Lim *et al*., 2012). Harmful pollutants like particulate matter and nitrogen dioxide reduce life expectancy by increasing mortality and morbidity risks from heart disease and strokes, respiratory diseases, lung cancer and other conditions (World Health Organization, 2013). Exposure reduces the life expectancy of everyone in the UK by 7-8 months, on average (Lancet, 2014; Department for Environment, Food and Rural Affairs, 2007). These life expectancy reductions amount to an estimated equivalent of 40,000 early UK deaths attributed each year to air pollution (Royal Colleges of Physicians and Child Health, 2016). The associated burden of disease is thought to cost society around £20 billion annually, through health care service provision and reduced productivity from lost work-days (Royal Colleges of Physicians and Child Health, 2016). It should also be noted that air pollution not only poses direct effects on individual and population health; interactions between pollutant exposure and wider health determinants are also known to modify associations between air pollution and health risks and can create disproportionate disease burdens between and within regions (Goodman *et al*., 2011; Jerrett *et al.,* 2001).

While general air quality across the UK has improved over recent decades, problems persist, and are especially evident at the local level. The scope of the problem is increasing too; because there is no 'safe' threshold of exposure for some pollutants, air pollution affects everyone to some degree. Given this situation, effective air quality management policy and practice that reduces localised air pollution, health risks and inequalities is essential. In the UK, since 1997, the statutory Local Air Quality Management (LAQM) regime has served to support local authority-led collaborative action to assess and manage local air pollution problems. This approach is intended to complement national and international-level air quality management work. The primary aim of LAQM is to protect and improve local public health and wellbeing. Its focus is on 'local' assessment and risk management because LAQM acknowledges that pollution sources are best managed at the lowest administrative level through proportionate, collaborative efforts that take account of the local context (Department of the Environment, Transport and the Regions, 2000).

Given the well-established adverse health effects associated with air pollution exposure and the relationships and interactions between air pollution and wider public health risk factors (see Chapter 2), it is essential that effective air quality management is informed by a comprehensive understanding of problems and solutions in a broad public health context (Bowen, 2002). Actions must be fully considerate of, and integrated with, wider public health priorities, policy and practice, and *vice versa*, in order to have the greatest potential for impact. Arguably, this is most important at the local level, where the products of effective policy and practice integrations are likely most 'visible' and meaningful amongst the public and other stakeholders.

Public health specialists are a key LAQM stakeholder; their engagement is vital in working with others to help scope, understand and solve problems.

1.2 Defining the research problem

The primary aim of the LAQM regime is to protect population health from air pollution risks. It seeks to achieve this through effective risk assessment and management activities. To tackle multi-faceted air pollution problems, LAQM relies on multi-discipline commitment and action from all relevant sectors, including transport, planning, regulation and health. To explore connections between the regime and public health policy and practice previously captured, reflected and reported on, the available literature was reviewed (see Chapter 3).

The literature, and a subsequent interpretation of findings, concluded that despite LAQM's health protection intentions and underpinning principles, the health sector – more specifically, public health bodies and specialists – tends not interact with, or support, LAQM as much as it could or should. From a public health perspective, LAQM is failing to achieve its full potential:.

Public health specialists can make a valuable contribution to LAQM. They have skills and resources that can inform and enhance health risk assessments, which can improve understanding of air pollution problems in a broader context (linked to other local public health priorities). Further, public health intervention can form part of the solution to air pollution problems e.g. communicating risk and changing behaviours amongst individuals and communities, promoting active and more sustainable travel, and influencing healthy community planning and design. Aligned collective efforts to change behaviours to reduce air pollution, reduce exposure, and promote local individual and population health can also help more people become less susceptible to the effects of exposure.

In contrast to other professional disciplines and sectors such as environmental health, land-use planning and transport, the role and expected contribution of public health in LAQM have been poorly considered and defined. This has led to a growing disconnect between air quality management and wider public health policy and practice which is doing little to tackle known interactions across public health problems and solutions e.g. promoting and facilitating active travel in a population to reduce physical inactivity and achieving co-benefits of reducing vehicle use and cutting transport-related air pollution emissions. Problems are compounded by the prescribed LAQM risk assessment and action planning processes being narrow in public health scope i.e. they fail to encourage stakeholders to consider air pollution problems and solutions in a broad public health context (aligned with tackling linked wider determinants of health).

Literature review findings suggested that addressing identified problems could help maximise the public health reach and impact of LAQM by making public health part of the solution to better-understood problems. While public health bodies and specialists are unable to single-handedly reduce air pollution, risks and inequalities, their contribution to LAQM should not be underestimated. Not having public health fully involved in LAQM represents a significant missed opportunity, especially given the interactions of air pollution with wider public health determinants. It is therefore hypothesised that greater public health integration and collaboration in LAQM can enhance air pollution risk assessment and management, and help the regime achieve its public health intentions.

1.3 Setting research questions and boundaries

Mindful of the problem defined, two research questions needed answering (see Chapter 4):

i. **Is there merit in assessing and managing local air pollution risks in a broader public health context** (than that currently prescribed)**, and advocating for action beyond Air Quality Management Areas?** (This latter term is defined in section 2.2.2).
ii. **How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?**

Although the LAQM regime applies to the whole of the UK, it was deemed impractical and counter-productive to carry out research to the required depth in all parts of the UK concurrently. To deliver meaningful research with the best chance of achieving positive and real-world change and impact, Wales was selected as the preferred case study area.

This decision was not just based on Wales having some of the most significant public health challenges in the UK and persistent localised air pollution problems, but because it has some specific characteristics that make it the most suitable part of the UK to conduct this research. Helpfully, it has a one-tier local authority system (to co-ordinate LAQM implementation) and a public health structure embedded in National Health Service structures. Most importantly, Wales has a forward-thinking policy and legislation landscape, headlined by the *Wellbeing of Future Generations (Wales) Act* (Welsh Government, 2015) and the national delivery strategy *Prosperity for All* (Welsh Government, 2017). Through these, and linked policy, all public bodies in Wales are required to think sustainably, set prevention-focused shared objectives, carry out joint planning and collaborative action, and work more effectively with people and communities.

While these characteristics make Wales the preferred case study research area, it should be noted that the Wellbeing of Future Generations Act is simply a vehicle that drives sustainable development, both in terms of ways of working and sustainable management of resources. Although perhaps not as explicit, the rest of the UK, and other countries in Europe and beyond, are required to work in the pursuit of effective sustainable change, so this research is applicable beyond the Wales context.

1.4 Aim and objectives of this research project

Clear aims and objectives were agreed to support research to investigate the research problem. The overall aim of the research project was **to generate evidence to help enhance the Local Air Quality Management regime in Wales to maximise public health awareness, integration, collaboration and impact**. To answer the research questions specified, two distinct yet connected Research Strands were specified; one relating to each research question. This provided clarity and focus to the research and allowed investigations to proceed without compromise or confusion.

To answer research question 1, Research Strand 1 aimed **to assess the merit of broadening prescribed LAQM risk assessment and management processes to ensure consideration of wider health determinants and potentially affected populations**. Its objectives were:

i. to assess Wales-specific air pollution risks in a broad public health context that is considerate of wider determinants of health (using deprivation status as a proxy measure) and relevant health outcomes;
ii. to describe the merits of broadening LAQM prescribed processes to assess and manage local air pollution problems in a broad public health context, and advocate for action beyond Air Quality Management Areas (this latter term is defined in section 2.2.2).

To answer research question 2, Research Strand 2 aimed **to assess how a better-defined role for public health bodies and specialists in LAQM could increase awareness, integration and collaboration, and add value to existing LAQM arrangements.** Its objectives were:

i. to define the role of public health bodies and specialists in LAQM;
ii. to describe the value added by better public health awareness, integration and collaboration;
iii. to identify opportunities to improve awareness, integration and collaboration;
iv. to identify the barriers and solutions to improving awareness, integration and collaboration.

1.5 Methodology and methods

Based on a comprehensive appraisal of research approaches and methods, an overarching mixed-methods research approach was selected to frame the whole research project (Chapter 5). This methodology placed an equal importance weighting on both quantitative and qualitative data overall, to help explore the research problem. The design and delivery of this mixed-methods approach was underpinned by a convergent parallel study design, which facilitated the implementation of each main research component, as follows:

- Research Strand 1's **ecological study** (to investigate research question 1).
  This research study linked, analysed and interpreted air pollution data in the context of wider health determinants to illustrate the importance and value added of doing so in Wales; it did not attempt to assess or quantify new links between air pollution and other variables.
- Research Strand 2's consensus-forming **Delphi study** (to investigate research question 2);
- **Mixing**, and interpreting in context, research outcomes from Research Strands 1 and 2 as well as the literature review; and
- **Validating and evolving findings, and assessing practical application of new ways of working** through an initial multi-disciplinary **stakeholder workshop** and subsequent **case study interviews** with experts.

Full details of the methodology and methods for each research component are provided in Chapter 5. While not listed above, it is also appropriate to acknowledge here the methods used to support the **literature review** (section 1.2 above, and Chapter 3). Briefly, these comprised an electronic database and internet search for relevant peer-reviewed and grey literature and a subsequent appraisal structured by the application of a well-established public health evaluation framework to ensure all aspects of the LAQM regime were considered.

Across-method evidence 'triangulation' and 'convergence' – comparing and contrasting outcomes from literature review, Research Strand 1, Research Strand 2, and mixing, validation and evolution phases, ensured the yielded research outcome 'whole' was greater than the sum of its parts.

A visual summary of research methodology and methods is provided in Chapter 5 (section 5.5).

1.6 Research originality

Since the important research problem outlined above has been largely ignored to date, the research presented in this thesis is the first of its kind. While its focus is on enhancing the LAQM regime in Wales, findings likely have relevance across the UK and in countries beyond where there exists a recognised disconnect between local air quality management and public health policy and practice, and a commitment to do something about it.

1.7 Thesis overview

The remainder of this thesis is set out as follows:

- Air pollution and health - scoping and managing problems

  Chapter 2 scopes air pollution problems in the UK and Wales and considers them in a public health context. It also introduces the importance, and practical application, of good air quality management. A scene-setting overview of the evolving need for effective air quality management is offered initially, followed by a detailed description of the Local Air Quality Management regime.

- Assessing public health awareness of, and integration and collaboration in, LAQM

  Chapter 3 considers the public health aspects of, perspectives on, and engagement in, LAQM. It presents a critique of available evidence that assesses LAQM strengths and limitations from a public health perspective. The value added that could result from better public health awareness, integration and collaboration in LAQM is also explored.

- Defining research context and boundaries

  Chapter 4 takes the findings from the evidence critique and uses them to define the research problem warranting further investigation. Ways in which LAQM might be enhanced to add value to existing arrangements are hypothesised. Research questions and boundaries are set around this hypothesis, and a rationale presented for Wales being the research study area of choice. The chapter concludes by specifying the overall research aim, and the sub-aims and objectives for Research Strands 1 and 2, to take forward to answer research questions and test the hypothesis.

- Research methodology and methods

  Chapter 5 discusses the appraisal and selection of approaches and methods for Research Strand 1's ecological study and Research Strand 2's Delphi study. These selected methods are framed in an overarching mixed-methods research methodological approach, underpinned by a convergent parallel study design. Given the requirements of the convergent parallel study design, the methods to mix, validate and evolve research outcomes are also described (i.e. a multi-disciplinary stakeholder workshop and area-based case study interviews).

- Results

  Chapter 6 presents the results of Research Strands 1's ecological study and Research Strand's Delphi study. The evidence generated through both studies is then mixed and interpreted in the context of literature review findings. The process of validating research outcomes via the multi-disciplinary workshop – to inform the development of a conceptual LAQM framework for Wales – is described. The chapter concludes by synthesising expert feedback on the local/regional appropriateness, applicability and acceptability of the conceptual framework, obtained through case study interviews.

- Discussion

  Chapter 7 discusses research results in the context of the research hypothesis and questions, and linked aim and objectives. The three main components of this project – 'Research Strand 1's ecological study', 'Research Strand 2's Delphi study' and 'mixing, validating and evolving research outcomes' – are considered in turn. Emphasis is placed on discussing how each has added to evidence and understanding.

  The transition between research theory and practical action to achieve real-world change is also explored. Drawing together all evidence from across multiple sources, the discussion builds to present the final research outcome that specifies drivers for change (and linked recommended enabling actions) to enhance LAQM in Wales, underpinned by better public health awareness, integration and collaboration. The Chapter closes with a reflection on research approaches and methods, and a discussion of confidence in research outcomes.

- Conclusions and recommendations

  Chapter 8 brings together all aspects of the research project to provide a coherent conclusion. To help initiate the transition from research theory to action that achieves change and real-world impact in Wales, some practical 'next steps' are suggested.

- Recommendations for further research

  Chapter 9 recommends further research to build on this research project.

- References

  Chapter 10 details all references relevant to this research.

2. AIR POLLUTION AND HEALTH – SCOPING AND MANAGING PROBLEMS

Chapter overview

This second thesis Chapter opens by scoping air pollution problems in the UK, with further detail provided on the situation in Wales. Air pollution is next considered in terms of it being a public health priority. Emphasis is given to describing the scale of the disease burden (including societal cost) and health effects associated with exposure to particulates and nitrogen dioxide pollution. Non-uniformity in health risks and impacts, resulting from variations in individual and population vulnerability and susceptibility, is also explained in the context of the 'triple jeopardy' concept.

After scoping problems, the chapter turns to highlight the importance, and practical application, of good air quality management. A scene-setting overview of the evolving need for effective air quality management is offered initially, which is followed by a detailed description of the Local Air Quality Management regime. This latter section specifies the regime's intentions and approach, prescribed processes supporting risk assessment and action planning, variations in UK implementation, and resources available to support LAQM implementation.

2.1 Scoping air pollution and health problems

2.1.1 Air pollution as a persistent and growing concern

Outdoor air pollution refers to the presence in outdoor air of toxic compounds at a concentration and/or a duration above natural levels, with the potential to produce an adverse effect (Seinfeld and Pandis, 2006). To elaborate, 'toxic compounds' refers to gases or contaminants in solid form (e.g. suspended particulates), and 'adverse effects' are increased health risks and environmental insults.

Air pollution is a persistent problem globally, especially in major urban areas of the world (World Health Organization, 2005). The highest concentrations of the “classical” pollutant indicators, such as particulate matter, are found in Africa, Asia and Latin America. However, even in Europe – where air pollution concentrations tend to be lower, generally – the downward trend in pollution observed at the end of the last century is now reversing and rising again (World Health Organization, 2005).

In the UK, air pollution problems are nothing new. Originally, they were a significant consequence of the UK industrial revolution during the early/mid-1800s, and before this in the 13th century when coal was first used. More recently, because of ongoing industrial developments and man’s reliance on fossil fuels to meet energy needs, concerns were brought to the fore when around 4000 people prematurely died from the infamous air pollution smog episode in London, 1952 (Wilkins, 1954).

Today, anthropogenic activities continue to be the cause of most outdoor air pollution but, to a lesser extent, natural processes also contribute. In terms of the former, managing industrial air pollution emissions remains important, but air quality management efforts have now shifted focus to reducing motor vehicle emissions since these are responsible for the majority of current localised air pollution problems. In the UK, air quality management policy and practice over the past couple of decades have been concerned with tackling a range of pollutants, inlcuding: benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulphur dioxide.

From a public health perspective, the pollutants of most concern are particulate matter, oxides of nitrogen and ozone (Royal Colleges of Physicians and Child Health, 2016). In the contemporary context of local air quality management in the UK (including Wales), the focus is on two of these three pollutants – particulate matter (PM) and nitrogen dioxide (NO_2) – with the anthropogenic sources of both being motor vehicle emissions primarily, but also domestic and industrial combustion emissions (Barnes *et al*., 2014; Zhang and Batterman, 2013; World Health Organization, 2006). The focus is on these pollutants because they are responsible for widespread problems, are the most detrimental to health, and most importantly, can be mitigated through effective action. Since ozone is not a primary pollutant, it cannot be managed directly at source; as such, mitigating other pollutants such as particulate matter serve to help reduce ozone concentrations.

To contextualise the scale of regional air pollution problems in the UK, of the 43 ‘zones’ the country is divided into for compliance reporting purposes, 37 exceeded the limit value for annual mean NO_2 concentrations in 2016 (Department for Environment, Food and Rural Affairs, 2017). At the local level, nearly 700 NO_2 and PM_{10} pollution ‘hotspots’ have been identified and declared as Air Quality Management Areas (Table 1). This latter term is defined and discussed further in section 2.2.2.

Table 1. UK Air Quality Management Areas, correct at February 2018 (Defra, 2018).

Pollutant	**England**	**Wales**	**Scotland**	**N. Ireland**	**London**
Nitrogen dioxide (NO_2)	479	39	29	18	34
Particulate Matter (PM_{10})	40	1	19	6	29

In Wales – the study area of focus in this research – local-level PM_{10} and NO_2 pollution problems persist. Of Wales’ 40 Air Quality Management Areas, 39 have been declared on the basis of consistently high NO_2 pollution (from road transport sources); the remaining one in Neath Port Talbot which has been declared as a result of PM_{10} emissions from local industrial sources (Figure 1). These areas vary in geographical size, from a street (for example, in the Rhondda Cynon Taf area in Wales) to nearly an entire borough (for example, in Swansea city in Wales).

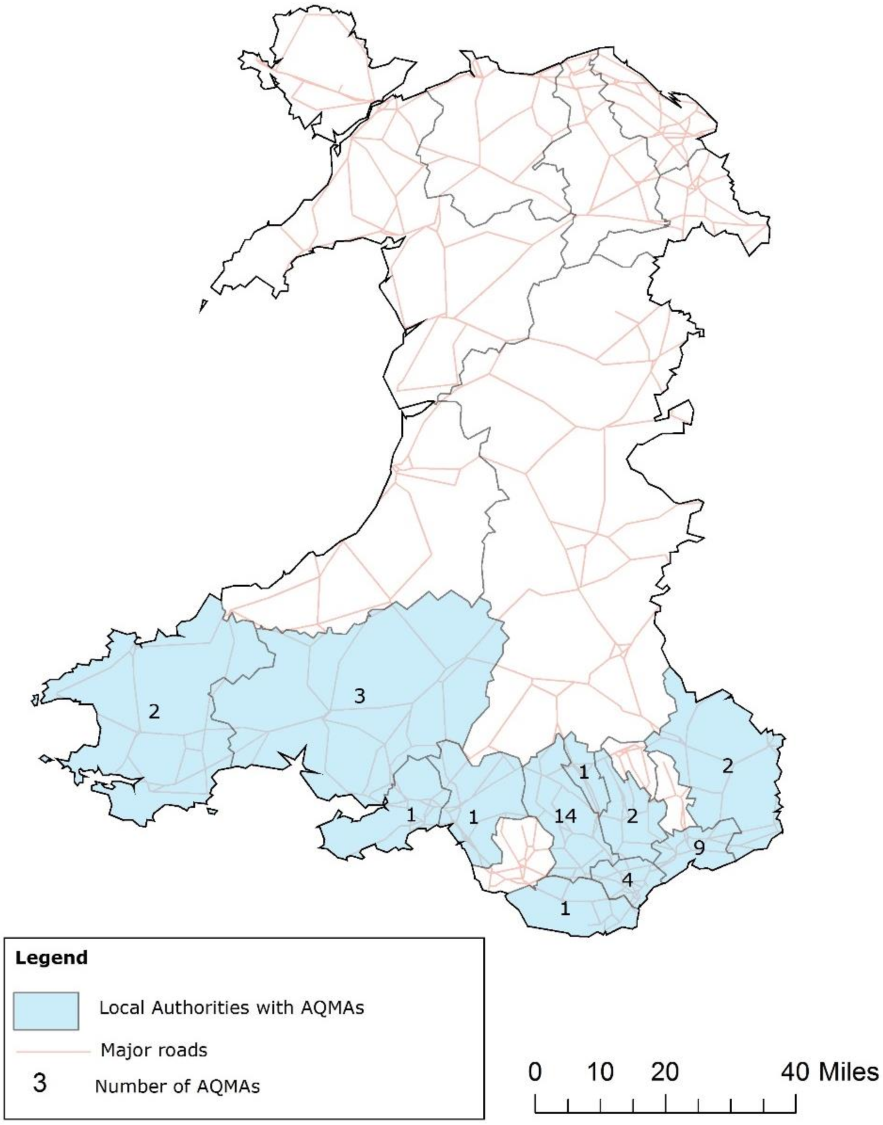

Figure 1. Wales local authorities with Air Quality Management Areas (AQMAs)

2.1.2 Air pollution as a public health priority

In its broadest sense, 'health' is a function of a person's socio-economic and environmental circumstances, as well as hereditary and personal influences (Barton and Grant, 2006; Dahlgren and Whitehead, 1991). While these latter factors have the greatest influence on health and wellbeing, the impact of environmental stressors on health is substantial (World Health Organization, 2013; Diez-Roux, 2003). Of all environmental factors (including climate and extreme weather, land and water quality, and environmental noise), outdoor air pollution is regarded as *the* most influential environmental determinant of health, particularly in high-income countries such as the UK (Landrigan *et al*., 2017; World Health Organization, 2015; Lim *et al*., 2012). Despite the relatively small size of the health effects linked with NO_2 and PM exposure, air pollution is recognised as a significant health problem at population level because such large numbers of people are affected. The burden of disease associated with exposure to PM and NO_2 is substantial:

- Worldwide, in 2000, air pollution was reported to account for approximately 1.4% of total mortality, 0.4% of all disability-adjusted life years, and 2% of all cardio-pulmonary disease (World Health Organization, 2004). In 2010, a global assessment of the disease burden attributable to 67 risk factors across 21 regions showed that the magnitude of disease from ambient air pollution was actually substantially higher than originally thought (accounting for 3.1% of all disability adjusted life years and 22% of disability adjusted life years due to ischaemic heart disease) (Lim *et al.,* 2012). The assessment estimated that, in 2010, ambient particulate air pollution was responsible for 3.1 million deaths globally, primarily as a result of cardiovascular events. By 2012, air pollution was believed to be responsible for 3.7 million premature deaths globally, 80% of which were caused by ischaemic heart disease and strokes, 14% by chronic obstructive pulmonary diseases or acute lower respiratory infections and 6% as a result of lung cancer (World Health Organization, 2013).

- In Europe, more than 80% of the population (some 40 million people) live in urban areas where particulate matter air quality guideline levels are exceeded (World Health Organization, 2013). In 2010, findings from the Global Burden of Disease study series suggested that over 430,000 premature deaths and over 7 million years of healthy life were lost each year in western, central and eastern Europe from exposure to fine particulate matter. This equated to 166,000 premature deaths in Western Europe, 95,000 deaths in Central Europe, and 169,000 deaths in Eastern Europe (Health Effects Institute, 2012). Average life expectancy was thought to be around eight months lower than it would otherwise be, because of anthropogenic particulate matter exposure. In 2012, air pollution was ranked 11th (of all public health risk priorities) in Western European countries (Lim *et al.*, 2012), lying just behind other risk factors such as tobacco, alcohol, physical inactivity and poor diet.

- In the UK (including Wales), in 2008, the Committee on the Medical Effects of Air Pollutants estimated that the health burden of fine particulate air pollution exposure is equivalent to nearly 29,000 premature deaths each year, or a loss of population life of 340,000 life years lost (Committee on the Medical Effects of Air Pollution, 2010). In 2010, attributable deaths (amongst people aged >25 years) from fine particulate exposure $PM_{2.5}$ numbered 25,000, 1,320, 2,094, and 553, in England, Wales, Scotland and Northern Ireland, respectively. The estimated number of associated life-years lost for the same year was reported to be 264,749, 13,549, 22,474, and 6,063, in England, Wales, Scotland and Northern Ireland, respectively (Gowers *et al.*, 2014). The health burden estimate linked with NO_2 exposure is also substantial; exposure is responsible for around the equivalent of 23,500 premature deaths or 277,000 lost life-years annually in the UK (Defra, 2015). Like the estimates for $PM_{2.5}$, NO_2 mortality estimates vary regionally; for example, in Wales, exposure is responsible for the equivalent of around 1,100 avoidable deaths and 13,200 lost life-years (Public Health Wales, 2016).

Acknowledging overlapping health impacts of PM and NO_2 exposure, and difficulties in disentangling the attributable impacts of each, it is estimated that an equivalent of 40,000 premature deaths (range 34,750-52,500) occur each year in the UK as a result of exposure to air pollution (Royal Colleges of Physicians and Child Health, 2016). On average, air pollution reduces the life expectancy of every UK resident by 7-8 months (Lancet, 2014; Defra, 2007).

The economic cost to society of the adverse health outcomes of air pollution exposure is significant. In 2010, the annual cost of air pollution-related impacts in the UK was believed to lie between £9 and £19 billion (Institute of Occupational Medicine, 2006). A more recent report suggests that the cost to individuals and society may be higher still – standing at around £20 billion annually - when the cost of reduced productivity (through lost work-days) is considered alongside health service costs (Royal Colleges of Physicians and Child Health, 2016). This equates to about 17% of the UK NHS budget (House of Commons Environmental Audit Committee, 2010). In Wales, the cost of air pollution is thought to be approximately £1 billion each year (Public Health Wales, 2016).

These estimates are comparable to the economic cost of obesity (over £10 billion) (Institute of Occupational Medicine, 2006). To prove context, it is estimated that the impact on life expectancy of a 10ug/m^3 reduction in ambient fine particulate matter would be much greater than either that of the elimination of all motor traffic accidents or that of the elimination of all passive smoking.

At the European level, the economic impact of exposure to air pollution across the European Union area is estimated at €240 billion annually (Royal Colleges of Physicians and Child Health, 2016). By 2030, it is estimated that spending €3.3 billion per year on pollution mitigation across Europe could yield savings worth at least €40 billion (Lancet, 2014).

2.1.3 Health effects of air pollution

The effects of short and long-term exposure to ambient air pollutants have been comprehensively researched and the link between air pollution and adverse health outcomes is now widely accepted. Consistently, air pollution exposure has been found to increase cardiovascular and respiratory disease morbidity and mortality risks (Landrigan *et al*., 2017; World Health Organization, 2013; Brunekreef and Holgate, 2002). Craig *et al.* (2008) describes the consequences of these increased risks in the form of a 'pyramid of air pollution health effects' (Figure 2). The UK Committee on the Medical Effects of Air Pollution says there is little doubt that long-term air pollution exposure affects mortality and decreases life expectancy (Committee on the Medical Effects of Air Pollution, 2010).

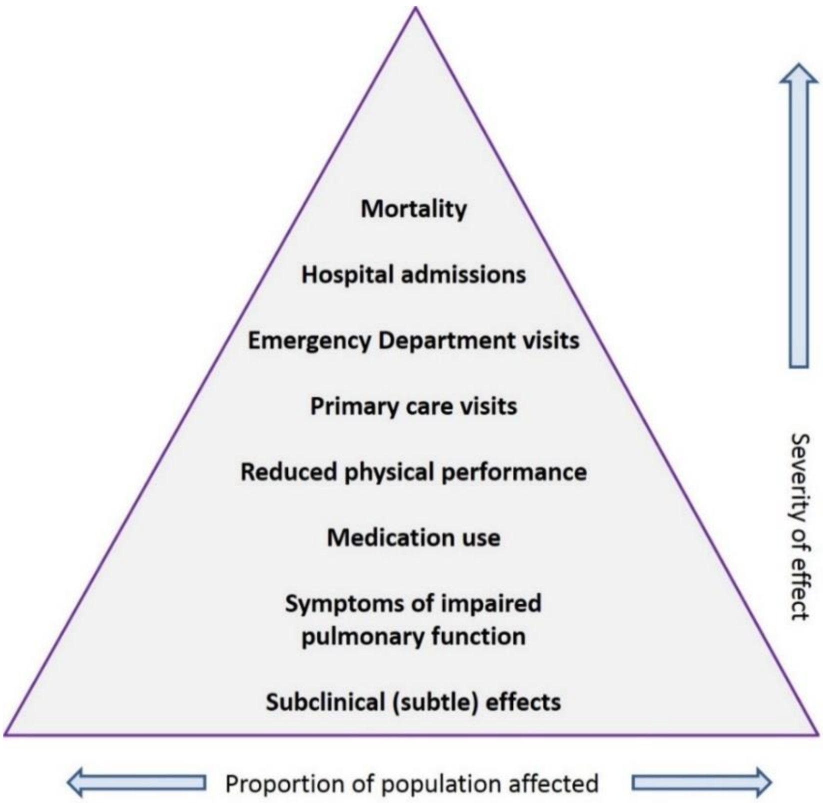

Figure 2. Pyramid of air pollution health effects

The overwhelming evidence of relationships between air pollution exposure and adverse health outcomes has prompted researchers to assess and attempt to communicate the scope of air pollution as a public health problem. While some research states that these links are becoming more difficult to delineate (because of the combination of the uncertainty around the air pollution-related health impact effect size *and* the continuously improving national air quality picture in the UK (Shah, 2014)), there is consensus that the health burden of air pollution exposure remains considerable.

The health effects of exposure to the two main pollutants of concern are described below. When assessing and quantifying health effects, it is important to acknowledge that pollutants, especially NO_2 and PM, can be temporally and spatially correlated with one another (up to 33% (World Health Organization, 2013)). As such, health impact estimates derived from the application of pollutant-specific exposure response functions cannot, and should not, be combined to reflect exposure to multiple pollutants. Until the evidence strengthens, impact estimates should be derived and considered separately, and interpreted as being due to exposure to individual pollutants (World Health Organization, 2000).

- <u>Particulate matter (PM)</u>

  The term 'particulate matter' (PM) essentially refers to small dust particles. When inhaled, particles less than 10µm in diameter (the PM_{10} 'thoracic' fraction) can penetrate, and get deposited in, the human upper respiratory tract. Particles less than 2.5µm in size (the fine $PM_{2.5}$ 'respirable' fraction') can penetrate deep into the alveoli of the lungs. Both induce the same biological mechanism which causes the lining of the lungs to become inflamed. Through the process of oxidative stress, pressure is placed on, and compromises the function of, various body systems.

  Studies (using cohort, panel, case-crossover and ecological research designs) have shown that chronic exposure to fine particulate matter increases morbidity and mortality risks through cardiovascular and respiratory impacts, but the main disease routes of increased risk are known to be coronary heart disease, cerebrovascular disease and heart failure. These links were first recognised in the 1990s (Pope *et al.*, 1995; Dockery *et al.*, 1993) and have since been corroborated and refined (e.g. Landrigan *et al.*, 2017; Beelen *et al.*, 2014). More recent evidence suggests that exposure is also associated with childhood respiratory disease and atherosclerosis (World Health Organization, 2013). It is now also believed that particulate matter exposure may also affect body systems other than cardiovascular and pulmonary systems, leading to adverse health outcomes that include damage to the endocrine (diabetes) and nervous systems (cognitive function) as well as poor birth outcomes and liver and kidney damage (e.g. Huang *et al.*, 2017; Royal Colleges of Physicians and Child Health, 2016; World Health Organization, 2013; Shah *et al*., 2013; Peng *et al*., 2008). Evidence of outdoor air pollution causing lung cancer has prompted the International Agency for Research on Cancer to classify diesel-engine exhaust and ambient air pollution (particulate matter) as carcinogenic to humans (World Health Organization IARC, 2013).

In light of the serious health implications of exposure to particulate matter, attempts have been made to quantify the effect size of health impacts associated with long-term exposure:

- For $PM_{2.5}$, an early meta-analysis of European studies suggested that a mean increase in mortality risk of 4-7% occurs per 10µg/m^3 PM_{10} increase in exposure (World Health Organization, 2004). In 2010, an updated best estimate of quantification was proposed – an increased all-cause mortality relative risk of 1.06 (95% CI: 1.02–1.11) associated with each 10µg/m^3 increase in $PM_{2.5}$ concentration (Committee on the Medical Effects of Air Pollution, 2010). More recently, the World Health Organization's *Review of Evidence on the Health Aspects of Air Pollution* has further refined the estimate and recommended the use of a concentration response function or relative risk of 1.062 (95% CI: 1.040 to 1.083). This can be interpreted as a 6.2% increase in all-cause (natural) mortality amongst those aged over 30 years for every 10µg/m^3 $PM_{2.5}$ concentration increase (Hoek *et al*., 2013).
- For PM_{10}, less evidence is available, but a concentration response function (relative risk) of 1.035 per 10µg/m^3 is suggested to quantify the impact of chronic exposure on all age all-cause mortality (Hoek *et al*., 2013).

As for short-term (daily) exposure, elevated concentrations of ambient particulate matter are reported to cause a range of adverse health effects, including: asthma exacerbation, lung function effects, increased risk of hospital admissions for cardiovascular and pulmonary conditions and mortality (World Health Organization, 2013). Acute, high-dose exposure is also linked to eye, nose and throat irritation, headaches, nausea, bronchitis and pneumonia (Halonen *et al*., 2009).

As well as the health effects linked to PM_{10} and $PM_{2.5}$, increasing attention is being given to possible impacts associated with exposure to ultrafine particles (smaller than 0.1µm). This is because it is believed these can pass through the alveoli into the blood stream before being deposited in organs and producing free radicals that subsequently provoke oxidative stress and inflammation of lung tissue. At present, evidence remains limited, but some studies that have explored these associations suggest that short-term exposure to ultra-fines not only affects cardio-respiratory health but also the central nervous system (World Health Organization, 2013).

Finally, it is important to note that concerns have broadened and now go beyond just the effects of particle size. Particulate air pollution (both primary or directly-emitted, and secondary or atmospherically-formed, particles) is now known to comprise chemicals such as sulphates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water from a range of different sources. The available evidence remains inconclusive to draw reliable conclusions about the relative toxicity of different sources and/or constituent components (World Health Organization, 2013).

- Nitrogen dioxide (NO_2)

  The health effects of nitrogen dioxide (NO_2) – a toxic gas which, like PM, causes inflammation of the airways and consequent impaired lung function – have not been researched to the same extent as those of PM; as such, they are less well defined. However, the literature agrees there are positive and statistically significant short-term associations between NO_2 exposure and all-cause and cause-specific mortality (World Health Organization, 2013). Associations are believed not to be confounded by the presence of most particulate matter metrics, especially those emitted from vehicles.

  Evidence from the United States is suggestive of stronger, likely causal, relationships between NO_2 exposure and adverse health impacts, particularly respiratory effects and linked hospital admissions, but less-so cardiovascular morbidity (US Environmental Protection Agency, 2013). There is some support, but not to the same degree as for short-term exposure, for the relationship to remain causal, for long-term exposure to nitrogen dioxide linked with respiratory and cardiovascular mortality, children's respiratory symptoms and lung function (US Environmental Protection Agency, 2013; World Health Organization, 2013).

In terms of health effects quantification, Hoek *et al*. (2013) suggest that, for NO_2 levels <20µg/m^3, a concentration response function (relative risk) of 1.055 (95% CI: 1.031 to 1.080) exists, indicating an increase in all cause (natural) mortality amongst those aged 30 years and above per 10µg/m^3. The Committee on the Medical Effects of Air Pollution has refined this estimate by taking into account both the Hoek *et al.* (2013) study and another meta-analysis by Faustini *et al.* (2014). They recommended that a coefficient of 1.025 (95% CI: 1.01–1.04) per 10µg/m^3 NO_2 could be used to reflect associations between long-term average concentrations of NO_2 and all-cause mortality (Committee on the Medical Effects of Air Pollution 2015).

2.1.4 Air pollution in a wider health determinants and inequalities context

The evidence of air pollution exposure health effects, and headline health burden statistics, provide important scope, context and profile to the UK air pollution and health problem. However, they mask important local-level variations in air pollution concentrations, exposures, risks and impacts. The variations that exist mean that some people may be more vulnerable than others mainly as a result of two connected pathways: 'differential exposures' and 'differential susceptibilities' (Lipfert, 2004). Put simply, some people suffer more because they live in areas where they are exposed to higher air pollution concentrations (i.e. more *vulnerable*), whereas others suffer more because they are *susceptible* to the effects of air pollution exposure. Some people may face both disadvantages (Royal Colleges of Physicians and Child Health, 2016). This unequal share of risks across society means there is the potential for health inequalities i.e. differences in health status or in the distribution of health determinants between different population groups (European Commission, 2016).

The 'differential exposures' pathway exists because air pollution concentrations are known to vary across small geographical areas. This is because they are influenced primarily by local transport emissions, and also by nearby domestic, industrial and agricultural sources, as well as more distant sources and meteorological conditions. The unequal distribution of area-level air pollution can lead to variations in the exposure potential for individuals and communities alike and render those living in more polluted places more vulnerable. Consequently, health risks and impacts can vary by area of residence (O'Neill *et al.*, 2008). The time-activity patterns of some individuals can also increase exposure potential beyond area of residence e.g. urban dwellers, traffic workers, commuters.

The ‘differential susceptibility’ pathway is a more complex concept. Even in the unlikely scenario where air pollution concentrations are uniform across an area or region, individuals and sub-groups within the population that live there are likely to be affected in different ways, and to different extents. This imbalance, where the health risks and impacts of air pollution exposure are influenced by other factors and stressors, reflects a complex matrix of health influences that determine an individual’s or population’s sensitivity or susceptibility. Such influencing factors may be ‘intrinsic’ (e.g. age, sex, genetics) and/or ‘acquired’ (e.g. income, education, housing, employment, service access, lifestyle or behaviour-related chronic illnesses) (Table 2).

Collectively, these determinants describe an individual’s or population’s capacity to cope with or manage air pollution exposure (Parkin and Balbus, 2000). This capacity is further influenced through interactions between the different factors that increase vulnerability status and can cause susceptible people to have a higher risk of adverse health effects, to experience more severe health outcomes, to show adverse health outcomes at lower exposure thresholds, or to be more likely to experience an above-threshold exposure to pollution (Royal Colleges of Physicians and Child Health, 2016).

Table 2. Air pollution and health associations in a broader risk factor context

Determinant	**Description**
Genetic and epigenetic influences	Human defence mechanisms are determined in part by genetic factors, but explain only a small part of individual variation in susceptibility. The 'epigenome' – the inheritable material other than DNA – may be influenced by environmental exposure (Janssen *et al.*, 2015). As such, past exposures to air pollution may influence how an individual responds in the future, favourably or unfavourably, to the same pollutants (Royal Colleges of Physicians and Child Health, 2016).
Age	The risk of death and hospitalisations associated with PM exposure amongst older people is about twice that observed in younger people (Bell *et al.*, 2013). These effects are likely the result of older people having higher prevalence of pollution-sensitive pulmonary, cardiovascular and metabolic diseases. Despite being less vulnerable relatively, children may be at a greater risk of exposure to ambient air pollution as they spend a much higher proportion of their time outdoors (Bateson and Schwartz, 2008) in high pollution areas such as school playgrounds.
Gender	The evidence for gender differences in vulnerability to air pollution is inconsistent; weak evidence suggests that in older adults, effects of air pollution may be more pronounced in women (Clougherty, 2011). However, in infants and young children, boys appear to be more affected than girls but it remains unclear why.
Pre-existing disease and illness	Those with pre-existing multiple co-morbidities are more susceptible to the effects of air pollution exposure. Those with respiratory conditions such as asthma or chronic obstructive pulmonary disease are more likely to suffer an 'attack' or have conditions exacerbated by exposure. Inhaled pollutants can enter the circulation from the lungs and become more systemically bio-available to influence harm on other organs such as the heart and brain. As such, people suffering with chronic cardiovascular diseases may be vulnerable to the effects of pollution; outcomes may include myocardial infarctions, hypertension and accelerated heart failure.
Obesity	Those overweight and obese are more vulnerable than others to air pollution risks and impacts (World Health Organization, 2013). Obesity acts as a modifier that influences associations between air pollution and markers of systemic inflammation, and between childhood asthma and respiratory symptoms. Some research has also proposed that air pollution may contribute to the development of obesity (Rundle *et al.*, 2012).
Diet	The main result of the mechanism though which air pollutants affect cardio-pulmonary health - 'oxidative stress' - can be protected against by diets that are rich in antioxidant nutrients (e.g. vitamins) (Romieu *et al.*, 2008). People living in more deprived areas may have limited access to healthy foods (Saunders *et al.*, 2015); a poor diet can reduce the body's defences against air pollutant exposures.
Deprivation	The risk or, and health impacts from, air pollution exposure may be influenced by deprivation factors, especially low income. People who have lower incomes tend to have poorer health (as a result of pre-existing and long-term limiting illnesses). This generally higher prevalence of poor health outcomes results from people living in low socioeconomic status neighbourhoods being less likely to engage in health-enhancing behaviour. In these areas, environmental quality may also be poor (Royal Colleges of Physicians and Child Health, 2016). It is plausible that these stressors compromise the body's defensive response to air pollution exposure.

It is important to recognise the significant role that social and economic factors play in determining an individual's or community's exposure to, and health risks and impacts from, air pollution. Regardless of air pollution status, the evidence for a socio-economic gradient in health is well-established. Those living in more deprived areas tend to suffer higher rates of ill-health and have greater risks of premature mortality than those living in less deprived areas (Thomas *et al.*, 2010; Poortinga *et al*., 2008). The inequalities gap that has resulted from this strong association between deprivation status and ill-health in the UK has been described as an average seven-year difference in life expectancy between most and least deprived area populations (Marmot, 2010).

Numerous pathways exist that help explain this phenomenon. Most of these are linked in some way to risk factors associated with multiple deprivation, such as:

- pre-existing ill-health (e.g. respiratory and cardiovascular disease, diabetes and obesity);
- adverse socio-economic factors (e.g. income, employment, education, healthcare access);
- poor lifestyle and behavioural choices (e.g. smoking, poor diet, physical inactivity);
- harmful aspects of the physical environment like poor housing conditions.

Several studies have explored these relationships in the context of air pollution, both in terms of the described 'differential exposures' and 'differential susceptibilities' pathways.

In terms of the former, research undertaken in the US, Canada and New Zealand has reported air pollution concentrations to be generally higher in socio-economically disadvantaged areas compared with less-deprived communities (Brochu *et al.*, 2011; Crouse *et al.*, 2009; Su *et al.*, 2009; *Pearce et al.*, 2008; Yanosky *et al.*, 2008; Pearce *et al.*, 2006). This has prompted some to suggest that the evidence for low income neighbourhoods to be exposed to higher concentrations of air pollutants is overwhelming (Landrigan *et al.*, 2017; Royal Colleges of Physicians and Child Health, 2016; Pearce *et al.*, 2010). However, suggestions such as these are equivocal because European research has generated findings that are more mixed (Fernandez-Somoano *et al*., 2013; Havard *et al*., 2009; Briggs *et al*., 2008; Walker *et al*., 2006; Mitchell and Dorling, 2003; Mcleod *et al*., 2000). A review of European evidence that explored social inequalities resulting from health risks related to ambient air quality reported that, in some instances, associations between air pollution and socioeconomic deprivation were found through poorer populations receiving a higher exposure, but in others, the reverse was true (Deguen and Zmirou-Navier, 2010).

As for ‘differential susceptibilities’, there appears to be more certainty. Deguen and Zmirou-Navier (2010) provided a balanced conclusion based on their evidence review and said that: beyond the variations observed in air pollution concentrations across areas of differing deprivation status, the general pattern is that deprived people, though not always more exposed, are more likely to suffer greater harm as a consequence of their exposure since they are more vulnerable to the effects of air pollution. This conclusion has been corroborated since (e.g. European Commission, 2016) with some suggesting that the greater harm suffered could have implications across the life-course, from the prenatal stage through to old age (Pruss-Ustun *et al.* 2017; Royal Colleges of Physicians and Child Health, 2016).

Socio-economic disadvantage can therefore be regarded to act to compound the influence of environmental deprivation, especially air pollution, on health status (Landrigan *et al.,* 2017; Naess *et al*., 2007; Finkelstein *et al.*, 2005; Jerrett *et al.*, 2004). The health of more disadvantaged groups is thus potentially compromised at multiple levels because air pollution, when combined with other aspects of an individual’s or population’s social, economic and physical environment, may result in differential exposure, health risks and impacts between and within affected populations. This ‘triple jeopardy’ concept describes how low socio-economic status, air pollution and already-impaired health stressors can interact to cause localised disproportionate and amplified disease burdens (Figure 3) (Goodman, 2011; O’Neill *et al*., 2003; Jerrett *et al*., 2001).

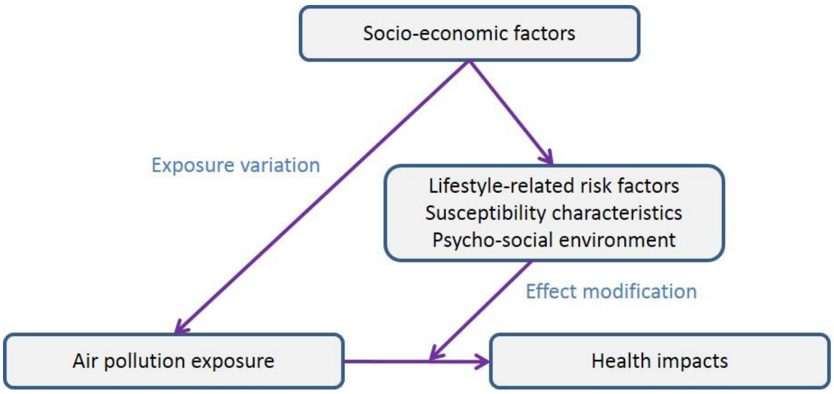

Figure 3. The ‘triple jeopardy’ mechanism – air pollution and health risk and impact modification

In summary, multiple deprivation-linked factors interrelate in a complex matrix to influence health and wellbeing. However, since the consequent impacts on health may be direct (e.g. through exposure to high air pollution concentrations that increase vulnerability) and/or indirect (e.g. through increased susceptibility resulting from health status and wider health and health-linked socio-economic stressors), the ill-health contribution from individual risk factors is almost impossible to tease out and quantify (Richardson *et al.,* 2013). Collectively and cumulatively, the result is significant; the reduction in life expectancy associated with air pollution exposure may be as extreme as nine years amongst the most vulnerable and susceptible people living in areas which are most polluted and socio-economically deprived (House of Commons Environmental Audit Committee, 2010).

In light of this evidence, it is important to acknowledge the 'triple jeopardy' concept since it may help explain some of the well-documented health inequalities picture.

2.2 Managing air pollution and health problems

2.2.1 The evolving need to manage air pollution problems

Although new evidence pertaining to the detrimental associations between air pollution exposure and health continues to emerge, knowing there is a need to protect health by effective air quality management action is nothing new; concepts and practice have evolved over many decades.

In the UK (including Wales), the first efforts to control air pollution (noxious and offensive gases) were set out in the Alkali Work Act 1863 and later, in the Public Health (Smoke Abatement) Act 1926. The smog conditions that prevailed in many large UK cities like London, Birmingham and Cardiff in the 1950s led to the development and passing of the Clean Air Acts in 1956 and 1968. These Acts, consolidated in 1993, prescribed a relatively narrow approach to managing air pollution from point sources such as industrial processes.

The introduction and implementation of these legislative tools brought about air quality improvements. Substantial reductions in air pollution were achieved over the course of subsequent decades, especially in terms of visible sulphur dioxide and black smoke emissions from domestic and industrial combustion sources (Brunekreef and Holgate, 2002). Shifts in fuel use from fossil fuels to natural gas, improved abatement systems and cleaner technologies (for example, tighter EURO standards on vehicles and fuels) have all further supported and enhanced the impacts of these legislative advances (Barnes *et al.*, 2014).

Despite these air quality improvements, the re-occurrence of urban air pollution episodes in the 1990s provided yet more evidence to suggest the framework for the control of air quality across the UK was inadequate and needed review and revision (Longhurst *et al*., 1996). These more-recent air pollution problems arose mainly because of increasing volumes of traffic on roads; the gains achieved from cleaner vehicle emissions, brought about through technological advances and associated policy implementation, were offset by steadily-rising numbers of vehicles. This trend of increasing vehicles is predicted to continue too, with UK road vehicle numbers expected to rise by 40% by 2025 (from a 2012 baseline), especially in rapidly growing cities like Cardiff (Department for Transport, 2012).

The inadequacies identified in air quality management arrangements across the UK in the 1990s were not unique; similar problems were observed in countries across Europe and beyond. In recognition of this, and also of the need for a more holistic approach to air quality management, the European Union developed policies and legislation that aimed to address problems at the international level. The Ambient Air Quality Directive (2008/50/EC)) provided legally-binding limits for EU countries (including the UK) for concentrations of major outdoor air pollutants that have the potential to impact public health (European Parliament, 2008). These developments at the European level required the UK Government to make arrangements to progress a new air quality management framework. In 1995, the Environment Act was passed, requiring the creation of policies and mechanisms to assess and manage air quality based around a reliance on scientific and expert consensus on the definition of the problem, and the establishment of a national legislative framework which also required action at the local level (HM Government, 1995). In response, the *UK National Air Quality Strategy* and the *Air Quality Regulations* were published in 1997 (Department of the Environment, 1997; HM Government 1997); the former being a framework to facilitate the achievement of legal requirements set out in the latter (in order to comply with EU direction).

The UK *National Air Quality Strategy* (the '*Strategy*') outlined commitments to ensure that all UK citizens have access to outdoor air without significant risk to their health, where economically and technically feasible (Department of the Environment, 1997). As directed by European drivers (notably the Air Quality Directive 2008/50/EC), the *Strategy* proposed a radical shift away from the previously-advocated source-based approach to one concerned with effects; it emphasised the need to protect human health from the cumulative impacts of air pollution by complying with health-based air pollution standards aligned with those across Europe. It set out that, at the national level, policy measures using financial, technological and legislative means should be used to reduce pollution and tackle larger-scale issues such as implementing fuel quality and engine technology standards. At the local level, through a regime called **Local Air Quality Management** (**LAQM**), responsibilities for identifying, assessing and managing air quality problems were given to local authorities, along with a suite of tools and resources to support them in their work to implement the regime. Figure 4 (below) illustrates how the UK has implemented legislation and policy-prescribed UK air quality management arrangements (at national and local/regional levels) in order to meet EU direction.

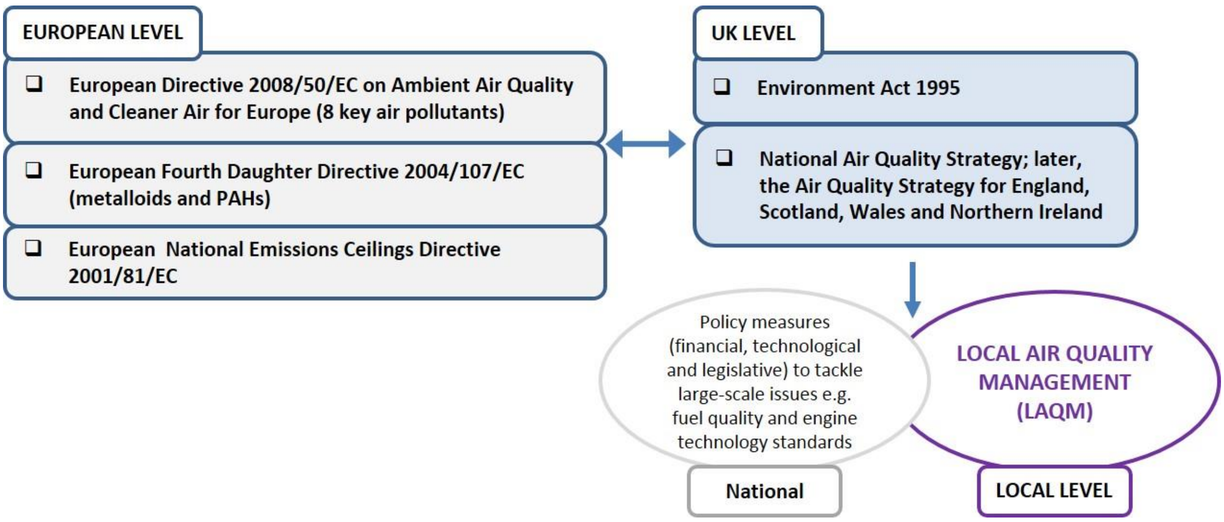

Figure 4. UK legislation and policy (national and local) to help achieve compliance with EU direction

Intending to protect human health and the environment, the Strategy specified health-based standards and objectives for eight different outdoor air pollutants (Table 3; the rows for PM_{10} and NO_2 are highlighted as they are most relevant in the context of this research). The standards and objectives specified needed to be at least as stringent as those directed by the EU Air Quality Directive. A description was provided of how different sectors such as industry, transport and local government departments could help achieve these through national and local-level action. Called Air Quality Objectives (AQOs), they incorporated a health-based standard and a timescale by which to achieve it, again aligned to the Directive issued by the EU (HM Government, 2010):

- The health-based *standard* (which needed to be at least as stringent as EU specification) was set at concentrations below which effects were considered unlikely – even in sensitive population groups – or below which risks to public health are believed to be exceedingly small. These were based on international scientific, clinical and epidemiological evidence of the effects of specific pollutants on health available at the time.

- The *timescale* set out the extent to which Government expected good air quality to be achieved and took account of economic efficiency, practicability, technical feasibility and timescales. As with the *standard*, the timescale selected needed to be at least as stringent as EU specification. The application of AQOs focused attention on local 'hotspots' with the highest air pollution concentrations.

While UK-specific AQOs drive air quality management in the UK (including Wales), it should be noted that other air pollutant standards exist. Of course, the European Directive Limits are the reference in this regard as these set the direction for EU counties (including the UK) and must be complied with, but more stringent standards exist in the form of the World Health Organization guideline values (World Health Organization, 2017) (Table 3).

Since its inception, the Strategy has been updated twice and is now formally entitled the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007; Department of the Environment, Transport and the Regions, 2000). Over the years, updates have reflected a variety of policy and scientific developments set out in published EU Directives, which have all been transposed into UK legislation through the Air Quality Standards Regulations 2010 (HM Government, 2010). The latest iteration of the Strategy introduced a new approach for controlling exposure to particulate matter in recognition of its non-threshold status i.e. there is no safe exposure level below which adverse health effects would not be expected. The new approach – directed by the European Union, and described as an 'exposure reduction' strategy – applies only to $PM_{2.5}$ and encourages a reduction in average exposure across bigger geographical areas rather than just in air pollution 'hotspots'. It is believed that, over time, this approach will produce a greater reduction in health effects of air pollution compared with concentrating on localised problems which remains the focus for the other pollutant AQOs (Table 3).

Table 3. UK Air Quality Objectives, European Directive limit values, and WHO guideline values

Pollutant	Applies	Objective	Measured as	Achieve by date	European Directive Limit	WHO guideline value
Particles (PM$_{10}$)	UK	50µg.m^{-3} (not to be exceeded >35 times/year)	24 hour mean	31 Dec 2004	50µg.m^{-3} not to be exceeded >35 times/year	50µg.m^{-3}
	UK	40µg.m^{-3}	annual mean	31 Dec 2004	40µg.m^{-3}	20µg.m^{-3}
	Indicative 2010 objectives for PM$_{10}$ (from 2000 Strategy and 2003 Addendum) replaced by exposure reduction approach for PM$_{2.5}$ (except in Scotland)					
	Scotland	50µg.m^{-3} (not to be exceeded >7 times/year)	24 hour mean	31 Dec 2010		
	Scotland	18µg.m^{-3}	annual mean	31 Dec 2010		
Particles (PM$_{2.5}$) Exposure Reduction	UK (not Scotland)	25µg.m^{-3}	annual mean	2020	Target value 25µg.m^{-3}	10µg.m^{-3} annual mean; 50µg.m^{-3} 24-hour mean
	Scotland	12µg.m^{-3}		2020	Limit value 25µg.m^{-3}	
	UK urban areas	Target of 15% reduction in concentrations at urban background		Between 2010 and 2020	Target of 20% reduction at urban background	
Nitrogen Dioxide	UK	200µg.m^{-3} (not to be exceeded >18 times/year)	1 hour mean	31 Dec 2005	200µg.m^{-3} (not to be exceeded >18 times/year)	200µg.m^{-3}
	UK	40µg.m^{-3}	annual mean	31 Dec 2005	40µg.m^{-3}	40µg.m^{-3}
Ozone	UK	100µg.m^{-3} not to be exceeded >10 times/year)	8 hour mean	31 Dec 2005	Target of 120µg.m^{-3} not to be exceeded >25 times/year over 3 years	100µg.m^{-3}
Sulphur dioxide	UK	266µg.m^{-3} (not to be exceeded >35 times/year)	15 minutes mean	31 Dec2005		500µg.m^{-3} ten minutes
	UK	350µg.m^{-3} (not to be exceeded >24 times/year)	1 hour mean	31 Dec 2004	350µg.m^{-3} not to be exceeded >24 times/year	
	UK	125µg.m^{-3} (not to be exceeded >3 times/year)	24 hour mean	31 Dec 2004	125µg.m^{-3} not to be exceeded >3 times/year	20µg.m^{-3}
Polycyclic aromatic hydrocarb-ons	UK	0.25ng.m^{-3} B[a]P	annual average	31 Dec 2010	Target of 1ng.m^{-3}	
Benzene	UK	16.25µg.m^{-3}	annual mean	31 Dec 2003		
	England & Wales	5µg.m^{-3}	annual average	31 Dec 2010		
	Scotland, Ireland	3.25µg.m^{-3}	annual mean	31 Dec 2010		
1,3-butadiene	UK	2.25µg.m^{-3}	running annual mean	31 Dec 2003		
Carbon monoxide	UK	10mg.m^{-3}	maximum daily running 8 hr mean/in Scotland running 8 hr mean	31 Dec 2003	10mg.m^{-3}	
Lead	UK	0.5µg.m^{-3}	annual mean	31 Dec 2004	0.5µg.m^{-3}	
		0.25µg.m^{-3}	annual mean	31 Dec 2008		

2.2.2 The Local Air Quality Management (LAQM) regime

The UK LAQM regime originates in Part IV of the 1995 Environment Act (HM Government, 1995) and the 1997 UK *National Air Quality Strategy* (Department of the Environment, 1997). When published, this *Strategy* committed that national policy measures were to tackle larger-scale issues (such as vehicle fuel quality, engine technology standards and emissions from combustion processes), but pushed most of the air quality management task to local authorities. Therefore, national level action (including that of the UK Devolved Administrations, as air quality management is a devolved responsibility), aims to manage background pollution concentrations and comply with EU limit values. As explained in more detail below, at the local level, LAQM was set up to identify and tackle localised air pollution 'hotspots' as it was considered more cost-effective for local authorities to take on this task (Barnes *et al*., 2018). The primary aim of LAQM is to ensure any breaches of Air Quality Objectives are identified, assessed and mitigated.

While both the national and local/regional-level approaches have different intentions, they intend to complement; as such, they have equal weight/status and have their own support resources. The national approach may appear to carry more relative status and power, but in reality, national government is constantly increasing the responsibilities of local authorities and looking for more to be done locally to bring about improvement through 'seen' action that delivers tangible outcomes (Barnes *et al*., 2018). The local approach is crucial to supporting air pollution problem recognition and diagnosis and in influencing collaborative solutions; without it there would be an absence of knowledge of local problems, communications and joined up actions that can make a real difference locally (Barnes *et al*., 2018; Olowoporoku *et al.*, 2012 and 2010).

The local approach, upon which this thesis focuses, recognises that pollution sources are best managed at the lowest administrative level through proportionate, collaborative action that takes local context into account (Department of the Environment, Transport and the Regions, 2000). This latter point is crucial because, given the complexity of many local air pollution problems, it is highly unlikely that a 'one size fits all' approach (that may be conceptualised nationally for local implementation would be effective. Rather, effective local air quality management will only be achieved if informed by local understanding of problems and solutions, tailored to the local context and designed to meet the specific needs of affected communities, and supported by all local stakeholders including public and private sector bodies and the public (Maantay, 2002; Bowen, 2002; Jerret *et al.*¸2001). Further, because air quality can vary considerably across small geographies, and individuals and communities can be affected by exposure in different ways, adopting a local approach is essential to undertake robust and accurate risk assessments that can inform communications, mitigation and adaptation actions, and intervention evaluations.

The LAQM regime places legal obligation on local authorities to periodically review and assess air quality within their areas and, if required, take action to tackle identified local air pollution problems to protect public health. Although led by local authorities (usually environmental health departments therein), LAQM calls for intra-departmental, multi-disciplinary and inter-agency collaboration to maximise synergies and co-ordinate efforts to work in pursuance of achieving specified air pollutant-specific health based standards. Consultation is required within local authorities (for example, across environmental health, transport, planning, building regulations, and sustainable development disciplines and elected members) as well as between them. Broader co-operation and collaboration is also recommended for effective LAQM implementation, with supporting roles suggested for external agencies such as highways and trunk road agencies, national parks, environmental regulatory agencies, health authorities, and the public too.
The legislative framework supporting the implementation of LAQM comprises two components:

- the provision of health and environment-based AQOs for pollutants that can be managed at the local level; and
- prescribed risk assessment and management processes intended to drive consistent implementation and air pollution risk reductions.

With specific regard to the first of these – AQOs – the regime requires that local authorities work towards their achievement. Once met, local authorities have a duty to maintain compliance in years beyond the specified deadline (Table 3). LAQM is concerned with seven of the eight key air pollutants for which health-based standards were specified in the original UK national *Strategy*; the secondary atmospheric formation and trans-boundary characteristics of ozone place its management beyond the remit of LAQM. As for the second component – LAQM risk assessment and management processes – this sets out two distinct stages: a Review and Assessment stage to scope problems across specified geographies, and collaborative Action Planning (and implementation) to tackle problems (Figure 5).

The LAQM two-stage, effects-based approach has remained largely unchanged since its inception (Barnes et al., 2014; Longhurst et al., 2009). However, it should be acknowledged that some elements underpinning the approach have been amended and streamlined over the years.

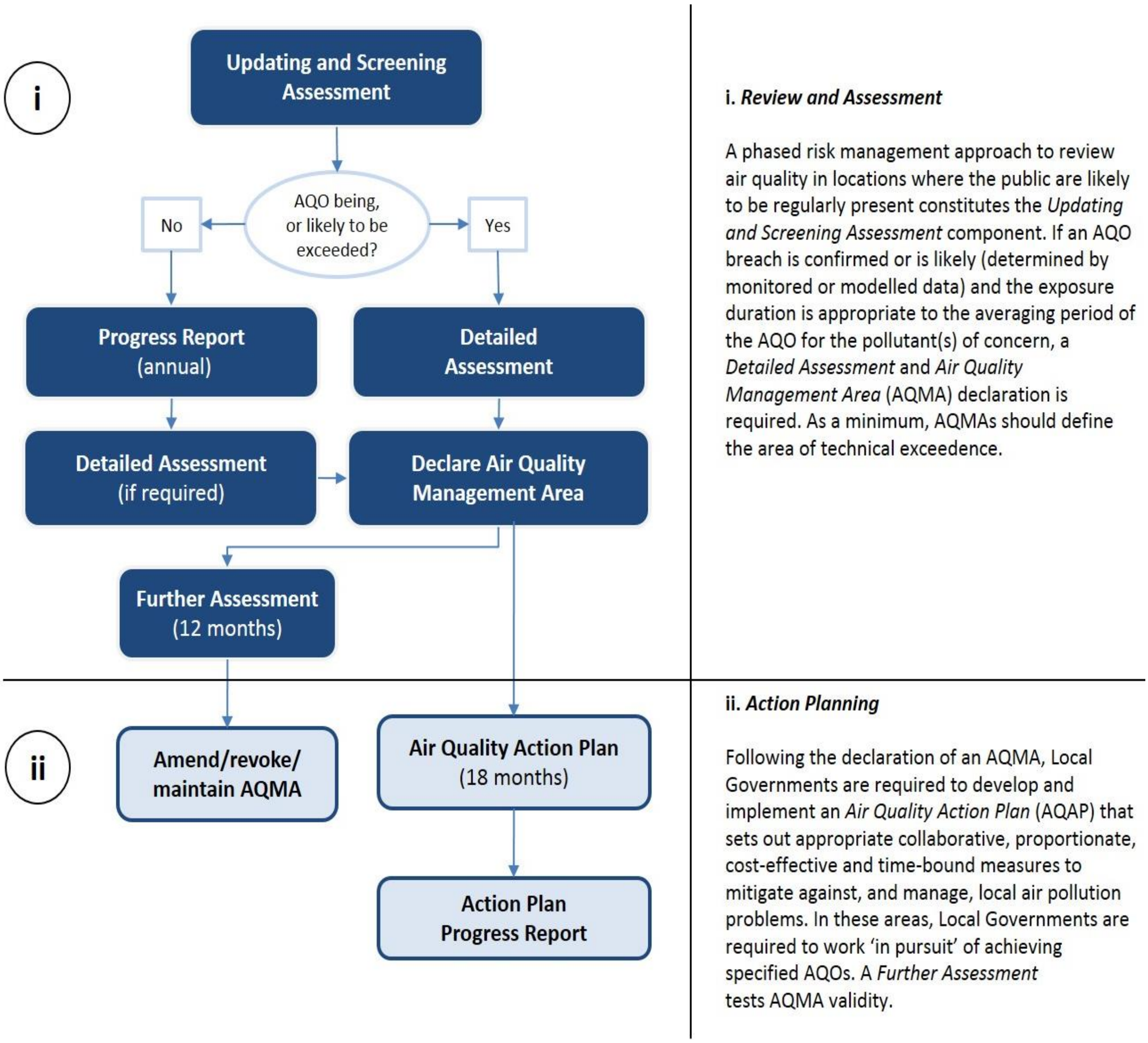

Figure 5. LAQM process pre-2017 (Brunt *et al.*, 2016a)

- <u>Review and Assessment</u>

  The *Review and Assessment* component of LAQM facilitates a comprehensive review of local air quality to identify areas where poor air quality coincides with likely public exposures in line with the averaging time associated with specified AQOs (HM Government, 1997). This activity is supported by detailed air quality monitoring and modelling strategies. In the context of air quality management, the risk assessment framework considers anthropogenic pollution which may pose health and environmental risks that are unacceptable, inequitable, inescapable, novel and/or poorly understood. Such risks may cause health impact consequences for current and future generations (Longhurst *et al*., 2006).

The Review and Assessment LAQM process has evolved over time:

At inception, LAQM *Review and Assessment* comprised three main steps, each underpinned by the use of sound science, a precautionary approach, a 'polluter pays' policy and sustainability principles (Beattie *et al*., 2001):

- desk-top study to identify local pollution sources that may cause air quality problems;
- screening assessment (using measured and modelled air pollution data) to identify areas where AQOs may be exceeded;
- detailed assessment of likely impacts.

Post review **in 2001**, *Review and Assessment* was simplified to a two-stage process which involved an *Updating and Screening Assessment* and, where the risk of exceeding an AQO was identified, a subsequent *Detailed Assessment* (Figure 5). The *Updating and Screening Assessment* (completed three-yearly and used to document and evidence review findings) served to identify any local changes that may have led to, or may lead to, an AQO being exceeded since the earlier *Review and Assessment* phase was completed. Annual *Progress Reports* were required in the intervening years between the three-yearly *Updating and Screening Assessment* reports; their purpose was to maintain LAQM process continuity. A checklist was provided to help identify relevant significant changes in localities that may warrant further consideration and, through a screening process, decide the extent to which such changes may result in a breach of air pollution standard.

The *Detailed Assessment* phase provided an opportunity to more-accurately assess the likelihood of any AQO exceedence in the context of human exposure by using quality-assured monitoring and validated modelling methods. It intended to provide local authorities with a greater degree of certainty to inform risk assessments and decision-making around whether or not to designate problem areas and take more formal action. In non-compliant areas, local authorities were, and are still, required to declare an *Air Quality Management Area* (AQMA) that, as a minimum, contains the geographical area of technical exceedence. This declaration is made by means of a legal order and a commitment to plan and take appropriate and proportionate action to reduce air pollution to protect population health in affected locations. The order – comprising a spatially-defined area showing the affected area and population – needs local authority elected member approval, which should also be made available to the public.

In the 12 months following the declaration of an AQMA, local authorities were advised to carry out a *Further Assessment* to allow for any AQMA boundary adjustments to be made. The *Further Assessment* supplements the information presented within the *Detailed Assessment* and to provide more focus on the relative contributions from local pollution sources on AQO non-compliance.

In 2016, *Annual Status Reports* (ASRs) have superseded *Updating and Screening Assessments*, *Detailed Assessments* and *Further Assessments.* A 'fast-track' AQMA declaration process has also recently been introduced which works on the assumption that most local authorities already have a good understanding of air quality in their areas as a result of historic LAQM work

Despite these subtle changes (further described below in the context of UK variation), the premise and purpose of the *Review and Assessment* component of LAQM has remained the same.

- <u>Action Planning</u>

  The LAQM *Action Planning* stage provides a mechanism that helps local authorities with identified air quality problems to construct, refine and implement an action plan within 18 months of an AQMA declaration.

At inception, *Air Quality Action Plans* (AQAP) were standalone plans that required stakeholders to outline appropriate, proportionate, cost-effective and time-bound actions to mitigate, and manage, local air pollution problems (Defra, 2007) (Figure 5).

The content of AQAPs were, and continue to be, acknowledged to differ since they are contextualised with regard to characteristics of each AQMA. However, they generally cover:

- details of the local sources of pollution;
- available options to help work towards achieving Air Quality Objectives;
- a cost-effectiveness assessment;
- consideration of which stakeholders can implement action and bring about change;
- quantitative and qualitative determination of the anticipated impact of actions;
- realistic timescales; and
- a strategy for evaluating progress.

Examples of the air pollution mitigation measures contained in action plans include smart choice options (such as sustainable travel guides, plans, car sharing and car clubs), cleaner transport fleets (such as buses, freight vehicles and taxis), development planning, urban traffic management, vehicle parking restrictions, low emissions zones and raising awareness and education.

Consultation with, and engagement of, a broad network of stakeholders is required to develop effective action plans. Many measures proposed in such plans either involve or depend on action taken by those working outside a local authority environmental health department (e.g. land use planners, transport planners, industry regulators and local businesses). Many other partners can also make a significant contribution to make to inform LAQM-related decisions and implement (and evaluate) action to reduce air pollution concentrations and associated public health risks. These include public health agencies and health authorities, sustainable development teams, local authority elected politicians and committees, and UK and devolved administrations). Additionally, members of the public have a key role to play e.g. engaging in and supporting local consultation processes, providing local knowledge and context, understanding problems, taking actions to help alleviate problems and changing behaviours to improve health and resilience to the effects of air pollution exposure. The success of Air Quality Action Plans is dependent upon all these stakeholders and influencing factors.

Unlike *Review and Assessment,* **in 2001** the *Action Planning* component of LAQM was not updated. However, **in 2016**, as a result of changes made through the most-recent iteration of LAQM policy guidance, AQAPs have been subsumed within *Annual Status Reports* (ASRs), which are considered ‘living’ documents subject to regular scrutiny and review. As such, they may be amended to reflect changes in local circumstances and profile e.g. tightening planned objectives, redefining an AQMA boundary or, if sufficient air quality improvements have been achieved, revoking an AQMA altogether. The *Progress Report* originally required to monitor and evaluate action implementation and impact once an AQAP was in place, has also now been incorporated into the ASR.

- <u>LAQM process evolution and variation across the UK</u>
  While LAQM applies to the whole of the UK, implementation responsibilities are devolved by UK government to devolved administrations like the Welsh and Scottish governments. As a result of various LAQM-related consultations and reviews carried out in different parts of the country (between 2013 and 2018), changes have been made to the regime over time – mostly administrative in nature – across the UK. This had led to the emergence of variations in LAQM policy and practice, as specified by UK and devolved administrations. Briefly:

  - In **<u>Wales</u>**, in relation to the *Review and Assessment* component of LAQM, *Annual Progress Reports* have replaced the previously-required *Updating and Screening Assessments*, *Detailed Assessments* and *Further Assessments* (Figure 6).

    Additionally, a ‘fast-track’ AQMA declaration process has been introduced which works on the assumption that most local authorities already have a good understanding of air quality in their areas as a result of historic LAQM work. The requirement to report on some outdoor pollutants (lead, carbon monoxide, benzene and 1, 3 butadiene) has also been removed. Although still not an LAQM requirement, advice on voluntary monitoring and modelling of fine particulate matter ($PM_{2.5}$) concentrations has recently been added. In terms of the *Action Planning* component, this is now subsumed within the *Annual Status Reports* (ASRs) as described above.

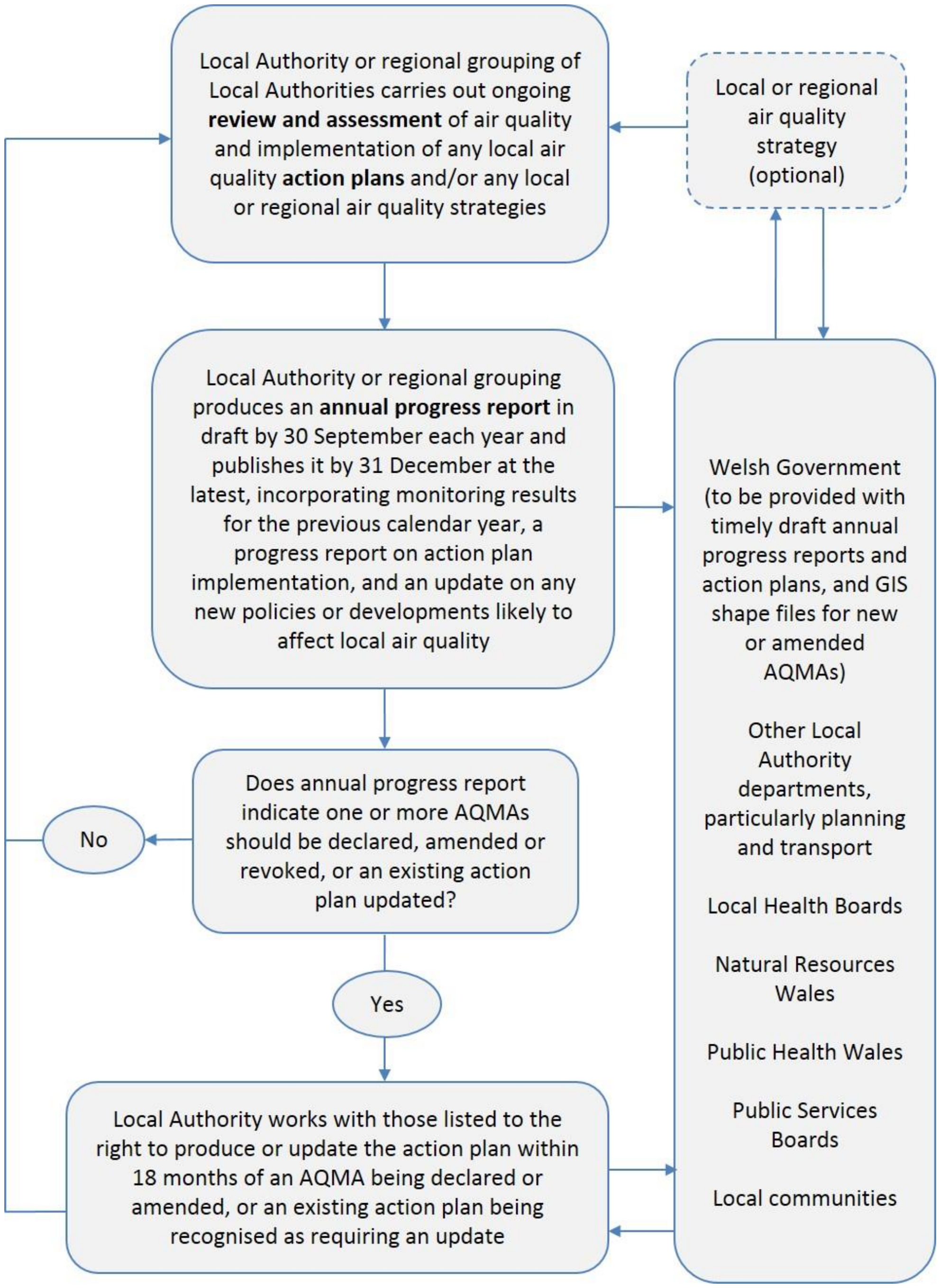

Figure 6. LAQM prescribed process in Wales, 2017 onwards (Welsh Government, 2017)

Other significant changes have occurred in addition to LAQM process streamlining. Welsh Government-issued LAQM policy guidance (Welsh Government, 2017) now calls for local authorities to adopt new ways of working as required by the sustainable development-driven Well-being of Future Generations (Wales) Act 2015. As these ways of working include prevention focused policy integration and collaboration with partners, it is now clearly recognised that LAQM must reach beyond local authority environmental health departments in order to convey the importance of joined-up working to achieve co-benefits. Further, the new policy direction encourages LAQM stakeholders to not wait for national AQOs to be breached before starting to do something about it; further, to acting to tackle localised air pollution problems, policy emphasises the need for a 'whole population' approach to keep exposure to air pollution as low as reasonably practicable for everyone in Wales.

- In England, process streamlining has been implemented as in Wales.

- In Northern Ireland, similar administrative process-streamlining changes to those in Wales and England have been made to the LAQM prescribed process.

- In Scotland, the 2015 *Clean Air for Scotland* strategy announced a 'refocused' LAQM system to address recommendations made following a Scotland-specific review undertaken in 2013. Anticipated changes include development of guidance that places more emphasis on planning and delivery, improved connection between local and national air quality management agendas, new LAQM performance measures, and better connection with wider policy (Scottish Government, 2015). Policy guidance released in 2016 also made it a requirement to measure and monitor $PM_{2.5}$ pollution as part of the LAQM regime (Scottish Government, 2016).

- Support resources

  Resources to support LAQM implementation have consistently been made available to local authorities and others to help them implement the regime. These have comprised:

  - *Monitoring networks and measured air pollution data*

    A comprehensive air quality monitoring network spanning the UK has been growing since 1995. Through the component monitoring networks that make up the UK Automatic Urban and Rural Network, ambient concentrations of a suite of different pollutants (nitrogen dioxide, ozone, particles, sulphur dioxide, carbon monoxide, volatile organic compounds, metals and acid deposition) are routinely measured. The aim of these networks is to provide a national picture of air pollution to aid compliance reporting in respect of relevant European Directives, support public education programmes and inform risk communications. The measured data obtained also serve to calibrate and validate modelling studies and data.

Perhaps of most importance is the use of data from the UK network by local authorities to support LAQM *Review and Assessment*. These data are often considered alongside data obtained from numerous other local authority-managed monitoring sites that may not be affiliated with the national air quality monitoring network.

- *Modelled air pollution data*

  Background modelling is routinely undertaken by UK Government (with support from devolved administrations). For NO_2 and PM pollutants, background air quality maps are produced (based on distinct spatially geo-coded 1km^2 grids) and used extensively by local authorities for *Review and Assessment* purposes. The modelling data used to construct these maps are derived from inventories of current and predicted emissions from a range of different sources and sectors, as well as meteorological, topographical and physical environmental parameters, atmospheric chemistry, pollutant behaviour and monitoring data calibration. This information resource has a number of useful applications in the context of LAQM including spatial assessments of local air quality, assessments of the contribution and significance of local sources to air pollution problems and action planning to address problems.

  UK Government and devolved administrations also provide modelling advice and tools for use by local authorities when undertaking LAQM-related activities. Guidance is made available in relation to the use of various types of modelling approaches and techniques in different scenarios (e.g. dispersion modelling to inform source apportionment exercises).

  Data obtained through modelling assessments may help by providing information on local air pollution profiles in addition to that obtained through monitoring data. Also, such data, in the absence of monitoring data, may be used to screen potential air pollution problems and affected areas to inform subsequent monitoring site location deliberations.

- *Policy and Technical Guidance*

  Statutory policy guidance is available for local authorities across the UK to support the *Review and Assessment* and *Action Planning* aspects of LAQM (for example, see Welsh Government, 2017). As well as setting these processes in an appropriate legal context, the guidance offers suggested strategies that may fulfil LAQM requirements and demonstrates where links should be made with other important policy areas such as land use and transport planning, climate change and noise.

To support policy guidance, more-detailed technical guidance provides specific details in relation to air quality assessment and report writing for local authorities. This guidance is intended to ensure that these aspects of LAQM are comprehensive, accurate and robust. Guidance specifies that pollutants are considered separately with attention given to site assessment, data gathering and data analysis methodologies. Through this, the guidance seeks to increase uniform and consistent approaches to LAQM across the UK.

- *UK Government support*

  The UK-AIR (Air Information Resource) web pages provide in-depth information on air quality and air pollution in the UK (https://uk-air.defra.gov.uk/). A range of information is available, including the latest pollution levels, pollution forecast information, a data archive, and details of the various monitoring networks.

  UK Government has also established telephone 'helpdesks' that can provide expert advice to local authorities on different aspects of LAQM: *Review and Assessment,* monitoring, modelling and emissions and *Action Planning*. Examples of the support available include expert advice relating to site-specific local air quality issues as they arise, modelled background concentrations and other data, and 'frequently asked questions' on topical LAQM-related issues. Data and reference documents are provided via internet web pages.

  UK Government and devolved administrations also critique local authorities' LAQM reports – a process intended to be comprehensive, critical and constructive. Again, this ensures consistency in approach and is strengthened by the overlap between appraisers who also provide advice through the telephone helpdesks. The appraisal process also allows UK Government and devolved administrations to gain a better understanding of the links between local and national air quality pictures and where particular local problems may exist. In turn, this is intended to facilitate compliance reporting to the European Commission against air quality directives.

3. ASSESSING CONNECTIONS BETWEEN LAQM AND PUBLIC HEALTH POLICY AND PRACTICE

Chapter overview

Despite its intentions and underpinning principles, the public health aspects of, perspectives on, and engagement in, LAQM have been poorly considered to date. This third thesis Chapter fills this knowledge gap by presenting the findings of a literature review that assessed LAQM strengths and limitations from a public health perspective. The added value that could result from better public health integration, interaction and collaboration in LAQM is also explored.

Certain aspects of this literature review have been published in a peer-reviewed journal (see Appendix A).

3.1 Public health as a core principle and partner in LAQM

The need for local authorities to consult with public health professionals around LAQM efforts is recognised, but rarely realised (Defra, 2016). The role of public health in LAQM has not been clarified or specified - a situation that is consistent across the UK (e.g. Welsh Government, 2017; Defra, 2016). LAQM policy guidance suggests that consultation with public health professionals is desirable but fails to describe why, how or what the value added is of doing so (Welsh Government, 2017; Defra, 2016). This guidance states that local authorities should work closely with local Directors of Public Health and health and wellbeing partnerships because this will increase support for measures to improve air quality and deliver co-benefits. However, only a few examples of such partnership working opportunities are suggested, such as:

- ensuring needs assessments incorporate information on population air quality impacts;
- creating greater opportunities to work together to address key emerging issues (such as those covered by Public Health Outcomes Framework indicators); and
- sign off on Annual Status Reports and Air Quality Action Plans.

To understand the contribution that public health specialists can make to LAQM policy and practice, it is important to understand the general functions and responsibilities of public health bodies which are similar across the UK, and beyond.

Public health is 'the science and art of promoting and protecting health and well-being, preventing ill-health and prolonging life through the organised efforts of society' (Faculty of Public Health, 2010). *Practice* is scientific insofar as it requires rigorous, evidence-based approaches to protect and improve population health based on critical understandings of disease patterns, distributions and causes (including links with wider health determinants) and knowledge of what works to bring about change. The *art* of public health refers to harnessing social, political, economic and cultural societal assets to facilitate collaboration around common causes (Riordan, 2015).

Working across the domains of *health protection*, *health improvement* and *health service quality* (each informed and supported by *health intelligence*) public health professionals and bodies have core responsibilities that can support the design and delivery of LAQM. These include:

- Monitoring health status to identify community health problems;
- Diagnosing and investigating community health problems and hazards;
- Informing, educating and empowering people about health issues;
- Mobilising communities to identify and solve health problems;
- Developing and implementing policies/interventions to protect and improve health;
- Enforcing laws and regulations that protect health;
- Linking people with services and ensure the provision of needs-based health services;
- Ensuring a competent public health workforce;
- Evaluating the effectiveness, accessibility and quality of public health services/interventions;
- Conducting research to identify innovative solutions to health problems;
- Using evidence to advocate for change through strategic leadership (adapted from Donaldson and Scally, 2009; and Harrell and Baker, 1994).

While there is little variation in public health roles and responsibilities across the UK, the position and structure of the specialist public health bodies *does* differ. For example:

- In Wales, the specialist public health function remains part of the Wales National Health Service structure. Each of the seven health boards in Wales has a statutory duty to protect and improve the health and wellbeing of the population they serve. One agency – Public Health Wales – works at local, regional and national levels to support health boards (working through the Executive Director of Public Health in the main) in their endeavour to achieve this by delivering a broad range of services spanning all domains of public health practice. Public Health Wales also provides evidence-based, independent and impartial advice and support to, and works collaboratively with, many other partners including local authorities, regulatory agencies, third sector bodies, Welsh Government and the public. Similar arrangements to these in Wales are in place in Scotland and Northern Ireland.
- In England, the public health function and the majority of the public health workforce transferred from the National Health Service (NHS) to Public Health England (national) and local authorities (local) in April 2013. This move was required by the Health and Social Care Act 2012. At the local and regional levels, single and upper-tier local authorities now have statutory duties to protect and improve health and wellbeing and to tackle determinants of health and health inequalities. A broad range of local public health services is delivered by local authorities, funded through ring-fenced budgets. Each local authority has a Director of Public Health regarded as a chief officer of the organisation and supported by a public health team. Local authorities directly employ medically-qualified staff in their public health teams, as well as non-clinical public health specialists.

The transfer of public health from National Health Service to local government in England has received mixed reviews since happening in 2013. Having public health specialists embedded in local authority structures certainly has the potential to improve the integration of health and wellbeing responsibilities with local government functions. It has been recognised that preventing illness and empowering people to remain well is a collaborative endeavour; no one organisation or group of professionals can achieve this in isolation because broader actions from across all sections of the community are required (Local Government Association, 2014). The premise of bringing together public health and other local authority functions is that it can align services and create more efficient and effective ways of working and service delivery.

While it is probably too early to determine whether the function transfer has improved public health (as there are often time lags between intervention implementation and health outcome impact), some successes have been reported beyond the more obvious benefits of budget-sharing and co-location. For example, there is evidence that some local authorities have adopted a less political and subjective approach to decision-making; now decisions are thought to be informed more by independent and impartial advice which draws on the analytical rigour and evidence-based expert practice of public health professionals (Phillips and Green, 2015, Local Government Association, 2014). There is also evidence pointing to some functions, such as planning, enjoying greater levels of integration and driving forward policy that embeds public health at its core (Carmichael *et al.*, 2013).

These output successes, and process ones such as a remarkably smooth transition period, are countered by evidence of more negative findings, however (Local Government Association, 2014). For example, the relationship has struggled to mature sufficiently for the public health challenge to positively impact all local government policy and practice mainly because of residual culture and language barriers (Carmichael *et al*., 2013). According to the King's Fund (2015), good intentions around prevention-focused action have not yet been translated into outcomes by local authorities, and the previously strong links wider healthcare services (upon which patient/client initiatives such as Making Every Contact Count depend) have been eroded. While the commitment to reform public health has been fulfilled, it appears local governments still have a long way to go to give public health the priority status promised (King's Fund, 2015).

In light of this verdict, it appears there may remain considerable benefit in the public health being embedded within NHS structures, as is still the case in Wales. In the UK, the NHS recognises it has operated a 'factory-model' of care with a poor track-record of community and stakeholder engagement and under-developed advocacy, action and policy to address broader influences of health and wellbeing (National Health Service, 2014). The NHS has been challenged to change, to forge closer, sustainable relationships across agencies and communities, develop new ways of working and place more emphasis on disease prevention by tackling major public health risks. As senior health officials, including Chief Medical Officers, have recognised, air pollution problems must be regarded as one such risk (Welsh Government, 2018, 2015 and 2014).

Regardless of the position and structure of the public health function, the type of advice and support, but not necessarily the level (because of capacity and resource variations) that can be offered to inform LAQM implementation, is consistent throughout the UK.

Public health bodies and specialists can make a valuable contribution to local-level policy and practice, and this is evident in LAQM. For example, specialist public health skills and resources can inform health risk assessments and improve understanding around air pollution problems in a broader context (linked to other local public health priorities). Additionally, public health intervention can form part of the solution to air pollution problems e.g. communicating risk and changing behaviours amongst individuals and communities, promoting active travel, influencing planning for sustainable healthy communities, and incident response. As such, it can be hypothesised that greater integration and interaction of public health bodies and specialists in LAQM can strengthen collaboration and align efforts to change behaviours to reduce air pollution, reduce exposure, and improve local individual and population health so more people are less susceptible to the effects of exposure.

However, in contrast to other professions and sectors such as environmental health, land-use planning and transport, the role of public health in LAQM has been poorly considered and defined. This represents a significant missed opportunity, especially given the interactions of air pollution with wider public health determinants where the ‘triple jeopardy’ principle suggests that the largest public health benefits can result not from simply reducing air pollution and associated exposure but by achieving this in areas where health needs are greatest (Samet and White 2004; Jerrett *et al.,* 2001). Public health specialists can not only help scope and define problems, but also be part of the solution to better-understood problems by aligning LAQM actions with wider public health policy and practice.

The potential value added from better public health integration and collaboration in LAQM has been a neglected research topic to date. While available evidence on this issue is therefore limited, much can be learned from investigations undertaken in other overlapping subject areas that share common characteristics with the research problem of focus in this thesis. An example of one such area more comprehensively explored and acted upon is the previously recognised disconnect between public health and planning policy and practice. Similarities can be drawn between this thesis and research on planning and public health connectedness because the effective delivery of both statutory regimes is dependent upon broad system and cross-sector/discipline awareness, integration, collaboration and action. As such, it is helpful to summarise here the available evidence on understanding and developments in this related research area.

The influence of the natural and built environment on health has long been recognised (e.g. Barton, 2009, World Health Organization, 2010). As such, a good understanding of the links between health and the built and natural environment is considered vital (Carmichael *et al*., 2013) to inform action that tackles public health priorities and reduces risks e.g. health inequalities and non-communicable diseases like obesity (Rao *et al.*, 2011; Marmot, 2010, Barton, 2009). Barton *et al.* (2010), for instance, highlights how good housing and public space access can impact positively on individual and population behaviours and community cohesion, while Croucher *et al.*, (2007) and Mitchell and Popham (2008) and Bond *et* al. (2013) describe how quality green space availability and access can encourage social interaction and physical activity, and reduce health inequalities, respectively. Some more negative impacts have also been observed; for example, land-use planning and transport policies have introduced unintended consequences by favouring and prioritising the car, which have contributed to increased levels of non-communicable diseases from physical inactivity, air pollution and injuries (Sallis *et al*., 2016).

Despite these strong influential links, the evidence of there being a disconnect between planning and public health policy and practice is well established (e.g. Sallis *et al*., 2016; Bond *et al.*, 2013; Carmichael *et al*., 2012 and 2013; Wooten, 2010; Brownson *et al*., 2006). Broadly speaking, the evidence puts the emergence of this disconnect down to organisational and professional silos, ignorance, resource limitations, and a reactive planning regime (Carmichael *et al*., 2013). All these issues are relevant in the context of LAQM.

The research evidence in this area agrees that the planning process must accept responsibility for the health implications of its decisions, and that public health stakeholders have a role to play to engage and support planning processes to ensure sustainable, prevention-focused action is taken (Bond *et al.*, 2013). In an attempt to achieve this and address the disconnect, many countries have tried to embed public health as a core consideration in planning policy and practice. For example, in England UK and the United States, planning guidance and policies have emerged that now highlight how health and wellbeing should be a key facet in the creation of fair and sustainable communities (e.g. CLG, 2012; Wooten, 2010).
Despite this good progress, however, some doubts remain about the extent to which such guidance is translated into practice (Carmichael *et al*., 2013). Several barriers have been highlighted that may have hindered progress in integrating and engaging public health in planning policy development and decision-making. These include:

- Poor understanding of respective professional roles and responsibilities (Carmichael *et al.*, 2012; Tewdwr-Jones, 2011); the planning profession is said to be ill-equipped to consider health and wellbeing in their actions (Bond *et al*., 2013);
- Poor leadership, commitment, knowledge and communications amongst politicians and practitioners (Carmichael *et al*., 2013; Bond *et al*., 2013; Carmichael *et al.*, 2012);
- Resource barriers such as lack of funding and skills and knowledge gaps (Carmichael *et al.*, 2012);
- Ineffective established partnerships (Carmichael *et al*., 2012);
- Planning proposals, and planners themselves, often adopting a weak, narrow and sometime tardy view of health, failing to acknowledge the social environment and wider determinants of health in application appraisals (Carmichael *et al*., 2013 and 2012; NICE, 2011; Bekker *et al*., 2005);
- Lack of engagement between health and planning professionals, compounded by different cultures, terminologies/languages, priorities and structures (NICE, 2011).

To counter these barriers, enabling actions have been identified and taken, including:

- Recognising health improvement as a necessary and material planning policy objective (Bond *et al*. 2013);
- Up-stream engagement of public health in local planning strategic policy development (CLG, 2012);
- More effective and efficient use of Health Impact Assessment tools (NICE, 2011);
- Using health data and analytical capabilities to identify areas where greatest health needs and potential gain exist, in order to inform planning decision-making (Wooten, 2010);
- Authoritative communications with the public, supported by public health (Wooten, 2010);
- Education of planners and public health professionals alike (Bond *et al.*, 2013);
- Refocusing how public health evidence is conceptualised, to incorporate multiple and political understandings of health and wellbeing (Phillips and Green, 2015);
- Developing shared visions across organisations and securing commitment to achieve shared objectives (Carmichael *et al*., 2012);
- Joint preparation of best practice guidelines, proactive joint strategies and plans, and joint appraisal exercises (Carmichael *et al*., 2013);

- Health-driven planning projects such as health action zones and WHO Healthy Cities (Carmichael *et al*., 2013), with greater role-recognition, investment and commitment from health (Bond *et al.*, 2013);
- Joint appointments and placing public health expertise in planning departments (aided by the move of public health from the NHS to local authorities in England), and *vice versa* (NICE, 2011).

Taking forward these enabling actions has facilitated greater integration of public health in planning policy and practice. This is most evident in England, UK, where the move of public health from National Health Service to local government has helped break down barriers (Carmichael *et al.,* 2013; Bond *et al*., 2013). Not only has this brought both parties physically closer together, it has encouraged the 'upstream' consideration of health in planning issues that takes account of the broader context of wider social determinants. It has also allowed public health to influence processes through the provision of more neutral and independent evidence to inform impartial and objective decision-making (Phillips and Green, 2015).

While the disconnect between planning and health is now better understood, and some corrective action has been taken (with varying success) to improve the situation, the problem is yet to be fully resolved. Despite the evolution of guidance that places public health at the core of planning processes, there appears to remain a lack of precision on *how* to interpret healthy planning and *how* to achieve and sustain changes on the ground (Carmichael *et al.*, 2013). To achieve developments in LAQM and public health policy and practice, as has been/is the case through planning and health research, this thesis presents research that not only investigates and understand the air quality management-health disconnect, but goes further to explain *how* LAQM can be enhanced to maximise public health awareness, integration, collaboration and impact.

3.2 Assessing LAQM and public health policy and practice connection

3.2.1 Approach to identifying relevant literature and structuring the review

Identifying relevant literature

Recognising the valuable contribution that public health bodies and specialists can make to LAQM implementation, the available literature was reviewed with the aim of **exploring the connections**

between the regime and public health policy and practice previously captured, reflected and reported on. Through the literature review, public health-relevant strengths and weaknesses of the regime - that influence the extent of connectedness between LAQM and public health work – were considered. This not only helped identify the problems with the current regime that should be addressed, but also went some way towards finding solutions, where improving public health integration and collaboration in LAQM can add value to existing arrangements.

To identify all relevant literature for the review, peer-reviewed papers were identified by searching electronic journal databases and *Google Scholar*, for the period 1993 to 2018. The following journal databases were searched: CAB Abstracts 1973, Environmental Analyst, Environmental Management, GEOBASE, Information Bridge, Science Direct, Taylor and Francis, Biomed Central, BMJ, Cambridge Journals Online, DOAJ, EMBASE, Free Medical journals, JSTOR, Medline, PubMed, SAGE Journals Online, Springer Link, Wiley Online. The search terms were:

- “local air quality management”, used as an independent search term;
- “local air quality management”, used in combination with the terms: “air pollution”, “health”, “public health”, “awareness”, “integration”, “collaboration”, “policy”, “review”, “assessment”, “evaluation” and “impact”.

A parallel *Google* search was also undertaken to identify grey literature such as reports, articles and other non-academic documents.

Literature was eligible for inclusion in the review if it reported on:

- any aspect of the UK LAQM regime, regardless any other search terms being met;
- public health-related awareness, integration and collaboration in a UK LAQM context;
- public health-related awareness, integration and collaboration in a more general UK local air quality management context;
- public health-related awareness, integration and collaboration in a non-UK local air quality management context.

Literature was excluded from the review if it reported on non-UK local air quality management aspects that were not of public health relevance.

Of seventy-seven peer-reviewed papers identified through the search, a total of fifty-eight met the criteria for inclusion in the review (Figure 7). Forty-eight of these were LAQM-specific and a further ten were eligible for review through reference to public health-relevant matters in local air quality management beyond the UK. Another seven grey-literature reports were identified that met eligibility criteria.

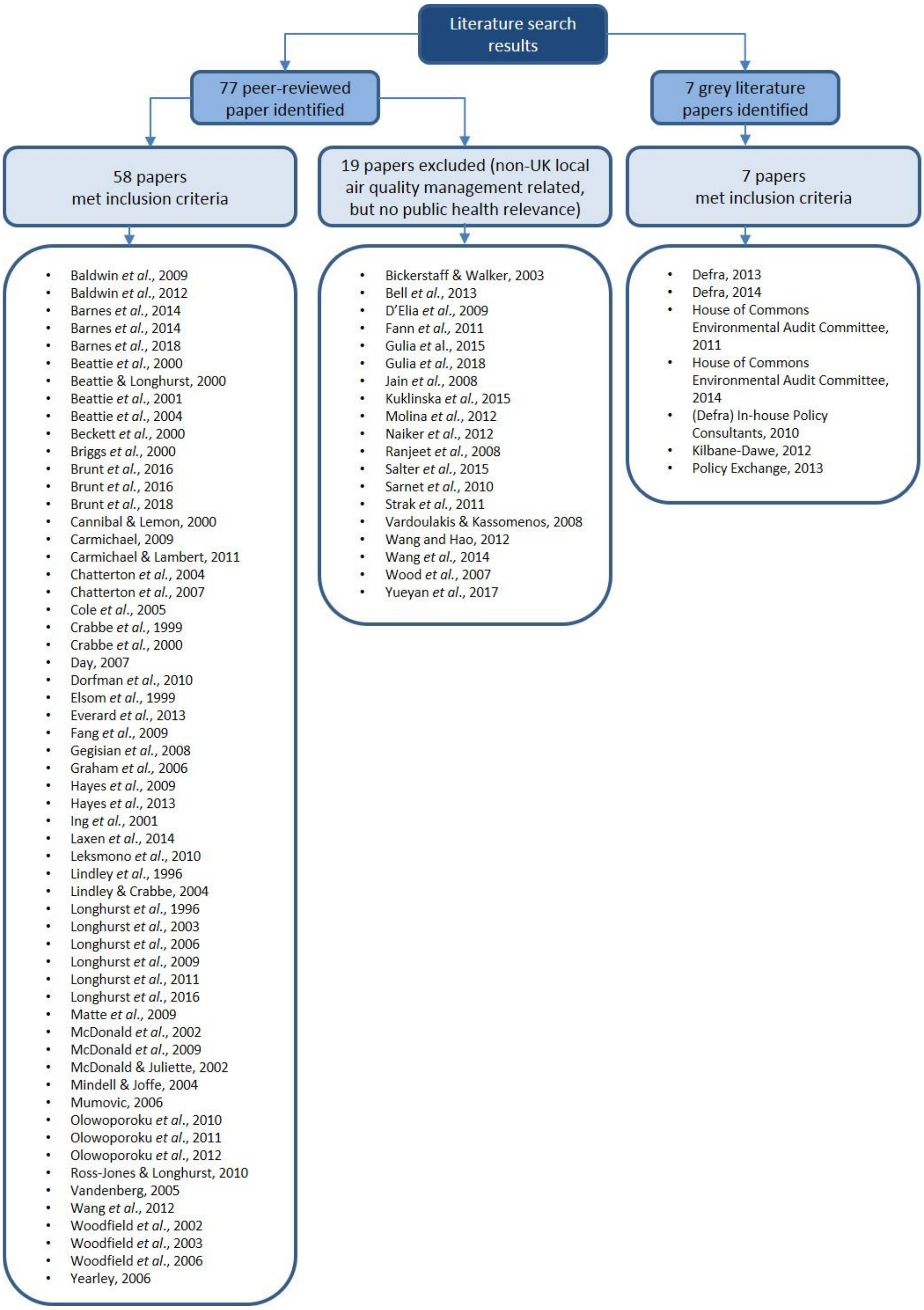

Figure 7. Literature search results

Structuring the literature review

To lend structure and rigour to the literature review, and ensure all aspects of the LAQM were considered, a 'whole-system' approach was adopted by applying an adaptation of the 'tried and tested' Donabedian public health evaluation framework (Donabedian, 2005; Donabedian, 1980). The Donabedian framework not only helped ensure a comprehensive consideration of LAQM aspects (from a public health perspective, it helped organise literature review findings. Tailored to meet the needs of the literature review, this framework required simultaneous assessments of 'structure', 'process' and 'outcome' measures and an exploration of relationships between them, where:

- 'structure' measures referred to the context in which the LAQM regime is delivered, the characteristics of its organisation, the physical and human resources required to deliver it, and training, finance, equipment and intelligence aspects;
- 'process' measures covered the interaction between stakeholders to deliver the LAQM regime, technical processes, actions taken and the manner in which they are taken;
- 'outcome' measures described the effects of the LAQM regime: air quality and population health impacts, organisational or population behaviour changes as a result.

The Donabedian framework has traditionally been used to assess healthcare service quality issues, for example: in primary care (Ng and Ng, 2013), midwifery (de Bruin-Kooistra *et al.*, 2012) and eye-care (Sheen *et al*., 2009). Its flexibility has also facilitated evaluations of non-clinical public health programmes such as oral-health (Ahn *et al.*, 2011), smoking cessation (Farmer *et al*., 2011), exercise-referral (Brunt, 2006), and nutrition (Glanz *et al*., 2005).

3.2.2 An assessment of LAQM 'structures'

- <u>Approach and design</u>

  The LAQM regime's main strength originates from the UK's model of air quality management making a distinction between 'national' and 'local' action. It acknowledges that local air pollution problems can impact local public health, and are best managed locally (Department for Environment, Food and Rural Affairs, 2009). While making this distinction between local and national approaches is helpful in respects, as it encourages local collaboration and action, it may also be perceived to be a regime weakness. For example, devolving air pollution management responsibilities to local agencies might have downplayed its importance as a public health priority (Carmichael and Lambert, 2011;

Longhurst *et al*., 2009). Further, the artificial divide placed between national and local air quality management processes has led to confused UK/European reporting (due mainly to the mismatch between local and national designated areas for action) which fails to take account of local problems and interventions (Hayes *et al*., 2009).

In terms of regime design, LAQM has strong underpinning public health principles. At its core is the concept of risk assessment. The *Review and Assessment* component requires that local air pollution problems are considered in the context of pragmatic AQOs based on clear health-based standards (Defra, 2009). The *Action Planning* component calls for coordinated, evidence-based intervention (with cost-benefit assessments of both environmental and health considerations) accompanied by progress assessment and evaluation reporting. The logical and structured prescribed LAQM framework, and its statutory status, supports an approach to air quality review and assessment that is uniform and consistent (Chatterton *et al*., 2007). Despite these positives, however, some have questioned whether LAQM's strong public health roots and underpinning principles actually inform and influence regime implementation in practice (Chatterton *et al*., 2007). To compound problems, the LAQM process design is said to be too centrally-driven, process-heavy and cumbersome, with excessive reporting requirements and bureaucracy (In-house Policy Consultants, 2010).

- <u>Scope of LAQM prescribed risk assessment processes</u>

  It has been suggested that LAQM's health effects-based approach is narrow in scope because the prescribed risk assessment process (and consequently, air pollution mitigation action) considers air pollution as an isolated issue (Barnes *et al.*, 2014; Everard *et al.*, 2013; Beattie *et al.*, 2001). From a public health perspective, this is unhelpful since the it is well-documented that air pollution can have both direct and indirect links with health (as discussed in Chapter 2 and Chapter 7). Despite the expectations outlined in Government LAQM policy guidance for a broader outlook on air pollution problems (e.g. Welsh Government, 2017; Defra, 2016), there is no requirement for LAQM stakeholders to have routine regard to the 'bigger picture'. Other broader, relevant datasets and information that can help explain air quality problems and allow stakeholders to understand them better, or place them in a broader public health context, is a rare occurrence (Brunt *et al.*, 2016). As it stands, the LAQM *Review and Assessment* component does not require any quantification of local air pollution-related disease burdens or assessments of air pollution relationships and interactions with other wider health determinants, to inform decisions and actions (Welsh Government, 2017; Defra, 2016). Such evidence is needed in LAQM to inform a better understanding of problems, facilitate action prioritisation and targeting according to health needs, and identify opportunities to link air pollution management and wider public health action (Maantay, 2002). There is limited consideration of this important issue in the literature.

Finally, even where there may be a desire to undertake broader-scope risk assessments (despite this not being formally required in LAQM), the necessary infrastructure, integration and engagement necessary to support such a task is likely lacking (Barnes *et al.*, 2014; Defra, 2013; In-house Policy Consultants, 2010; Olowoporoku *et al*., 2010; Baldwin *et al*., 2009). This makes it difficult for stakeholders to share local health, air pollution and other data, and work together to assess risks through expert data linkage, analysis and interpretation.

- <u>Regime adaptability</u>

  The LAQM regime has been described previously as a dynamic process reflecting developments in legislative, technology and scientific advances (Chatterton *et al.*, 2007). One UK Government review of LAQM commented that, over the years, the regime has changed to accommodate AQO amendments (set out in legislation that provide the statutory basis for the AQOs under the LAQM system) (Defra, 2013).

  However, relatively minor adaptations may still be considered insufficient. For example, it could be argued that the UK health-based AQOs – upon which LAQM risk assessment and action hinges – are insufficiently protective of health. Evidence confirms that exposure to $PM_{2.5}$ (Beelen *et al*., 2014; Cesaroni *et al*., 2014) and nitrogen dioxide (World Health Organization, 2013) at concentrations below even the more-stringent European limit values can result in measurable adverse health impacts. Further, for $PM_{2.5}$, AQOs in the UK commit to address exposure problems, but due to the pollutant's characteristics, the LAQM approach to its management is through national and regional UK-wide 'exposure reduction' principles (similar to the prevention paradox, Rose, 1981). It is anticipated that reductions in overall mean background pollution levels on a wider spatial scale increases the potential for greater public health benefits (Longhurst *et al*., 2009). From the LAQM perspective, despite there being an appetite to assess and formally report on $PM_{2.5}$ (Hayes *et al*., 2009), local authorities are still only encouraged to monitor and report on this pollutant; it is not mandated. This approach is considered acceptable since $PM_{2.5}$ is largely a trans-boundary pollutant (and so beyond the scope of LAQM), and also because PM_{10} mitigation will help reduce local $PM_{2.5}$ levels in any case. With the evidence of ill-health effects associated with air pollution exposure, some believe there remains a need to tighten European and UK air quality health standards further to ensure that the health-based standards used in LAQM reflect Government's view on acceptable health risk (Longhurst *et al*., 2006). Ideally, for LAQM, any changes should be accompanied by a statutory obligation to at least comply with AQOs rather than the existing requirement to merely *work towards* achieving them (Chatterton *et al.*, 2007).

On a less technical note, the LAQM process has demonstrated it can adapt to stakeholder feedback; processes have been streamlined to reduce administrative/reporting burdens (Defra, 2013; Hayes, 2009).

- Public health role and expertise/resource development

  Public health, as an acknowledged key LAQM stakeholder, has much to contribute to the regime (see section 3.1 above and 3.4 below for more detail). This his has been recognised on several separate occasions in the past (Laxen *et al*., 2014; In-house Policy Consultants, 2010; Welsh Government, 2009; Defra, 2007; Longhurst *et al*., 2006; Beattie *et al*., 2001; Lindley *et al.*, 1996). However, no attempt has ever been made to clarify or specify the role of public health in, or their expected contribution to, the regime. The literature does not elaborate on why this is the case.

  To compound problems of disengagement and disconnection, public health bodies and specialists have generally failed to develop expertise, resources and capacity in air quality assessment and management. This is in contrast to local authority personnel – who have taken advantage of LAQM support resource development and provision by growing human resource, structural and asset-based capabilities and expertise to assess air quality locally using sophisticated monitoring and modelling techniques (Olowoporoku *et al.*, 2010; Baldwin *et al.*, 2009; Woodfield *et al*., 2003).

3.2.3 An assessment of LAQM 'processes'

- Co-ordination, consultation and collaboration

The diversity of air pollution problems and solutions dictates that collaboration in air quality management is critical (Defra, 2016; Defra, 2013; Leksmono *et al.*, 2010; Woodfield *et al.*, 2006; Beattie *et* al., 2001; Longhurst *et al.*, 1996). In recognition of this, LAQM (usually led and co-ordinated by local authority environmental health departments) encourages stakeholder cooperation, collaboration and policy/action co-ordination.

To support stakeholder consultation, engagement and collaboration, local authority roles (e.g. environmental health, planning, transport, economic development and climate change) have been well defined and described previously, along with those of external bodies like environmental regulators and agencies responsible for road networks (Defra, 2016). Despite this awareness raising around roles and responsibilities, only limited multi-agency/discipline collaboration has been reported in the literature. The best examples of this are in multiagency Air Quality Action Plan development (Olowoporoku *et al.*, 2012; Hayes *et al*., 2009; Woodfield *et al.*, 2006; Beattie *et al*., 2000). However, even then, examples relate in the main to partnership working *within* and *between* local authorities, rather than with external agencies such as health and environmental regulation (In-house Policy Consultants, 2010). Only one source of evidence in this review referred to public health stakeholder involvement in Air Quality Action Plan development groups, and then reported only limited engagement (Hayes *et* al., 2009). Generally, there has been minimal dialogue or LAQM-related collaboration between local authorities and public health (Leksmono *et al*., 2010).

Historic reviews of LAQM suggest that the limited multi-agency/discipline collaboration identified in LAQM to date is due to there being a lack of support for air quality management from policy agendas other than environmental health (Defra, 2013; In-house Policy Consultants, 2010). However, from a health perspective, it remains unclear whether this is actually the case, or whether other reasons underpin observed disengagement and disconnection. There is no evidence to suggest that this issue has ever been investigated, but some evidence suggests it has been ignored. For example, one government review of relationships commented that the whole purpose of LAQM is to protect public health, and air pollution needs to be considered in the context of what is known about its health impacts and how these compare with other public health risks, but then failed to consult public health (In-house Policy Consultants, 2010). This is also true of other formal LAQM consultations (e.g. Welsh Government, 2009).

Given there is a common belief that public health bodies and specialists are disengaged from the regime (Longhurst *et al*., 2006), it is vital that a better understanding of these reasons is obtained in order to improve engagement and collaboration.

- Communication (general and tailored)

  Communications to explain risks and improve public understanding around local air quality issues are considered poor in the main (Dorfman *et al.*, 2010; Leksmono *et al.*, 2010; McDonald *et al*., 2002). A survey undertaken to assess public perception of air pollution found that, while the public are generally aware that health problems are associated with exposure, most could not understand and relate their own experiences to much of the science behind air quality assessment and policy (McDonald *et al*., 2002). To compound problems, even where it is believed that people have a better understanding of air pollution problems and risks, those living in disadvantaged areas apparently feel less empowered and able to do anything about it (Day, 2007).

  An observation based on available literature is that general air pollution and health communications (i.e. those not tailored to local population characteristics) tend to imply that any linked health risks and impacts are evenly distributed across areas. They often disguise the fact that substantial impacts may be suffered by a vulnerable minority (In-house Policy Consultants, 2010) e.g. highly-deprived people living alongside major roads, suffering greater adverse health impacts through increased susceptibility. In light of this, it is accepted that air pollution and health messages should be carefully-crafted, contextualised and conveyed authoritatively (In-house Policy Consultants, 2010; Day, 2007; McDonald *et al*., 2002). A concern has been raised that some local authorities are ill-equipped to communicate such complex public health messages on their own (Barnes *et al.,* 2014). With public health specialists disengaged from LAQM, it is alleged that local authorities struggle to communicate health messages with expertise and authority (Beattie *et al*., 2001).

  This is an important aspect of LAQM since greater public understanding of local air pollution risks and solutions can inform individual and community behaviour change that can reduce air pollution as well as benefit health (House of Commons Environmental Audit Committee, 2009). A lack of public understanding about local air pollution problems is not only detrimental in this regard, but it can also reduce public engagement, increase opposition to new policies and, in turn, hinder progress. As observed in the rejection of Manchester and Edinburgh congestion-charging schemes (House of Commons Environmental Audit Committee, 2009), policy development can be stunted when politicians are reluctant to introduce publically-contentious policies (Bannister, 2008).

- Public engagement

  It appears that the public health community is not unique in being disengaged and disconnected from LAQM; the general public/local communities are too (Beattie *et al*., 2001). This disengagement is problematic since community-based participation can play an important role in documenting and understanding health concerns and inequities, and fostering corrective action (Day, 2007). It is believed that if the public is aware of local problems, and understand causes and solutions, then there is an increased likelihood they can assist by co-operating and taking ownership by providing valuable local knowledge and context, and becoming more informed, empowered and willing to take and promote behaviour-modifying action (Cannibal and Lemon, 2000). Through such behaviour changes, local air quality and health co-benefits can result, but these ‘win-win’ situations will only be realised if public consultation and communication mechanisms are effective, implemented early and highlight some actual or perceived public benefit (e.g. health gain) (Leksmono *et al*., 2010). The strong links that public health bodies and specialists often have with communities (through well-established networks) could help facilitate and foster stronger public engagement (Barnes *et al*., 2014).

3.2.4 An assessment of LAQM ‘outcomes’

- Risk review and Assessment

  The literature is agreed that the sound, repeatable and efficient characteristics of LAQM’s *Review and Assessment* component have strengthened air quality assessment science and helped generate a comprehensive picture of local-level air pollution across the UK (Longhurst *et al*., 2009; Chatterton *et al*., 2007; Longhurst *et al*., 2006; Beattie *et al*., 2001). This said, some variations in the practical implementation of LAQM risk assessment processes have been noted. For example, instances were reported where air pollution monitoring and modelling methods were inconsistently applied and public air pollution exposure was insufficiently considered (Woodfield *et al*., 2003), and where there has been poor quantification of exposure amongst affected population groups (Hayes *et al.*, 2009).

From a public health perspective, not being able to identify communities and populations affected by unacceptably high concentrations of air pollution with confidence, is most unhelpful (Woodfield *et al.*, 2003; *Beattie et al.*, 2001). Further, it is these risk assessment outputs that inform AQMA decision-making, declarations and boundary setting (Woodfield *et al*., 2006), so it essential that they are robust and accurate.

Another concern highlighted in the literature was that it is rare for AQMA boundary-setting decisions to take into account baseline population health profiles (Barnes *et al*., 2014; Beattie *et al*., 2001). This is important since acknowledging population health profiles can inform both risk assessment, intervention implementation and evaluation. It is also unhelpful that there is no consistency in AQMA boundary-setting across the UK; AQMAs can vary in size, from single dwellings or road junctions to entire towns or even boroughs (Longhurst *et al*., 2009; Chatterton *et al*., 2004; Woodfield *et al*., 2002).

- <u>Action Planning</u>

  Acting to address identified local air pollution problems is a critical part of the LAQM regime (Defra, 2016, Defra, 2013), but it is suggested that the *Action Planning* component of LAQM has been relatively ineffective in the main (Barnes *et al.*, 2014; Longhurst *et al*., 2009). Air pollution reduction interventions implemented have been generally weak, with few cases of true air quality improvement having been reported (Longhurst *et* al., 2011; Hayes *et al*., 2009; Chatterton *et al.,* 2007). Even fewer instances have been recorded of AQMAs being revoked on the basis of significant air quality improvement (Chatterton *et al*., 2007). Further, it is important to note that LAQM's legislation-prescribed processes require stakeholders to act only in areas where actual or likely breaches of Air Quality Objectives are identified only (Barnes *et al*., 2014). As such, interventions are only targeted in the worst air pollution affected areas. Opportunities are being missed to act to reduce risks beyond small geography air pollution 'areas of technical exceedance'; targeted risk reduction interventions are not encouraged in areas compliant with AQOs but with poor health (high susceptibility) status, neither is universal action encouraged to reduce risks for everyone (Brunt *et al.*, 2016b).

Cost-effective air pollution mitigation can result from an integrated approach that delivers across multiple policy agendas. For example, measures to promote active travel (walking and cycling over vehicle use) contribute towards meeting public health, air quality and climate change goals. One review (in London, UK) identified that the benefit-to-cost return on such interventions was substantial: £620 in benefits for every £100 spent (Kilbane-Dawe, 2012). However, evidence of intervention effectiveness is limited (Everard *et al*., 2013), probably due to challenges in establishing the required reliable systems for tracking both air quality and health outcomes data (Matte *et al*., 2009).

Not being able to predict or measure, with confidence, both air quality improvement and health risk reduction is unhelpful. In order to develop and implement evidence-based policy and practice, it is important to know what actions, and in what combination(s), will have what results (Policy Exchange, 2013).

- <u>Policy and practice connection and integration</u>
  A general point is made in the literature about LAQM not being sufficiently supported by broader policy of relevance to air quality management (House of Commons Environmental Audit Committee, 2014; Defra, 2013; In-house Policy Consultants, 2010). However, some more-detailed examinations of this potential shortfall undertaken in certain subject-specific areas such as climate change (Baldwin *et al*., 2009) and transport planning (Olowoporoku *et al*., 2012; Beattie *et al*., 2001) have reported more positive findings. These assessments (exploring various specific situations in England, particularly in the context of transport planning) have confirmed that good policy integration – where it has occurred – has facilitated better stakeholder co-operation and action (Olowoporoku *et al*., 2012; Olowoporoku *et al*., 2011; Olowoporoku *et al*., 2010; Baldwin *et al*., 2009). The literature does not capture or report on any equivalent LAQM/public health-related policy integration assessments.

  As with the policy connection work undertaken to date across public health and planning (described in section 3.1), the success of the LAQM regime is dependent upon establishing strong, cross-cutting, reciprocal and sustainable links between air pollution management and other policy areas. Integrating policy in this way can increase the potential for multiple and diverse 'wins' across policy areas (Everard *et al*., 2013; Stern, 2006). However, such policy integration and subsequent collaborative is often hindered because these 'wins' rarely deliver positive impacts in the short-term; the benefits of air pollution reduction, although real, may not be as immediately obvious as the costs (Farber, 2013). Convincing policy-makers to invest in air quality management is challenging, but it appears that local Air Quality Strategies (currently an optional aspect of LAQM) have helped local authorities to start to raise the profile of air pollution and connect policy (Barnes *et al.*, 2013).

3.3 Evidence interpretation, elaboration and discussion

The available literature provides evidence that the public health aspects of, perspectives on, and extent of integration and interaction in, LAQM have largely been ignored to date. By exploring the connections between the regime and public health policy and practice previously captured, reflected and reported on, this review has helped develop a better understanding of the inter-relationships of these factors. However, there remain uncertainties around several issues heighted in this review; these warrant further exploration as understanding them and addressing may be key to breaking down barriers and improving public health integration and collaboration in LAQM. Some of the more significant findings from the literature review are elaborated on here:

- **Defining the public health role in LAQM**
  Little attempt has been made to clarify or specify the role of public health in, of their expected contribution to, the regime (Brunt *et al.*, 2016). The literature does not elaborate on why this is the case, but this failure to do so may have contributed to the disconnect observed today between LAQM and public health policy and practice and hindered the evolution of a public health-driven and supported LAQM framework.

  It is possible that this, at least in part, may be due to the LAQM guidance and resources made available being local authority-focused, too technical for non-air quality specialists and tailored to the needs of professionals in local authorities. This lack of support resources for non-local authority staff may have discouraged public health engagement in LAQM, with many public health professionals (especially those working outside of the 'health protection' discipline lacking the knowledge, skill and confidence to support LAQM. In turn, this may have resulted in public health professionals generally failing to regard air pollution as a local public health priority and recognise and realise the contribution the could make to air pollution assessment and health risk reduction.

It is plausible that a poorly defined public health role in LAQM (and a lack of support resources to encourage engagement) have hindered public health integration and collaboration in the regime. There are likely many other contributing factors too. However, because the literature – especially reviews of LAQM operation and implementation – reports only on LAQM interaction assessments across and between local authorities, the views of public health bodies and specialists have not been sought and the reasons for disconnection remain unconfirmed.

- **Assessing risks and impacts**
  The relevance and usefulness of considering 'big picture' public health data and evidence in LAQM has largely gone unnoticed to date. This may mean that the recommendation for LAQM stakeholders to work to the principle *that the largest public health benefits will result not from simply reducing air pollution, but by doing so in areas where health needs are greatest* (Jerrett *et al*., 2001) has not been realised in practice. Not only has this resulted in missed opportunities to connect policy and practice beyond LAQM, but the current arrangements may have been detrimental. This is because it is believed that acting to manage local air pollution problems and protect health on a limited understanding of scope and relationships, or worse, ignoring them altogether, can compound problems through poorly-informed, ill-conceived decisions and actions (Bowen, 2002).

  Adopting a blinkered approach to air pollution risk assessment not only prevents stakeholders reaching a full understanding of problems, but also compromising impact evaluation (because little scientific thought is applied to setting AQMA boundaries). AQMA boundaries are often incompatible with administrative boundaries (which determine the collection and analysis of health and other data. Evaluating the public health impacts of air quality management interventions therefore becomes enormously challenging. Considering local air pollution problems in a broader public health context and allowing local population health profiles to influence AQMA boundaries would help address this problem but, again, public health expertise is needed to support this process.

- **Managing risks**
  The literature suggests that improving stakeholder integration and collaboration in LAQM can create opportunities for, and facilitate delivery of, more effective and efficient action. However, the available evidence does not elaborate on this. From a public health

perspective, it is plausible that aligning air pollution reduction interventions with, and framing them in the context of, wider public health action can increase the reach and impact of actions taken. For example, influencing local planning decision-making processes can help minimise air pollution impacts and reduce inequalities as well as create health, fair and sustainable communities that promote health and wellbeing; and, active travel initiatives can help improve air quality while simultaneously improving health. It is therefore advantageous to consider not only risks, but also solutions, in a broader public health context.

Not being considerate of 'big picture' public health (not just in terms fo assessing risks, but also managing them) is a major failing of LAQM. The regime requires stakeholders to act only in places where actual or likely breaches of Air Quality Objectives occur. This means that areas with persistent air pollution problems that fall just short of non-compliance *and* poor population health (i.e. high susceptibility) status are ignored. Air pollution mitigation action in these areas should seek to improve air quality, while aligned public health action could improve baseline health status and reduce individual and population-level susceptibility to the effects of air pollution exposure. The current situation in LAQM not only fails to address existing environmental health inequalities, but also increases the potential of creating new ones (Brunt *et al*., 2016b). In addition to adopting targeted approaches to risk reduction, given the interactions of air pollution with wider public health determinants and the non-threshold status of some pollutants (such as particulate matter), LAQM should require and facilitate universal actions that reduce risks for everyone and prevent problems occurring where they do not currently exist.

It may be helpful to consider the approach to risk management described above in the context of **proportionate universalism**. This term refers to an approach where universal resources, services and interventions are tailored and delivered to provide a gradient of support for populations with differing needs (Marmot, 2010). The term was used extensively in Professor Sir Michael Marmot's independent review of effective evidence-based strategies to reduce health inequalities in England, UK – *Fair Society, Healthy Lives* – (Marmot, 2010). The review recognised that reducing inequalities (resulting from social inequalities) is rooted in fairness and social justice (Graham, 2007); it suggested that focusing efforts solely on the most disadvantaged in society will not reduce health inequalities sufficiently. Doing so actually fails to recognise the health needs of other sections of the population (Egan *et al.*, 2016). Rather, to reduce the steepness of the social gradient in health, universal actions are required that are proportionate to the level of disadvantage. The aim of this approach is to improve the overall health of the population and reduce the steepness of the health gradient – a concept known as *levelling up* (Whitehead and Dahlgren, 2006).

The *Marmot Review* argued that resources should be allocated in a way that allows all social strata to benefit from them, but where benefits increase according to need (Marmot, 2010). While this theoretical principle is ideal, achieving it in practice is a significant challenge because of considerable uncertainties around defining need and disadvantage and variations in mechanisms of resource allocation (Hutt and Gilmour, 2010). Proportionate universalism *is* achievable however; studies in some countries such as Nordic states have proven that the implementation of more universal policies has resulted in lower rates of risk and inequalities (Niedzwiedz *et al*., 2014). Some have offered an explanation for this outcome, commenting that universalism destigmatises and increases the acceptability of government spending on health and welfare (McKee and Stuckler, 2011). The point is that all members of society receive some of the benefit from universal services or actions, but the benefits accrued from such entitlements may be felt more amongst disadvantaged communities and individuals (Benach *et al*., 2012).

Delivering resources, services and interventions aligned with proportionate universalism principles presents significant challenges. Good examples can be seen in housing-led area renewal projects (Egan *et al.*, 2016), and health and social care services such as flu vaccine programmes (National Collaborating Centre for Determinants of Health, 2013), postnatal home visiting schemes and school-delivered learning support for children (Burstrom *et al*., 2017). In these proportionate universal services, the key to their successful delivery has been the organised across-discipline collaboration between relevant local-level partner agencies (e.g. health and social services) (Burstrom *et al*., 2012). However, it is fair to say that some resources, services and interventions have struggled to apply the proportionate universalism approach. For example, green space access programmes have advantaged people already in favourable positions (which widens the inequality gap) (Frohlich and Potvin, 2008) and healthy food subsidy initiatives have addressed consequences of inequalities rather than root causes (National Collaborating Centre for Determinants of Health, 2013).

There appears to be enormous public health potential in delivering the LAQM regime in ways that align with the principles of proportionate universalism. To achieve this, more evidence is required to assess the merits of broadening the public health scope of prescribed risk assessment and management processes and acting on air pollution and/or public health problems beyond Air Quality Management Areas. Good collaboration across sectors and amongst LAQM stakeholders is also required to make the approach work, as is integrated and connected policy and practice.

- **Policy connection and integration**

  It is logical to assume that identifying and making connections with wider public health policy will improve the design and delivery of LAQM. Doing this just because air pollution exposure has been linked in broader literature with ill-health is not sufficient, however. It is also necessary to raise the profile of air pollution as a local public health priority, encourage local collaboration with public health stakeholders, consider local air pollution problems and solutions in the context of wider determinants of health, identify shared priorities, and act more effectively and efficiently to achieve greater levels of health gain.

  At the national level, calls have been made for greater cooperation across air quality and public health agendas (House of Commons Environmental Audit Committee, 2014; Policy Exchange, 2013). Missing opportunities to replicate this at the local level – where it can be argued that greater opportunities for collaboration exist, and an increased potential for more tangible improvements to be realised more quickly – will only serve to inhibit LAQM development and delivery, and widen further the growing disconnect between LAQM and public health policy and practice.

3.4 Conclusion

This evidence critique helped move on understanding of the extent and importance of public health integration and interaction in LAQM by identifying the 'structure' and 'process' weaknesses that have likely contributed to preventing the regime deliver effective 'outcomes'. Whether separately or cumulatively, directly or indirectly, the identified limitations – such as risk assessment uncertainty, ineffective communications and shallow intervention evaluation – have led to missed opportunities to engage public health and connect policy and practice. Resulting problems have likely stemmed from two main regime shortfalls: a prescribed risk assessment and management process that is too narrow in terms of public health scope, and a poorly defined public health role in LAQM.

As a result of several identified ‘structure’ and ‘process’ limitations, LAQM appears to be falling short of achieving its full public health potential. Although the regime has been described previously as a strong example of a public health-*oriented* environmental management programme (Longhurst *et al*., 2009), the findings of this literature review suggest that several opportunities exist to enhance the regime’s reach and impact through greater public health integration and collaboration. To facilitate such change, LAQM must become public health-*driven*, where integration and action are not just triggered and informed by local air quality assessments but also by local air pollution-related health needs assessments. Achieving this will ensure that public health professionals and interventions can be part of the solution too.

At present, the limitations highlighted here have combined to create a situation where local authorities fail to routinely consult and collaborate with public health because it is not specifically prescribed, and where public health fails to engage and contribute because they are not aware, competent, confident, or routinely invited to do so by local authorities. The scope of this phenomenon across the UK is unknown, but it is reasonable to conclude that increasing public health integration and collaboration in LAQM can help solve identified problems and add value to the existing process.

The limitations of the current regime highlighted through this literature review (Figure 8**Error! Reference source not found.**) have likely hindered public health integration with LAQM policy and practice and stunted the regime’s evolution. While several areas ripe for LAQM enhancement are highlighted, two fundamental shortfalls stood out as being pivotal to addressing all other linked limitations. These were:

- a poorly defined public health role in LAQM (which has led to public health policy and practice disengagement and disconnection),
- the regime’s blinkered prescribed risk assessment and management processes (which fail to encourage consideration of air pollution problems and solutions in a broad public health context and action beyond Air Quality Management Areas).

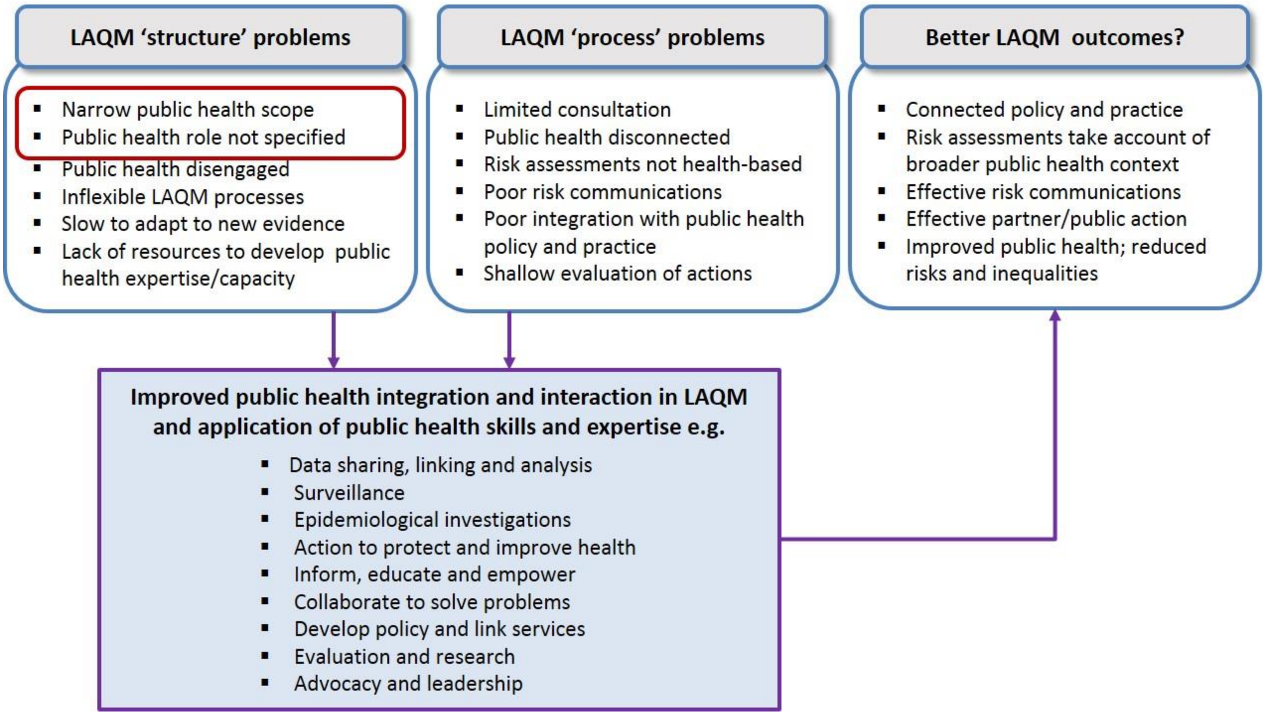

Figure 8. LAQM and public health problems, solutions and value added from better integration and collaboration

More specifically, for each component of LAQM:

- *Review and Assessment* - sharing and interpreting health data and evidence of population health-needs would improve risk assessments and ensure they frame local air pollution problems in a broader public health context. Results can inform decisions, priority-setting and targeted action. In turn, this could improve risk communications which, through new channels, for example, through Director of Public Health annual reports (Defra, 2013) would be more meaningful, authoritative and accessible. This would raise the profile of air pollution as a local public health priority amongst public bodies and the public. Consequently, raised public awareness and engagement could prompt behaviour change that reduces pollution levels, minimises exposures and improves baseline health status to reduce susceptibility and impacts.
- *Action Planning* – targeting action in areas where the greatest health gain can be achieved is desirable. Air pollution mitigation (particularly action intending to deliver air quality and health co-benefits e.g. promoting active travel and working with planning authorities to design and develop communities that facilitate this) should be implemented jointly by local authorities and public health bodies with increased efficiency and effectiveness. Wider

public health interventions could also be targeted in polluted areas to improve baseline health status and reduce individual and population susceptibility to air pollution exposure. While targeted action is important in the most vulnerable and susceptible communities, this should not occur at the expense of universal action to reduce risks for everyone. Rather, the approach to delivering risk reduction action should be aligned with the principles of proportionate universalism i.e. where the resourcing and delivery of universal services is at a scale and intensity proportionate to the degree of need.

Finally, ensuring that AQMA boundary-setting is influenced by health data would support intervention evaluations (that explore air quality and health impacts) to help determine 'what works' best in practice.

More generally, given the broad range of issues that public health professionals are interested in, it would also be possible for them to recognise opportunities to advocate for, and authoritatively lead evidence-based change through policy connection and development.

If LAQM is to remain the framework of choice to manage local air quality, and there is certainly the appetite for this *and* for public health principles to continue to underpin it (In-house Policy Consultants, 2010), then change is needed now. It has been suggested that, if LAQM were to not exist, there would be no local incentive or pressure to sufficiently support local action to improve air quality; removing the regime now (with increasing economic pressures on public bodies as they are), may lead to local air quality management actions being cut or even disbanded altogether (Defra, 2013). This is not an option.

Public health and local authorities must therefore commit to work together and invest in action to reduce local air pollution problems in a broader public health context. Enhancing LAQM to bring about these changes has the potential to not only improve air quality, lower health risks and inequalities and improve quality of life, but also reduce the burden on public body (especially healthcare) services ultimately. Defining the public health role in LAQM and broadening process scope to require risk assessments and management action based on local air pollution problems in the context of broader health determinants and needs should be prioritised. These changes are likely to act as a catalyst to achieve the added value described (Figure 8).

Acting to bridge the disconnect between public health and LAQM would not only enhance local policy and practice but also inform national policy direction and design. While public health bodies and specialists are unable to single-handedly reduce air pollution risks, their contribution to assessment and management could be significant. Improving public health awareness, integration and interaction in LAQM would help realise opportunities to solve the problems highlighted in this review and add value through:

- increased engagement and collaboration;
- improved risk assessment by scoping local air pollution problems in a broader context;
- enhanced risk communications;
- prioritised and targeted health needs-based action (that extends beyond simply reducing air pollution levels);
- connecting policy and practice; and
- evaluating intervention effectiveness.

Acting now to bring about such change is also timely from both LAQM and public health perspectives. The regime remains the only mechanism which protects local public health through air pollution assessment and management; it is essential that the process is as inclusive, efficient and effective as possible. Even if the LAQM regime, in its current guise, is abandoned in years to come, there will still be a need for some form of tool to manage air quality at the local level. The findings of this critical review will therefore remain relevant. Not only is LAQM at a crossroads, so too is public health (specifically the National Health Service (NHS)). In the UK, the NHS recognises it has operated a 'factory-model' of care with a poor track-record of community and stakeholder engagement and under-developed advocacy, action and policy to address broader influences of health and wellbeing (National Health Service, 2014). Change is required to forge closer, sustainable relationships across agencies and communities, develop new ways of working and place more emphasis on disease prevention by tackling major public health risks. As senior health officials – such as Chief Medical Officers have recognised – air pollution problems must be regarded as one such risk (Welsh Government, 2018, 2015 and 2014).

While the literature review presented in this chapter focuses on the UK position, it is likely that findings are relevant, and of interest to stakeholders, beyond.

3.5 Literature review relevance beyond the UK

As explained in Chapter 2, air quality management and improvement action in the UK is driven by EU legislation in the main through the 2008 ambient air quality directive (2008/50/EC). In response to this EU directive, the UK, through the Environment Act, required the production of a national air quality strategy setting out the UK's air quality objectives and frameworks for action delivery at national, regional and local levels. It devolved implementation responsibilities to each UK country. All other EU member states are required to implement the directive, but the EU is flexible on *how* obligations are met (Knill and Lenschow, 2004). The task is left to the discretion of individual countries so they can put in place arrangements, legislation and policy drivers tailored to structures and needs.

To determine how findings from this literature review may be use interest, relevance and use beyond the UK, equivalent LAQM arrangements in some other countries are considered here:

- In the Netherlands, a similar approach to air quality management has been specified to that in the UK, with different actions prescribed and adopted at local, regional and national levels (Busscher *et al.*, 2014). There, national authorities have responsibility for air quality monitoring, evaluating delivery of municipality action plans, communications activities and national road infrastructure management; municipalities are required to produce action plans to tackle problems e.g. local regulation, managing pollution linked to municipal roads and local planning decision-making. A major difference between the Dutch and UK regimes is that local agencies are not responsible for undertaking any air quality monitoring.

  An investigation of how EU obligations are being met across Dutch municipalities – using a similar component consideration framework to the Donabedian framework used in this literature review – revealed that considerable variation existed in air quality management implementation (Bondaruk and Liefferink, 2017). Although no evidence was found to suggest the public health aspects of the Netherlands regime have been explored, 'vertical' differences between the national policy and its local translation were noted, and also 'horizontal' differences between local implementers were identified (despite extensive local-level multi-agency communication and knowledge exchange) (Bondaruk and Liefferink, 2017). The findings of this literature review could be of use to colleagues in the Netherlands to introduce consistency in public health integration and collaboration at municipality level.

- In Italy, as in the UK and other EU member states, legislation was introduced to support implementation of the 2008 EU air quality directive (2008/50/EC). Delivering on the EU directive remains a national responsibility, but duties to act to achieve this – through Italy's LAQM equivalent 'air pollution prevention, improvement and preservation' regime – is assigned to the country's 20 administrative regions (D'Elia *et al*., 2009). As a result, several different Regional Air Quality Management Plans exist, each outlining processes and activities undertaken locally/regionally around air quality assessment (including monitoring and modelling), planning and management.

  Italy's developments in respect of modelling capabilities have received a great deal of attention (e.g. Zanini *et al*., 2005; Amann *et al*., 2004), but no evidence was found to suggest that public health integration and collaboration in the country's air quality management regime has been explored. That said, a review of Air Quality Management Plan implementation found that the most effective measures to reduce air pollution and improve public health outcomes are not always taken by regions (D'Elia *et al*., 2009). Nevertheless, given that a similar distinction is made between national and regional/local air quality management responsibilities in Italy's framework as in the UK's, it is conceivable that findings from this literature review will be of interest and relevance in Italy.

- In Denmark, it appears that air quality management is not as developed as other EU member states such as the UK. Jensen *at al*. (2001) have previously commented that, while monitoring and alert information systems have been routinely used to inform action and communications in localised urban areas, national emissions inventories have only been used to a limited extent to understand and inform air quality assessment mapping and action plans. The regime in Denmark is not well described in the literature, and there seems to be blurred boundaries between responsibilities and actions at local, regional and national levels. However, there is reference in the literature to this situation changing, with local authorities taking on more responsibilities (with more emphasis on technological data linkage and mapping developments) to lead collaborative efforts to assess and manage localised air quality (Jensen *et al*., 2001). This literature review could therefore support facilitate local-level air quality management change and improvement in Denmark.

- In France, again, air quality management arrangements mirror those in the UK i.e. a distinction is made between national and local/regional responsibilities and actions (Padilla *et al.*, 2014). Akin to the UK approach, the French system requires national bodies and Government to tackle large-scale national and international air quality-related issues and local partner agencies to work together to assess and manage risks locally and regionally. Like the UK's LAQM regime, local air quality monitoring networks are well established to support action across sectors and agencies. Within the local/regional approach, specific consideration has been given to air quality-related health inequalities (Laurian and Funderburg, 2013, Deguen and Zmirou-Navier, 2010), especially in large cities/metropolitan areas such as Lille, Marseille, Lyon and Paris (Padilla *et al*., 2014). This suggests there could be a high level of interest in this review's findings to strengthen greater public health awareness, integration and collaboration in local air quality management arrangements.

In the countries considered above, and others such as Sweden and Hungary (European Environment Agency, 2006), and Spain (Soret *et al.*, 2011) air quality management regimes have evolved over time, taking into account existing local, regional and national organisational responsibilities and structures. There is often not a single authorised body within countries with responsibility to deliver air quality management in its entirety (European Environment Agency, 2006). As such, strong working links across sectors, disciplines and partner agencies to facilitate policy integration and practice collaboration, is essential to delivering on the local air quality management task. Across Europe, the unification of responsibilities across agencies could improve the current situation by facilitating knowledge and evidence exchange within and between countries, and encouraging more effective and consistent approaches to air quality management, especially at the local level (European Environment Agency, 2006).

Other countries beyond the EU face similar challenges to integrate public health and local air quality management policy and practice. For example, a divide between government-led environmental management and health departments in South Africa, and an ambiguity in roles, has led to poor local air quality management-related collaboration and health-risk communications (Naiker *et al*., 2012). In China, government departments continue to debate how to develop an effective air quality management regime which emphasises the need to understand air pollution-related health impacts and take informed, integrated action at the local and regional levels to deliver and measure co-benefits (Wang and Hao, 2012; Fang *et al*., 2009). These countries, and many others including India (Gulia *et al*., 2018; Gulia *et al.*, 2015), can benefit from the findings of this review despite its focus on the UK LAQM experience. Some points raised here may be more-readily transferrable to places with established air quality models similar to UK LAQM (such as South Africa, New Zealand and United States (Longhurst *et al*., 2009)) or others where air quality management development is in its infancy and there are real opportunities to shape it.

Since the principles of preventing and controlling air pollution, and core public health functions are broadly similar world-wide, this evidence critique has global relevance regardless of a country's specific air quality management arrangements.

4. DEFINING RESEARCH CONTEXT & BOUNDARIES

Chapter overview

This fourth thesis Chapter takes the findings from the evidence critique and uses them to define the research problem needing further investigation. Based on the consolidated knowledge and new insights presented in Chapter 3, ways in which LAQM might be enhanced to add value to existing arrangements are hypothesised. Research questions and boundaries are then set around this, and a rationale presented for Wales being chosen as a case study area to undertake research and investigate the research problem. The Chapter concludes by specifying the research aim and objectives to take forward to answer research questions and test the hypothesis.

4.1 Research problem

As discussed in the previous chapters, the well-established UK LAQM regime aims to protect health by facilitating and supporting collaborative efforts to assess and manage local air pollution problems. It is of surprise and concern then, that despite this intention and the regime's underpinning public health principles, the public health aspects of, perspectives on, and extent of integration and interaction in LAQM have been so poorly considered prior to this research. The literature review presented in the preceding chapter consolidated existing knowledge of these aspects of LAQM by assessing the regime's public health-related strengths and limitations, and revealed new insights to help explore how greater public health integration, interaction and collaboration in LAQM could add value to existing arrangements.

To reiterate, the literature review highlighted that LAQM is failing to achieve its full public health potential. It found that several 'structure' and 'process' weaknesses have contributed to the failure of LAQM to deliver effective 'outcomes' to protect and improve population health. Problems identified (such as inadequate risk assessment, ineffective action and shallow evaluation, poor communication and disconnected LAQM and public health policy and practice), stemmed from two main shortfalls:

- ***LAQM's prescribed risk assessment and management processes are narrow in public health scope i.e. they fail to encourage consideration of air pollution problems and solutions in a broad public health context. Further, under current arrangements, action is only required in non-compliant Air Quality Management Areas.***

  To add some context to this problem, it is a mistake and a missed opportunity to ignore the complex interactions between air pollution and wider health determinants, and the influence that associations between risk factors can have on individual and population health. Acting to manage local air quality problems and protect public health on a limited understanding of relationships and problems, or worse ignoring them altogether, can compound problems (Maantay, 2002). Further, because air pollutants hold non-threshold status (where there is no 'safe' level of exposure), taking action to reduce air pollution, risks and inequalities should not be restricted to just localised air pollution hotspot areas.

- ***Public health policy and practice are disconnected from LAQM. Since the role of public health bodies and specialists has been poorly defined to date, they are largely disengaged from LAQM activities.***

  The disconnect between LAQM and public health policy and practice is considerable, and growing. To date, reviews of LAQM-related stakeholder collaboration have failed to reach out to public health bodies and specialists, so it remains uncertain why most do not support LAQM as much as they could or should, but the literature review revealed a number of possible explanations. The added value that could result from greater public health integration and collaboration in LAQM policy and practice, and *vice versa*, is significant but has never been fully explored or properly defined.

The evidence critique concluded that these two fundamental LAQM shortfalls have shaped an LAQM regime that is failing to adequately consider and act to protect and improve public health. Together, they have compromised the integration, interaction and collaboration of public health bodies and specialists in LAQM activities and stunted the regime's evolution.

The critique recommended that the LAQM regime should become public health-*driven* rather than being merely public health-*oriented*. To achieve this, the current 'silo-approach' air pollution-only assessments should be extended and replaced with a broader, more comprehensive public health risk assessment approach that considers air pollution problems and solutions in the broadest possible health context. Further, informed action should not be restricted to localised air pollution ‘hotspot’ areas (i.e. small geographies with Air Quality Objective non-compliance) and should be fully integrated with public health policy and practice and *vice versa*.

4.2 Research hypothesis

It is hypothesised that ***enhancing the LAQM regime – by broadening the public health scope of the regime’s prescribed risk assessment and management processes and specifying the public health role therein – can maximise public health awareness, integration, collaboration and impact.***

Enhancing LAQM in the ways outlined in the research problem could improve the public health reach and impact of LAQM by making public health part of the solution to better-understood problems. While public health bodies and specialists are unable to single-handedly reduce air pollution, risks and inequalities, their contribution to LAQM should not be underestimated. For example, increasing public health integration and engagement in LAQM can:

- connect different yet relevant areas of policy and practice;
- improve health risk assessments and raise awareness of air pollution and wider health determinants links;
- inform health needs-based actions (that extend beyond reducing air pollution concentrations) in ‘at risk’ areas;
- align and co-ordinate air pollution mitigation and broader health improvement intervention;
- evaluate intervention effectiveness.

By strengthening the main *Review and Assessment* and *Action Planning* components of LAQM, more effective outcomes could be achieved.

Given the broad range of issues that public health bodies are interested in, it would also be possible for specialists to recognise opportunities to advocate for, and provide authoritative leadership to bring about, evidence-based change through policy connection and development.

Enhancing LAQM to address these problems is a priority. Without change, the future of the regime looks bleak. If the worst-case scenario materialises, where LAQM is disregarded or abandoned because it is failing to deliver, there would be no local incentive or pressure to support local action to improve air quality and protect health. This would have serious adverse consequences, especially for population health, and also for local authorities e.g. local air quality monitoring, assessment and management activities may be cut or even disbanded altogether (Defra, 2013). Such a scenario is not the reality fortunately; there is considerable multi-agency support for LAQM to remain *and* for it to continue to be underpinned by strong public health principles (In-house Policy Consultants, 2010). As such, every effort should be made to enhance the current LAQM regime to render it fit for purpose to reduce local air pollution, health risks and inequalities.

Public health bodies and specialists, local authorities and other stakeholders should commit to invest in, and work together on, co-ordinated action to assess and manage local air pollution and risks. Specifically, enhancements such as acting to extend the scope of the LAQM regime and define the role of public health therein should be prioritised since these enhancements are likely to act as a catalyst to add value to existing arrangements and help LAQM realise its full potential. It is in the interests of all partners to do this; effective risk assessments and informed action can not only reduce air pollution and exposures but also burdens on already- stretched public services.

Acting now to bring about these changes is timely from both LAQM and public health perspectives. In terms of the former, LAQM remains the only mechanism by which local public health can be protected by air quality management action and so it is essential that the process is inclusive, efficient and effective. However, in its current form, it does not have a certain future. As for the latter, not only is LAQM at a crossroads, so too is public health (and more broadly the NHS). In the UK, the NHS recognises it has operated a 'factory-model' of care and repair with a poor track record of community and stakeholder engagement and under-developed advocacy, action and policy to address broader influences of health and wellbeing (National Health Service, 2014). Change is required to forge closer, sustainable relationships across public bodies and communities, to develop new ways of working that place emphasis on disease prevention by tackling public health risks.

4.3 Research questions and boundaries

To comprehensively address the research problem and test the hypothesis, two distinct, yet complementary, research questions needed answering (Figure 9):

i. **Is there merit in assessing and managing local air pollution risks in a broader public health context** (than that currently prescribed)**, and advocating for action beyond Air Quality Management Areas?**

ii. **How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?**

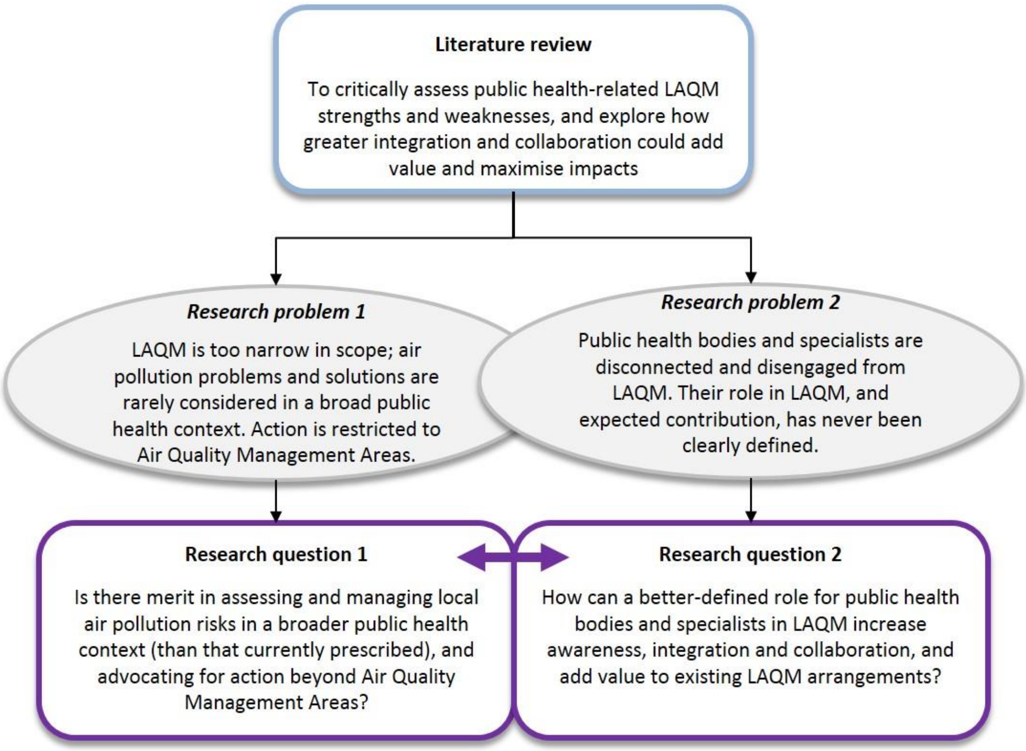

Figure 9. Research problems and questions

These questions were linked because each intended to address problems that overlapped. For example, assessing local air pollution problems and solutions in a broader public health context requires greater public health integration and engagement in LAQM policy and practice, and the only way to achieve the latter is to clearly define the role of public Health bodies and specialists in LAQM.

While these two questions set a clear direction for research, the necessity to define boundaries around them was recognised early. Given that the literature review – from which these research questions evolved – considered the public health aspects of, perspectives on, and extent of integration and engagement in, LAQM policy and practice, it was considered important that research did not stray into any broader dimensions or stakeholder perspectives. For example, it was agreed at the outset that it was beyond the scope of this research project to explore how the LAQM regime linked with other stakeholder disciplines such as transport or land-use planning. Further, the research questions posed required a focus on LAQM in the context of UK (including Wales) legislation and policy only; any international developments (e.g. EU legislation and policy changes in light of ongoing BREXIT negotiations) were not accounted for during this research project.

4.4 Rationale for selecting Wales as a case study area for this research

As alluded to in Chapter 2, the LAQM regime applies to the whole of the UK. However, because the UK Government has delegated responsibility for its implementation to devolved administrations, subtle variations in LAQM legislation, policy and practice have emerged over time across England, Scotland, Wales and Northern Ireland. These variations presented challenges in taking forward this research; it was considered impractical, too superficial and potentially counter-productive to carry out research in the required depth concurrently in all parts of the UK. Such a national-level research approach would have been unable to adequately account for known (and unknown) regional variations in LAQM policy and practice and differences in local authority and public health organisational structures, and might have generated findings that were not representative [or worse, misleading or even detrimental] of any one particular part of the UK.

It was recognised that meaningful research *with impact* would only result from adopting an approach that focused on just one well-defined geographical area of the UK. The rationale for this was based on the need for consistent organisational structures (both local authority and public health), clearly defined geographical boundaries, legislative and policy framework uniformity, limited variation in LAQM implementation, expert resource and good quality data availability.

Mindful of these criteria, Wales was selected as the preferred study area for this research. The rationale for this decision was based, in part, on Wales having the following characteristics:

- Wales is relatively small geographically; it is regarded as a UK 'region' because of its size and population of just over 3 million people;
- Wales has a varied geography with a mix of urban conglomerations, rural space and areas with an historic industrial heritage;
- Air quality management responsibilities are devolved from UK Government to the Welsh Government. As such, the LAQM legislative and policy framework is consistent across Wales;
- LAQM implementation is also fairly consistent across Wales since it facilitated by the multi-agency Welsh Air Quality Forum - a partnership of local authority and other stakeholders that promotes best-practice sharing and collaborative problem-solving;
- Air pollution, health and socio-economic status are known to vary locally. The existence of health inequalities is well documented;
- Good quality air pollution, health and socio-economic data are available at high geographical resolutions in Wales;
- Some 40 Air Quality Management Areas have been declared by local authorities across Wales (39 NO_2-related; one PM_{10}-related). These provide evidence of the existence of localised air pollution problems and suggest local variations in linked health burdens;
- In contrast to other parts of the UK, the LAQM regime in Wales has never been the subject of full formal review. As a result, findings from this research could inform significant changes that might have more impact in Wales than elsewhere. Further, opportunities to evaluate, and act upon, the public health aspects of LAQM have been missed elsewhere;
- All 22 Welsh local authorities have unitary authority status i.e. they all have the same level of LAQM implementation responsibility. Other parts of the UK – for example, England – have different tiers of local authority structure which has the potential to confuse LAQM delivery;
- The seven health boards in Wales (with boundaries coterminous with local authority 'clusters') have statutory responsibilities to protect and improve health and wellbeing in the population they serve. Since 'health' is also a UK Government-devolved responsibility which falls to the Welsh Government, there exists a consistent legislative and policy framework in this area too;
- Each health board is supported in protecting and improving public health by just one specialist public health body - Public Health Wales – which remains part of the NHS in Wales. This is not the case in some other parts of the UK where the specialist public health function has moved out of the NHS into local authorities.

- While relationships between air quality and socioeconomic factors have been explored to some extent previously in Wales, research in air quality and health fields have remained largely separate realms. Local-level air pollution, health and social characteristics have never been considered simultaneously in the context of LAQM policy and practice and so research of the kind specified in this thesis can break new ground and move understanding/practice on;
- It could be argued that there is a greater need to investigate links between air pollution, health and socio-economic factors in Wales than in other parts of the UK since earlier research into associations between air pollution and deprivation status in Wales has shown non-conformity with general patterns observed elsewhere (Defra, 2006). Such inconsistencies, along with the existence of high levels of social deprivation and health inequalities in parts of Wales, make it a priority to undertake research of this kind in Wales.

These characteristics, while combining to make a compelling argument for Wales being the preferred case study area on their own, were only part of the draw to undertake this research in Wales. Perhaps the most important influence on this decision was based on Wales having a unique legislative and policy landscape that could support the public health-driven evolution of LAQM that is so desperately needed. There are two primary drivers in this regard: the *Wellbeing of Future Generations (Wales) Act 2015*, and the Act's national delivery strategy *Prosperity For All*.

The Wellbeing of Future Generations (Wales) Act 2015 (hereafter called WFG Act) aims to improve the social, economic, environmental and cultural well-being of Wales (Welsh Government, 2015). At the core of this Act are seven 'well-being goals' that require all 44 public bodies in Wales (which includes health boards, Public Health Wales and local authorities) to think sustainably, set prevention-focused shared objectives, carry out joint planning and collaborative action, and work more effectively with people and communities (Figure 10).

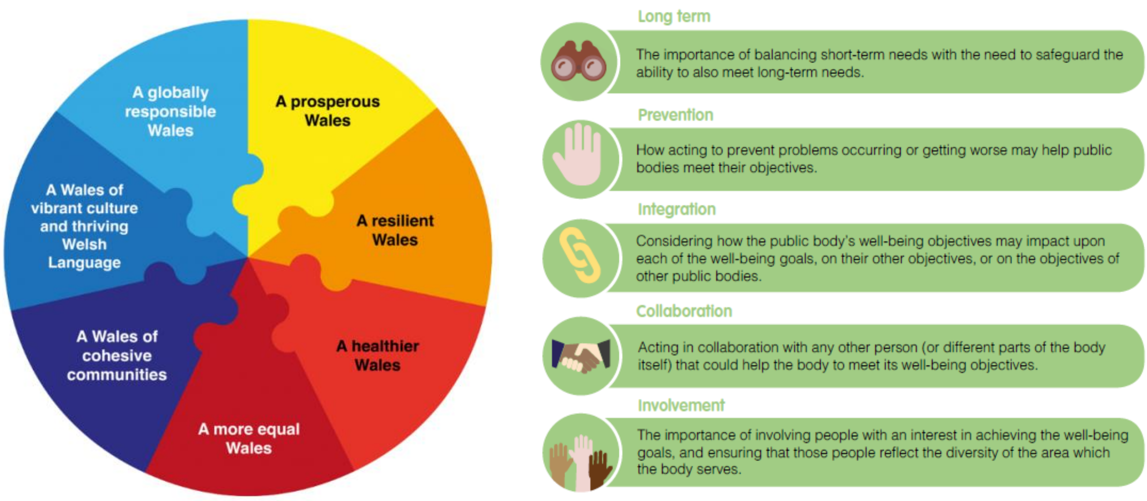

Figure 10. Wellbeing of Future Generations Act 2015 goals (left) and sustainable ways of working (right) (Welsh Government, 2015; Intellectual Property Office © Crown copyright 2015)

The WFG Act therefore placed Wales in a unique position. Through it, air pollution has been recognised as a shared priority for collaborative action as it can be linked with most, if not all, wellbeing goals. An air quality-specific national *Wellbeing* and *Public Health Outcomes Framework* indicator further demonstrates how Wales is taking seriously the challenge of reducing air pollution, risks and inequalities. The WFG Act offers real opportunities to enhance existing LAQM policy and practice using new powers that can support existing legislative and policy requirements. Specifically, the WFG Act sets out a commitment to establish local Public Services Boards across Wales with representation from local authorities, health boards (supported by Public Health Wales) and Natural Resources Wales (Wales' environmental regulatory body). Each Public Services Board has the task of achieving the specified well-being goals through the implementation of *Local Well-being Plans* that all public bodies are committed to help deliver. The emphasis the WFG Act places on collaboration underpinned by the five ways of sustainable working resonated well with the research questions specified above.

Wales' national strategy to support, implement and achieve the WFG Act is called *Prosperity for All* (Welsh Government, 2017). It sets out how Welsh Government will deliver for Wales and seeks to establish long-term foundations for the future; in so doing, it guides priority-setting and service deliver across public bodies. Recognising that prosperity is not just about having material wealth, but about everyone having a good quality of life and living in strong, safe communities, it specifies four clear well-being objectives: prosperous and secure, healthy and active, ambitious and learning, and united and connected. Within the healthy and active objective, the narrative under themes such as ‘building healthier communities and better environments’ and ‘promoting good health and well-being for everyone’ demonstrate how air quality is regarded as a national public health priority and how solutions to environmental problems link with wider public health action.

In addition to the WFG Act, other linked policy drivers for change also exist, requiring public bodies to work together to develop sustainable environments and healthy communities. For example, the Environment (Wales) Act 2016 requires partner agencies to jointly produce State of Natural Resources Area Statements and plans that serve to preserve and improve natural resources in Wales in order to improve population health and wellbeing (Welsh Government, 2016). The Planning (Wales) Act 2015 provides a modernised framework for the delivery of planning services (Welsh Government, 2015). The Active Travel (Wales) Act 2013 makes for the provision for enhanced active travel routes and related facilities to promote walking and cycling and move people away from routine vehicle use (Welsh Government, 2013). The Public Health (Wales) Act 2017 highlights the importance of applying Health Impact Assessment approach to inform significant policy and project decisions and implementation (Welsh Government, 2017). Since air pollution plays a key role in the process of climate change, the Climate Change Act 2008 (HM Government, 2008) and the 5-yearly UK Climate Change Risk Assessments are important levers too. All these legislative tools combine to make a call to action for public bodies to work with communities to reduce air pollution to protect current and future generation health and wellbeing.

From a health perspective, other developments also helped influence the decision to focus this research in Wales. In contrast to other parts of the UK, the Welsh Government has prioritised the need to tackle air pollution problems and reduce associated health risks. Wales’ Chief Medical Officer has called for a multi-agency endeavour to understand more about the health impact of air pollution and how joint action between local and national public bodies could help reduce the health burden associated with it (Welsh Government, 2014). The following year, and again in 2018, the Chief Medical Officer’s annual report reiterated that air pollution remains a public health priority and called for more local-level collaboration to address problems (Welsh Government, 2015; Welsh Government, 2018).

Notable characteristics of Wales, relevant to this research, are summarised here (Figure 11).

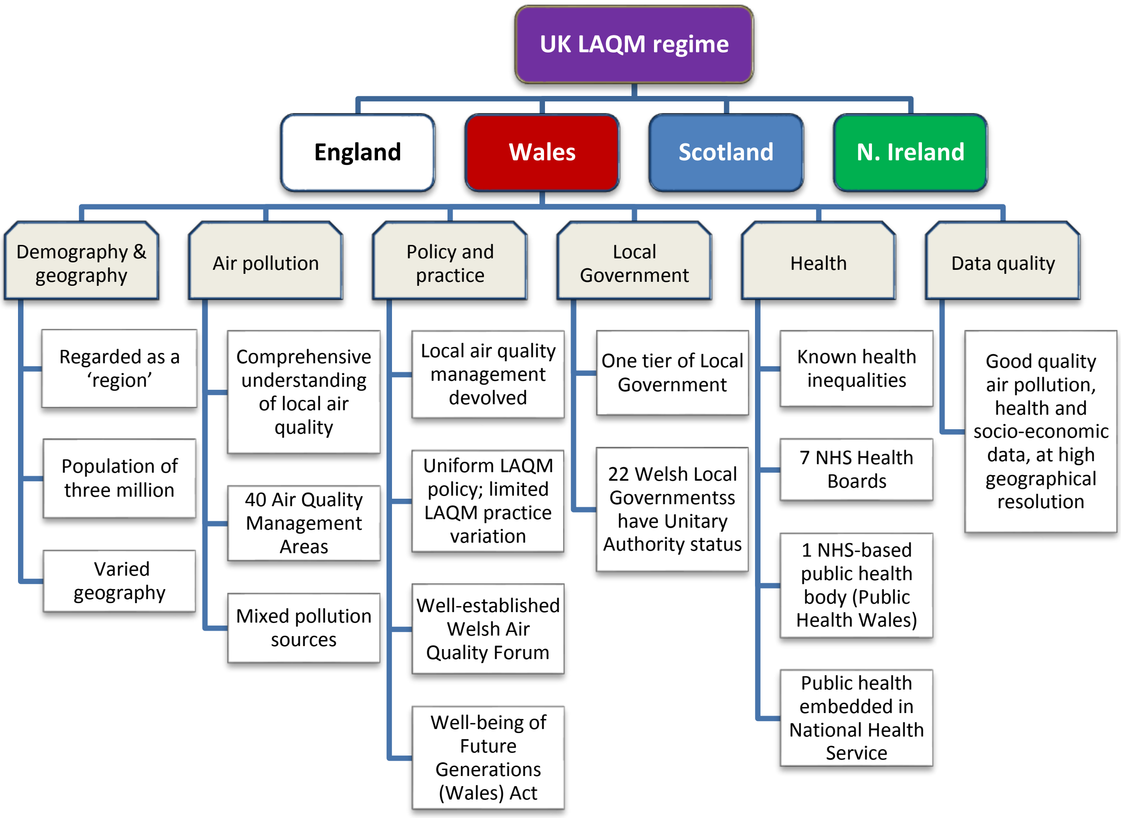

Figure 11. Notable characteristics of Wales

This research focuses on the situation in Wales, where it is intended that findings will go on to inform policy and practice development. While the choice of Wales as the case study area for this research may be questioned in light of some of its unique characteristics, it is important to emphasise that many outcomes from this research are transferrable and can be helpful in supporting LAQM enhancement in other parts of the UK. This is made possible because:

- the LAQM regime applies to the whole UK;
- the UK has committed to act to achieve the United Nation's Sustainable Development Goals https://www.un.org/sustainabledevelopment/) upon which Wales' WFG Act 2015 is based, to drive improvements in social, economic, environmental and cultural well-being. So, even though Wales has a unique policy and legislative framework, the principles and requirements from which it is derived are common to the whole UK.

Further, given that many other countries operate air quality management regimes which share similarities with LAQM (see Chapter 3), and will also be committed to work in pursuit of the UN's Sustainable Development Agenda, findings will be of significance beyond the UK context too.

4.5 Research aim, sub-aims and objectives

With Wales selected as the preferred case study area, the overall aim of the research project was **to generate evidence to enhance the Local Air Quality Management regime in Wales to maximise public health awareness, integration, collaboration and impact** (Figure 12). To answer the two distinct, yet inter-related, research questions set, this overall research aim was broken down further into two complementary Research Strands, each with a specified sub-aim and linked objectives. Research Strand 1 sought to answer research question 1, and Research Strand 2, research question 2. This approach offered the clarity and focus needed to allow research investigations to proceed without compromise or confusion.

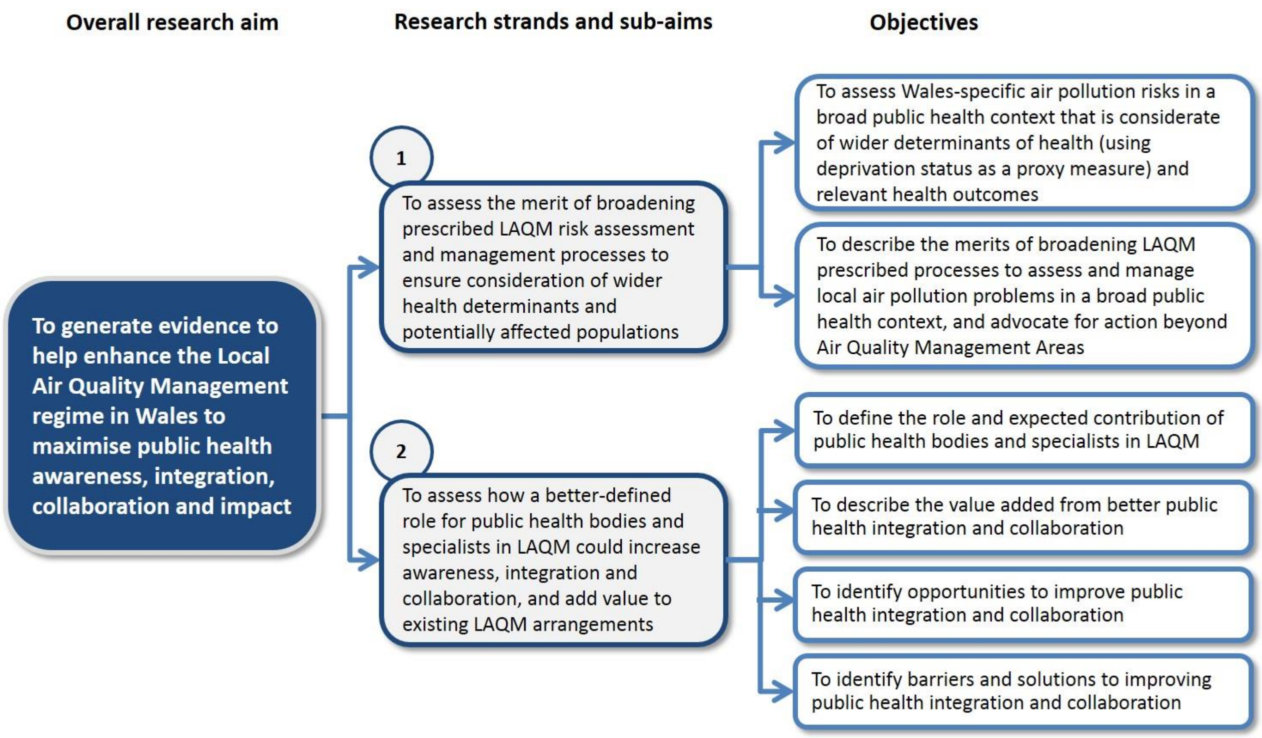

Figure 12. Overall research aim, and research aims and objectives for Research Strands 1 and 2

A detailed discussion of the approach and methods selected for both Research Strands, and subsequent mixing, validation and evolution phase, is provided in the next Chapter.

5. METHODOLOGY AND METHODS

Chapter overview

With the aim and objectives of Research Strands 1 and 2 specified, this fifth thesis Chapter opens with a discussion of how both Research Strands were framed in an overarching mixed-methods research approach. It also describes how the design and delivery of each was underpinned by a convergent parallel study design.

Next, an appraisal of methods for each Research Strand is presented. An ecological study was selected to take forward Research Strand 1, and a consensus-forming Delphi study for Research Strand 2. The rationale for methods used is explained in detail.

Finally, given the requirements of the convergent parallel study design, the methods used to maximise the mixing, validation and evolution of research outcomes are described. These comprised a multi-disciplinary research update and development workshop and area-based case study interviews. A research methodlogy and methods visual summary is provided at the end of this Chapter.

__Note__

It is appropriate to acknowledge here the methods used to support the literature review, which explored the connections between the regime and public health policy and practice previously captured, reflected and reported on. These methods, described in detail in Chapter 2, are not repeated here. However, briefly, they comprised:

- *An electronic database and internet search for relevant peer-reviewed and grey literature using pre-agreed search terms and specified inclusion and exclusion criteria;*
- *A critical review of relevant papers identified; applying the Donabedian public health evaluation framework ensured all aspects of the LAQM regime were appraised (i.e. 'structure', 'process' and 'outcome' measures).*

5.1 Research methodology

5.1.1 Selecting an overarching mixed-methods research approach

Traditionally, two research philosophies have been described:

- Quantitative research paradigm – based on positivism, it is believed that all phenomena can be reduced to empirical indicators which represent the truth. Its ontological position is that one objective reality exists independent of human perception. Epistemologically, researcher and the researched are independent, meaning that a problem can be researched without being or causing influence (Guba and Lincoln, 1994);

- Qualitative research paradigm – based on interpretivism (Secker *et* al., 1995) and constructivism (Guba and Lincoln, 1994), it is assumed there are multiple realities based on different perceptions, and that reality is socially constructed and constantly changing (Berger and Luckmann, 1966). Epistemologically, researcher and the study object are linked so that findings are mutually created within the research context (Guba and Lincoln, 1994).

From a public health, or more specifically an epidemiology, perspective, it is fair to say that the quantitative research approach has been favoured historically. However, the ever-increasing multidisciplinary characteristics of public health problems and solutions mean that public health research is [legitimately] now drawing more upon the qualitative paradigm, *and* a third, more-recently introduced, *mixed-methods* research approach:

- Mixed-methods research paradigm – where quantitative and qualitative research techniques, methods, approaches, concepts or language are combined in a single study (Johnson and Onwuegbuzie, 2004). It bridges the schism between quantitative and qualitative research by covering the area in the research continuum that places the quantitative approach at one pole and the qualitative approach at the other (Johnson and Onwuegbuzie, 2004) (Figure 13**Error! Reference source not found.**). The premise of the mixed-method research approach is that it can draw from each paradigm to maximise strengths and minimise weaknesses of both in single research studies and across studies.

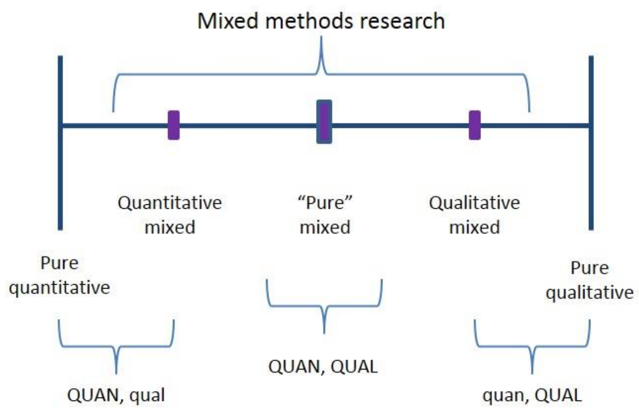

Figure 13. Mixed methods research and qualitative/quantitative emphasis context

Modern research is increasingly complex in that it is multi-disciplinary, multi-dimensional and dynamic. Mixed-methods research offers a *pragmatic* approach to address this complexity (e.g. Johnson and Onwuegbuzie, 2004; Maxcy, 2003); its methodological pluralism can result in superior quality research, compared with mono-method research (Johnson and Onwuegbuzie, 2004). When considered from a public health perspective, it is difficult to understand why, in appropriate circumstances, the two more-traditional research paradigms should not be combined. Public health is, theoretically and practically, a multi-disciplinary programme of work. This fits with the premise that more often than not, public health problems are multi-faceted; they tend to be multi-dimensional with many possible causes and solutions. This makes public health very much a multi-disciplinary and multi-method endeavour and suggests that important and innovative research is likely to result from combining conceptual beliefs and research tools across different disciplines.

Given that the methods selected to take forward Research Strands 1 (quantitative ecological study) and 2 (mixed-methods Delphi study) borrowed from the philosophies of both constructivism and positivism, **an overarching mixed-methods research paradigm was chosen to frame this research**.

In light of the complexity of the research problem and its constituent parts, the benefits of adopting both quantitative and qualitative elements in an overall mixed-methods research approach were clear. Adopting this approach of pragmatism permitted the tried and tested combination of at least one qualitative and at least one quantitative component in a single research project (Bergman, 2008). The mixed-methods research paradigm provided a 'best of both worlds' approach intended to generate a fuller understanding of the research problem than a mono-method approach, with minimal compromise. In the context of this research, the mixed-methods approach had the potential to encourage the gathering and use of multiple worldviews, allow the strengths of one approach to offset the weaknesses of the other, and facilitate the generation of more comprehensive and convincing evidence to answer research questions. Additionally, the emphasis on pragmatism stimulated a more practical approach to address the research problem by using multiple techniques and approaches, in line with the recommendation to use 'what works' (Howe, 1988). This is said to apply especially well when research *with impact* is needed (i.e. research that leads to practical developments in the real world), as was most certainly the case here (Howe, 1988).

5.1.2 Selecting an underpinning convergent parallel study design

With a mixed-methods research approach selected, affiliated study designs were appraised, to settle upon the right one to frame the research. For researchers without extensive experience in mixed-methods research, using a typology-based design is recommended (Hall and Howard, 2008). This was the case here, so a typology-based study design was preferred to a more complex dynamic or synergistic one. To inform and influence study design selection, these issues were considered:

- <u>Level of interaction</u> – the extent to which quantitative and qualitative approaches are kept independent or interacts with each other (Greene, 2007). In the context of this research, interaction was considered important, so outcomes from Research Strands 1 and 2 could be mixed and contemplated prior to final overall interpretation and validation.

- <u>Priority</u> (relative importance) – of the research approaches, which may be 'QUAN, QUAL' (equal weighting or dominance of quantitative and qualitative), 'QUAN, qual' (quantitative dominance) or 'quan, QUAL' (qualitative dominance). In this study, the need to obtain numerical and non-numerical data to investigate each research problem was considered equally important.

- <u>Timing</u> (or pacing or implementation) – the stage at which data are collected or the order in which the results from the two sets of data are used. The two most commons forms are 'sequential' (where integration occurs between, and informs, chronological study phases) and 'convergent' or 'parallel' (where data collection and analysis are independent but are integrated at the same time within the analysis). The latter approach was selected since it allowed the two separate, yet complementary Research Strands, to run in parallel and then be brought together ultimately to deliver a research 'whole' that was more than the just the sum of its parts.

- Data mixing (or integration) - data from Research Strands may be "merged", "connected", "embedded" or "bound". The first of these - 'merging' - was considered most appropriate for this research since the method of integration was through bringing findings together after Research Strands had been completed i.e. the interface point was after separate analyses of Research Strands 1 (quantitative data) and 2 (qualitative/quantitative data).

The decisions made above pointed to the need for the chosen study design type to support the conduct of parallel, rather than sequential, research strands. With this in mind, the six main mixed-methods research study designs were considered (Creswell & Plano Clark, 2011) (Table 4**Error! Reference source not found.**).

Table 4. Typology-based mixed-methods research study designs

Typology-based design	**Description**
Convergent parallel	Quantitative and qualitative data collection and analyses are undertaken in parallel prior to their comparison and ultimate interpretation
Explanatory sequential	Quantitative data collection and analysis is followed up with qualitative data collection and analysis prior to ultimate interpretation
Exploratory sequential	Qualitative data collection and analysis builds to quantitative data collection and analysis prior to ultimate interpretation
Embedded	Qualitative or quantitative data collection and analysis is nested within (and occurs before, during or after) an overarching quantitative or qualitative data collection and analysis strand
Transformative	Quantitative data collection and analysis is followed up with qualitative data collection and analysis before interpretation
Multiphase	The overall program objective specifies two distinct studies; the first (qualitative) study informs the second (quantitative) study which subsequently informs a third (mixed methods) study

As the only typology-based study design to wholly accept and accommodate the decisions made above, **the convergent parallel study design type was selected to underpin the mixed-methods research approach and frame Research Strand 1's ecological study and Research Strand 2's**

Delphi study. This was the only design type where complementary research strands – generating quantitative and qualitative data that aim to help address connected aspects of the same research problem – run in parallel (Teddlie and Tashakkori, 2009). In this study design, Creswell and Plano Clark (2011) suggest that research strands are carried out in parallel and that the priority status attributed to qualitative and quantitative data is equal. Also, the two parallel Research Strands remain independent during analysis, but results from each are then mixed at an interpretation stage to inform subsequent research discussion, validation and conclusions (Figure 14**Error! Reference source not found.**).

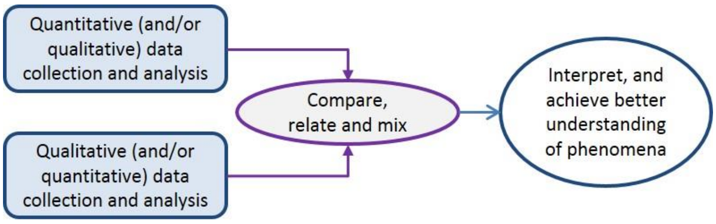

Figure 14. Mixed-methods convergent parallel study design schematic

The defining feature of the convergent parallel study design is that data from the two Research Strands remain relatively independent of one another until after their respective analyses stages. This approach facilitates the collection and analysis of quantitative and qualitative data in the same research phase before merging them in an overall interpretation. As a result, neither data nor analysis is dependent upon the other, but following integration/mixing and interpretation, the 'whole' that results is greater than the sum of its parts. Merging datasets in this way allows the researcher to obtain different but complementary data on the same topic to really understand the research problem (Morse, 1991). Creswell and Plano Clark (2011) state that the intention of this study design is to triangulate quantitative and qualitative data from different sources, and synthesise related results to develop a more complete understanding of a phenomenon.

The convergent parallel design is rooted in the concept of **triangulation** where the two different methods (quantitative and qualitative data collection and analysis) are used to obtain triangulated results about a single topic. As such, the design may also be considered as a 'mixed-methods convergent parallel across-method triangulation' design. Using two or more research methods is beneficial since it strengthens the study design so that the ability to interpret findings is increased (Polit and Hungler, 1995). In this research project, as recommended, outcomes from Research Strands 1's ecological study and Research Strand 2's Delphi study were triangulated with those of the literature review too, to improve data confirmation and completeness (Jick, 1979), enhance validity and minimise risks of partial or inaccurate data interpretation (Guest and Namey, 2015).

5.2 Methods to take forward Research Strand 1

As described in Chapter 4, Research Strand 1 needed to answer the question:
Is there merit in assessing and managing local air pollution risks in a broader public health context (than that currently prescribed), and advocating for action beyond Air Quality Management Areas?

The aim of this Research Strand was **to assess the merit of broadening prescribed LAQM risk assessment and management processes to ensure consideration of wider health determinants and potentially affected populations.** Its objectives were:

i. To assess Wales-specific air pollution risks in a broad public health context that is considerate of wider determinants of health (using deprivation status as a proxy measure) and relevant health outcomes.
ii. To describe the merits of broadening LAQM prescribed processes to assess and manage local air pollution problems in a broad public health context, and advocate for action beyond Air Quality Management Areas.

It should be noted at the outset of this methods appraisal that this Research Strand did not require research that assessed or quantified new relationships between air pollution and other variables. There is already comprehensive literature on this subject (see Chapter 2). Rather, to investigate the above research problem, this Research Strand required local-level air pollution data to be linked, analysed and interpreted in the context of population-level wider health determinants data, in order to illustrate the importance and value added of doing so routinely in Wales.

5.2.1 Selecting an epidemiological approach and ecological study design

It was not necessary to attempt to establish new insights on air pollution epidemiology in this Research Strand. However, acknowledging that some form of population-level data linkage study (combining air pollution, wider health determinants and health outcome data) would likely be beneficial in investigating known associations – in Wales, for the first time – thought was given to the potential usefulness of epidemiological study design types. To achieve the aim of this Research Strand, the application of a classical quantitative epidemiological approach was considered as it was believed that such an approach could facilitate exploration of known associations between air pollution exposure and relevant health outcomes in the context of wider health determinants.

A quantitative research paradigm was considered most appropriate for this Research Strand given the emphasis of this philosophical research approach:

- on facts and causes of behaviour (Bogdan and Biklen, 1998);
- that information is numerical and can be quantified and summarised (Golafshani, 2003);
- the mathematical process is the norm for analysing numeric data (Golafshani, 2003);
- the final result(s) is/are expressed in statistical terminologies (Charles, 1995).

Although considered, it was agreed that qualitative data would add little to a quantitative epidemiological investigation of this kind.

With a classic quantitative epidemiological approach selected, consideration was given to the appropriateness of recognised observational or experimental research methods that supported actions to gather, organise and analyse data i.e. epidemiological research designs. Given the aim and objectives specified for this Research Strand, it was possible to reject experimental study designs since there was no requirement for the research(er) to intervene to change a disease determinant or the progress of disease. Of the classical observational study design types available, including simple descriptive studies and analytical studies such as cross-sectional, case-control, cohort and ecological studies, only the ecological study design facilitated the investigation of relationships between health outcomes and other variables at the population level. **The ecological study design type was chosen as the most appropriate for Research Strand 1.**

Ecological studies, or correlational studies, determine whether associations exist between health outcomes and other variables of interest. Since ecological studies cannot demonstrate the existence of a causal association, they are often used to generate hypotheses of possible causes or disease determinants. The study design makes use of routinely collected data and is therefore relatively inexpensive and quick compared to other study design types. Ecological studies are most often used for health service planning, investigating possible correlations, surveillance of health states, studying disease clusters and monitoring the effectiveness of health-based interventions. Unlike all other epidemiological studies, the units of analysis are populations or groups of people rather than individuals. The strengths and limitations of this study design are:

- Strengths:
    - utilisation of routinely collected data;

- relatively inexpensive and quick;
- exposure data are often available at area-level;
- differences in exposure between areas may be bigger than at the individual level;
- Geographical Information Systems (GIS) software can be used to examine the spatial framework of disease and exposure;
- hypotheses can be generated for onward examination.

- Limitations:
  - measures of exposure are only a proxy based on the average in the population;
  - the potential for systematic differences between areas in recording disease frequency;
  - the potential for systematic differences between areas in exposure measurement;
  - there is often a lack of available data on confounding factors.

It was also recognised that, since data from ecological studies describe group characteristics, the main risk associated with this design type is to apply to individuals, conclusions drawn from the group level. If such an inference is made, the 'ecological fallacy' is said to exist (Hart, 2011; DeAngelis, 1990). The ecological fallacy does not remain a risk if the application is kept to the group and not the individual. Several methods are available to help minimise the likelihood of the ecological fallacy occurring (Salway and Wakefield, 2008; Wakefield and Shaddick, 2006).

5.2.2 Data sources

When discussing data, sources and utilisation in context, it is useful to remember that 'health' in its broadest sense is a function of a person's socioeconomic and environmental circumstances, as well as hereditary and personal influences (Dahlgren and Whitehead, 1991). To explore the merits of broadening the scope of LAQM to consider air pollution problems and solutions in the broadest possible context, and act in areas beyond localised pollution 'hotspots', data were drawn from a number of different sources. These, and a rationale for the use of each, are discussed in turn here:

- <u>Geographical unit</u>

  In Wales, as in England, Super Output Areas (SOAs) support the collection and publication of small area statistics (Office for National Statistics, 2011). Released in 2004, the two layers of SOAs – Lower-layer Super Output Areas (LSOAs) and Middle-layer Super Output Areas (MSOAs) – form a hierarchy based on aggregations of Output Areas (OAs) up to the area of the Local Authority. At present, SOAs have the greatest potential to aid cross-country comparisons since the units are more similar in population size than, for example, older electoral wards (which varied greatly in size from fewer than 100 to more than 30,000 residents). Their intention to represent a more stable geography facilitates the release of data that could not have been released previously and also helps support policy and intervention evaluations.

LSOAs were first developed using data from the 2001 Census, but have been updated to reflect 2011 Census boundary changes. They have an average of 1,600 residents (range: 1,000 to 3,000) and 650 households (range: 400 to 1,200), and take into account proximity and social homogeneity. MSOAs (of which 0.11% changed following the 2011 Census) have a minimum size of 5,000 residents and 3,000 households with an average population size of 7,500. They fit within local authority boundaries and each MSOA and each LSOA has its own unique nine-character code. In Wales, there are currently 410 MSOAs and 1,909 LSOAs.

To date, studies investigating local-level air pollution-related health inequalities and inequities have used a variety of different geographical units in their analyses. These have included: postcodes (see Finkelstein *et al.*, 2005; Wheeler and Ben-Schlomo, 2005; Neidell, 2004), Census area wards or units (see Pearce *et al.*, 2010; Pearce *et al.*, 2006; Defra, 2006; Wheeler, 2004; Mitchell and Dorling, 2003), districts (see Briggs *et al.*, 2008), local authorities (see Gowers *et al.*, 2014) single cities (see Jerrett *et al.*, 2004; Villeneuve *et al*., 2003; Jerrett *et al.*, 2001) multiple cities and agglomerations (see Pye *et al.*, 2001; King and Stedman, 2000) and regions (McLeod *et al*., 2000). While there appears to be no obvious geographical unit of choice, it is thought that using large geographical areas (regions or countries) is inappropriate since these are more likely to fail to reflect important localised variations in pollution concentrations and population characteristics (Pearce *et al.*, 2006).

Selecting the right geographical boundary system to use in local air pollution-related health inequality studies is crucial, the choice made significant by the potential for it to influence analyses and subsequent results. For this Research Strand, it was important that the geographical unit chosen facilitated air pollution, health and socioeconomic dataset linkage, and risk assessment and mitigation. To account for geographical variation, emphasis was placed on the need for units to be *small*; this is because it is suggested that, generally, data aggregated at any lower a resolution will provide a less reliable picture of disproportionate burdens and be less accurate at identifying affected populations (Maantay, 2002).

Based on a consideration of these points, **LSOAs were selected as the most appropriate geographical unit to use in Research Strand 1's ecological study**.

- <u>Air pollution status</u>

  Estimating exposure is the most challenging aspect of any air pollution and health research. In UK research, a variety of methods have been used to estimate population exposure, including: air pollution dispersion models, land-use regression models, and assigning exposure based on air pollution measurements from nearby air quality monitors. According to Jerret *et al*. (2001), relatively minor changes in exposure-estimation methods can significantly alter the relationships between air pollution and the variables used to represent aspects of the social and demographic environment. As such, it is important to select the method that most accurately represents the exposure under consideration.

  Both air pollution dispersion models and land-use regression models are considered to produce results that more accurately reflect air pollution exposure at the area-level than the relatively crude method of using measurements from the nearest monitor (Krewski *et al*., 2009). This is due to the often-significant distances between receptors and monitors and the high probability of air pollution levels varying between the two. It has also been suggested that land-use regression models are considered inferior to the more sophisticated dispersion models, the latter being considered more reliable (especially in urban settings) because they provide a better representation of the process under study (Jerret *et al*., 2005).

  In light of this, **modelled air pollution data were preferred to measured data. For this study, modelled annual mean ambient NO_2, PM_{10} and $PM_{2.5}$ concentration data at 1x1 km grid resolution were averaged for the study period of 2011 to 2013**. Data were obtained from the UK Government's Pollution Climate Mapping model. This model generates validated annual estimates of area-level pollutant concentrations (based on 2011 as a baseline year, and projected annually). Models for each pollutant are constructed by identifying known emission sources by emission sector and estimating quantities of emissions, allowing pollutant concentrations to be calculated by summing pollutant measures from distant sources, point sources (calculated using land-use regression and air dispersion models) and local sources (calculated using kernel-based air dispersion models) (Stedman *et al.*, 2003).

The emission sectors comprise: combustion in commercial, residential, agricultural and industrial sectors, production processes, fossil fuel extraction and distribution, solvent use, road/other transport, waste treatment and disposal, agricultural/other land use change. The models also account for meteorological conditions; a key requirement according to Jerret *et al*. (2001). Based on the model, maps are produced to fulfil the UK's EU Directive compliance assessment and reporting requirements. Prior to their use in this study, air pollution data were converted to population-weighted LSOA exposure estimates using standard methods (Welsh Government, 2014).

- <u>Health outcomes</u>

  Given the wealth of evidence linking air pollution exposure with ill-health, a variety of plausible health outcome measures needed to be considered in Research Strand 1 analyses.

  Mortality data (not only hospital deaths) for years 2011-2013 were obtained from the Office for National Statistics through the NHS Wales Information Service. Deaths data for health outcomes of interest in the context of air pollution exposure were identified by using appropriate International Classification of Diseases (ICD, version 10) codes. These were: all-cause non-accidental mortality (excluding injuries and external causes) (ICD-10: A00-R99), cardiovascular diseases (ICD-10: I00-I99), cerebrovascular diseases (ICD-10: I60-I69) and respiratory diseases (ICD-10: J00-J99). Mortality data for chronic liver disease (ICD10: K70, K73, K74) were also obtained to act as a 'control' outcome (Richardson *et al.*, 2013) since this outcome is influenced by deprivation-related risk factors (Major *et al.*, 2014) but not by air pollution (noting emerging evidence from animal studies (Kim *et al.*, 2014).

  Hospital admissions data – records of all inpatient and day case activity undertaken in NHS Wales (morbidity) – were also obtained from the *Patient Episode Database for Wales* (PEDW) for the same health outcomes, and the same three-year study period. This database is a large and rich dataset containing information about in-patient and day-case activity in Wales, and for all Welsh residents treated in English hospitals. Its limitations are similar to other hospital activity-recording databases e.g. data quality issues associated with activity coding variations, but regular timeliness and data quality validation checks ensures that PEDW is fit for purpose and as accurate possible (Bottle *et al*., 2002; Croft *et al*., 2007). There is no alternate hospital admissions data collection system in Wales.

Mortality and morbidity data were stratified by five-year age bands and linked to study-period-averaged mid-year LSOA population estimates obtained from the Office for National Statistics (Office for National Statistics, 2015). Age and sex standardised rates were calculated to adjust for age and sex as confounding factors for health outcomes of interest.

- Population denominators

  Deriving appropriate population denominators for small area studies such as this has been described previously as a "significant task" (Welsh Government, 2011). In this case, **UK 2011 Census data were used in this study**. Age and sex-specific mid-year population estimates for LSOAs in Wales were obtained from the NHS Wales Information Service. To directly standardised rates, European standard population data were also obtained.

- Deprivation status

  Socio-economic status is recognised as a confounder and effect modifier in air pollution and health epidemiology (O'Neill *et al*., 2003). Socio-economic, or deprivation, data fall into two main groups: individual and area-based measures. Individual-level data are considered unstable, as meanings and values constantly change over people's lives (Liberatos *et al*., 1988). Further, in the context of this ecological study, it was inappropriate to consider the deprivation status of individuals when air pollution status is an area-level concern. As such, **area-based deprivation measures were preferred to individual-level measures** since these provide a rating for geographical areas in terms of social and economic characteristics and tend to be the data source of choice in public health planning (Liberatos *et al*., 1988).

  Across the UK, it has been Government policy since the 1960s to create and use indices to measure local deprivation (Noble *et al*., 2006). To inform epidemiological investigation, various area-based measures are available e.g. Townsend Index of Material Deprivation, Carstairs and Morris Scottish Deprivation score, Jarman Under-Privileged Area score, and the Index of Multiple Deprivation. All have tended to use the same basic theme – a number of indicators are selected, sometimes weighted and then combined to give an overall 'score'.

  With the focus of Research Strand 1's ecological study being Wales, **the official Welsh Index of Multiple Deprivation (WIMD) was used**. Deprivation scores for LSOAs were obtained from the Welsh Government (Welsh Government, 2016). The WIMD assigns each

LSOA in Wales a summary score derived from a weighted combination of data from eight domains: income (23.5%); employment (23.5%); health (14%); education (14%); access to services (10%); community safety (5%); housing (5%) and physical environment (5%). Each domain includes several indicators of deprivation e.g. income-deprivation is a measure reflecting the proportion of residents with income below a defined level; it is calculated from LSOA numbers of income-related benefit claimants, tax credit recipients and supported asylum seekers.

For this ecological study, it was inappropriate to use the LSOA-level summary WIMD scores since their composition had been influenced by health and air pollution data. As other researchers have recommended, to avoid 'double-counting' these component data, income-deprivation domain data were used as an indicator of multiple deprivation (Fecht *et al.*, 2015; Richardson *et al.*, 2013; Kruize and Driessen, 2007; Naess *et al.,* 2007).

5.2.3 Data analysis

Research Strand 1's ecological study required two phases of data analysis:

i. Linking and describing LSOA data

Each LSOA was assigned one of five income-deprivation status classifications. Quintiles were derived by ranking income-deprivation composite scores for all LSOAs and dividing the data into five equal parts (each with around 380 LSOAs and an approximate population of 600,000 people). LSOAs were also assigned an air pollution status classification of being a 'low', 'moderately' or 'high' polluted area. Cut-off points for tertiles were determined by ordering the distribution of LSOA air pollution concentrations (for each pollutant) and dividing the data falling between the 5^{th} and 95^{th} percentile values into three equal parts. LSOAs with data values below the 5^{th} percentile (n=40 for NO_2, n=97 for PM_{10}, n=90 for $PM_{2.5}$) or above the 95^{th} percentile (n=94 for NO_2, n=90 for PM_{10}, n=77 for $PM_{2.5}$) were assigned either 'low' or 'high' polluted area status, as appropriate.

Area-level air pollution and income-deprivation status data, and mortality and hospital admissions data, were linked by LSOA using Microsoft Excel and ArcGIS 10.2.2 software. Linked data were subsequently aggregated based on deprivation and area-level NO_2, PM_{10} and $PM_{2.5}$ air pollution status. Using mortality and hospital admissions numerator data and mid-year population denominator estimates, European Age-Standardised

Rates (EASR) with 95% confidence intervals were calculated for each health outcome (Figure 15Figure 15) (Armitage and Berry, 1994; Breslow and Day, 1987). Through this method of direct standardisation (explained below in more detail), age-adjusted rates were derived by applying crude mortality or hospital admissions rates for each health outcome of interest (calculated after data aggregation) to a single reference population, in this case the European standard population. The result was standardised rates, adjusted for differences in the age structure of the population, which facilitated comparisons over time and place.

More detailed explanation of direct standardisation method:

Formula for age standardised mortality rate = $\frac{\sum(P_k m_k)}{\sum P_k}$

Where: P_k = standard population in sex/age group k
M_k = observed mortality rate (deaths per 100,000 persons) in sex/age group
$_k$ = age/sex group 0, 1-4, 5-9, ... , 80-84, 85 years and over

- Step 1: calculate age-specific mortality rates for each age group in the population (local);
- Step 2: choose hypothetical European population as 'standard' (reference);

Age	Population	Age	Population
01-04	5,000	50-54	7,000
05-09	5,500	55-59	6,500
10-14	5,500	60-64	6,000
15-19	5,500	65-69	5,500
20-24	6,000	70-74	5,000
25-29	6,000	75-79	4,000
30-34	6,500	80-84	2,500
35-39	7,000	85-89	1,500
40-44	7,000	90+	1,000
45-49	7,000		
		Total	**100,000**

- Step 3: Multiply the age-specific mortality rates of the local population with the number of persons in each age group of the standard/reference population to achieve the expected deaths from all age groups;
- Step 4: add the number of expected deaths from all age groups;
- Step 5: divide total number of expected deaths by the standard/reference population to get European age-standardised mortality rates.

Mortality rates are presented alongside 95 per cent confidence intervals as a measure of the precision of the calculated rate.

Formula for 95% confidence interval (CI) = $r \pm 1.96.\frac{r}{\sqrt{\sum n_k}}$

Where: r = age-standardised mortality rate
n_k = number of deaths in sex/age group $_k$

Figure 15. Methods to calculate European Age Standardised rates and 95% confidence intervals

ii. Assessing associations

Air pollution-health associations, and deprivation-health associations, were assessed separately using rate ratios (RR) with 95% confidence intervals (Newcombe, 2013; Newcombe and Bender, 2013). These RRs compared health outcome-specific European standardised rates in ‘high’ polluted or ‘most’ deprived areas with those in reference ‘low’ polluted or ‘least’ deprived areas. In these reference areas, RRs had the value 1.0; if comparison areas had higher rates of ill-health than reference areas, then RRs were above the value 1.0, but if comparison areas had lower rates than references areas, RRs were below the value 1.0.

The air pollution-deprivation-health association assessment – which considered air pollution and deprivation interactions and their combined association with health outcomes – adopted the same method to compare rates in reference ‘low’ polluted and ‘least’ deprived areas with ‘most’ polluted and ‘most’ deprived areas.

More sophisticated approaches might have been used to analyse the data, for example negative binomial regression. However, because this research intended to inform LAQM and public health policy and practice amongst a broad and varied audience (across local public health teams and local authorities), a decision was made to use relatively simple statistical techniques to assess associations. In contrast to more complex statistical approached, the methods described are easily understood and repeated, and deliver robust, meaningful results. This follows the principle stated by Fann *et al.* (2011) that the use of simple statistical and visual methods can improve understanding, encourage collaboration and facilitate decisions and actions that can maximise risk reduction and minimise health inequalities.

5.2.4 Ethical considerations

Since this ecological study used routinely-collected NHS data, ethics guidance was consulted at the design stage. The NHS Research Ethics Committee states that research limited to the secondary use of information previously collected in the course of normal care (without an intention to use it for research at the time of collection) is generally excluded from review, provided that the patients or service users are not identifiable to the research team in carrying out the research. Completing an online NHS ethics checklist confirmed that **ethics approval was not required for this study**.

5.3 Methods to take forward Research Strand 2

As described in Chapter 4, Research Strand 2 needed to answer the question:
How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?

The aim of this Research Strand was **to assess how a better-defined role for public health bodies and specialists in LAQM could increase awareness, integration and collaboration, and add value to existing LAQM arrangements**. Its objectives were:

i. To define the role and expected contribution of public health bodies and specialists in LAQM
ii. To describe the value added from better public health integration and collaboration
iii. to identify opportunities to improve public health awareness, integration and collaboration;
iv. to identify the barriers and solutions to improving awareness, integration and collaboration.

5.3.1 Selecting a mixed-methods approach and Delphi study design

To meet the specified aim and objective of this Research Strand, an approach that facilitated the generation of deep, rich and contextualised data from multiple experts in the field was required. While it was recognised that numerical data on their own would be insufficient to address objectives, it was deemed important to be able to analyse important qualitative data quantitatively, to standardise and, where possible, generalise findings. The most appropriate methodological approach for Research Strand 2, therefore, was one that comprised both qualitative and quantitative components. **A mixed-methods research approach was therefore selected**.

With this approach selected, an appraisal of common mixed-methods research study designs was undertaken. This included participant observation, focus groups, in-depth interviews and traditional surveys, but all were deemed unsuitable for this Research Strand. Participant observation methods were inappropriate; focus groups may have resulted in participants feeling uncomfortable when/if discussing issues which may have been critical of others present in the group; and in-depth interviews were an impractical option given the number of people to interview over a large geographical area. Using traditional surveys was considered an appropriate and practical option, but because the target population this research hoped to reach was relatively small (i.e. hundreds of people), and a representative sample of this population would be smaller still, the small sample size would have yielded findings that were not sufficiently robust to generalise.

While this initial appraisal was inconclusive, it did suggest that if survey-related sample size problems could be overcome, it may be an appropriate method to take forward Research Strand 2. To overcome problems, emphasis was placed on ‘group’, over ‘individual’, opinion. This is especially relevant given that group opinion is regarded as being more valid and reliable than individual opinion (Keeney *et al.*, 2011), and in certain ‘specialist’ subject areas like air quality and public health, it is worth noting that only small groups of experts hold knowledge on a particular issue (De Vet *et al*., 2005). This evolution of thought from the more-traditional survey to ‘collective agreement’ methods led to the need to identify recognised group consensus methods.

Consideration was given to the research methods that can help researchers investigate complex problems and achieve consensus, namely: the consensus conference (Jones and Hunter, 1995), nominal group technique (Carney *et al.*, 1996) and Delphi technique. The strengths, limitations and appropriateness of each were next appraised in the context of this Research Strand’s aim and objectives. Consensus conferences (including focus groups and group interviews) were found to suffer from the possibility that they may make participants uncomfortable, and strong-minded or more-persuasive people may dictate the direction of discussion. Nominal Group Technique methods tend not to allow for full idea development so can be a less stimulating group process than others. However, **the Delphi technique proved an excellent fit for this Research Strand, and was selected**.

Of all methods to generate, develop consensus of, and understand group opinion, the Delphi method is asserted to be the most reliable (Moynihan *et al.*, 2015; Kenney *et al*., 2011). In contrast to other methods, it allows outcome generalisability through its iteration of survey rounds for data collection and analysis, guided by democratic participation and anonymity principles (Day and Bobeva, 2005). Despite the method being a multi-stage survey, unlike a traditional questionnaire that attempts to identify ‘what is’ from individual feedback, Delphi seeks to determine ‘what could and/or should’ through a more-credible group consensus approach (Miller, 2006).

5.3.2 Understanding the Delphi technique

Originally developed to inform military strategy, the Delphi technique has evolved to become a valid, reliable and widely-accepted research method. It is a multi-stage research method that facilitates structured group communication to achieve convergence of opinion (concerning real-world knowledge) solicited from experts in certain subject areas. It is 'multi-stage' insofar as each stage of the Delphi process builds on the results of the previous one. Over iterative survey rounds (usually three) interspersed with feedback, the process works through phases of 'brainstorming', 'narrowing down' and 'rating' or 'ranking', to reach consensus amongst participants on an important and complex problem or subject where none existed previously. The process is predicated on the rationale that two heads are better than one, or ... *n* heads are better than one (Dalkey, 1972). Kenney *et al.* (2011) provided a useful and contemporary illustration of Delphi by suggesting that is akin to the option of 'asking the audience' in the game show *Who Wants To Be A Millionaire?* There, the audience acts as the expert panel (albeit using the term 'expert' loosely) and the contestant asks their opinion on a difficult question. The main premise of Delphi is thus based on the assumption that the opinion of a group is more valid than the opinion of an individual (Keeney *et al.*, 2011).

Delphi is a widely used and accepted technique capable of setting priorities, gaining consensus and generating ranges of opinions (and predicting future events) to inform decision-making and policy development (Okoli and Pawlowski, 2004). It is appropriate for use in situations when judgements need exploring, when informed opinions need to be generated or correlated, and/or when diverse views on complex phenomena need to be exposed. It is particularly effective in circumstances where research problems cannot be precisely analysed but benefit from subjective opinion, where the study population is geographically and professionally diverse and where it may not be feasible to hold frequent meetings (as a result of time and costs constraints).

The practical 'research with impact' approach of Delphi means that it is useful in many different research areas. The Delphi technique has been applied in a broad range of subject area including government, medical, health, environmental and social studies, and also business, information and industrial research (Linstone and Turoff, 2002). Of relevance here is that it has been applied in environmental and public health research (e.g. Moynihan *et al.*, 2015; Bailey *et al.*, 2012; Aarts *et al.*, 2011; Ratnapradipa *et al.*, 2011; Waterlander *et al.*, 2009). It has previously proven useful in environmental health policy evaluation and development too (e.g. Hsueh, 2015; Sherriff, 2014; Frewer *et al.*, 2011).

The Delphi method is not without limitation, however. It has been criticised for forcing consensus and not allowing participants to discuss and elaborate upon a particular issue (Walker and Selfe, 1996). Also, because it places significant emphasis on communication, some have perceived it as merely a data collection method, but this is unjust since iterative feedback develops an insight which, in its totality, amounts to more than the sum of its parts (Turoff and Hiltz, 1996).

5.3.3 Tailoring and implementing the Delphi technique

- Approach and participant selection

  The 'classical' variant of Delphi was selected for this Research Strand. This was necessary because of the limited evidence available on the research problem under investigation; it meant that the first survey round was used to generate expert opinions and ideas. As recommended, the number of survey rounds was restricted to three, to strike a balance between forming consensus and risking expert participant attrition (Figure 16) (Bloor *et al.*, 2015; Radestad *et al*., 2013; Boulkedid *et al.*, 2011).

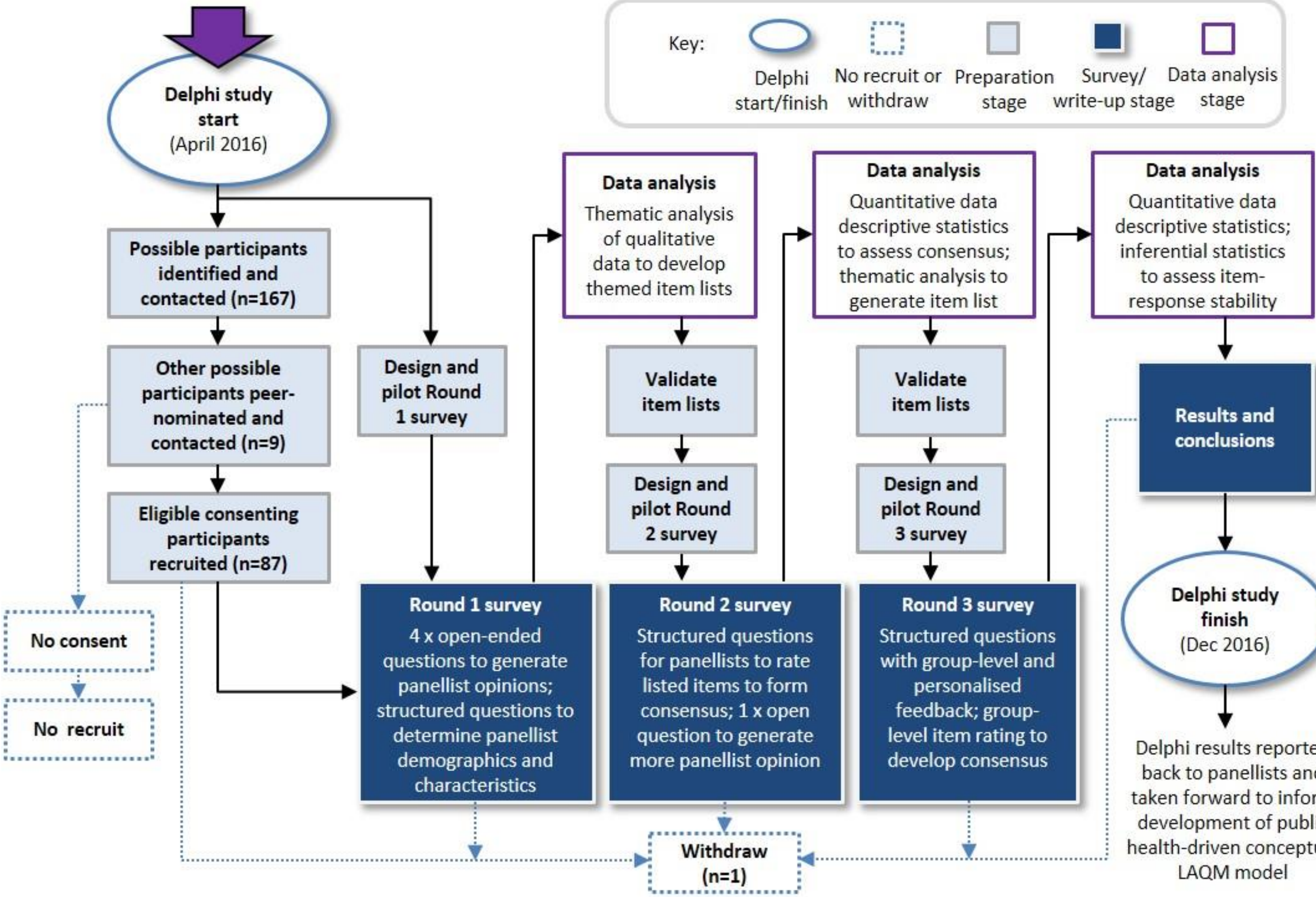

Figure 16. Three-round Delphi method overview

It is accepted that there rarely exists just one definable community as a source of expertise, knowledge and opinion for complex problems, but Delphi participants need not be representative of the target population nor have specialist knowledge of the entire issue under review (Devenish *et al*., 2012; De Meyrick, 2003). As such, in this study, 'information-rich' participants were purposefully selected using a *knowledge resource nomination* process which helped identify and categorise possible participants and ensured no source of expertise was overlooked (see Okali and Pawlowski, 2004).

This process identified a heterogeneous and geographically dispersed group of possible participants from different disciplines, in an attempt to achieve a broad spectrum of opinion on the subject under investigation (Keeney *et al.*, 2011). Each potential participant was e-mailed an invitation, information pack and consent form, in line with recommended best practice (Appendix B), as recommended (McKenna, 1994). The information pack provided important background information and context relating to: air pollution health effects, air quality management (with a specific emphasis on the role of LAQM), and a summary of the evidence that informed the research problem under investigation here (Brunt *et al*., 2016a). Other supporting information described the study aim, objectives and the Delphi process, and specified participant requirements and the following eligibility criteria:

- Specialist air quality management, environmental health and/or public health qualification;
- Minimum five years post-qualification work experience;
- Have experience of undertaking public health and/or air quality management work in Wales at any point in the last five years;
- Motivated to address the problem under investigation;
- Interest, capacity and willingness to participate.

Assurances around data collection, security and governance, and anonymity were also given. Emphasis was placed on there being no obligation to take part; participants could decline/withdraw at any time (with no penalty) even after consenting (Figure 16, Appendix B).

Through the invitation process, other possible participants could be peer-nominated and contacted. Participants who consent forms and met eligibility experts were recruited to the

Delphi panel and assigned by the research team to one of three sub-panels in order to facilitate comparison of different groups' perspectives. The sub-panels – 'public health', 'air quality management' and 'other' – mirrored the expertise categories used in the knowledge resource nomination exercise. Briefly:

- the 'public health' sub-panel comprised health service-employed public health practitioners;
- the 'air quality management' sub-panel comprised local authority-employed air quality management and environmental health professionals (who have statutory responsibility for LAQM co-ordination and implementation in Wales);
- the 'other' sub-panel comprised all other experts employed by organisations with an interest in public health and/or air quality e.g. policy makers, academics, regulators.

More detail on sub-panel composition and characteristics is presented in Chapter 6.

- <u>Delphi survey pilot</u>

  Prior to issue, Delphi surveys were piloted amongst a small [non-Delphi panel] group of known air quality management and public health experts from the University of West of England, Bristol City Council and South Gloucestershire Council. These exercises helped assess the extent to which survey questions were appropriate, concise and clear, and any supporting information and instructions were meaningful and helpful. For each survey, pilot group members were asked to provide feedback on the helpfulness of survey completion instructions, aspects of the survey that were liked and/or disliked, question clarity, and survey completion time. Surveys were refined to take account of the feedback received.

- <u>Delphi survey round 1</u>

  Data were collected through an English-language online survey designed using Bristol Online software (www.onlinesurveys.ac.uk) and distributed via personalised e-mail. Panellists were given three weeks to complete it. As recommended by Schmidt (1997), to maximise chances of unearthing important and contextualised issues not captured in the literature, open-ended questions were asked:

  1) *What is the role of public health bodies and specialists in LAQM in Wales?*

  2) *What opportunities are there to improve public health integration and collaboration?*

  3) *What barriers stand in the way?*

  4) *What value added could result?*

Panellists were asked to provide at least three ideas in response to each question along with a one-sentence explanation. Closed questions were asked about demographics, employment, expertise and experience (Day and Bobeva, 2005). A copy of the survey is provided in Appendix C.

Individual-level qualitative data were subject to thematic analysis (Keeney *et al*., 2011; Braun and Clarke, 2006). This recursive staged approach made it possible to group and theme data, combining sufficiently similar ideas/opinions (referred to from here on as 'items') into as few as possible without changing meanings or losing information (Braun and Clarke, 2006; Denscombe, 2003). Doing this offered an insight into the broad areas of panel opinion which meant that outcomes could legitimately inform subsequent survey design (Nadin and Cassell, 2007; Schmidt, 1997; Glaser and Strauss, 1967). Ultimately, four themed lists of 20 items each were produced and validated with panellists to ensure contributions were accurate and fairly represented.

- <u>Delphi survey round 2</u>

  The round 2 survey was distributed as before. Panellists were asked to indicate their level of agreement with each listed item using a five-point Likert scale. While seven- (De Vet *et al*., 2005), nine-(Gijsbers, 2016) and eleven-point (Phillips *et al*., 2014; Banks *et al.*, 2009) scales may have been selected, the five-point agree-disagree scale used in this study is believed to yield the highest quality data (Revilla *et al*., 2014; Becker *et al*., 2009) and was the preferred choice of those who piloted the survey. Five fully-labelled response options were offered to participants – 1 ('strongly disagree'), 2 ('disagree'), 3 ('indifferent'), 4 ('agree'), 5 ('strongly agree') – and, to minimise any potential confusion, brief descriptions of response options were provided in the survey completion instructions. Further, one more open-ended question was asked: *Having seen the group opinion around barriers to increasing public health integration and collaboration in LAQM, what do you think the solutions are?* This question was asked in the second round because panellists needed to be aware of suggested *barriers* before proposing *solutions*. A copy of the survey is provided in Appendix D.

  Individual-level qualitative data obtained from the open-ended question were subject to thematic analysis as in the first round. Quantitative data generated for each item (i.e. Likert scale responses) were analysed at the sub-panel level; this approach prevented one group's opinions influencing other's (and biasing outcomes), facilitated ultimate sub-panel comparison and captured differences in group perspectives that may have important policy implications for policy and practice in different disciplines (Keeney *et al*., 2011).

Consensus was measured using descriptive statistics rather than pre-agreed agreement levels (or majority rule); the latter are often arbitrary and considered subjective and scientifically questionable (linstone). The *median* (the 50th percentile) was selected as the measure of central tendency since it is the appropriate measure to use for ordinal data from scales with more than a few values and avoids problems associated with data outliers (Argyrous, 2005; Gordon, 2003; Jacobs, 1996). The *inter-quartile range* (IQR) - considered the most objective and rigorous method of determining consensus (von der Gracht, 2012) - was used to measure data dispersion around the *median* and represented the extent to which the middle 50% of all panellists agreed with one another. An IQR of 1.0 was interpreted as 'good' consensus having been achieved on a five-point Likert scale (De Vet, 2005; Linstone and Turoff, 2002; Rayens and Hahn, 2000; Raskin, 1994); in other words, more than 50% of all opinions fall within one point on the scale. An IQR value <1.0 indicated 'very good' consensus, whereas an IQR value >1.0 indicated no consensus achieved. In summary then, consensus was assessed for each item at the sub-panel level using a combination of *median* and IQR descriptive statistics. Any items failing to achieve consensus, or achieving it with a response of 3 ('indifferent'), were carried forward to the next round to be reconsidered by panellists.

- <u>Delphi survey round 3</u>

  In the round 3 survey, distributed as before, panellists were asked to rate their agreement with listed items; these comprised those items carried over from the previous round as well as new suggested *solutions*. A copy of the survey is provided in Appendix E. For new items, consensus was measured as in round two. For carried-over items, panellists were asked to re-evaluate, and if they wished, revise their rating response. To help, participants were given statistical feedback (which comprised sub-panel-level median score and inter-quartile range for each listed item) and reminded of their responses to the previous round.

Panellists' response stability for each carried-over item was assessed (at sub-panel level) using the non-parametric Wilcoxon matched-pairs signed-ranks test. This approach has been used in other Delphi studies (e.g. Kalaian and Kasim, 2012; Banks *et al*., 2009; De Vet *et al*., 2005) The test uses paired data from the same group of individuals to derive a 'before and after' comparison that quantifies whether any difference in group opinion between survey rounds is statistically significant. Where the test *z*-statistic asymptotic *p*-value is <0.05, responses are considered unstable (Privitera, 2012; Argyrous, 2005; Riley *et al*., 2000). In this study, paired data were a panellist's responses to the same item in rounds 2 and 3; it should be noted that 58 (67%) Delphi participants responded to both survey rounds 2 and 3. The use of the Wilcoxon test was appropriate because the number of sub-panel experts responding was <30 and data were not normally distributed (Kalaian and Kasim, 2012).

5.3.4 Ethical consideration

Ethics refers to having respect for human dignity, justice, beneficence, non-maleficence and the role of the researcher. Since the Delphi technique involves human participants, each of these issues needed careful consideration:

- <u>Dignity</u> is concerned with the right to self-determination. Panel members were provided with a written explanation of the study, its research context, their involvement in it and expectations. This information was provided in the form of a participant information pack. A consent form was included in the participant information pack and written confirmation of consent was required from each participant prior to their involvement in the study. As the study progressed, detailed instructions and information was provided to participants with each survey round so participants fully understood the process. The information provided stated there was no obligation to take part in the study. It clearly indicated that participants could decline and/or withdraw from the study at any time (with no penalty) even if they have previously consented to take part by completing and returning a consent form.

- <u>Justice</u> is concerned with anonymity and confidentiality. Assurance was given to hold personal data in accordance with the requirements of the Data Protection Act 1998 and UWE policies and procedures. Only the researcher would know panel members and their responses. As a safeguard, all participants were given a unique identity code on receipt of consent forms. The unique participant identifier was generated automatically by the online survey design and administration software, Bristol Online Survey. This code was used throughout the process instead of participant names or other identifiers.

- Beneficence requires researchers to do good. Benefits (to participants, target population and wider community) were communicated through the participant information pack at the recruitment stage where each was informed that "while it cannot be guaranteed that this study will help participants as individuals, the information obtained through this research should enhance LAQM to maximise public health integration and collaboration in Wales".
- Non-maleficence emphasises that above all else, researchers should do no harm. The risk of causing harm in a Delphi study is generally low. Nevertheless, participants were advised that it was their personal opinions on LAQM and public health that were required, as opposed to opinions of employing organisations. Any conflict between the two would not pose a problem ultimately since the opinions of all participants would remain anonymous amongst other panel members.

All this information was documented in a formal application for ethics approval by the UWE Faculty Research Ethics Committee. Approval was obtained in February 2016 (FET/16/02/028) (Appendix F).

5.4 Mixing, validating and evolving research outcomes

Following the completion of Research Strands 1's ecological study and Research Strand 2's Delphi study, outcomes from each were brought together and considered in the context of the original literature review and overall research aim and objectives. This exercise constituted the 'mixing' phase of the convergent parallel study design, and facilitated multiple-source data validation, across-method triangulation and the further exploration and evolution of findings. It comprised a multi-disciplinary research update and development workshop and area-based case study interviews, both of which are discussed in turn here.

5.4.1 Research update and development workshop

This multi-disciplinary research update and development workshop, held on 13th June 2017, aimed to:

- provide attendees with a mixed and consolidated update of all aspects of research undertaken, placing a relative greater emphasis on the need to discuss Research Strand 2's Delphi study outcomes set in the context of the broader research project;
- elaborate on the suggested solutions to problems identified through Research Strand 2's Delphi study, and evolve thinking around research findings to move from the 'what' (i.e. suggested solutions) to the 'how' (i.e. specifying enabling actions to help achieve pre-identified solutions), to help drive policy and practice change.

All 86 members of the Delphi panel (from Research Strand 2) were invited by e-mail to participate in the research update and development session. Those accepting the invitation were subsequently sent relevant joining instructions and supporting paperwork including venue details, agenda and published papers.

The research update and development session was held in Cardiff, south Wales, with a video link to Mold in north Wales. Although doing this presented logistical and technological challenges in terms of organisation, adopting a two-venue approach increased opportunities for people to attend from different parts of Wales, either in person or virtually.

In terms of practical arrangements and format of the session, four discussion tables were set out in 'cabaret' style in Cardiff, while in Mold, there was one discussion table. Using panellist characteristics data obtained in the Delphi study and in-keeping with the Delphi study sub-panels (i.e. ‘public health’, ‘air quality management’ and ‘other’), table and seating plans were set in advance to ensure each discussion table comprised a good mix of discipline and expertise (Figure 17).

Figure 17. Research update and development session - Cardiff (top), video-link to Mold, north Wales (bottom) (permission sought from participants to use photographs)

An independent facilitator (a member of the researcher’s supervisory team) was allocated to each table. Facilitators were briefed in advance of the session and advised they should not influence group discussions but should guide and support workshop delegates through set tasks as appropriate, and record salient points of group discussions. To prevent delegates being influenced by the researcher, the researcher did not act as facilitator; as session lead, the researcher’s role was to advise, support, co-ordinate and time-keep.

Two task-specific group activities were incorporated into the research development workshop:

- <u>Activity 1</u> aimed to identify and agree enablers (i.e. practical next steps, stepping-stone actions or change pathways) to help achieve pre-identified suggested solutions.
  One person from each table was asked to select 3 of 15 ‘solutions cards’ which were placed face-down on a table. This approach of choosing pre-identified solutions at random

eliminated the possibility of groups selecting their preferred or 'pet' solutions. Groups were then tasked with collectively identifying and agreeing three enablers that could help achieve each of the three randomly selected solutions selected. Flexibility was given around the number of enablers to generate, in case some groups could not manage to identify and agree three but others felt sufficiently strongly about something and wished to generate more. A one sentence rationale was also requested from the group for each suggested enabler.

Delegates had one hour to complete the task. Although supported by an independent facilitator to scribe, each group was asked to appoint a spokesperson to feedback on behalf of the discussion group to the whole audience.

Between workshops 1 and 2, a feedback summary was collated and shared with participants.

- Activity 2 aimed to prioritise enablers according to importance, cost, feasibility (ease to take forward and acceptability) and impact (from a public health perspective).

  Delegates were asked once again to select three solutions to discuss, explore and prioritise in this exercise but their choice was not restricted to the solutions they selected at random for the first workshop; they could select *any* three of the fifteen pre-identified solutions. For each solution, delegates were asked to consider the associated enablers (either that they or other discussion groups had suggested). Delegates were advised they could suggest more enablers if they wished. In groups, delegates were asked to score their suggested enablers for solutions to prioritise them (resulting in the completion of one score sheet per solution per table) (Figure 18). Attendees had one hour to complete the task. While supported by an independent facilitator, each table was asked to appoint a spokesperson to feedback on behalf of the discussion group.

Solution						
Enabler	**Importance** (1=low; 5=high)	**Cost** (1=high; 5=low)	**Feasibility** (ease to take forward and acceptability) (1=low; 5=high)	**Impact** (1=low; 5=high)	**Score** (importance + cost + feasibility + impact)	**Comments**
1.						
2.						
3.						
4.						Additional enabler
5.						Additional enabler
6.						Additional enabler

Figure 18. Workshop 2 score sheet to help prioritise suggested enablers to solutions

Following the second workshop activity and feedback, the research update and development session was brought to a conclusion by the researcher. Closing comments summarised discussions with emphasis was given to key points arising from the session. A commitment was given to write up workshop outcomes in the form of a report and share this with all delegates.

It was intended that the outcomes from the research update and development workshop could be used to inform the development of an evidence-based, public health-driven conceptual LAQM framework for Wales.

A week after the research update and development session, allowing time for reflection, delegates were e-mailed again and asked to evaluate the event by providing feedback on what they thought went well or not so well, what they learned, and what they will do differently in the future.

5.4.2 Area-based case study interviews

The public health-driven conceptual LAQM framework for Wales was developed using information from the ecological and Delphi studies, literature review and research update and development workshop. It sought to demonstrate how existing LAQM arrangements can and should be enhanced to increase facilitate better public health awareness, integration and collaboration.

Although evidence-informed, it was necessary to obtain feedback on the proposed LAQM framework in terms of its acceptability and applicability in different parts of Wales. This was achieved through four separate area-based case study interviews, involving 18 public health and air quality management experts. Interviews took place during September and October 2017, with each seeking to explore how LAQM conceptual framework could be applied in a specific geographical area.

Areas were selected on the basis of their defining environmental and social characteristics, and the experiences of local stakeholders in implementing LAQM. Major urban cities were included, as well as other urban areas comprising dispersed small-medium size towns separated by poor transport infrastructure links. Places with semi-rural and very rural characteristics were also included. There was considerable variation in the socio-economic status across the areas selected too, taking in those areas of Wales that are most and least deprived. More than half (25 of 40) of Wales' localised air pollution 'hotspots' AQMAs were covered through the areas selected, spread across five (of seven) health boards and 16 (of 22) local authorities in Wales. The population covered by selected areas totalled 2,396,857.

Holding area-based case study discussions ensured that consideration was given to applying the LAQM conceptual framework in places with varied population, socio-economic status, air pollution and urban/rural characteristics, and LAQM implementation experience. Importantly, it was considered beneficial to carry out case study discussions at the health board area level rather than at local authority area level as this encouraged experts to think about the application of the conceptual LAQM in a broader geographical and collaborative context. Since local authority clusters are co-terminous with health boards in Wales, it meant that several local authorities could engage. Indirectly, bringing together local public health and air quality management experts to consider LAQM from a local-regional perspective also started to encourage interaction and collaboration.

In advance of the meetings, experts – who must have participated previously in Research Strand 2's Delphi study, and who were nominated to attend the meetings by the all-Wales Directors of Public Health Group and Welsh Air Quality Forum – were e-mailed with a copy of the research update and development session summary report and the LAQM conceptual framework. A reminder was also given of Wales' existing LAQM arrangements so experts would be able to compare these with the proposed LAQM framework to identify and understand differences between the two models. With specific regard to the LAQM conceptual framework, experts were also asked to consider the following questions (on which case study discussions would be based) prior to attending meetings:

i. How easy is it to understand and follow?
ii. Would you be happy to adopt the new way of working in your area?
iii. Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?
iv. Given your engagement in this research, would you add or change anything about it?
v. What do you think the most challenging aspects are to secure buy-in for and implement?
vi. Do you think it will make a difference in practice in your area?
vii. What should happen next to turn theory into reality?

Findings from these case study discussion sessions were considered and used to inform the delivery of the final research outcome - evidence-based drivers for change that could help create an enhanced, public health-driven LAQM framework for Wales based on better public health integration and collaboration.

5.5 Research methodology and methods – a visual summary

Given this Chapter's detailed discussions of research approaches and methods, it was thought helpful to provide a visual summary of those selected here (Figure 19). This framework illustrates how the overarching mixed-methods approach and convergent parallel study design frame the quantitative and qualitative approaches of the complementary Research Strand 1 ecological study and Research Strand 2 Delphi study, to address specific research questions. It emphasises the relevance of triangulating evidence from different research phases, and demonstrates the value added to research from mixing, interpreting and evolving research findings to ensure the overall research outcome is greater than the sum of its component parts.

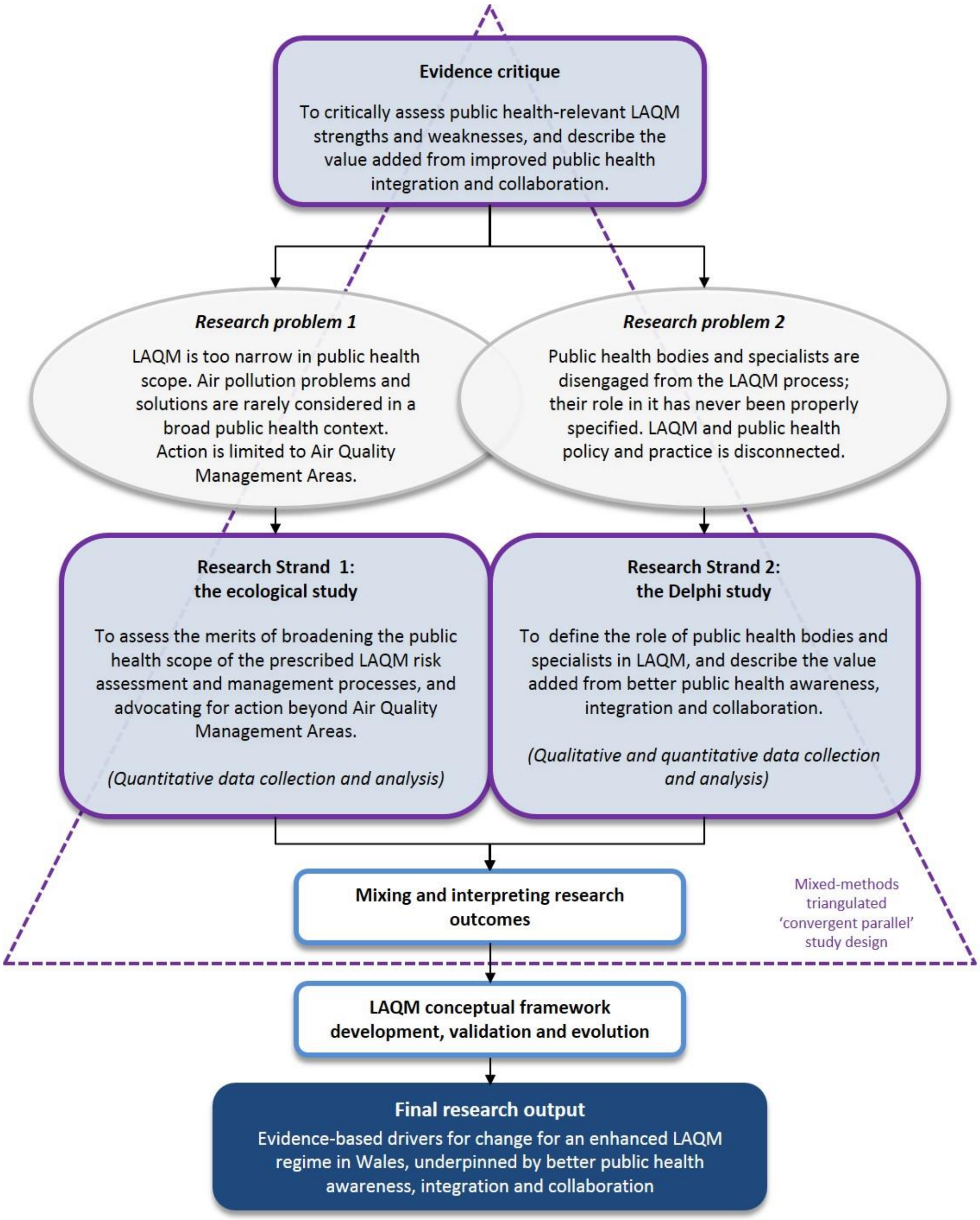

Figure 19. Research methodology framework – a visual summary

6. RESULTS

Chapter overview

This sixth thesis Chapter opens by presenting the results of Research Strands 1's ecological study and Research Strand's Delphi study. The evidence generated through both studies is then mixed and interpreted in the context of literature review findings to achieve data confirmation and completeness, and multi-source triangulation. The process of validating research outcomes – via a multi-disciplinary workshop – to inform the development of a conceptual LAQM framework for Wales designed to maximise public health integration, collaboration and impact, is then described. The Chapter concludes by synthesising expert feedback on the local/regional appropriateness, applicability and acceptability of the conceptual framework, obtained through case study interviews.

The ecological study (Brunt *et al.*, 2016b) and Delphi study (Brunt *et al.*, 2017) are published in peer-review journals (see Appendix A).

6.1 Findings from Research Strand 1's ecological study

To recap, Research Strand 1 needed to answer the question:

Is there merit in assessing and managing local air pollution risks in a broader public health context (than that currently prescribed), and advocating for action beyond Air Quality Management Areas?

The aim of this Research Strand was **to assess the merit of broadening prescribed LAQM risk assessment and management processes to ensure consideration of wider health determinants and potentially affected populations.** Its objectives were:

i. To assess Wales-specific air pollution risks in a broad public health context that is considerate of wider determinants of health (using deprivation status as a proxy measure) and relevant health outcomes.
ii. To describe the merits of broadening LAQM prescribed processes to assess and manage local air pollution problems in a broad public health context, and advocate for action beyond Air Quality Management Areas.

The results of each of the ecological study's two analysis phases are presented here.

6.1.1 Linking and describing air pollution, deprivation and health data

- <u>Local-level air pollution</u>
  Across Wales' LSOAs, the annual mean NO_2 concentration was 17.7 μg/m^3 (5th percentile: 6.6 μg/m^3; 95th percentile: 36.7 μg/m^3), for PM_{10} it was 14.1 μg/m^3 (5th percentile: 11.4 μg/m^3; 95th percentile: 17.3 μg/m^3), and for $PM_{2.5}$ it was 9.5 μg/m^3 (5th percentile: 7.5 μg/m^3; 95th percentile: 11.8 μg/m^3). When air pollutant concentration quintiles were mapped, local-level variations in air quality were observed (Figure 20).

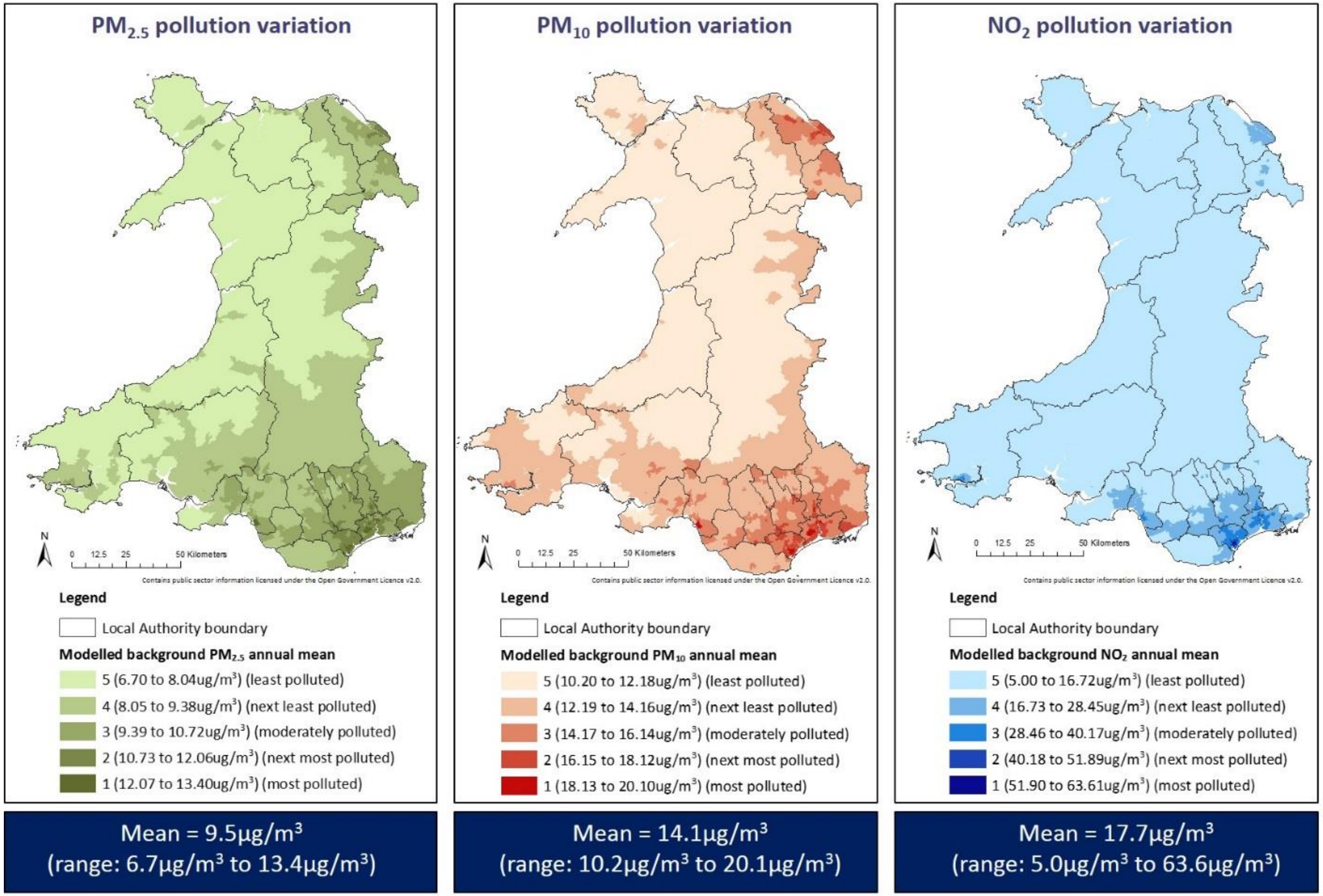

Figure 20. All-Wales three-year average LSOA-level modelled annual mean air pollution concentrations estimates, 2011-2013.

For all analyses, air pollution data were split into tertiles, with every LSOA being assigned either 'low', 'moderate' or 'high' pollution status. From this, it was evident that local-level NO_2 concentrations varied more than PM_{10} and $PM_{2.5}$ concentrations. NO_2 concentrations were greatest in town and city agglomerations in south-east Wales, along main traffic routes such as the M4 motorway running between the south-east and mid-south Wales, and in heavily-industrialised areas like the busy sea port where several oil refineries are located in south-west Wales (Figure 21).

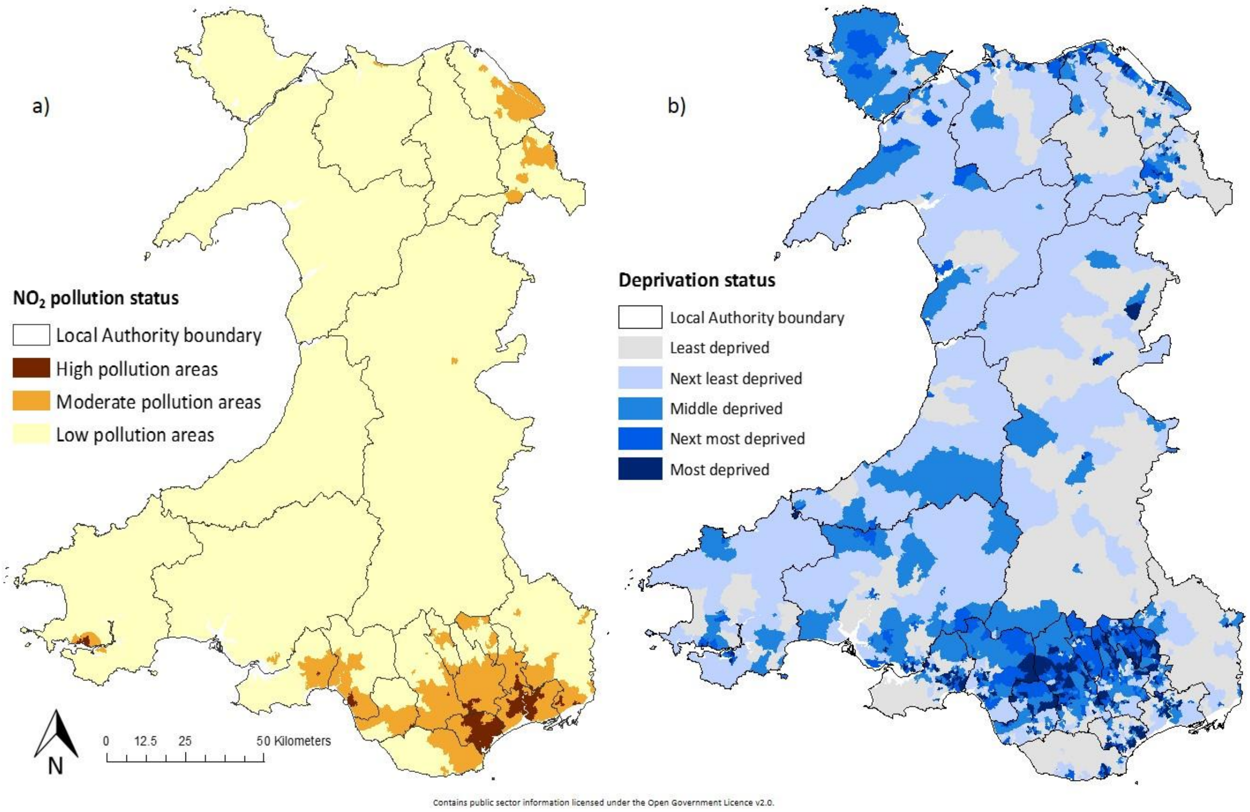

Figure 21. Wales map of local-level distribution patterns for a) NO_2 air pollution; b) income deprivation status

- <u>Local-level deprivation</u>

  Income-deprivation status also varied across LSOAs too (Figure 21). The income-deprivation composite scores that lie under LSOA classifications revealed that the proportion of people living in income deprivation ranged from 5% in some LSOAs to 31% in others (all-Wales average, 16%). Only 12% of 'most' deprived areas could be described as being rural compared with 27% of 'least' deprived areas; 'next least' deprived areas were least urbanised.

- <u>Air pollution variation by deprivation status</u>

  In the context of deprivation, a marked ‘u’-shaped, non-linear NO_2 air pollution concentration-value distribution pattern was observed across quintiles. Average concentrations were highest in ‘most’ deprived areas and next highest in ‘least’ deprived areas (Figure 22). The patterns for PM_{10} and $PM_{2.5}$ were similar to that of NO_2 but less pronounced.

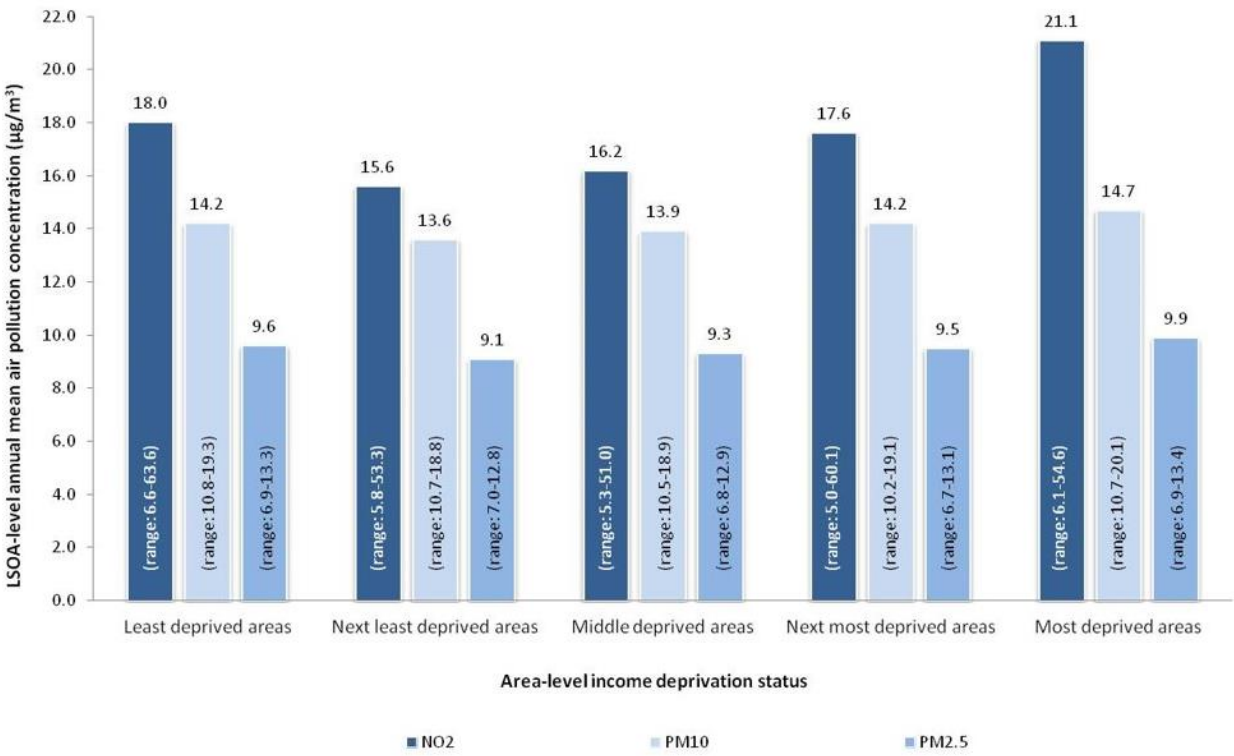

Figure 22. Local-level annual mean air pollutant concentrations by income-deprivation status.

- <u>Health - mortality and morbidity</u>

  In the context of health, the average annual all-cause non-accidental death count in Wales was 30,035 (Wales EASR = 100.5 per 10,000; 95%CI: 99.4 to 101.7) (see Figure 15 for calculation methods). Cardiovascular disease accounted for 31% (n=10,512) of these (EASR = 30.9 per 10,000; 95%CI: 30.3 to 31.6), respiratory disease 16% (n=4,806) (EASR = 15.7 per 10,000; 95%CI: 15.3 to 16.2), cerebrovascular disease 8% (n=2,408) (EASR = 7.6 per 10,000; 95%CI: 7.3 to 8.0) and chronic liver disease 1% (n=300) (EASR = 1.4 per 10,000; 95%CI: 1.3 to 1.6). For each death, there were 3.3, 9.7, 2.3, and 2.2 times as many hospital admissions for the same diseases, respectively.

6.1.2 Illustrating air pollution, deprivation and health interactions

- Air pollution-health associations

  The *air pollution-health* association analysis revealed that rates of only all-cause non-accidental mortality (Rate Ratio (RR) = 1.27; 95% CI: 1.10 to 1.45) and respiratory disease mortality (RR = 1.43; 95% CI: 1.03 to 1.96) increased as NO_2 air pollution worsened and were significantly higher in 'high' polluted areas compared with 'low' polluted areas (Figure 23; Table 5). Similar associations were observed for $PM_{2.5}$ (all-cause mortality: RR = 1.15; 95% CI: 1.10 to 1.20; respiratory disease mortality: RR = 1.37; 95% CI: 1.22 to 1.52) and PM_{10} (all-cause non-accidental mortality: RR = 1.14; 95% CI: 1.08 to 1.20; respiratory disease mortality: RR = 1.31; 95% CI: 1.15 to 1.50; respiratory disease morbidity: RR = 1.17; 95% CI: 1.12 to 1.21).

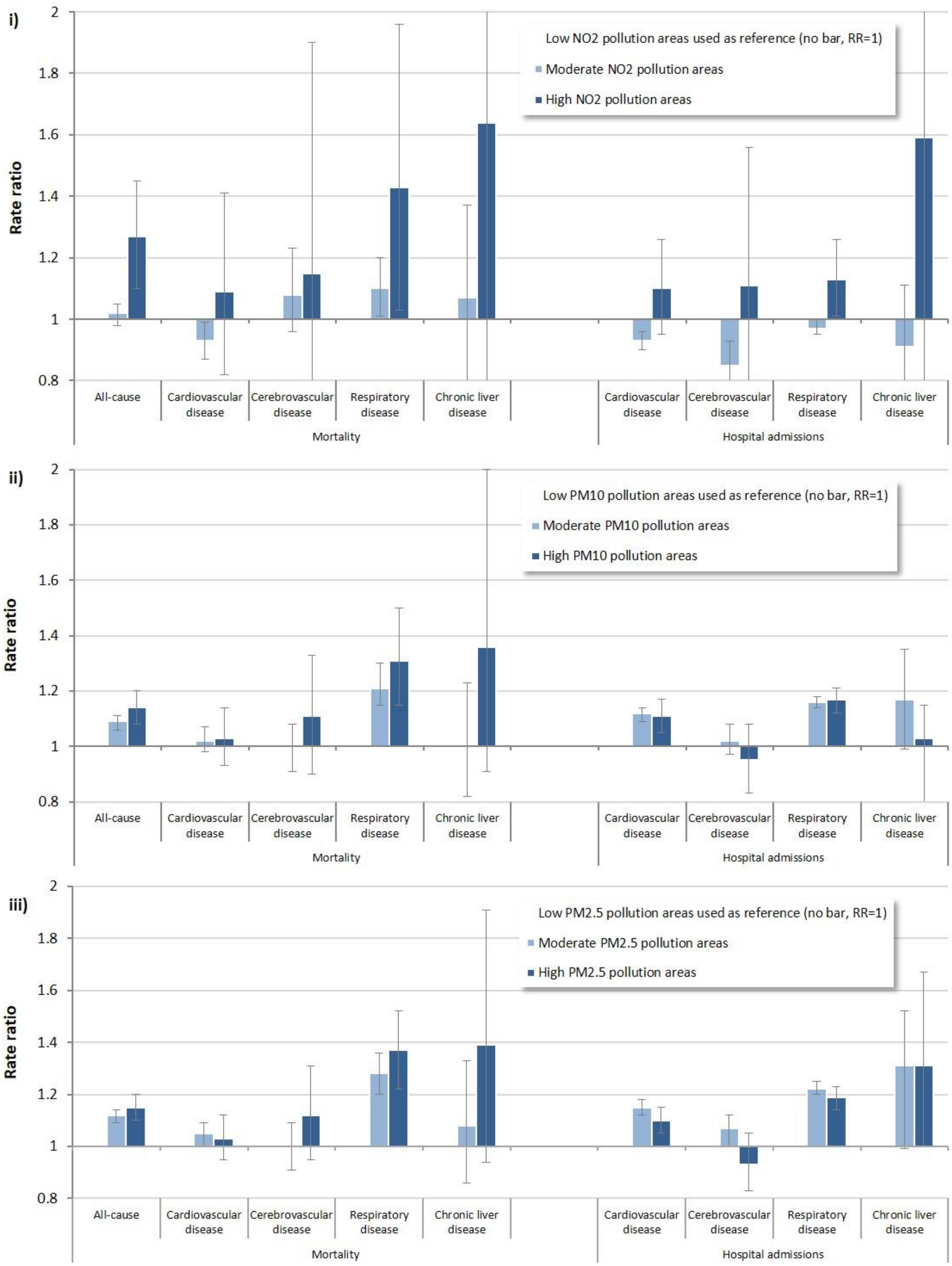

Figure 23. Associations of: a) NO_2; b) PM_{10}; and c) $PM_{2.5}$ status with health outcomes ('low' pollution areas held as reference)

Table 5. Local-level air pollution status association with health outcomes ('low' polluted areas held as reference)

			Low polluted areas (Ref)	Moderately polluted areas	High polluted areas
Nitrogen dioxide (NO_2)	**Mortality rate ratio** (95%CI)	***All-cause non-accidental***	-	1.02 (0.98 to 1.05)	**1.27 (1.10 to 1.45)**
		Cardiovascular disease	-	0.93 (0.87 to 0.99)	1.09 (0.82 to 1.41)
		Cerebrovascular disease	-	1.08 (0.96 to 1.23)	1.15 (0.64 to 1.90)
		Respiratory disease	-	**1.10 (1.01 to 1.20)**	**1.43 (1.03 to 1.96)**
		Chronic liver disease	-	1.07 (0.67 to 1.37)	1.64 (0.36 to 3.95)
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	-	**0.93 (0.90 to 0.96)**	1.10 (0.95 to 1.26)
		Cerebrovascular disease	-	**0.85 (0.78 to 0.93)**	1.11 (0.77 to 1.56)
		Respiratory disease	-	0.97 (0.95 to 1.00)	**1.13 (1.01 to 1.26)**
		Chronic liver disease	-	0.91 (0.74 to 1.11)	1.59 (0.75 to 2.92)
Particulate matter (PM_{10})	**Mortality rate ratio** (95%CI)	***All-cause non-accidental***	-	**1.09 (1.06 to 1.11)**	**1.14 (1.08 to 1.20)**
		Cardiovascular disease	-	1.02 (0.98 to 1.07)	1.03 (0.93 to 1.14)
		Cerebrovascular disease	-	1.00 (0.91 to 1.08)	1.11 (0.90 to 1.33)
		Respiratory disease	-	**1.21 (1.15 to 1.30)**	**1.31 (1.15 to 1.50)**
		Chronic liver disease	-	1.00 (0.82 to 1.23)	1.36 (0.91 to 2.00)
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	-	**1.12 (1.09 to 1.14)**	**1.11 (1.05 to 1.17)**
		Cerebrovascular disease	-	1.02 (0.97 to 1.08)	0.95 (0.83 to 1.08)
		Respiratory disease	-	**1.16 (1.14 to 1.18)**	**1.17 (1.12 to 1.21)**
		Chronic liver disease	-	1.17 (0.99 to 1.35)	1.03 (0.75 to 1.15)
Particulate matter ($PM_{2.5}$)	**Mortality rate ratio** (95%CI)	***All-cause non-accidental***	-	**1.12 (1.09 to 1.14)**	**1.15 (1.10 to 1.20)**
		Cardiovascular disease	-	1.05 (1.00 to 1.09)	1.03 (0.95 to 1.12)
		Cerebrovascular disease	-	1.00 (0.91 to 1.09)	1.12 (0.95 to 1.31)
		Respiratory disease	-	**1.28 (1.20 to 1.36)**	**1.37 (1.22 to 1.52)**
		Chronic liver disease	-	1.08 (0.86 to 1.33)	1.39 (0.94 to 1.91)
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	-	**1.15 (1.12 to 1.18)**	**1.10 (1.05 to 1.15)**
		Cerebrovascular disease	-	1.07 (1.00 to 1.12)	0.93 (0.83 to 1.05)
		Respiratory disease	-	**1.22 (1.20 to 1.25)**	**1.19 (1.14 to 1.23)**
		Chronic liver disease	-	1.31 (0.99 to 1.52)	1.31 (1.00 to 1.67)

BOLD = Statistically significant result.
BOLD UNDERLINED = Statistically significant result; RR increased as area-level air pollution status worsened.

- Deprivation-health associations

  The *deprivation-health* association analysis showed that income-deprivation status was positively and significantly associated with all health outcomes, especially chronic liver disease mortality and morbidity (Figure 24).

  Deprivation-health associations were stronger than *air pollution-health* associations. With the exception of the ‘control’ chronic liver disease outcomes, income-deprivation status was most strongly associated with respiratory disease mortality (RR = 1.97; 95%CI: 1.79 to 2.17) and morbidity (RR = 2.05; 95%CI: 1.98 to 2.11).

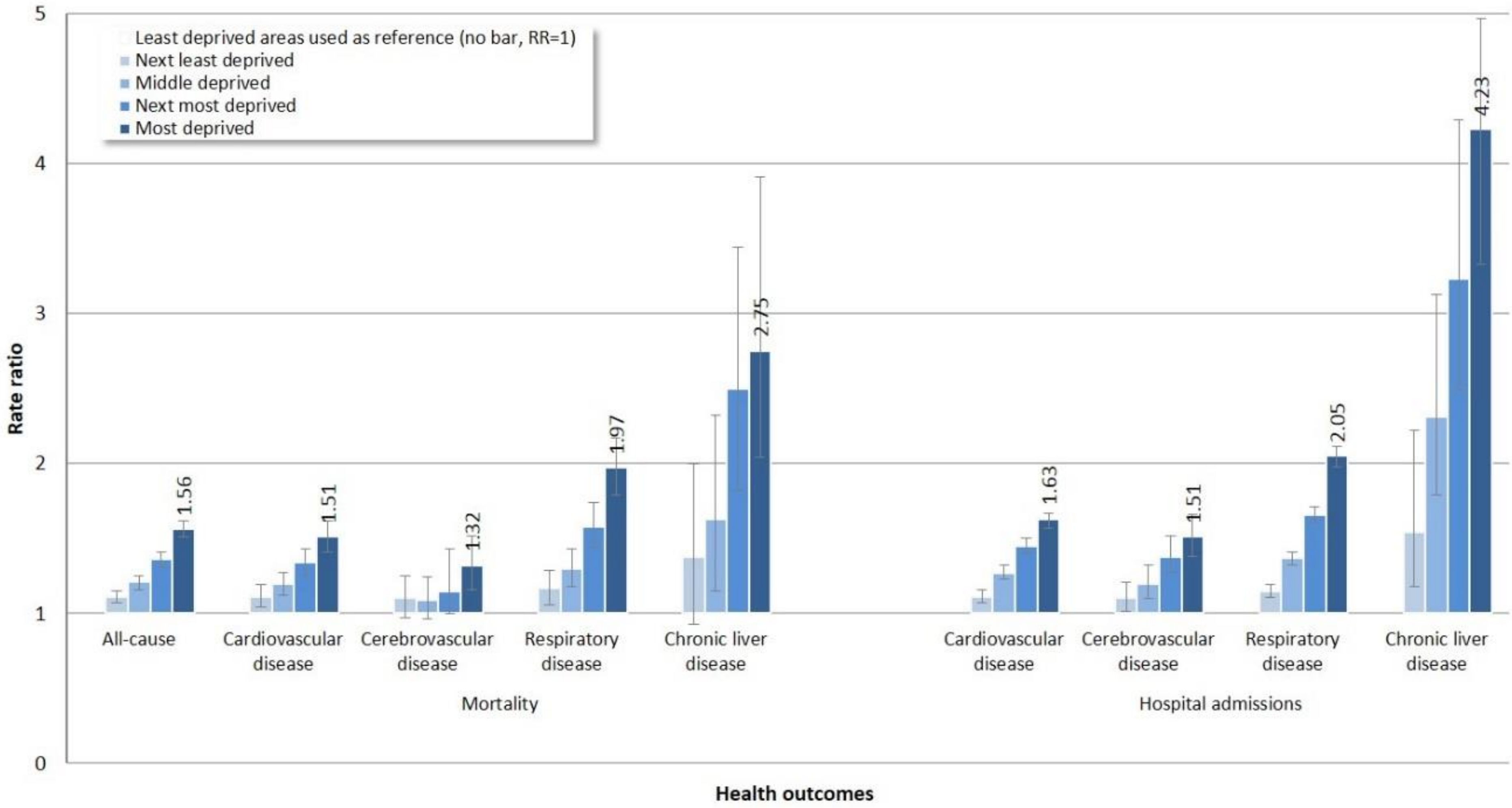

Figure 24. Local-level income deprivation status associations with health outcomes ('least' deprived areas held as reference)

- <u>Air pollution-deprivation-health associations</u>

  As for air pollution-deprivation-health association assessment, when considered in the context of air pollution, positive associations between deprivation status and health persisted (Table 6). All health endpoints were positively associated with income deprivation; rates were higher in ‘most’ deprived/‘low’ polluted areas than in reference ‘least’ deprived/‘low’ polluted areas, regardless of air pollution status. Chronic liver disease outcomes were most strongly associated with deprivation, followed by respiratory disease outcomes. Simultaneously considering income deprivation and air pollution status (all pollutants) strengthened associations observed previously in the deprivation-health analysis for all-cause non-accidental and respiratory disease mortality only.

Table 6. Air pollution-deprivation-health associations ('low' polluted and 'least' deprived areas held as reference)

			Deprivation status	Low polluted areas (reference)	Moderately polluted areas	High polluted areas
Nitrogen dioxide (NO_2)	Mortality rate ratio (95%CI)	***All-cause***	Least	-	1.01 (0.92 to 1.07)	1.09 (0.28 to 2.09)
			Most	**1.41 (1.36 to 1.45)**	**1.43 (1.34 to 1.52)**	**1.62 (1.37 to 1.89)**
		Cardiovascular disease	Least	-	0.94 (0.84 to 1.06)	1.17 (0.03 to 3.95)
			Most	**1.40 (1.32 to 1.48)**	**1.26 (1.14 to 1.40)**	1.32 (0.93 to 1.78)
		Cerebrovascular disease	Least	-	1.04 (0.83 to 1.27)	0.41 (0.01 to 2.84)
			Most	**1.15 (1.03 to 1.29)**	**1.31 (1.05 to 1.59)**	1.39 (0.67 to 2.44)
		Respiratory disease	Least	-	1.14 (0.97 to 1.32)	1.17 (0.04 to 15.94)
			Most	**1.70 (1.57 to 1.84)**	**1.80 (1.58 to 2.06)**	**2.10 (1.38 to 3.03)**
		Chronic liver disease	Least	-	1.00 (0.54 to 1.88)	0.67 (0.22 to 4.58)
			Most	**2.33 (1.81 to 3.17)**	**2.33 (1.49 to 3.62)**	3.56 (0.88 to 8.94)
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	Least	-	**0.92 (0.86 to 0.98)**	1.05 (0.24 to 2.22)
			Most	**1.51 (1.47 to 1.56)**	**1.39 (1.31 to 1.47)**	**1.44 (1.20 to 1.69)**
		Cerebrovascular disease	Least	-	**0.80 (0.68 to 0.94)**	0.95 (0.01 to 6.81)
			Most	**1.42 (1.32 to 1.53)**	**1.22 (1.05 to 1.39)**	1.37 (0.87 to 2.05)
		Respiratory disease	Least	-	**0.92 (0.87 to 0.97)**	1.02 (0.11 to 1.65)
			Most	**1.80 (1.75 to 1.85)**	**1.73 (1.66 to 1.80)**	**1.70 (1.49 to 1.93)**
		Chronic liver disease	Least	-	0.75 (0.42 to 1.25)	0.81 (0.13 to 6.44)
			Most	**3.25 (2.66 to 4.11)**	**2.69 (1.96 to 3.71)**	**4.13 (1.79 to 8.24)**
Particulate matter (PM_{10})	Mortality rate ratio (95%CI)	***All-cause***	Least	-	1.02 (0.96 to 1.08)	1.06 (0.91 to 1.24)
			Most	**1.56 (1.46 to 1.66)**	**1.58 (1.50 to 1.66)**	**1.65 (1.50 to 1.80)**
		Cardiovascular disease	Least	-	0.95 (0.86 to 1.05)	1.05 (0.78 to 1.38)
			Most	**1.54 (1.37 to 1.73)**	**1.46 (1.33 to 1.61)**	**1.38 (1.16 to 1.64)**
		Cerebrovascular disease	Least	-	1.02 (0.82 to 1.24)	1.21 (0.68 to 1.96)
			Most	**1.33 (1.04 to 1.68)**	**1.36 (1.11 to 1.64)**	1.33 (0.91 to 1.87)
		Respiratory disease	Least	-	**1.19 (1.02 to 1.39)**	1.35 (0.86 to 1.95)
			Most	**2.05 (1.73 to 2.41)**	**2.21 (1.92 to 2.53)**	**2.38 (1.89 to 2.95)**
		Chronic liver disease	Least	-	1.14 (0.60 to 2.17)	1.57 (0.28 to 5.50)
			Most	**3.71 (2.07 to 7.16)**	**2.71 (1.62 to 5.04)**	**4.71 (2.32 to 9.79)**
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	Least	-	1.04 (0.98 to 1.10)	1.03 (0.80 to 1.20)
			Most	**1.65 (1.55 to 1.76)**	**1.68 (1.60 to 1.77)**	**1.57 (1.43 to 1.72)**
		Cerebrovascular disease	Least	-	0.97 (0.85 to 1.11)	0.93 (0.61 to 1.35)
			Most	**1.58 (1.35 to 1.84)**	**1.48 (1.30 to 1.68)**	**1.31 (1.03 to 1.66)**
		Respiratory disease	Least	-	1.04 (0.98 to 1.09)	0.96 (0.84 to 1.09)
			Most	**2.03 (1.92 to 2.15)**	**2.11 (2.01 to 2.21)**	**2.02 (1.88 to 2.18)**
		Chronic liver disease	Least	-	1.08 (0.70 to 1.82)	0.83 (0.16 to 2.82)
			Most	**5.17 (3.39 to 8.16)**	**4.58 (3.12 to 7.01)**	3.92 (0.22 to 6.84)
Particulate matter ($PM_{2.5}$)	Mortality rate ratio (95%CI)	***All-cause***	Least	-	1.04 (0.98 to 1.10)	1.08 (0.91 to 1.18)
			Most	**1.57 (1.49 to 1.70)**	**1.58 (1.50 to 1.67)**	**1.61 (1.48 to 1.74)**
		Cardiovascular disease	Least	-	0.96 (0.87 to 1.07)	0.97 (0.79 to 1.18)
			Most	**1.57 (1.38 to 1.78)**	**1.48 (1.34 to 1.63)**	**1.40 (1.20 to 1.62)**
		Cerebrovascular disease	Least	-	1.05 (0.86 to 1.29)	1.11 (0.74 to 1.59)
			Most	**1.41 (1.07 to 1.84)**	**1.33 (1.09 to 1.63)**	**1.50 (1.09 to 2.01)**
		Respiratory disease	Least	-	**1.21 (1.04 to 1.42)**	1.26 (0.89 to 1.60)
			Most	**2.15 (1.79 to 2.59)**	**2.19 (1.90 to 2.53)**	**2.34 (1.91 to 2.85)**
		Chronic liver disease	Least	-	1.14 (0.60 to 2.08)	1.43 (0.40 to 4.09)
			Most	**4.29 (2.33 to 8.30)**	**2.86 (1.67 to 5.20)**	**3.71 (1.92 to 7.50)**
	Morbidity rate ratio (95%CI)	***Cardiovascular disease***	Least	-	1.05 (0.99 to 1.11)	0.95 (0.77 to 1.06)
			Most	**1.60 (1.48 to 1.72)**	**1.71 (1.62 to 1.80)**	**1.56 (1.44 to 1.69)**
		Cerebrovascular disease	Least	-	0.99 (0.86 to 1.13)	0.79 (0.59 to 1.06)
			Most	**1.54 (1.29 to 1.83)**	**1.50 (1.32 to 1.71)**	**1.76 (1.46 to 2.12)**
		Respiratory disease	Least	-	**1.06 (1.01 to 1.12)**	0.94 (0.85 to 1.04)
			Most	**2.03 (1.91 to 2.15)**	**2.14 (2.04 to 2.24)**	**2.04 (1.91 to 2.18)**
		Chronic liver disease	Least	-	1.17 (0.72 to 1.88)	0.83 (0.63 to 1.88)
			Most	**4.75 (2.99 to 7.67)**	**4.58 (3.15 to 7.05)**	**4.58 (2.86 to 7.56)**

BOLD = Statistically significant result.
BOLD UNDERLINED = Statistically significant result; RR increased as area-level air pollution status worsened.

In ‘least’ deprived areas, rates of all-cause non-accidental and respiratory disease mortality rose as NO_2, PM_{10} and $PM_{2.5}$ air pollution status worsened, but associations were non-significant. In ‘most’ deprived areas, strong positive associations were observed between air pollutants and all-cause non-accidental and respiratory disease mortality (Table 6). In these areas, for these health outcomes, air pollution increased the significance of *deprivation-health* associations.

To illustrate this with an example drawn from the data (Table 7):

For PM_{10}, the respiratory mortality rate was a significant 2.05 times higher in ‘low’ polluted/‘most’ deprived areas (RR = 2.05; 95%CI: 1.73 to 2.41) compared with reference ‘low’ polluted/’least’ deprived areas. In ‘most’ deprived areas, associations strengthened as air pollution status worsened, becoming 2.21 times higher (RR = 2.21; 95%CI: 1.92 to 2.53) in ‘moderately’ polluted areas and 2.38 times higher (RR = 2.38; 95%CI: 1.89 to 2.95) in ‘high’ polluted areas. Similarly, the all-cause non-accidental mortality rate was a significant 1.56 times higher in ‘low’ polluted/‘most’ deprived areas (RR = 1.56; 95%CI: 1.46 to 1.66) compared with reference ‘low’ polluted/’least’ deprived areas. In ‘most’ deprived areas, associations strengthened as air pollution status worsened, becoming 1.58 times higher (RR = 1.58; 95%CI: 1.50 to 1.66) in ‘moderately’ polluted areas and 1.65 times higher (RR = 1.65; 95%CI: 1.50 to 1.80) in ‘high’ polluted areas.

Table 7. Air pollution-deprivation-health associations (extract from Table 6)

		Air pollution status (PM_{10})		
		Low	**Moderate**	**High**
All-cause mortality	Least deprived	-	RR = 1.02 (0.96 to 1.08)	RR = 1.06 (0.91 to 1.24)
	Most deprived	**RR = 1.56** (1.46 to 1.66)	**RR = 1.58** (1.50 to 1.66)	**RR = <u>1.65</u>** (1.50 to 1.80)
Respiratory disease mortality	Least deprived	-	**RR = 1.19** (1.02 to 1.39)	RR = 1.35 (0.86 to 1.95)
	Most deprived	**RR = 2.05** (1.73 to 2.41)	**RR = 2.21** (1.92 to 2.53)	**RR = <u>2.38</u>** (1.89 to 2.95)

BOLD = Statistically significant result
<u>BOLD UNDERLINED</u> = statistically significant result; rate ratio (RR) increased as area-level air pollution status worsened

These patterns of association, highlighted above in the context of PM_{10} pollution status association with all-cause and respiratory mortality, were also observed for NO_2 and $PM_{2.5}$ pollution status with the same health outcomes.

It should be noted that significant negative associations were found in 'most' income-deprived areas between: NO_2 and respiratory disease morbidity; PM_{10} and cardiovascular disease mortality, cerebrovascular and chronic liver disease morbidity; and $PM_{2.5}$ and cardiovascular disease mortality.

6.1.3 Summary of main findings

In summary, air pollution concentrations, especially NO_2, showed LSOA-level variation. Average air pollution concentrations were relatively high in both 'most' and 'least' deprived areas, but were highest in the former. Substantial local-level deprivation-related health inequalities were observed; the magnitude of *deprivation–health* associations was greater than *air pollution–health* associations. That said, not accounting for deprivation status, each pollutant was positively and significantly associated with all-cause non-accidental and respiratory disease mortality, and PM_{10} with respiratory disease morbidity too. When considered simultaneously, the interaction between air pollution and deprivation status modified and amplified associations with all-cause non-accidental and respiratory disease mortality endpoints, especially in 'most' deprived areas where Wales' most-vulnerable populations live. While action is needed to reduce air pollution concentrations and associated risks everywhere, for these health outcomes in these areas, lowering air pollution and deprivation status to that of 'low' polluted and 'least' deprived areas could achieve a substantial additional health gain.

The findings of this ecological study confirmed there is merit in routinely linking environmental, health and other relevant data to assess and understand air pollution problems and solutions in the context of wider health determinants. Further, the analyses of interactions between these inter-connected health influences suggested that greater health gain can be achieved by adopting a two-pronged approach to action to LAQM, namely: i) universal action to reduce risks for everyone; and ii) targeted action to reduce risks in places with poor air quality (but not necessarily at levels that breach standards) *and* poor population health status. With regards the latter, the current LAQM regime requires action to tackle local air quality problems in only those areas where Air Quality Objectives are [actually or likely] breached. Research Strand 1's new evidence highlighted the importance of targeting action in other areas where interactions between poor air quality and poor population health can compound problems and create disproportionate disease burdens. Such areas would benefit from integrated collaborative interventions that seek to simultaneously lower risks by reducing air pollution as well as individual and population-level susceptibility to effects of exposure.

The approach to LAQM advocated for here aligns with the principles of proportionate universalism, where the resourcing and delivery of universal services is at a scale and intensity proportionate to the degree of need. In the context of LAQM, the evidence generated here suggests that action is required to reduce air pollution universally, recognising that mass diseases and mass exposures require mass remedies (Rose, 1981). However, because some places have especially poor air quality, population health status and socio-economic status – and that interactions between these can create disproportionate health consequences – the intensity of action may need to be increased and better integrated with broader public health intervention to narrow the inequalities gap.

6.2 Findings from Research Strand 2's Delphi study

To recap, Research Strand 2 needed to answer the question:

How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?

The aim of this Research Strand was **to assess how a better-defined role for public health bodies and specialists in LAQM could increase awareness, integration and collaboration, and add value to existing LAQM arrangements**. Its objectives were:

i. To define the role and expected contribution of public health bodies and specialists in LAQM
ii. To describe the value added from better public health integration and collaboration
iii. to identify opportunities to improve public health awareness, integration and collaboration;
iv. to identify the barriers and solutions to improving awareness, integration and collaboration.

The results of the Delphi study are presented here.

6.2.1 Delphi panel characteristics and response rates

A heterogeneous and geographically-dispersed group of 167 possible participants from different disciplines were identified to take part in the Delphi study. Through their invitation, nine additional possible participants were peer-nominated and contacted. Of 176 possible participants, 87 returned consent forms and met eligibility criteria but one immediately withdrew because of other work pressures. Ultimately, 86 (49%) experts were recruited to the Delphi panel and assigned by the research team to one of the three sub-panels: 'public health', 'air quality management' or 'other'. Up-take rates across sub-panels showed some variation – 'public health' (35/80; 44%), 'air quality management' (31/60; 52%) and 'other' (22/36; 61%) – with public health specialists showing least interest in participating, relative to 'air quality management' and 'other' experts. That said, the actual number of public health experts recruited was still greater than in other sub-panels. Other than assigned group type, non-participants characteristics were unknown.

Feedback from the round 1 survey revealed that most (75%) panellists worked in Wales permanently, at practitioner level (41%) and were employed by the NHS (48%) (Table 8). While 77% of panellists reported undertaking public health-related work daily, just 23% said they did air quality management work at the same frequency. The Delphi panel comprised an experienced group of experts; 70% had >10 years relevant work experience, and 77% held masters-level or higher qualifications.

Table 8. Delphi panel characteristics

Characteristic	**Panel feedback**
Employer	Local government (30%): National Health Service (48%); civil service (12%); academic (6%); other (4%)
Position held	Practitioner (41%); manager (26%); 'other' including consultant (15%); advisor (12%); researcher (6%)
Work in Wales	Permanently (75%); frequently (9%); occasionally (16%)
Do public health work	Daily (77%); few times/week (3%); few times/month (10%); few times/year (3%); never (7%)
Do air quality work	Daily (23%); few times/week (15%); few times/month (20%); few times/year (30%); never (12%)
Years of relevant experience	5-10 (30%); 11-19 (33%); 20-29 (26%); 30+ (11%)
Highest relevant qualification	Bachelor's degree (23%); masters/other degree (61%); doctorate (16%)

Panel response rates were 78%, 80% and 76% in rounds 1, 2 and 3, respectively (Figure 25). Sub-panel response rates across survey rounds ranged from 83% to 91% in 'public health', 66% to 72% in 'air quality management', and 68% to 77% in 'other'. Despite decreasing over consecutive survey rounds, uptake was consistently highest in the 'public health' sub-panel.

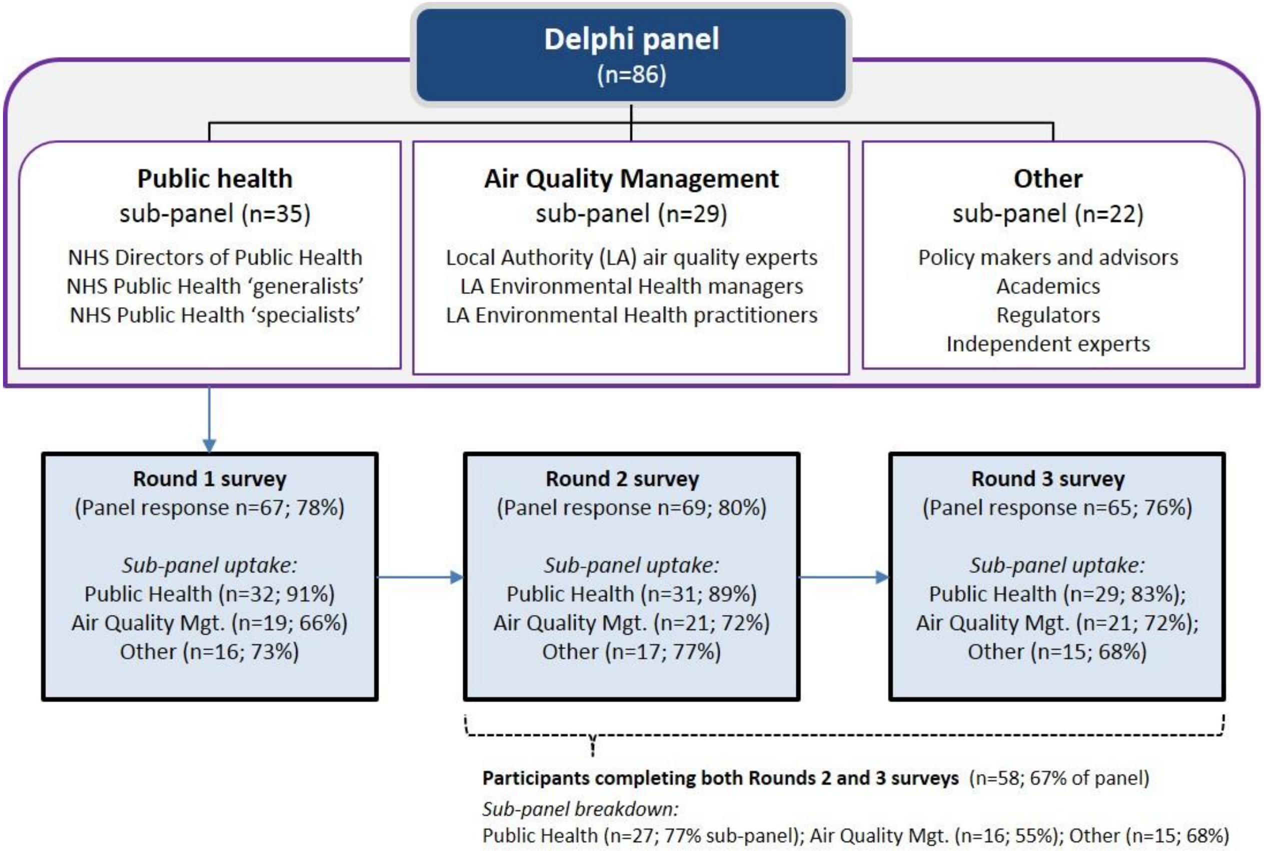

Figure 25. Delphi panel composition and extent of participation by survey round

6.2.2 Role of public health bodies and specialists in LAQM

Main findings are presented here. Supplementary analysis results are provided in Appendix G.

In round 1, suggested roles of public health bodies and specialists in LAQM included the need to support broader mainstream risk assessment and management efforts and enabling functions such as communications, evidence appraisal and research, advocacy and leadership (Table 9).

In round 2, the median response value to each suggested role item was at least 4 ('agree') in each sub-panel. Two suggested roles relating to evidence interpretation and raising public and professional awareness (items 1.4 and 1.12) scored universal median response values of 5 ('strongly agree'). Good consensus – indicated by the symbol '+' in Table 9 – was achieved across all sub-panels for 17 (85%) items. Very good consensus – denoted by the symbol '++' in Table 9 – was achieved for items relating to risk assessment, understanding broader public health consequences and developing health-focused policy and practice in the 'other', 'public health' and 'air quality management' sub-panels, respectively (items 1.3, 1.7 and 1.15).

Table 9. Suggested role of public health bodies and specialists in LAQM

Ref.	**Role of public health bodies and specialists in LAQM** (suggested by panellists in Round 1)	**Public health sub-panel**			**Air qual. mgt. sub-panel**			**Other sub-panel**		
		R	**C**	**S**	**R**	**C**	**S**	**R**	**C**	**S**
1.1	Help others assess air pollution risks in the broadest possible public health context	5	+		5	+		4	+	
1.2	Use expertise and resources to share, link and analyse data to assess risks and impacts	5	+		5	+		4	+	
1.3	Determine how air pollution-related risks vary *between* and *within* communities	5	+		4	+		4	++	
1.4	Interpret evidence, and use it to set shared priorities and inform others' decisions	5	+		5	+		5	+	
1.5	Advocate for, and support evidence reviews to, assess intervention effectiveness	5	+		4	+		4	+	
1.6*	Undertake new research to evaluate the air pollution *and* health impacts of action	4	+	✓	4	+	✓	4	+	✓
1.7	Understand broader public health consequences of action to reduce air pollution/risks	5	++		5	+		4	+	
1.8*	Provide independent scrutiny of evidence-based and innovative action	5	+	✓	4	+	✓	4	+	✓
1.9	Work with others to promote and facilitate active-travel for all	5	+		4	+		4	+	
1.10	Work with others to improve public health and reduce susceptibility to air pollution	5	+		4	+		5	+	
1.11*	Champion the principles of environmental sustainability in and beyond the NHS	5	+	✓	4	+	✓	4	+	✓
1.12	Raise professional and public awareness of air pollution as a health priority	5	+		5	+		5	+	
1.13	Let others know 'what works' to reduce air pollution and associated risks	5	+		4	+		5	+	
1.14	Work with others to provide timely advice to the public on how to minimise risks	5	+		5	+		4	+	
1.15	Help others locally to develop health-focused LAQM policy and practice	4	+		4	++		4	+	
1.16	Use local-level learning to inform national-level policy development	4	+		4	+		4	+	
1.17	Connect LAQM policy and practice with other public health priority work areas	4	+		4	+		4	+	
1.18	Advocate for, and support, integrated air pollution/public health action everywhere	4	+		4	+		5	+	
1.19	Advocate for, and support, targeted action in 'high risk' areas to reduce inequalities	4	+		4	+		5	+	
1.20	Help shape others' policy and practice to reduce air pollution-linked health risks	4	+		4	+		5	+	

The results from Round 2 (or Round 3, if the item did not initially achieve consensus) are provided to the right of each suggested item

R = RESPONSE median (Likert scale: 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree)
C = CONSENSUS extent (- = consensus not achieved (inter-quartile range (IQR) = >1.0); + = good consensus (IQR = 1.0); ++ = very good consensus (IQR = <1.0))
S = STABILITY of round 2→3 responses (✓ = no significant change, *p*-value = >0.05; ✗ = significant change, *p*-value = <0.05); no data = consensus achieved Round 2
***** = item did not achieve consensus in survey round 2 and was carried over to round 3; only round 3 result shown

The 'public health' sub-panel failed to reach consensus agreement on items linked with undertaking new research and providing independent scrutiny of action (1.6 and 1.8), and the 'other' sub-panel on the statement about public health acting as champions for environmental sustainability improvement (1.11). These three items – marked with an asterisk after the item number in Table 9 – were taken forward for re-consideration in Round 3.

In Round 3, the three carried-over items were unanimously agreed, with good consensus and response stability, the latter being annotated with a '✓' symbol. Ultimately, all 20 suggested role items were agreed by sub-panels.

6.2.3 Opportunities to increase public health awareness, integration and collaboration

Main findings are presented here. Supplementary analysis results are provided in Appendix G.

In Round 1, suggested opportunities to increase public health integration and collaboration included: influencing Government LAQM policy development, calling for air pollution problems and solutions to be considered in a broader public health context, and action to extend beyond localised 'hotspots' (Table 10). Panellists commented that reducing air pollution and risks should not be regarded as an isolated priority; they felt that integrating LAQM with broader public health policy and practice can increase opportunities for joint work-planning around shared problems, effective collaboration, informed policy development and co-ordinated action. Opportunities offered by the requirements of Wales' WFGA were specifically mentioned. Finally, it was considered that the high levels of interest in air pollution and health matters amongst professionals, politicians and public also presented worthwhile opportunities to raise awareness, engage stakeholders and stimulate further debate.

Table 10. Suggested opportunities to increase public health awareness, integration and collaboration

Ref.	**Opportunities to increase public health integration and collaboration in LAQM** (suggested by panellists in Round 1)	Public health sub-panel			Air qual. Mgt. sub-panel			Other sub-panel		
		R	C	S	R	C	S	R	C	S
2.1	Capitalise on political, media and public interest in air pollution as public health priority	4	+		5	+		4	+	
2.2	Evidence of no 'safe' air pollution exposure level encourages action beyond 'hotspots'	4	+		5	+		4	+	
2.3	Evidence calls for air pollution problems/solutions to be considered in broader context	5	+		4	+		5	+	
2.4*	LAQM responsibilities are devolved; opportunities exist to enhance the regime in Wales	4	+	✓	4	+	✓	4	+	✓
2.5	Welsh Government is reviewing existing LAQM arrangements so influence is timely	4	+		4	+		4	+	
2.6*	The WFGA 2015 calls for environmental sustainability action that can support LAQM	5	+	✓	4	+	✓	4	+	✓
2.7	In Wales, there is a focus on prevention; 'treating' effects is no longer acceptable	5	+		4	+		5	+	
2.8	Wales' national air quality indicator can help inform local action and evaluations	4	+		4	+		4	+	
2.9*	Public Health Wales is well-placed to encourage action across wider NHS and beyond	4	+	✓	4	++	✓	4	+	✓
2.10	Good rapport between Welsh Government and other bodies can facilitate change	4	+		4	+		4	+	
2.11*	The Welsh Air Quality Forum offers opportunities to increase collaboration and action	4	-	✓	4	+	✓	4	+	✗
2.12	WFGA Public Service Boards are required to agree and address joint priorities	5	+		4	+		4	+	
2.13	Public bodies are encouraged to work regionally on priorities that cross boundaries	4	+		4	+		5	+	
2.14	Understanding broader links can help align public health and LAQM action	4	+		4	+		5	+	
2.15	Increasing collaboration (especially academics) can create research opportunities	4	+		4	+		5	+	
2.16	Communicating messages in a public health context can influence broader audiences	4	+		4	+		4	+	
2.17	Good, less technical, communications can increase understanding and engagement	4	+		4	++		4	++	
2.18	Good quality local-level data can inform risk assessments, surveillance and action	4	+		5	+		5	+	
2.19*	There is currently an increased willingness to share data, intelligence and expertise	3	+	✓	4	-	✓	4	+	✓
2.20	Public health specialists have expertise to support Local Authority-led risk assessments	4	+		4	+		4	+	

The results from Round 2 (or Round 3, if the item did not initially achieve consensus) are provided to the right of each suggested item

R = RESPONSE median (Likert scale: 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree)
C = CONSENSUS extent (- = consensus not achieved (inter-quartile range (IQR) = >1.0); + = good consensus (IQR = 1.0); ++ = very good consensus (IQR = <1.0))
S = STABILITY of round 2→3 responses (✓ = no significant change, *p*-value = >0.05; ✗ = significant change, *p*-value = <0.05); no data = consensus achieved Round 2
***** = item did not achieve consensus in survey round 2 and was carried over to round 3; only round 3 result shown

In Round 2, median response values for each item were at least 4 (‘agree’) across ‘public health’ and ‘air quality management’ sub-panels. In the main, this was the case in the ‘other’ sub-panel, except for a median response of 3 (‘indifferent’) for item 2.19 which was concerned with willingness to share data and other information. Good response consensus was achieved within each sub-panel for the same 16 (80%) items, including item 2.19. Consensus was not achieved for items relating to opportunities offered through devolved responsibilities, the WFG Act and wider NHS action (2.4, 2.6, 2.9) in the ‘other’ sub-panel, and through the Welsh Air Quality Forum (2.11) in the ‘public health’ sub-panel.

In Round 3, three of the five carried-over items relating to devolved responsibilities, the Wellbeing of Future Generations (Wales) Act and the contribution of the wider NHS (2.4, 2.6 and 2.9) achieved stable consensus agreement in each sub-panel. The remaining two items (2.11 and 2.19) failed to reach universal stable consensus agreement. Ultimately, all sub-panels agreed with, and achieved good and stable consensus on, 18 (90%) items.

6.2.4 Value added of increased public health awareness, integration, collaboration in LAQM

Main findings are presented here. Supplementary analysis results are provided in Appendix G.

In Round 1, panellists reported that increasing public health integration and collaboration in LAQM could add real value. This may be in the form of, for example, more efficient, creative and productive collaboration, more meaningful risk assessment, better-informed action, connected and integrated policy and practice, effective communications, and robust research and evaluation (Table 11).

Table 11. Suggested value added from increased public health integration and collaboration in LAQM

Ref.	**Added value of increased public health integration and collaboration in LAQM** (suggested by panellists in Round 1)	Public health sub-panel			Air qual. Mgt. sub-panel			Other sub-panel		
		R	C	S	R	C	S	R	C	S
3.1*	Defining the public health role in LAQM can increase expertise, confidence and support	4	+	✓	4	++	✓	4	++	✓
3.2*	Increased public health support for Local Authorities can help increase capacity	4	+	✓	4	++	✗	4	+	✓
3.3	Improved public health support can facilitate broader air pollution risk assessment	4	+		4	+		4	+	
3.4	Understanding risks in a broader context can improve communications and their reach	4	+		4	+		4	+	
3.5	'Big picture' evidence can help link air pollution with other local public health priorities	4	+		4	+		5	+	
3.6	Making links with other priorities helps public health integrate LAQM with the 'day job'	4	+		4	++		4	+	
3.7	A broader outlook on LAQM helps connect it with 'prevention-focused' WFGA practice	4	+		4	+		4	+	
3.8*	Connecting policy and practice can create more efficient and effective ways of working	5	+	✗	4	+	✓	4	+	✓
3.9	Better integration can inform shared objective-setting, work planning and action	4	+		4	++		4	+	
3.10*	Better connection can encourage action to reduce risks for all *and* target 'at risk' areas	4	+	✓	4	+	✓	4	+	✓
3.11	Greater collaboration can lead to more creative and innovative solutions to problems	4	+		4	+		4	+	
3.12	Using public health to inform, educate and empower others can link 'whole systems'	4	+		4	+		4	+	
3.13	Effective LAQM policy and practice has potential to deliver multiple health co-benefits	4	+		4	+		4	+	
3.14*	Protecting public health through LAQM can reduce the burden on NHS services	5	+	✓	5	+	✓	4	++	✓
3.15	Better collaboration (especially academics) can create opportunities for new research	4	+		4	+		4	+	
3.16	New research in Wales can add to the evidence-base on intervention effectiveness	4	+		4	++		4	+	
3.17	Positive LAQM impacts can encourage future prevention-focused service investment	4	+		4	+		4	+	
3.18	Improving public health involvement can increase LAQM inclusiveness and transparency	4	+		4	++		4	++	
3.19	Raising LAQM's profile reduces the likelihood of missing opportunities to connect policy	4	+		4	+		4	+	
3.20*	Enhancing LAQM can act as an exemplar for evolving policy and practice in other areas	4	++	✓	4	+	✓	4	++	✓

The results from Round 2 (or Round 3, if the item did not initially achieve consensus) are provided to the right of each suggested item

R = RESPONSE median (Likert scale: 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree)
C = CONSENSUS extent (- = consensus not achieved (inter-quartile range (IQR) = >1.0); + = good consensus (IQR = 1.0); ++ = very good consensus (IQR = <1.0))
S = STABILITY of round 2→3 responses (✓ = no significant change, *p*-value = >0.05; ✗ = significant change, *p*-value = <0.05); no data = consensus achieved Round 2
***** = item did not achieve consensus in survey round 2 and was carried over to round 3; only round 3 result shown

In Round 2, median response values for each item were at least 4 ('agree') across all sub-panels. Good consensus was achieved universally for 14 (70%) items. There was no dissent in agreement amongst 'air quality management' sub-panel members for items highlighting added value resulting from linking LAQM with other public health priorities, sharing priority-setting and work-planning, connecting policy and practice around universal and targeted action, undertaking new research, improving LAQM transparency, and applying learning from LAQM enhancement to other public health priorities (3.6, 3.9, 3.10, 3.16, 3.18 and 3.20). The same was true in the 'other' sub-panel for these latter two items, as well as another relating to the benefits of defining the role of public health in LAQM (3.1). The 'air quality management' sub-panel failed to reach consensus agreement on item 3.1, the 'public health' sub-panel on items 3.2 (increased capacity), 3.8 (more efficient and effective ways of working) and 3.20 (applying learning from LAQM enhancement elsewhere), and the 'other' sub-panel on items 3.10 (connecting policy and practice around universal and targeted action) and 3.14 (reducing healthcare service burdens).

In Round 3, all six carried-over items achieved good consensus agreement across sub-panels, but responses over rounds 2 and 3 were unstable for two of these – the item for increasing capacity (3.2) in the 'air quality management' sub-panel, and the item relating to more efficient and effective ways of working (3.8) amongst 'public health' experts. Ultimately, all sub-panels agreed with, and achieved good stable consensus on, 18 (90%) suggested added value items.

6.2.5 Barriers to increasing integration and collaboration

Main findings are presented here. Supplementary analysis results are provided in Appendix G.

In Round 1, suggested barriers that hinder increasing public health integration and collaboration in LAQM included air pollution being regarded as an isolated problem, and being perceived to be too technical and complicated for many to understand and resolve locally (Table 12). Additionally, local authorities and the NHS have assigned it low priority status with little accompanying support resource, and there is no formal requirement to act on problems beyond localised 'hotspot' areas.

Table 12. Suggested barriers to increasing public health awareness, integration and collaboration

Ref.	**Barriers to increasing public health integration and collaboration in LAQM** (suggested by panellists in Round 1)	Public health sub-panel			Air qual. Mgt. sub-panel			Other sub-panel		
		R	C	S	R	C	S	R	C	S
4.1	Air pollution has a relatively low profile in Local Authorities and across the NHS in Wales	4	++		4	++		4	+	
4.2	Most people, especially politicians and public, are unaware of problem scope/solutions	4	+		4	++		4	+	
4.3*	The NHS in Wales also perceives air pollution to be 'someone else's problem'	4	+	✓	4	+	✓	4	+	✓
4.4*	Too often, air pollution is seen as an isolated problem, rarely linked to other priorities	4	+	✓	4	++	✗	4	-	✓
4.5*	Air pollution is too technical; most people lack understanding and confidence to engage	4	+	✓	4	++	✓	4	+	✓
4.6*	LAQM is disconnected from many relevant aspects of public health policy and practice	4	+	✓	4	+	✗	4	++	✓
4.7	LAQM action is only required in areas where Air Quality Objectives are/likely breached	4	+		4	++		4	+	
4.8	LAQM is reactive; proactive public health/air pollution action is not encouraged	4	++		4	++		4	++	
4.9*	LAQM's risk assessment and action planning processes are cumbersome and confusing	4	+	✓	4	++	✓	3	+	✓
4.10	There is lack of guidance on comprehensive air quality public health risk assessments	4	+		4	+		4	+	
4.11*	Information governance and IT data systems/policies discourage data sharing/linking	4	++	✓	3	+	✓	3	+	✓
4.12	Information on air pollution mitigation intervention [cost] effectiveness is lacking	4	+		4	+		5	+	
4.13*	There is no 'one size fits all' answer to air pollution problems; solutions are complex	4	+	✓	5	+	✓	4	+	✓
4.14	It is perceived that air pollution needs a national solution and little can be done locally	4	+		4	++		4	+	
4.15	LAQM aims to reduce air pollution; it ignores complementary risk reduction approaches	4	+		4	+		4	++	
4.16*	It is becoming increasingly difficult to secure 'buy-in' from essential LAQM stakeholders	4	-	✓	4	+	✓	4	+	✓
4.17	Public health is disengaged from LAQM; role and expected contribution poorly defined	4	+		4	+		4	+	
4.18*	Public health specialists have received no training/guidance on how to support LAQM	4	++	✓	3	+	✓	3	+	✓
4.19*	Public health is part of NHS Wales and sits outside of Local Authority structures	4	+	✓	4	+	✓	4	+	✓
4.20*	Local Authorities tend not to engage with public health and academics on LAQM issues	3	-	✓	3	-	✓	3	+	✓

The results from Round 2 (or Round 3, if the item did not initially achieve consensus) are provided to the right of each suggested item

R = RESPONSE median (Likert scale: 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree)
C = CONSENSUS extent (- = consensus not achieved (inter-quartile range (IQR) = >1.0); + = good consensus (IQR = 1.0); ++ = very good consensus (IQR = <1.0))
S = STABILITY of round 2→3 responses (✓ = no significant change, *p*-value = >0.05; ✗ = significant change, *p*-value = <0.05); no data = consensus achieved Round 2
***** = item did not achieve consensus in survey round 2 and was carried over to round 3; only round 3 result shown

In Round 2, median responses across sub-panels for 13 (65%) items were at least 4 (‘agree’). For remaining items, at least one sub-panel had a median response value of 3 (‘indifferent’). Good consensus was achieved across sub-panels for 10 (50%) items; the level of consensus achieved for item 4.8 (LAQM being too reactive) was universally very good. All sub-panels failed to reach consensus on item 4.19 which related to the position of the main public health body in Wales outside local authority structures.

In Round 3, four of 11 carried-over items reached good consensus agreement across sub-panels with response stability. For each of the remaining seven items, at least one sub-panel failed to agree, reach consensus or deliver stable responses. Ultimately, all sub-panels agreed with, and achieved good stable consensus on, 13 (65%) suggested barriers.

6.2.6 Solutions to increase integration and collaboration

Main findings are presented here. Supplementary analysis results are provided in Appendix G.

In Round 2, panellists suggested a range of solutions to highlighted barriers. These included specifying the role of public health bodies and specialists in LAQM and increasing engagement through multi-sector local/regional air quality management groups; and evolving policy to extend LAQM’s scope to consider air pollution in the context of wider health determinants. Also, encouraging universal risk reduction action alongside more-targeted intervention; integrating LAQM with the ‘day job’ across the public health workforce; appraising evidence; communicating risks, behaviour change and action effectiveness; and, making work placements and funding available to facilitate investment and action (Table 13).

Table 13. Suggested solutions to increasing public health awareness, integration and collaboration

Ref.	**Solutions to barriers to increase public health integration and collaboration in LAQM** (suggested by panellists in Round 1)	Public health sub-panel			Air qual. Mgt. sub-panel			Other sub-panel		
		R	C	S	R	C	S	R	C	S
5.1	Extend the scope of LAQM to require targeted *and* universal local action	4	++		4	++		4	++	
5.2	Shift LAQM accountability from Local Authorities to WFGA Public Services Boards	2	+		2	+		2	+	
5.3	Statutorily require Public Health Wales and Health Boards to support all parts of LAQM	4	-		4	++		4	-	
5.4	Specify the LAQM role of NHS public health bodies and specialists in supporting LAQM	4	++		4	++		4	++	
5.5	Prescribe a broader LAQM risk assessment approach to stimulate NHS interest/action	4	++		4	++		4	+	
5.6	Promote LAQM integration with the 'day job' for health specialists (all disciplines)	4	+		4	++		4	++	
5.7	Target action in poor air pollution *and* health areas to reduce risks and inequalities	4	+		4	+		5	+	
5.8	Fully integrate Health Impact Assessment principles and processes with LAQM action	4	+		4	++		4	+	
5.9	Tighten Air Quality Objectives to support delivery of an extended LAQM regime	4	+		3	+		4	+	
5.10	Create multi-sector local or regional LAQM groups	4	+		4	+		4	+	
5.11	Raise profile of LAQM in/across Welsh Government to improve cross-sector working	4	+		4	+		4	+	
5.12	Use independent public health voice to advocate for LAQM change, as necessary	4	+		4	+		4	+	
5.13	Invest in technology; making it easier to 'see' air pollution can stimulate interest/action	4	+		5	+		4	-	
5.14	Establish recurring funding stream for air quality and environmental sustainability work	4	+		4	+		4	++	
5.15	Make public health bodies statutory consultees in planning processes	4	+		4	+		4	-	
5.16	Interpret and communicate evidence, and encourage new research and evaluation	5	+		4	+		5	++	
5.17	Work closer with communities to raise awareness; undertake 'citizen science' research	4	++		4	++		4	++	
5.18	Train all public health specialists on LAQM risk assessment, management and evaluation	4	+		4	+		4	+	
5.19	Raise awareness amongst public bodies, policy-makers, politicians and public	4	+		4	+		4	+	
5.20	Create and support air pollution/health placements and projects across public bodies	4	+		4	++		4	+	

The results from Round 2 (or Round 3, if the item did not initially achieve consensus) are provided to the right of each suggested item

R = RESPONSE median (Likert scale: 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree)
C = CONSENSUS extent (- = consensus not achieved (inter-quartile range (IQR) = >1.0); + = good consensus (IQR = 1.0); ++ = very good consensus (IQR = <1.0))
S = STABILITY of round 2→3 responses (✓ = no significant change, *p*-value = >0.05; ✗ = significant change, *p*-value = <0.05); no data = consensus achieved Round 2
***** = item did not achieve consensus in survey round 2 and was carried over to round 3; only round 3 result shown

In Round 3, median response values for most items were at least 4 ('agree') across all sub-panels. The exceptions were: the suggested solution of shifting LAQM accountability from local authorities to WFG Act Public Services Boards (which all sub-panels reached consensus disagreement with), and another concerning tightening statutory national air quality standards (which the 'air quality management' sub-panel was 'indifferent' about. Ultimately, consensus agreement was achieved for 15 (75%) items across all sub-panels.

6.2.7 Consensus variation, convergence and divergence

In summary, agreement with good consensus (and response stability where appropriate) was achieved across all sub-panels for 84/100 items. Those experts in the 'public health' sub-panel reached agreement with consensus on 93 items, 'air quality management' experts on 91 items, and 'other' experts on 90 items (Table 14).

Table 14. Summary of item opinion convergence and divergence by sub-panel

	Delphi sub-panel	No. items agreed, with consensus (round 2)	No. items carried forward	No. items agreed, with consensus and stability (round 3)	Final no. items agreed, with consensus and stability
Suggested roles	Public health	17 of 20	3	3 of 3	20
	Air quality management	17 of 20		3 of 3	20
	Other	17 of 20		3 of 3	20
Suggested opportunities	Public health	19 of 20	5	3 of 5	18 (not 2.11, 2.19)
	Air quality management	17 of 20		4 of 5	19 (not 2.19)
	Other	16 of 20		4 of 5	19 (not item 2.11)
Suggested added value	Public health	17 of 20	6	5 of 6	19 (not 3.8)
	Air quality management	19 of 20		5 of 5	19 (not 3.2)
	Other	18 of 20		6 of 6	20
Suggested barriers	Public health	15 of 20	11	9 of 11	18 (not 4.16, 4.20)
	Air quality management	15 of 20		6 of 11	15 (not 4.4, 4.6, 4.11, 4.18, 4.20)
	Other	12 of 20		6 of 11	15 (not 4.4, 4.9, 4.11, 4.18, 4.20)
Suggested solutions	Public health	19 of 20 (not 5.3)	N/A		
	Air quality management	18 of 20 (not 5.2, 5.9)			
	Other	17 of 20 (not 5.3, 5.13, 5.15)			

A total of 25 items failing to achieve consensus agreement in Round 2 were carried over for reconsideration in Round 3. Of these, 14 (56%) subsequently achieved universal consensus agreement with response stability. This result is characteristic of the Delphi process where participants have regard to the opinions of others in the sub-panel and gradually move closer to agreeing as a group. Overall, 47% of responses to Round 3 carried-over items were revised by participants; this broke down as 37%, 44% and 69% in the 'public health', 'air quality management' and 'other' sub-panels, respectively.

6.2.8 Summary of main findings

The Delphi method proved successful in eliciting multiple viewpoints from a range of experts on this complex research problem. It helped generate valuable evidence that can be used to inform the future development of LAQM to maximise public health integration, collaboration and impact.

Experts in each sub-panel ultimately achieved consensus agreement on all **suggested roles** for public health in LAQM. These included:

- supporting risk assessments of air pollution in the context of wider determinants;
- integrating air pollution and risk mitigation with the 'day job' to address linked priorities;
- undertaking research and evaluation;
- appraising and interpreting evidence.

Experts agreed that these roles, together with the application of other core public health skills such as authoritative communication, advocacy and leadership, could inform evidence-based LAQM policy development and more effective implementation. The only item (in the entire study) to achieve universal strong consensus agreement was the suggested public health role to raise professional and public awareness of air pollution as a health priority.

Experts reached consensus agreement (with response stability, where appropriate) on most **suggested opportunities** to increase public health integration and collaboration. These included: transferring existing public health skills to help improve air quality risk assessments and surveillance, communicate with broader audiences in less technical ways to raise awareness and encourage stakeholder 'buy in', and influence policy development. Some policy advances in Wales that require public bodies to work collaboratively in more sustainable ways across regions, and encourage universal action to complement targeted intervention to reduce air pollution, risks and inequalities, were also seen as positive drivers for change.

Two suggested items were not universally accepted. The first: experts in all three sub-panels agreed that the existing Welsh Air Quality Forum (which helps local authorities translate LAQM policy into consistent practice across Wales) could increase public health collaboration and action, but public health and 'other' experts could not reach consensus and/or response stability on this item. Since the Welsh Air Quality Forum partnership is local authority and LAQM compliance-focused, this finding suggests that very few non-local authority experts know about it or are engaged in its work. The second: neither public health nor air quality management experts were confident that an increased willingness to share data, intelligence and expertise existed. Possible explanations for this include public health experts not understanding the LAQM process, and air quality experts being unfamiliar with public health data and analytical capabilities on offer.

The **value added** from better public health integration and collaboration was significant:

- increased public health expertise and confidence and LAQM support;
- improved risk assessment and understanding;
- evidence-based universal and targeted action to reduce inequalities;
- better alignment of action with other public health interventions.

In turn, more creative and productive collaboration could result, along with more effective communications, good opportunities for research and evaluation, connected policy, and prevention-focused investment. Two suggested items were not universally accepted. The first: despite strongly agreeing (with good consensus) that better connected policy and practice could create more effective and efficient ways of working, public health expert responses were unstable. This result suggests that the majority of public health experts came into the Delphi process with only a limited understanding of how their work linked with air quality management, but over time – learning from others' opinions and changing their own – started to identify overlaps and recognise opportunities for greater connection and collaboration. The second: air quality management experts achieved consensus agreement (without response stability) with the item proposing that increased public health support for local authorities would help increase capacity. It is possible that this finding stems from the majority of air quality management experts being unfamiliar with the role of public health experts since relatively few actively support LAQM at present and they struggled to grasp what any increased support and capacity might look and feel like for them in reality.

Several **barriers** were thought to hinder action in this area. The following items achieved consensus agreement (with response stability where appropriate):

- the public health role in LAQM is poorly defined;
- air pollution has a low profile in local authorities and health services;
- the topic is perceived as too technical and too complicated to attempt to resolve locally;
- disconnected policy;
- the scope of LAQM prescribed processes is narrow and action is restricted to AQMAs.

Some suggested barriers failed to achieve agreement and/or consensus and/or response stability too. These included:

- public health specialists receiving limited training and guidance;
- problems sharing and linking data;
- weak relationships with public health and academic partners;
- LAQM processes being too cumbersome.

It is possible that some experts raised uncertainty around these latter points because they felt that others were better placed to consider them, or were not sufficiently familiar with LAQM processes and lacked confidence to comment. Nevertheless, these findings add weight to the argument that LAQM (and its relevance in a broader public health context) is not well-understood across relevant professional groups.

Finally, to address identified barriers, a number of **solutions** were agreed by experts with consensus:

- extending the scope of LAQM;
- improving communications to raise the profile of air pollution as a public health priority;
- letting people – both professionals and the public – know what can be done to tackle it;
- making funding available to support prevention-focused investment and sustainable action.

Other suggested solutions, specific to public health expert development, included: clarifying the role of public health in LAQM, highlighting opportunities for a broader public health audience to integrate aspects of LAQM with the 'day job', and providing training and resources to support work in this area. Just one item achieved universal disagreement with consensus; this was concerned with shifting LAQM accountability responsibilities away from local authorities to WFG Act-required Public Services Boards.

6.3 Mixing, validating and evolving research outcomes

The ‘mixing’ phase of the convergent parallel study design facilitated multiple-source data validation, across-method triangulation, and the further exploration of findings and evolution of research outcomes. Findings from both the research update and development workshop and subsequent case study discussion meetings are presented here.

6.3.1 Findings from the research update and development workshop

Of 86 Delphi experts invited to the research update and development workshop, 56 (65%) attended. Adopting the same Delphi sub-panel categories, discussion groups comprised: 22 ‘public health’ experts, 20 ‘air quality management’ specialists, and 14 'other' experts.

To set the scene for the workshop, participants were presented with a summary of findings from the literature review and Research Strand 1’s ecological study, and suggestions of how these linked with, and complemented, Research Strand 2’s Delphi study-generated evidence. The added value of better public health integration and collaboration in LAQM (Figure 26) (achieved through broadening the public health scope of LAQM and defining the public health role in the regime) was described in the context of the existing LAQM framework (Figure 27).

Figure 26. Broad public health roles in LAQM (left) and added value of better public health awareness, integration and collaboration in LAQM (right) – as suggested by Delphi panellists

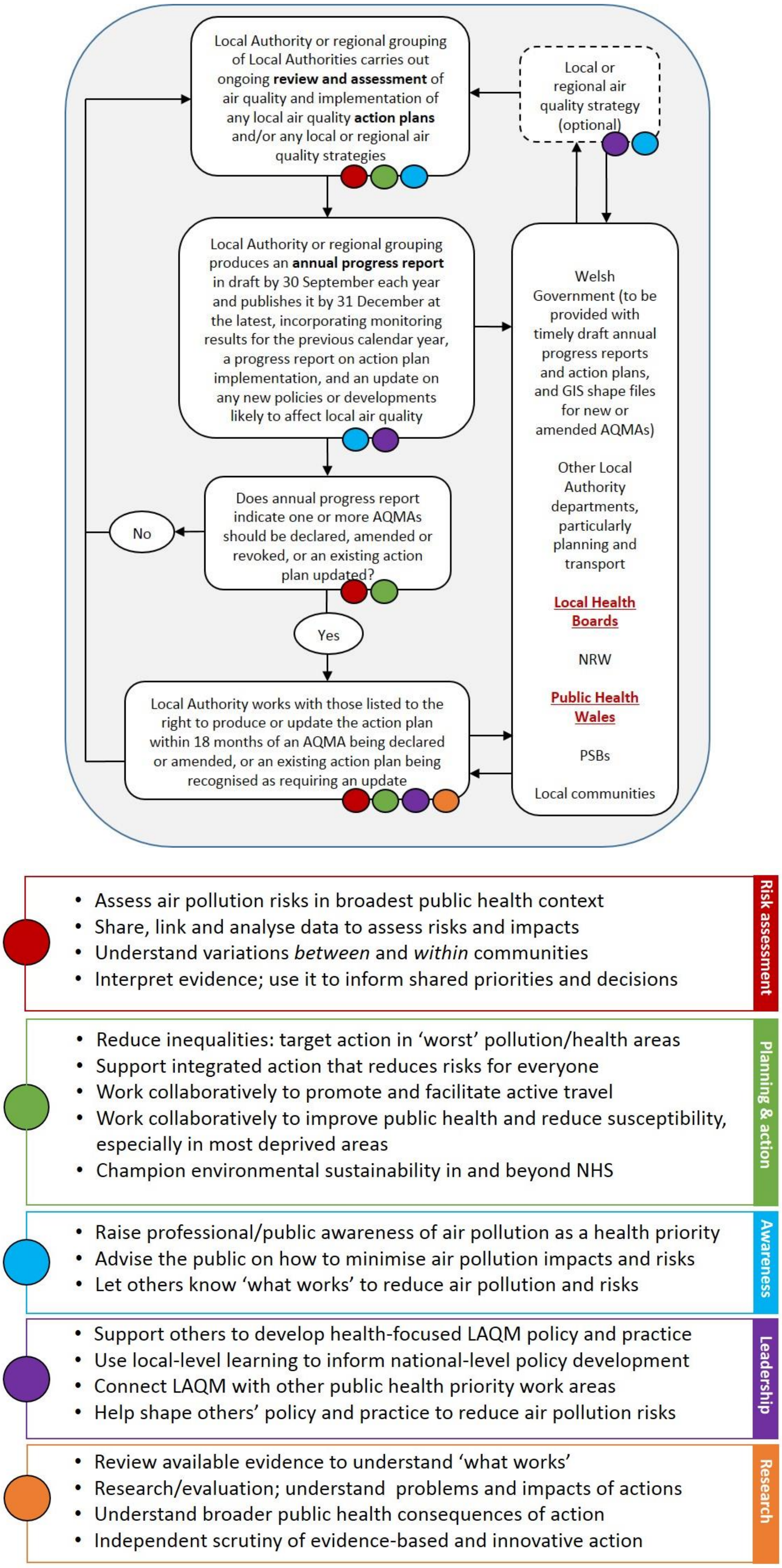

Figure 27. The public health role LAQM, in context of existing arrangements

While these enhancements could facilitate better public health integration, interaction and support in LAQM, it was acknowledged that achieving them would not be straight-forward. As derived from the Delphi study, the countering suggested opportunities and barriers for change were highlighted.

With emphasis placed on Delphi study-derived suggested solutions (Table 15), participants engaged in practical exercises to explore *how* these LAQM enhancements could be achieved in practice.

Table 15. Solutions to facilitate better public health awareness, integration, interaction, support in LAQM

Suggested solution	**Description**
1. Specify and communicate the public health role in LAQM	To describe the ways in which public health bodies and specialists can support LAQM. Effective communication is required to reach out to specialists from different disciplines to raise awareness of roles, highlight the added value of improved integration and collaboration, and guide practice.
2. Prescribe broader LAQM approach to stimulate interest and integration	Considering air pollution problems and solutions in a broad public health context can improve understanding of their links with wider health determinants. Making LAQM of relevance and importance to more stakeholders (especially across the NHS) can stimulate interest and promote integration, collaboration, action and investment.
3. Extend LAQM scope to encourage targeted and universal action	LAQM currently requires action in only those areas with actual or likely Air Quality Objectives breaches. While it is accepted that greater efforts will be needed to tackle problems in the worst affected areas, there remains a need to act universally to reduce risks for everyone. LAQM action should not be restricted to worst affected areas.
4. Integrate LAQM with the 'day job' for public health specialists (all disciplines)	Making LAQM relevant and important to more Public Health specialists (i.e. those working outside of 'health protection') can stimulate interest and improve integration, collaboration and action. For example, improved links between those working on LAQM and physical inactivity/active travel can create efficiencies, solutions and impacts.
5. Focus on reducing air pollution and inequalities	A complementary LAQM approach of targeted and universal action can facilitate proportionate action to reduce inequalities. This is a public health priority; this solution stresses the importance of understanding relationships, and linking action on air pollution with that aiming to address wider health determinants.
6. Integrate Health Impact Assessment	Health Impact Assessment is a formal process to understand the impacts (both positive and negative) of a policy or action on population health. Incorporating it into LAQM decisions could help improve outcomes.
7. Create multi-sector local or regional	Establishing local or regional LAQM-specific groups may bring more stakeholders together from across different sectors and disciplines to

LAQM expert groups	facilitate joint assessments, work planning, integration and action. At present, multi-agency groups are formed in problem areas only to implement action plans; this solution suggests convening a wider remit group (with broader membership, including NHS and public) to consider targeted *and* universal action across bigger areas such as Health Boards.
8. Interpret and share evidence; encourage research/evaluation	Better evidence synthesis and interpretation can improve understanding of intervention effectiveness. Findings must be communicated to share best practice and inform decisions and actions. If evidence gaps are identified, public health (with academics) could add value by undertaking research and evaluations.
9. Raise awareness amongst public bodies, policy-makers, politicians and public	Increasing awareness of air pollution problems (especially in a broader public health context i.e. relative to, and links with, other priorities) can raise the profile, and encourage greater engagement, commitment, support, investment and action. There may be a need to work harder to improve communications /reach certain groups.
10. Raise profile of LAQM in/across Welsh Government departments to help cross-sector working	Raising awareness of LAQM's broader links with other sectors and systems (e.g. health, planning, transport, sustainability) across Welsh Government departments can facilitate improved understanding, more connected and integrated policy development (e.g. LAQM and public health), and investment. If policy officials and politicians acknowledge links and provide support, this could pave the way for more creative and effective action at local and regional levels amongst public bodies.
11. Use public health independence to advocate for LAQM change, as necessary	Public Health bodies and specialists, while part of the NHS in Wales, have a responsibility to provide independent, evidence-based advice and support to partners. Using this advocacy role to greater effect in LAQM can help achieve impartial policy and practice changes. Further, public health specialists can provide independent scrutiny in LAQM.
12. Establish funding to support air quality improvement action	There is no dedicated LAQM funding stream. Given the links between air pollution, transport, planning, health and other systems, creating a recurring funding stream to support air quality improvement action (accessible across a broad range of sectors, disciplines and communities) would help. Funding for research and evaluation is essential.
13. Work with communities: raise awareness, change behaviour	Engaging and involving the public in air quality improvement work is crucial. Raising awareness with the public can not only help improve understanding around problems but can highlight measures to take to reduce risks , change individual and community behaviours to help solve problems, and support 'citizen' research and evaluations.
14. Train public health specialists on all aspects of LAQM	A training package, tailored to meet public health specialists' needs, could help raise awareness, promote a better and consistent understanding of the role of Public Health in LAQM, and facilitate action that is integrated with 'the day job' for many. Training provision should be ongoing, not a 'one-off'.
15. Create and support work placement and air pollution/health project options	Creating opportunities for Public Health specialists to work with other partners on air quality projects (including initiatives, research and evaluations) can help encourage greater integration and collaboration. Work/project placements need to be formally recognised and supported (including funded, as appropriate) by and across public bodies.

Through the task set in the first practical exercise, each discussion group proposed a number of enablers that could help achieve the Delphi study-generated suggested solutions (Table 16).

Table 16. Enablers that could help achieve the Delphi study-generated suggested solutions

Suggested solutions	**Suggested enablers**
1. Specify and communicate the public health role in LAQM	a. Develop new guidance to clarify LAQM public health roles; promote and facilitate engagement b. Identify air pollution as shared strategic priority to maximise joint working c. Advocate to drop the 'L' from LAQM to encourage regional collaboration
2. Prescribe broader LAQM approach to stimulate interest, integration, interaction	a. Work to draft joint air quality and health responses to maximise influence on planning system decisions b. Raise public awareness of behaviour-change interventions that deliver air pollution <u>and</u> health benefits c. Help develop new national policy and support infrastructure to require broader approach and joint working
3. Extend LAQM scope to encourage targeted and universal risk reduction action	a. Help support development of local/regional air quality strategies to specify LAQM dual approach b. Identify air pollution as a shared priority to raise profile and change approach c. Apply evidence; call to extend LAQM scope to require action in <u>and</u> beyond hot-spots
4. Integrate LAQM with the 'day job' for public health specialists (all disciplines)	a. Share existing, and develop new, training resources; integrate with CPD b. Meet regularly with LAQM specialists (regionally); align priorities and action c. Promote relevance of LAQM across public health; encourage joint action d. Encourage Directors of Public Health to prioritise LAQM action – supported by Health Boards and Welsh Govt. e. Recognise air quality as a public health priority in shared plans and actions
5. Focus on reducing air pollution inequities and health inequalities	a. Target action in health hotspots (as well as most polluted areas); consider wider deprivation links b. Connect LAQM with wider work to reduce health inequalities c. Target action in schools to raise awareness (e.g. link to Eco Schools)
6. Integrate Health Impact Assessment into LAQM process	a. Recognise HIA role in LAQM in regulations to support the new Wales Public Health Bill b. Require integration of HIA (and through it, LAQM) with the planning system c. Evaluate use/impact of HIA in LAQM annual review assessments over time
7. Create multi-sector local or regional LAQM expert groups	a. Meet regularly as part of an LAQM local/regional collaboration and develop regional air quality progress reports and strategies b. Identify funding to develop resources to support local/regional collaboration c. Improve regional multi-agency working by making use of public health skills e.g. risk assessment data analysis and communications, and research
8. Interpret and communicate evidence; encourage research and evaluation	a. Know the evidence and communicate it widely e.g. highlight merits of acting to reduce risks beyond air pollution hotspots b. Support the development of best practice guidance to support risk assessment data analysis, communications and intervention evaluation c. Identify, invest in and use more effective methods to communicate and engage the public; note methods will differ by target audiences

9. Raise awareness amongst agencies, policy-makers, politicians, public	a. Publish, share and communicate new evidence regularly b. Increase use of social media to convey air pollution messages to a broad audience c. Support partners and the public to clean air strategies to raise awareness
10. Raise profile of LAQM in/across Welsh Govt. departments to facilitate cross-sector working	a. Support Government policy officials to work across divisions to reach out and make subject relevant to others e.g. health, planning and transport b. Support professional groups to raise awareness with Government policy officials across divisions and through politicians c. Engage and support LAQM partner collaboration to find the "hook" that succeeds in extending appeal to "new" partners
11. Use public health independence to advocate for LAQM change, as necessary	a. Gain public/ partner trust; authoritative communications can empower people and support change advocacy b. Work with academics so research is easier to do, understand and apply c. Speak up to ensure Welsh context is considered in any UK LAQM changes d. Advocate for more accountability in air quality management action
12. Establish funding to support collaborative air quality improvement action	a. Assess level of resource required to support LAQM collaboration and action; determine whether existing resources can be reconfigured or re-allocated b. Identify and seize opportunities to access funding (e.g. Lottery) to implement air quality improvement projects and action c. Help others to identify and seize opportunities to cross-fund linked air quality and transport improvement projects d. Raise awareness of air pollution, public health, transport and planning links amongst policy makers at national level e. Assess feasibility of national hypothecation of vehicle taxes to fund air quality improvement action ('polluter pays')
13. Work with communities: raise awareness, change behaviour	a. Introduce a mechanism to support air pollution 'alert' messaging to raise public awareness and reduce risks b. Support the development of regional supplementary planning guidance that can help raise public awareness and support lifestyle change c. Help develop regional air quality strategies to raise public awareness, change behaviour and encourage support for local initiatives
14. Train public health specialists on all aspects of LAQM	a. Carry out scoping exercise to determine which public health 'groups' should know more about air pollution and LAQM, and agree what they should know b. Develop online training support resources and other materials that can help raise awareness amongst public health specialists c. Ensure that public health specialists know about available on-line resources and refer to in regular formal training d. Advocate for public health training and curriculum changes to emphasise importance of air quality as a health priority
15. Create and support work placement and air pollution/health project options	a. Broaden the remit of the existing Welsh Air Quality Forum and identify a range of projects that would benefit from a joint LAQM and public health approach; seek to implement b. Produce a directory of air quality and public health expertise and skills to help develop an on-line information network; identify strengths/weaknesses c. Work with universities; identify students wishing to do public health and air quality improvement projects and link with new skills/expertise network

Through the task set in the second practical exercise, using a prioritisation scoring matrix, the above enablers for each solution were scored and ranked in terms of attributes of importance, cost, feasibility and potential impact (Appendix H). All groups chose to score those solutions and associated enablers they suggested in the first workshop, but some groups also progressed to score others' solution-related enablers because they recognised overlaps across solutions and enablers.

While a total of 52 enablers were proposed (all scored in Appendix H) to help achieve the 15 pre-identified solutions to enhance LAQM through better public health integration, interaction and support, the top-ranking enablers (by solution) are summarised here for ease of reference (Table 17):

Table 17. Top-ranking solution-specific enablers

Solution	**Top-ranking enabler(s)**
1. Specify and communicate role of Public Health bodies and specialists in supporting LAQM	Advocate to drop the 'L' from LAQM to encourage regional collaboration and action
2. Prescribe a broader LAQM approach to stimulate interest, integration, collaboration and action	Help develop new national policy and support infrastructure to require broader approach and joint working
3. Extend scope of LAQM to encourage targeted and universal risk reduction action	Identify air pollution as a wellbeing priority to raise profile and need for dual approach
4. Promote LAQM integration with the 'day job' for public health specialists (all disciplines)	Encourage Directors of Public Health to prioritise LAQM action – supported by Health Boards and Welsh Government
5. Focus on reducing air pollution inequities and health inequalities	Target action in health hotspots (as well as most polluted areas); consider wider deprivation links
6. Integrate Health Impact Assessment (HIA) process/ principles with LAQM regime	Recognise role of HIA in LAQM to support the new Wales Public Health Act, and to require integration of HIA (and through it, LAQM) with the planning system
7. Create multi-sector local or regional LAQM groups	Identify funding sources to help develop resources to facilitate local/regional collaboration
8. Interpret and communicate evidence, and encourage new research and evaluation	Know the evidence and communicate it *and* identify, invest in and use more effective methods to communicate and engage the public; note methods will differ by target audiences
9. Raise awareness in public bodies, policy-makers, politicians and public	Publish, share and communicate new evidence regularly

10. Raise LAQM profile in/across Welsh Govt. to support cross-sector working	Support professional groups to raise awareness with policy officials across divisions and through politicians
11. Use independent public health voice to advocate for LAQM change	Speak up to ensure the Welsh context is considered and reflected in any UK LAQM changes
12. Establish funding stream to support collaborative LAQM action	Raise awareness of air pollution, public health, transport, planning links with national policy makers
13. Work with communities: raise awareness, change behaviour and 'citizen science' research	Help develop regional air quality strategies to raise public awareness, change behaviour and encourage support for local initiatives
14. Train public health specialists on LAQM risk assessment, management and evaluation	Develop online training support resources and other materials that can help raise awareness amongst public health specialists
15. Create and support opportunities for air pollution/public health work placements and projects	Broaden the remit of the existing Welsh Air Quality Forum and identify a range of projects that would benefit from a joint LAQM and public health approach; seek to implement

These findings added a further layer of detail to research outcomes from the literature review, ecological study and Delphi study. All new evidence, when mixed, validated, and evolved, informed the development of a conceptual framework for a public health-driven LAQM regime in Wales.

6.3.2 A public health-driven LAQM conceptual framework for Wales

The evidence-informed conceptual LAQM framework for Wales described a new approach to LAQM to maximise public health awareness, integration, collaboration and impact (Figure 28). To validate the framework, air quality management and public health experts scrutinised it during area-based case study interviews. This served to 'test' its appropriateness, applicability and acceptability. Deciding to make Health Board areas the focus for this was pertinent given that a top-ranked enabler called to "drop the 'L' from LAQM to encourage greater regional collaboration and action" (see Table 17).

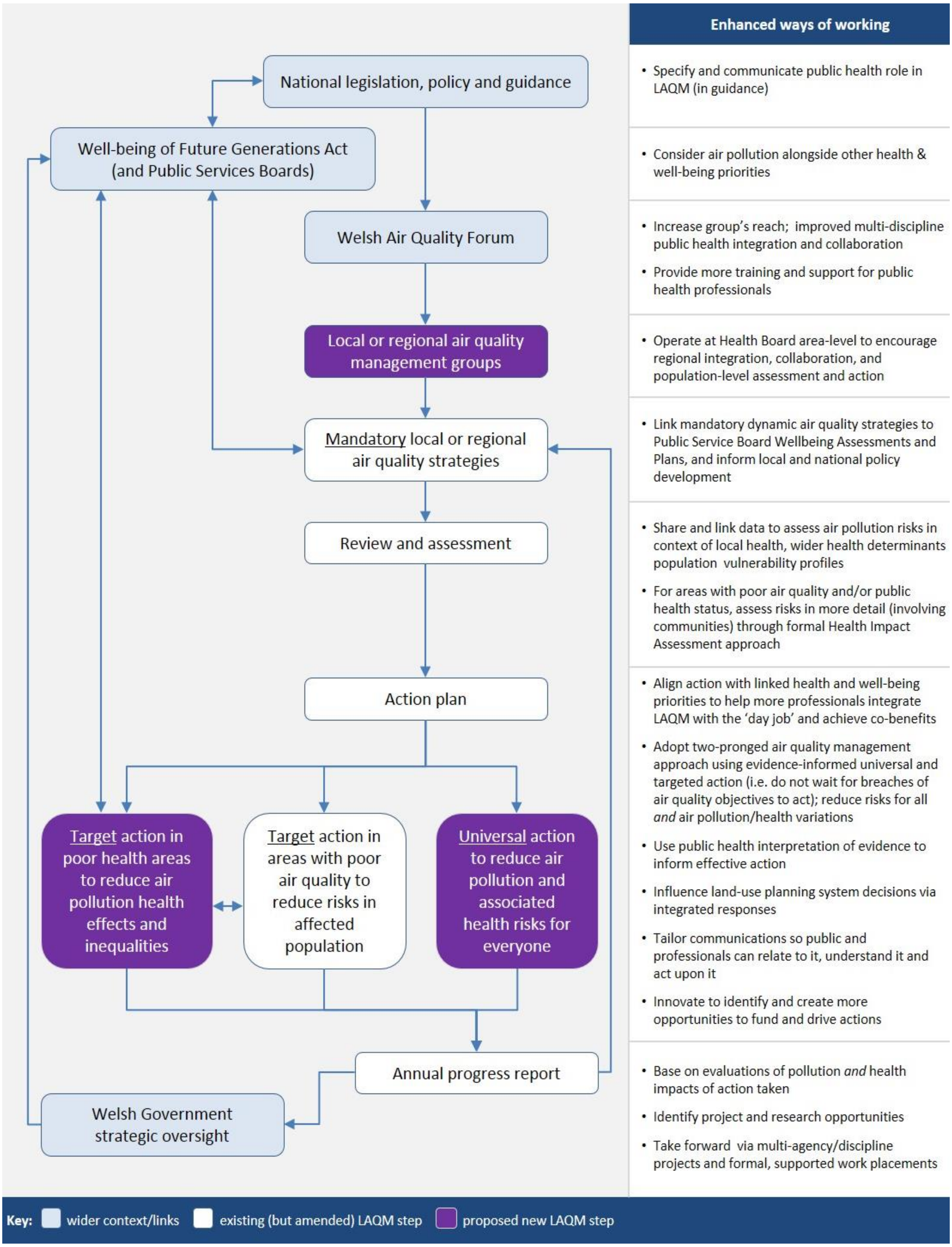

Figure 28. Evidence-based, public health-driven conceptual LAQM framework for Wales

The conceptual LAQM framework differed from existing LAQM arrangements in Wales in the following ways:

- It suggested that the role of public health bodies and specialists is recognised in LAQM, and that they are trained to develop a better understanding of LAQM so that they can deliver in this role;
- It presented the LAQM regime in a broader public health and wellbeing, planning and transport policy context, to emphasise that the regime should not be regarded as a standalone tool to address air quality and health problems;
- It stressed the importance of LAQM being connected with, and informing, national air quality management endeavours;
- It recognised, and proposed the evolution of, the role of the multi-agency Welsh Air Quality Forum at the Wales level, and recommended that Health Board area-level air quality management groups be established to implement LAQM locally/regionally;
- It called for the production of local air quality strategies to be mandatory, and linked with Public Services Board Wellbeing Assessments;
- It described a new approach to risk assessment where air pollution problems and solutions are considered in the context of wider health determinants, using Health Impact Assessment principles if appropriate;
- It proposed that air pollution mitigation actions should be aligned with other work to tackle linked health and wellbeing priorities, and that action should adhere to the principle of proportionate universalism i.e. that existing requirements to target action in poor air quality areas are complemented by requirements to target action in poor air quality areas (where AQOs may not necessarily be breached) and where population health status is poor, and requirements to take universal action to reduce risks for everyone;
- It proposed that LAQM is better integrated and aligned with the 'day job' for a broader (trained) public health workforce;
- It highlighted the need for better evidence interpretation to inform evidence-based action, and also more research and evaluations;
- It recognised the importance of ongoing protected funding to support sustainable action;
- It recommended that mechanisms be established to support multi-agency placements and projects;
- It also called for more effective risk communications amongst policy makers, politicians and the public, and suggested that streamlined annual progress reports should be considered by Public Services Boards to inform priority setting and work plan development.

6.3.3 Findings from the area-based case study interviews

A total of 18 experts participated in the four area-based case study interviews where the LAQM conceptual framework was evaluated. This comprised eight public health, and 10 air quality management, specialists.

Feedback from participants on the conceptual framework was extremely positive and constructive. A summary is provided here (Table 18) but more detail is available in Appendix I.

Table 18. Feedback on the appropriateness, applicability and acceptability of LAQM conceptual framework

Question	**Feedback from case study interviews**
How easy is it to understand and follow?	• Participants considered the framework easy to understand in the main. • Uncertainty around the read-across between 'enhanced ways of working' (right side of the figure) to the different LAQM stages (left side) made parts of it difficult to follow for some. • Some found the framework title confusing, stating that the framework being 'public health-driven' implied [incorrectly] that LAQM should be led and delivered by public health bodies and specialists. The term should refer to public health as a subject, not as an organisation. • While it was considered helpful to frame the framework in a broader policy context, doing so made it quite difficult to make a distinction between LAQM-specific components and those which are complementary to, but beyond, the remit of the regime. Alternative ways to present the framework were suggested e.g. a driver diagram or logic model; both approaches would highlight the need to link LAQM with, and help achieve the requirements and objectives of, 'bigger picture' public health legislation and policy. • Participants stated that the framework demonstrated the extra depth and breadth of LAQM activity that could result through better public health integration, interaction and support. • Benefits linked with evolving partnerships with others e.g. Welsh Air Quality Forum, Public Services Boards and academia, were acknowledged.

	• Clarification was sought on certain aspects of the framework and it was suggested that LAQM stages had accompanying timescales e.g. if local or regional air quality strategies are aligned with Public Services Board plans, then the former would need to adopt a five year cycle. • The specified steps of acting to reduce air pollution and risks for everyone, while also targeting action to reduce air pollution *and* health susceptibilities/ inequalities, were considered helpful. However, participants commented that it was unclear whether air quality management action plans must deliver against all, or just some of these, three risk reduction approaches. • Participants suggested that the flow of LAQM stages – from 'air quality strategies', through 'review and assessment' and 'action planning', to 'annual progress reporting' – was too linear, even misleading. Strategies offer the overarching local air quality management-related aim and objectives; delivery against strategic intentions comprises three main components: 'review and assessment', 'action planning' and 'progress reporting'.
Would you be happy to adopt the new way of working in your area?	• All participants were happy to adopt the proposed LAQM framework, but many could foresee problems with making changes to a well-established legal process. It was suggested that the 'new ways of working' principles would be easier to adopt and implement than a new formal LAQM process, and that the added value outcomes of this would be the same. • Most participants requested that the new LAQM framework is trialled in parts of Wales as a new way of working (and its impacts evaluated) prior to any wholesale roll out and adoption. • While it was recognised that local or regional air quality management groups are needed to drive and support LAQM-related activity, convening entirely new stakeholder groups may not always be necessary. It is possible that LAQM can be incorporated into work of existing partnerships which can be used as mechanisms to develop joint priorities, overlapping work plans and collaborative working opportunities to deliver LAQM objectives (linked with broader public health and wellbeing goals). The framework should be flexible on the step of forming local LAQM oversight groups (so developments align with local situations and needs).

	• Everyone noted the need for greater LAQM strategic direction, leadership and support locally. However, some thought that new, standalone local/regional strategies may not be needed. It may be more efficient reflect LAQM strategy in broader strategies e.g. Wellbeing Plans. • There was some concern that the conceptual framework's extra stages (compared with the existing process) introduced more work for LAQM stakeholders. In the context of decreasing resources to support LAQM delivery – particularly in local authorities – this was regarded as a problem and possible barrier to framework adoption. But, upon further consideration, all participants could see how better public health integration, interaction and support could actually increase process efficiencies rather than make LAQM more burdensome. • Since the LAQM framework is statutory, like other linked public health functions, producing a new local air quality strategy may be an unnecessary additional step in the new conceptual framework way of working. • Participants requested more guidance to help work through the proposed more comprehensive air pollution and public health risk assessments process. Further, the framework should clarify that this extra burden would not fall to local authority air quality management specialists alone; it would be shared with collaborating public health experts.
Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?	• All participants agreed that the framework could add value to existing LAQM arrangements. • There was general consensus that the conceptual framework did a good job of stressing the importance of assessing risks and acting to reduce them in areas where air pollution is having adverse impacts on public health but is not breaching air quality standards. The approach advocated by the conceptual framework – i.e. universal action to minimise risks for everyone, running in parallel with targeted air pollution reduction action – is key to reaching out to and engaging a wider public health audience. It relates to broader public health work (e.g. physical inactivity initiative) seeking to reduce health inequalities. • Considering air pollution in a broader public health context was perceived as a good way to make LAQM more relevant to a wider range of public

	health professionals. Participants suggested that, failing to consider the wider context would hinder collaboration and make the task of tackling problems more difficult; further, unintended adverse consequences could result from ill-informed decisions and actions. • Building on the preceding point, participants noted the importance of broadening the role and membership of the Welsh Air Quality Forum at an all-Wales level so that more public health specialists get involved. The more public health specialists know about air quality, the more informed they will be to link LAQM with their 'day job'. Further, if the Forum becomes a multi-sector leadership group, then there is more chance of it setting shared priorities for action and research that connect with broader public health and other priorities. • Providing tailored training could facilitate better public health engagement. • Participants said that the proposed framework would help rebuild lost stakeholder relationships by encouraging public health and local authority colleagues to come together to work towards a common goal: co-benefits of reduced air pollution, risks and inequalities.
Given your engagement in this research, would you add or change anything about it?	• Participants agreed that the framework was an accurate reflection of research outcomes, but some improvements were suggested. • The 'review and assessment' stage was said to require clarification that it calls for the implementation of a much more comprehensive risk assessment process that goes beyond air pollution risk assessment to consider risks in the context of wider health determinants. • Most participants agreed that the framework does a good job of stressing that the 'action plan' element of LAQM should frame a broader and more coherent LAQM approach with prioritised action based on a review and assessment of air pollution in the context of wider health determinants. However, some believed the 'action plan' step should be informed by the 'risk assessment' component. The framework has this the wrong way around. • More emphasis on the role of Health Impact Assessment in LAQM was requested, particularly how it can facilitate links with both reactive and proactive strategic planning e.g. Local Development Plans, carbon

	management plans and green travel plans. Since such assessments are used to inform decision-making around new policies and developments, it should feature in LAQM 'action planning' rather than 'review and assessment'. • As described above, participants argued that the 'mandatory air quality strategy' step is unnecessary if LAQM sits alongside broader local/regional strategic plans e.g. wellbeing plans, physical activity/active travel plans, transport plans, planning strategies. • Everyone felt that having local or regional air quality management groups would facilitate public health engagement and most certainly add value to LAQM work and reach, but only if the purpose and remit of these groups is specified. The framework should describe: whether groups should just focus on LAQM implementation, whether they endeavour to link LAQM with 'bigger picture' public health policy and practice, whether they hold stakeholders accountable for action or whether they do all these and more?
What do you think the most challenging aspects are to secure buy-in for and implement?	• The feedback received from all participants demonstrated that there was a real belief in the new ways of working proposed for LAQM in Wales. However, a number of air quality management and public health specialists raised concerns about the feasibility of changing a well-established, legislation-prescribed process such as LAQM. It was suggested that a more flexible approach is needed to guide and support stakeholders in achieving change locally. • Participants raised concerns in establishing ownership of local/regional air quality strategies. Based on existing requirements, local authorities were assumed to take on this role. But, if LAQM strategies formed part of broader strategic intentions 'owned' by local Public Services Boards then this might solve a number of problems around ownership, accountability and progress-reporting. Participants wanted the framework to be flexible on this; so long as the policy principle is clear and accepted, it is most appropriate to let each locality decide what works best for them (taking into account local circumstances and structures). This approach would also offer each area opportunities to define what is 'local' or 'regional'.

	• Another challenge was thought to be the new risk assessment approach proposed and the need for this step to be underpinned by mechanisms and commitments to share and link data and analytical expertise. This concern related to earlier comments about this being an extra LAQM dimension that has the unintended possibility of making LAQM more onerous. • Participants also said that it remains a challenge to produce so many LAQM-related reports. To secure buy-in from all stakeholders, there were requests for the new framework to offer a more streamlined approach to LAQM reporting i.e. through one review and assessment report that also specifies informed action - covering universal and targeted risk reduction action - and any other work that can improve understanding of new and emerging problems. This could be updated annually. The need to produce standalone plans for each Air Quality Management Area was considered short-sighted, overly bureaucratic and a waste of scarce time and other resources across already heavily-burdened air quality management and public health specialists. A separate brief progress report (just a couple of sides of A4) should be all that is required to inform the work of relevant local and regional partnerships. • Some were concerned that the framework was calling for public health to take over LAQM responsibilities from local authorities, and weaken or erode their statutory role/function in LAQM. Participants were reassured that this was not so and that the framework sought to introduce new way of working to add value to existing LAQM arrangements. • Some were also concerned that the suggested approach of assessing air pollution risks in a broader public health context, and acting to reduce risks for everyone, will only happen if made a formal requirement of the LAQM process and supported by policy and guidance. • There was general consensus that air quality management remains a daunting subject; its perception as a technical specialty/subject puts many practitioners off engaging in LAQM activity. In order to secure buy-in at local/regional levels, the framework must be kept simple to encourage understanding and engagement.

Do you think it will make a difference in practice in your area?	• A resounding 'yes' was received in response to this question. Everyone agreed that the proposed framework could help evolve LAQM into a public health-driven tool that can help air quality management specialists relate it to broader public health work, and *vice versa*. This was believed to be achievable through partners being able to embed the new ways of working in broader policy and practice (through relevant local and regional partnerships). • Participants summarised that the framework asks for more to be done, but justifies why. It describes how, through better public health engagement and synergies – extra work burdens can be shared so action becomes more efficient and effective. • The framework was seen to have the potential to improve public health integration and collaboration in LAQM and strengthen relationships with local authority stakeholders, especially environmental health professionals. In turn, collaboration and engagement would create opportunities to access more funding and resources to support action. • Participants recognised that the new framework could play an important role in organising efforts to tackle emerging problems as well as existing ones. This prevention-focused approach aligns with the requirements of the WFG Act sustainable ways of working.
What should happen next to turn theory into reality?	• Participants suggested several good examples of practical next steps, including seizing opportunities to refer to the new framework in relevant consultations so as to influence and inform policy and practice development. Specifically, participants thought it important to consider the framework in the context of calls to design new LAQM reporting tools. • The need to commence awareness-raising and training to support practical delivery of the framework was also recognised. Raising greater awareness around the proposed approach amongst policy officials was seen as a priority. With regards training, participants said that it would be a missed opportunity to train public health specialists in isolation - the added value of training public health specialists alongside other LAQM stakeholders could be substantial. • Participants wanted to identify areas in which to pilot the new way of working for LAQM. They suggested a briefing for Public Services Boards be

	drafted to seek to secure senior-level commitment to trial (and evaluate) the framework, highlighting its sustainable approach, policy connections and potential added value. • Participants suggested that the role and membership of the Welsh Air Quality Forum be reviewed and revised to take account of the new framework approach(es). • Finally, everyone thought it would be beneficial to connect LAQM work to Public Health Wales' research priorities to raise the profile across public health specialties and increase chances of funding to support research projects and cross-organisation work placements.

This feedback, obtained through area-based case study interviews, was overwhelmingly positive. In summary, public health and air quality management experts reported that they truly believed in the LAQM new ways of working and that they could maximise public health integration, collaboration impact. However, the concerns raised around the feasibility of changing the well-established, legislation-prescribed LAQM process were noted, as was the call for a more flexible approach to achieve the LAQM enhancements described in the framework.

7. DISCUSSION

Chapter overview

This seventh thesis Chapter discusses the results presented in Chapter six in the context of the research hypothesis and questions, and linked aim and objectives. The three main components of this project – 'Research Strand 1's ecological study', 'Research Strand 2's Delphi study' and 'mixing, validating and evolving research outcomes' – are considered in turn. Emphasis is placed on discussing how each has added to evidence and understanding.

The transition between research theory and practical action to achieve real-world change is explored next. Drawing together all evidence from across multiple sources, the discussion builds to present the final research outcome that specifies drivers for change (and linked recommended enabling actions) to enhance LAQM in Wales, underpinned by better public health awareness, integration and collaboration.

The Chapter closes with a reflection on research approaches and methods, and a discussion on the extent to which it is possible to have confidence in the outcomes achieved.

To lend structure to this discussion of research and its outcomes, it is useful to re-visit the research hypothesis and questions, and linked aim and objectives, agreed at the outset.

As set out in Chapter 4, it was hypothesised that **enhancing the LAQM regime – by broadening the public health scope of the regime's prescribed risk assessment and management processes and specifying the public health role therein – can maximise public health awareness, integration, collaboration and impact.** The overall aim of the research was therefore **to generate evidence to help enhance the Local Air Quality Management regime in Wales to maximise public health awareness, integration, collaboration and impact**, but two questions needed answering to achieve this:

i. **Is there merit in assessing and managing local air pollution risks in a broader public health context (than that currently prescribed), and advocating for action beyond Air Quality Management Areas?**
ii. **How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?**

The first research question was answered by Research Strand 1's ecological study which assessed the merits of broadening the scope of the prescribed LAQM risk assessment and management processes. The second question was answered by Research Strand 2's Delphi study which defined the role of public health in LAQM, and described the value added that could result from better integration and support. The third main research element, which involved mixing, validating and evolving research outcomes from both these Research Strands, together with evidence generated through the literature review, multi-disciplinary workshop and case study interviews, helped meet the overall research aim. These three main research components are discussed in turn.

7.1 Research Strand 1's ecological study

7.1.1 Answering research question 1

Q. *Is there merit in assessing and managing local air pollution risks in a broader public health context (than that currently prescribed), and advocating for action beyond Air Quality Management Areas?*

A. This ecological data-linkage study found that interactions between air pollution and deprivation status (the latter acting as a proxy for wider health determinants) modified and compounded associations with important health outcomes such as all-cause and respiratory disease mortality. It provided evidence that there is considerable merit in broadening the public health scope of LAQM's prescribed risk assessment and management processes, and highlighted that it is a mistake and a missed opportunity to consider air pollution concerns in isolation. Rather, given the interactions of air pollution with wider public health determinants, air pollution problems should be routinely assessed and managed in the context of wider public health priorities, and *vice versa*.

Further, the observed connectedness between air pollution and broader health-influencing factors made a compelling case for LAQM to adopt a new approach. This should involve universal action to reduce risks for everyone, enhanced through the targeted, more-intensive action in places with poor air quality (which may or may not breach standards) and population health status, in order to narrow inequalities gaps. This approach aligns with the principles of 'Rose's prevention paradox' (where population health gain is maximised through mass remedies) and of 'proportionate universalism' (where the resourcing and delivery of universal services is at a scale and intensity proportionate to the degree of need).

7.1.2 The evidence base prior to this research

The evidence for a socio-economic gradient in health is well-established. The average seven-year life-expectancy difference between 'most' and 'least' deprived areas in Wales (Welsh Government, 2015) and the UK (Marmot, 2010) is mostly attributed to multiple deprivation risk factors, especially lifestyle behaviours and choices (Frohlich and Abel, 2014). This study corroborated findings that *deprivation-health* associations are stronger than *air pollution-health* associations (Richardson *et al.*, 2013). However, as also found in this research, air pollution is a known environmental health determinant that adds to already-strong *deprivation-health* associations (Lim *et al.*, 2012). This is supported by unequivocal evidence of independent, likely causal relationships between air pollution exposure and cardio-pulmonary and other health impacts (World Health Organization, 2013).

Several studies have assessed air pollution and deprivation associations. In the US, Canada and New Zealand, higher air pollution levels have been reported in socioeconomically-disadvantaged compared with less-deprived communities (see Brochu *et al.,* 2011; Crouse *et al*., 2009; Pearce and Kingham, 2008; Su *et al.*, 2009; Yanosky *et al*., 2008; Pearce *et al*., 2006). This pattern appears to be mirrored in Asia and Africa too, although only limited evidence is available from research undertaken in these parts of the world (Hajat *et al*., 2015). However, the situation in Europe appears to be less straight-forward; findings from studies across Europe have generated mixed results (see Fernandez Somoano *et al.*, 2013; Deguen and Zmirou-Navier, 2010; Havard *et al.*, 2009; Briggs *et al.*, 2008; Walker *et al.*, 2006; Mitchell and Dorling, 2003; McLeod *et al.*, 2000). In the UK, Walker *et al*. (2006) reported findings that are consistent with those of this study, that both 'most' and 'least' deprived areas were disproportionately affected by high NO_2 concentrations. A number of possible explanations for these inconclusive research findings have been offered; all relating to characteristics of urbanised areas. For example, a study comparing local, regional and national-level associations between air pollution and socioeconomic factors in England and the Netherlands suggested that more-deprived areas are often in close proximity to mixed/high-traffic roads (Fecht *et al.*, 2015). A study exploring the same relationships (at local authority level) in England and Wales explained that areas of mixed deprivation are often adjacently-located in urban areas (McLeod *et al.*, 2000), which may be the result of city gentrification and land-use planning decisions (Fecht *et al.*, 2015). Lastly, although beyond the UK context, a study that examined the environmental inequity of traffic-related air pollution in Toronto, Canada, proposed those living in 'least deprived' urban areas tolerate more pollution in lieu of living, social and employment benefits (Buzzelli and Jerrett, 2007).

A number of studies have also explored air pollution and deprivation associations in the context of vulnerable people affected. Environmental justice analyses of air quality in the UK have found that children are disproportionately exposed (and are more vulnerable) to higher levels of air pollution (Mitchell and Dorling, 2003; Barnes and Chatterton, 2017). This present study found that 'most deprived' areas contained the highest proportion of children aged <15 years in any deprivation quintile (24%; estimated population: 122,458). Additionally, Laxen *et al*. (2014), unlike Fecht *et al*. (2015), found that older people were disproportionately exposed to air pollution in the city of Bristol, UK. This study identified that 'least' deprived areas had high air pollution concentrations and contained the highest proportion of older people aged 75+ years in any deprivation quintile (23%; estimated population: 57,332). Despite having a high proportion of older people, it should be noted that less-deprived populations are generally healthier and so are likely to be less susceptible to the effects of air pollution (Makri and Stilianakis, 2008).

A relatively small number of studies have extended the research boundaries beyond air pollution and deprivation to also consider health impacts. There is consensus agreement from these that area-level air pollution status is associated with significant increases in all-cause non-accidental, cardiovascular and respiratory disease mortality risk in high-deprivation compared with less-deprived areas (see Chi *et al.*, 2016; *Richardson et al.*, 2013; Richardson *et al.*, 2011; Pearce *et al.*, 2011; Pearce *et al*., 2010; Forastiere *et al.*, 2007; Naess *et al.*, 2007; Finkelstein *et al.*, 2005; Jerrett *et al.*, 2005; Villeneuve *et al*., 2003). Weak relationships of air pollution and deprivation with morbidity (respiratory hospital admissions) have been reported (Pearce *et al.*, 2011; Wheeler and Ben Schlomo, 2005). While it is often difficult to compare studies because of inconsistencies in research approaches and methods, in the main, interactions between air pollution and socio-economic factors have been found to modify and compound the health effects associated with each variable individually (Forastiere *et al.*, 2007; Zeka *et al.*, 2006; Jerrett *et al.*, 2004).
To summarise, a balanced review of European evidence suggests the general pattern is: that deprived people, while not always exposed to higher levels of air pollution, are more likely to suffer greater harm as a consequence of their exposure since they are more vulnerable to its effects (Deguen and Zmirou-Navier, 2010).

7.1.3 How this study has evolved evidence and understanding

This study did not intend to identify or assess new relationships between air pollution, deprivation and health outcomes. As discussed in the preceding section and Chapter 2, there is already comprehensive literature on this subject. Rather, to investigate the research problem of interest here, this Research Strand required local-level air pollution data to be linked, analysed and interpreted in the context of population-level wider health determinants data, in order to illustrate the importance and value added of doing so routinely in Wales.

Prior to this study, little was known about the relationships between air pollution, deprivation and health in Wales, especially at the local level. Findings raise important issues that should now inform debates around the future development of LAQM and public health policy and practice in Wales and beyond. The significant, and complex, interactions between these variables confirm that it is both a mistake and a missed opportunity to consider air pollution problems and solutions in isolation. Rather, air pollution should be regarded as a local public health priority that is inextricably linked with other behavioural, societal and environmental determinants of health. For example, people living in poorly-designed communities where sustainability and active travel is not promoted may be overly-dependent on the use of cars. This may lead to physical inactivity that, when coupled with other more-likely behaviours in most deprived areas such as high alcohol consumption, poor diet and smoking, increases the risk of poor health outcomes like cardio-respiratory diseases, obesity, diabetes, cancer and mental ill-health. This poor health status makes people susceptible to the effects of air pollution (which is highest in most deprived areas) and exacerbates problems.

Considering local problems and solutions in the broadest possible public health context must therefore be prioritised. Air pollution mitigation and public health intervention should be evidence-informed, targeted and co-ordinated. Public health bodies and specialists can make a valuable contribution to this work. Specifically, in the context of LAQM policy and practice, greater public health integration, interaction and collaboration in LAQM can add value through:

- *Risk assessment* – data sharing, linkage, analysis and interpretation can improve population risk assessments. Results will be more comprehensive, accurate and meaningful in terms of scoping problems, defining at-risk populations, and understanding relationships, causes and solutions. Appreciating this 'big picture' can inform targeted risk communications and interventions.
- *Management* – better collaboration and joint action can help achieve air quality and public health co-benefits e.g. active travel interventions that encourage walking and cycling over vehicle use. Also, implementing strategies to improve individual and community baseline-health status can reduce susceptibility e.g. promoting nutrition, smoking cessation and service access, educating and enabling people to change behaviours, and helping design sustainable and healthy communities by separating people from pollution sources (Giles *et al.*, 2011).
- *Intervention and policy development* – facilitating intervention evaluations (assessing air pollution reduction *and* health impacts together) to determine what works in real-world

situations. Also, advocating for, and providing authority, leadership and autonomy to bring about evidence-based change through stronger policy connection and change.

The connectedness between air pollution and broader health-influencing factors observed in this study made a compelling case for LAQM to adopt a new approach. It showed that it remains important to reduce air pollution exposures and associated risks for everyone, but also that greater public health gains (maximised risk reduction and minimised inequalities) can result from reducing air pollution and exposure potential alongside efforts to tackle broader health determinants in areas where health needs are high. Typically, this is in 'most' deprived and polluted areas where, as this study found, rates of cardio-respiratory mortality could be up to 2.4 times lower if air pollution and income-deprivation status were reduced to those of 'low' polluted and 'least' deprived areas.

To achieve this, a dual approach to air quality management is required which should involve universal action to reduce risks for everyone, enhanced through the targeted, more-intensive action in places with poor air quality (which may or may not breach standards) <u>and</u> population health status, in order to narrow inequalities gaps. This approach aligns with the principles of 'Rose's prevention paradox' (where population health gain is maximised through mass remedies) and of 'proportionate universalism' (where the resourcing and delivery of universal services is at a scale and intensity proportionate to the degree of need).

Examples of universal actions that all areas could benefit from include:

- <u>Assessing air pollution risks in the broadest possible public health context</u> – a more comprehensive understanding of the interactions between air pollution, health and wider social determinants would generate evidence to inform shared and aligned priority setting, planning and action;
- <u>Communicating risks with the public</u> – not only because people *should* be informed about risks, but because they *want* and *expect* to be informed. It is important that information and advice is co-ordinated across public bodies so as not to confuse or dilute important messages.
- <u>Driving forward planning policy that is considerate of public health and linked wider social determinants context</u> – this can embed principles of evidence-based air quality management and environmental sustainability in planning policy and practice. Not only can

this help tackle and avoid worsening of existing local air pollution problems, it can also help prevent new ones occurring in places where air quality is currently good.

- Strategic planning and engaging senior local decision-makers to lead and support action – make tackling existing air pollution problems (and preventing new ones occurring) strategic priority amongst senior local policy and decision-makers. Achieving this through advocacy and leadership can facilitate the development of shared goals and purposeful, co-ordinated action across public bodies, with communities. Further, professionals can work others to help them accurately predict the likely health consequences of different options early on in and decision-making process and so make informed decisions based on all the relevant scientific evidence.
- Promoting and facilitating active travel – it is best practice to put in place a combination of measures to help increase acceptability, appeal and safety in active travel i.e. cycling and walking over vehicle use. There are multiple benefits associated with this, including reduced air pollution road transport sources, increased levels of physical activity, reduced adverse health outcomes (such as obesity, diabetes and cardiovascular disease), and reduced levels of susceptibility to the effects of air pollution exposure generally. Encouraging active travel, especially for short journeys, should be complemented by other initiatives that push the use of more sustainable forms of travel (e.g. public transport) for longer journeys.
- Championing air quality improvement amongst public and private sector bodies – air pollution mitigation should be championed in a broad environmental sustainability improvement context. Opportunities should be seized to influence ways in which organisations operate to reduce environmental impacts e.g. assess air quality impacts of policies and decisions (including through proportionate use of health impact assessments), invest in sustainable local services, upgrade equipment/technology, estates and vehicle fleets to reduce emissions, and promote environmental sustainable behaviours across staff bodies.

Examples of intensified actions that may be best targeted in areas where air quality is poorest and health needs are greatest include:

- Enhancing communications (tailored to address known localised problems) – members of the public should be reminded that they can act to realise opportunities to improve their own health e.g. through reducing personal exposure to air pollution, reducing personal contributions to air pollution, and/or supporting and advocating actions to tackle air pollution locally. Increasing public awareness around, and involvement in, local initiatives can also lead to greater opportunities to measure air pollution and evaluate intervention impacts.

- Developing supplementary guidance to place additional requirements on planning decision-makers – this could be air quality, health specific, or both. The premise of supplementary guidance is that it requires that additional measures (over and above more general best practice principles) that prevent developments that are likely to lead to further local air quality or community health status deterioration.
- Implementing area-specific interventions to reduce air pollution – for example, through Clean Air Zones, a package of complementary interventions can be delivered which may include: low emission zones, congestion charging zones, behaviour change programmes that promote smoother driving styles and less accelerating/decelerating in built-up areas, 20mph limits, low/zero emission sustainable travel options, greener vehicle fleets, zero emission last mile delivery initiatives and engine idling enforcement schemes.
- Implementing area-specific interventions to reduce individual and population susceptibility – for example, intensified behaviour change and healthy lifestyle promotion initiatives that seek to promote and facilitate active travel, require increased physical activity through GP exercise referral schemes, targeted smoking cessation services and healthy eating campaigns, medicines management initiatives.

7.2 Research Strand 2's Delphi study

7.2.1 Answering research question 2

Q. *How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?*

A. The consensus-forming Delphi study specified the role of public health in LAQM. This includes public health bodies and specialists: supporting public health risk assessments, integrating action to reduce air pollution, risks and inequalities with the 'day job' to help address linked priorities and achieve co-benefits, undertaking research and evaluation, and appraising and interpreting evidence. Experts suggested that these roles, along with the application of other core public health skills such as effective and authoritative communications (to raise professional and public awareness), advocacy and leadership could inform evidence-based LAQM policy and practice development and implementation.

The value added through better public health integration and collaboration in LAQM was considered significant. It included: increased public health expertise and confidence and LAQM support, improved risk assessment and understanding, evidence-based universal and targeted action to reduce inequalities, better alignment of action with other public health interventions. In turn, more creative and productive collaboration could result, along with more effective communications, good opportunities for research and evaluation, connected policy, and prevention-focused investment.

Several opportunities were proposed to help achieve this added value. Opportunities were countered with several barriers that might hinder progress, but experts agreed that a number of solutions existed to overcome these.

7.2.2 The evidence base prior to this research

This study corroborated others' research findings (Everard *et al*., 2013), that the effects-based approach of LAQM is narrow in scope. This is because the current approach encourages LAQM work to take place in isolation; there is no requirement to acknowledge the significant overlaps that exist with other public health priorities and work to tackle wider health determinants at population level. It is important to understand air pollution problems and solutions in this broader public health context to maximise health gain and reduce health inequalities (Jerrett *et al*., 2001) since acting on a limited understanding of scope and relationships, or worse ignoring them altogether, might exacerbate or create new problems (Bowen, 2002). The ‘big picture’ evidence needed to inform LAQM risk assessments and action can be generated by drawing upon public health expertise around data sharing, linkage, analysis and interpretation (Brunt *et al*., 2016a).

The regime also has a history of poor, low-profile risk communications which can be improved if better-informed and supported by public health specialists (Barnes *et al*., 2014; Beattie *et al*., 2001). Also, there is the need to draw upon public health expertise around evidence appraisal, research and evaluation to improve LAQM impact by communicating information about what actions, in what combination(s), are most effective (Policy Exchange, 2013).

As for the Delphi technique, this has evolved into a valid, reliable and widely-accepted research method. As was the case here, the approach is best suited for use in circumstances where scientific knowledge of an issue is scarce, (Crutzen *et al*., 2008), where research problems cannot be precisely analysed but benefit from subjective opinion, and where study populations are not easily reached as they are geographically and professionally diverse (Green *et al.*, 1999). Delphi has been used with success in other areas of environmental and public health research (e.g. Moynihan *et al*., 2015; Bailey *et al*., 2012; Aarts *et al*., 2011; Ratnapradipa *et al*., 2011; Waterlander *et al*., 2009) as well as policy evaluation and development (e.g. Hsueh, 2015; Sherriff, 2014; Frewer *et al*., 2011).

7.2.3 How this study has evolved evidence and understanding

This study made a substantial contribution to the evidence-base in this research field. There have been previous calls for the reorientation of LAQM such that public health is a core driving principle rather than merely a hopeful outcome (Brunt *et al.*, 2016a). In response, this study generated much-needed, previously unavailable, evidence that can be used to inform and support future LAQM enhancements that can maximise public health integration, collaboration and impact.

The Delphi method confirmed and clarified the significant contribution that public health bodies and specialists could and should make to LAQM. This essential guidance has been lacking since the regime’s inception – its absence is largely responsible for the growing disconnect between LAQM and public health agendas evident today. The value added, arising from a more public health focused and supported LAQM regime, was also presented, and was regarded as considerable.

This study went beyond role specification. Expert opinion elaborated on opportunities, barriers that might hinder, and solutions that might enable, 'real world' policy and practice change. On occasion, panellists' opinions were specific to the situation in Wales e.g. highlighting the importance of seizing unique opportunities offered by joining up LAQM, public health and broader wellbeing and environmental sustainability (WFG Act) legislation and policy to facilitate action. However, most findings were sufficiently generic to have relevance outside Wales e.g. consensus opinion suggested that integration and collaboration could be increased by extending LAQM's scope and encouraging universal action to reduce risks for all alongside more-targeted intervention. These enhancements could increase LAQM-related interest and importance amongst a wider public health workforce and pave the way for better integration of LAQM into the core responsibilities of many more specialists. Greater opportunities could result for connected policy development, aligned planning and action, effective communication, multidisciplinary research, and change advocacy, leadership and management.
The findings of this study resonated well with the requirements of the WFG Act in Wales. Enhancing the LAQM regime in the ways suggested aligns with the sustainable development principles of collaboration, integration and involvement to facilitate long-term, prevention-focused action. Seizing opportunities to recognise and realise synergies, and create and adopt more effective and efficient ways of working across LAQM and public health agendas, can only serve to help to achieve the Act's broader well-being goals too. For example, increasing public health integration and collaboration in LAQM can support joined-up action (where air pollution problems and solutions are considered in context alongside broader public health priorities) that has the potential to deliver multiple positive health impacts amongst the Welsh population. Further, broadening the scope of LAQM can help identify and reduce air pollution and associated health inequalities to create a fairer Wales. In turn, these improvements can increase population resilience, productivity and prosperity, and community cohesion, and contribute to Wales being a globally responsible country.

In addition to generating new evidence to inform and support LAQM policy and practice development, this study highlighted the usefulness and applicability of the Delphi technique in guiding and supporting complex environmental public health research.

7.3 Mixing, validating and evolving research outcomes

The approach adopted to mixing, validating and evolving research outcomes from the original literature review and Research Strands 1 and 2 was robust. The iterative process followed proved constructive, and helped build a confirmed and complete picture that tested the research hypothesis and achieved the overall research aim.

7.3.1 Testing the hypothesis and achieving the overall research aim

Q. *Can enhancing the LAQM regime – by broadening the regime's scope and specifying the public health role therein – maximise public health awareness, integration, collaboration and impact?*

A. The findings of the evidence critique, Research Strand 1's ecological study and Research Strand 2's Delphi study, suggested that enhancing LAQM in ways specified could add value. However, even though evidence from multiple sources concurred, it was still important (and required, by the selected mixed-methods study design) to undertake further research to mix, validate and interpret it in context, to make the case for change as robust as possible.

The first 'further research' stage – a multi-disciplinary research update and development workshop – helped validate and evolve evidence. It concluded that taking forward action on suggested enablers could help achieve solutions to identified LAQM 'structure', 'process' and 'outcome' limitations. The workshop helped identify overlaps and connections between enablers, solutions and limitations, and recommended actions (especially to broaden LAQM's scope and define the public health role in the regime) that could create a truly public health-driven LAQM framework. It confirmed that enhancing LAQM could add value by improving understanding around problems in a broader context and allow public health to become part of the solution. The workshop outputs made it possible to develop an evidence-informed, public health-driven conceptual LAQM framework for Wales.

The second 'further research' stage – area-based case study interviews – sought expert opinion to test the conceptual framework's local-level appropriateness, applicability and acceptability. These interviews also helped validate and evolve the mixed and interpreted research outcomes, but this time the research outcomes were presented to experts in the form of a single conceptual model. The interviews revealed that public health and air quality management experts were overwhelmingly supportive of the conceptual LAQM framework, in principle (noting concerns of the feasibility of changing an established, legislation-prescribed process). Participants confirmed that the framework reflected and incorporated all research outcomes and that it could help evolve a public health-driven LAQM approach in Wales that added value to existing arrangements. The broader outlook advocated for LAQM, where air pollution risks are assessed and managed in the context of linked wider health determinants, was welcomed. Experts agreed that there is considerable merit in connecting LAQM with 'big picture' public health policy and practice; doing so could improve public health awareness, integration and collaboration, and deliver positive real-world population health impacts.

Mixing, validating and evolving research outcomes built a coherent and compelling case for LAQM change, and recommended actions to enhance the regime so that public health awareness, integration, collaboration and impact would be maximised.

7.3.2 More on the learning from the research update and development workshop

The workshop's first group activity generated some excellent suggested enablers to pre-identified solutions to improved public health integration, interaction and collaboration in LAQM. The second activity, to score enablers, also proved successful. While it was not possible to compare enabler scores 'across' solutions (because the approach taken to prioritise enablers was subjective, relating to 'within- group' discussion and consensus only), the findings revealed that participants considered there to be strong connections and overlaps between many different LAQM-enhancing solutions and enablers (Figure 29). The evidence generated suggested that a complex matrix of influence exists between solutions and enablers which would offer public health bodies and specialists considerable opportunity to work collaboratively and in an integrated manner to act, and support others' action, to reduce air pollution, risks and inequalities. This was an important finding given that resources to take forward suggested enablers to achieve LAQM-enhancing solutions are limited. It strengthened the case for LAQM stakeholders to work together in innovative and sustainable ways – in line with the principles of the WFG Act – to maximise impacts. For example, acting to develop policy that calls for a more public health-conscious implementation of LAQM can help achieve other solutions including: defining the role of public health bodies and specialists in LAQM, prescribing a broader LAQM risk assessment and action approach, reducing health inequalities, and helping public health specialists integrate LAQM work with the ‘day job’. Just this one action could also help deliver on other suggested enablers.

Through triangulation, workshop findings were observed to corroborate evidence from the original literature review too. That critique identified, and described how, several LAQM ‘structure’, ‘process’ and ‘outcome’ limitations were underpinned by just two main regime shortfalls i.e. prescribed risk assessment and management processes that are narrow in public health scope, and public health disengagement and disconnection resulting from a poorly defined role. The solutions and enablers to address these shortfalls (suggested through Research Strands 1 and 2 and the subsequent research update and development workshop, summarised above), related directly back to, and built upon, the same LAQM problems that were highlighted in the original literature review.

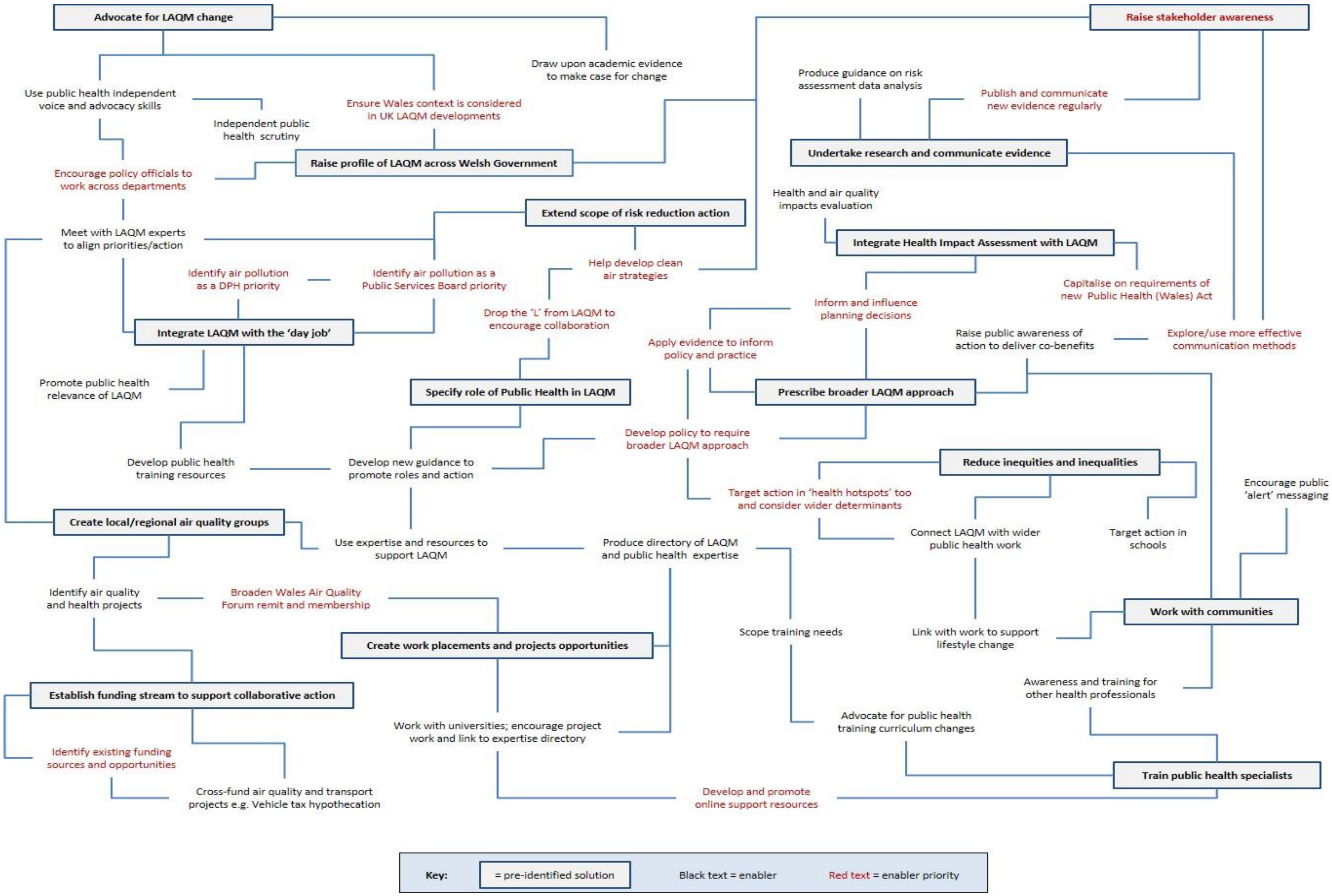

Figure 29. LAQM-enhancing solution and enabler connectedness

7.3.3 More on the learning from the case study interviews

The development of the conceptual LAQM framework, informed by information obtained through the research update and development workshop, might have been regarded as an appropriate point at which to conclude this research project. However, a decision was made to adopt a more robust and rigorous route through to conclusion. The conceptual framework was subsequently scrutinised by air quality management and public health experts through a series of case study interviews to 'test' its local-level appropriateness, applicability and acceptability.

In terms of main findings, the interviews revealed that public health and air quality management experts were overwhelmingly supportive of the conceptual LAQM framework, in principle. Importantly, those taking part in the interviews confirmed they would be happy to accept and adopt the new ways of working proposed in the conceptual framework in the area in which they worked (subject to pilot and evaluation of impact(s) on reducing air pollution, health risks and inequalities). Participants helpfully proposed opportunities to take forward the proposed approach too.

The interviews also elicited useful opinions to improve the conceptual framework; some feedback sought clarity on certain elements of the framework. For example, experts asked for the role of new local-regional groups (to drive and co-ordinate LAQM activity) to be defined, and requested that the mechanism through which these groups should link locally to other strategic health and wellbeing partnerships (e.g. with Public Services Boards) and nationally (e.g. with the Welsh Air Quality Forum) be specified. Other suggested improvements referred to LAQM process changes. For example, some experts felt uncomfortable about proposed changes to the risk assessment approach (i.e. to link air pollution with public health data). In relation to this point, initially, this change was perceived to be overly complicated and too onerous, but fears were alleviated when it was explained that greater public health collaboration could support air quality management specialists to do this, so any additional burdens are shared through more efficient ways of working.

The most important finding of the interviews was the consensus concern of the practical difficulty in introducing a 'new' LAQM regime in Wales, as was intended by the conceptual LAQM framework. Participants' worries about the feasibility of making changes to an established, legislation-prescribed LAQM process, and these were noted. A solution to this problem, put forward by participants, was to present the evidence-based, public health-driven, new ways of working in LAQM in the form of a logic or driver diagram. This suggestion was inspired; reflecting on it concluded that the approach could still guide and enable stakeholders to work together to introduce an enhanced LAQM framework, but would avoid the need for, and problems associated with, formal legislation change.

To explain, driver diagrams act as a type of structured logic chart that can help planning by providing a 'theory of change'. Usually, they propose three or more levels that comprise: i) a goal or vision; ii) high-level factors that should be influenced to achieve the goal (i.e. primary drivers); and iii) specific actions that would act upon these factors (i.e. secondary drivers). As is the intention here, driver models inform policy and practice change because they:

- break problems down into separate parts, and communicate and explain change strategy;
- help diverse groups relate to connected factors and actions to achieve a shared goal.

These positive attributes of the logic model approach can be used to succinctly illustrate and describe problems and solutions, and secure stakeholder commitment to achieve change.

7.4 Transitioning from research theory to practical action and real-world impact

The evidence-based concepts underpinning the enhanced public health-driven LAQM conceptual framework received overwhelmingly positive support. Experts working in the field reported they truly believed in the LAQM new ways of working, but raised concerns around the feasibility of changing the established, legislation-prescribed LAQM process. They called for a more flexible approach to achieve the specified LAQM enhancements.

Recognising the practical difficulties, long timescales and un-guaranteed success of introducing a modified LAQM framework in Wales, and taking into account the pragmatic solution suggested by experts, the new ways of working for LAQM in Wales are framed here as a suite of drivers for change rather than a prescriptive framework (Figure 30). This final research outcome, supported by detailed recommended enabling actions (Figure 31), can help guide and support stakeholders to turn grounded research theory into action that achieves real-world change. Enhancing LAQM in the ways specified can maximise public health awareness, integration, collaboration and impact, and it can all be achieved *within* the constraints and boundaries of the existing LAQM regime.

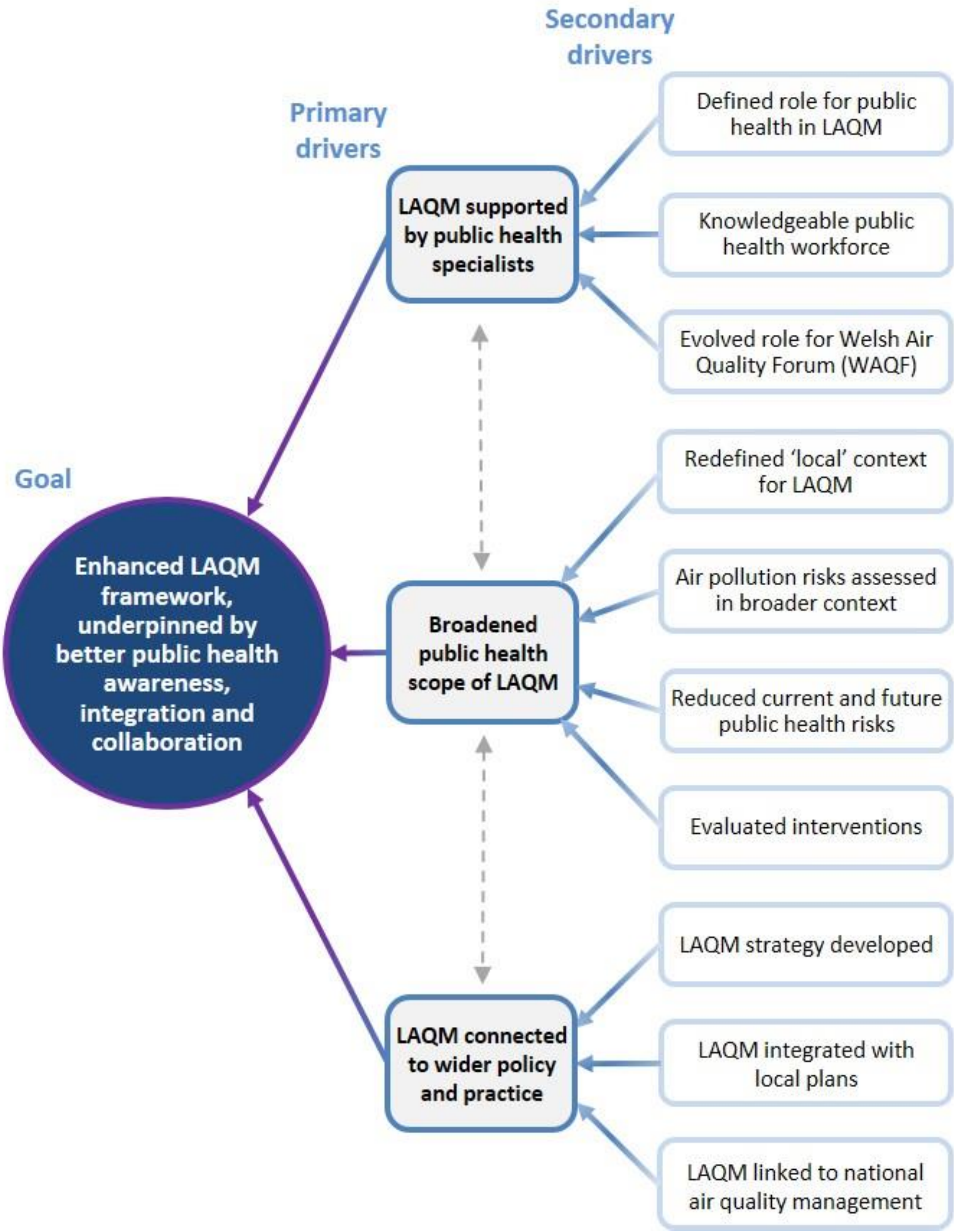

Figure 30. Drivers to enhance LAQM in Wales, underpinned by public health awareness, integration and collaboration

Secondary drivers | **Enabling actions**

Defined role for public health in LAQM

- Share, link, analyse and interpret data to understand problems
- Make LAQM part of the 'day job'; tackle air pollution alongside wider health priorities
- Work with others to realise creative solutions to problems and achieve health co-benefits
- Communicate with authority; influence policy makers, politicians professionals and public
- Interpret evidence, and support new research and evaluation, to inform effective action
- Advocate for, lead and support evidence-based policy and practice change

Knowledgeable public health workforce

- Train public health specialists (alongside others) to raise awareness, expertise, confidence
- Offer formal opportunities for cross-agency projects and work exchange placements

Evolved role for Welsh Air Quality Forum

- Engage public health specialists (all disciplines); work alongside other LAQM stakeholders
- Consider air pollution in the context of other priorities e.g. health, transport, planning
- Develop WAQF's all-Wales leadership role, guided and supported by public health

Redefined 'local' context for LAQM

- Establish new or use existing multi-agency groups to drive and co-ordinate LAQM activity
- LAQM groups should think and act regionally to tackle local problems
- Avoid unintended consequences of actions by considering the 'big picture' in local actions

Air pollution risks assessed in broader context

- LAQM groups should consider air pollution risks in context of wider health determinants
- Identify risk overlaps to inform action that can achieve co-benefits e.g. active travel
- Identify where [and what] effective action can make a difference to reduce risks
- Gather evidence on predicted impacts through Health Impact Assessment application

Reduced current and future public health risks

- Apply principle of proportionate universalism to reduce risks and health inequalities:
- Take evidence-based universal action to improve air quality for everyone
- Take evidence-based targeted action to reduce air pollution in worst affected areas
- Take evidence-based targeted action to reduce risks in most susceptible populations

Evaluated interventions

- LAQM groups evaluate actions by assessing air pollution and public health outcomes
- Document and share research/evaluation findings; evolve evidence, inform future action

LAQM strategy developed

- LAQM groups agree strategic direction locally; link to WAQF leadership goals
- Clearly set out LAQM direction (aim, objectives and specific actions) in strategy
- Brief partners and public (annually) to report on progress made against LAQM strategy

LAQM integrated with local plans

- Use LAQM strategy to raise profile in strategic partnerships e.g. Public Services Boards
- Highlight connections with wider health priorities to secure stakeholder buy-in
- Encourage shared priority setting and joint work planning to achieve health co-benefits
- Integrate LAQM strategy with other local plans e.g. health/wellbeing, transport, planning
- Integrate LAQM strategy with corporate NHS work plans
- Through stronger collaboration, create more innovative and sustainable ways of working
- Collaborate to increase opportunities to access funding to support action

LAQM linked to national air quality management

- Develop strong information exchange with relevant Welsh Government departments
- Advocate national air quality management to take account of LAQM action
- Share best practice beyond Wales and learn from elsewhere to inform effective action

Figure 31. Recommended enabling actions to help achieve LAQM-enhancing drivers for change

7.5 Reflecting on research methods and having confidence in outcomes

7.5.1 Mixed-methods approach and convergent parallel study design

Using the mixed-methods approach for this research project was not only appropriate, but proved extremely successful in supporting the implementation of both quantitative and qualitative research methods. The words, pictures and narrative generated through the qualitative research aspects added meaning and value to the quantitative research-generated numbers, and *vice versa*. The complementary Research Strands enhanced the investigation; the strengths of one method helped address weaknesses of the other, generated insight and understanding that may have been missed otherwise, and informed and tested grounded theory. Ultimately, the mixed-methods approach proved to be a valuable framework that helped answer a broad and complex research question. As suggested, it encouraged advanced research planning and design, and subsequently supported its careful implementation to achieve a complete picture of the subject under investigation to inform theory and practice (Creswell and Plano Clark, 2011).

Despite all these positives, taking forward the mixed-methods research in this research project proved challenging at times. Setting aside methodological purists' reservations about the approach, the fact that the mixed-methods research paradigm continues to evolve means that methodological uncertainties remain. This can make for an unnerving feeling amongst researchers of simply 'muddling through' (Creswell and Plano Clark, 2011). In the case of this research, where the researcher had more prior familiarity with quantitative research, these uncertainties were recognised and addressed at the outset; significant time and effort were invested in understanding qualitative research theory to facilitate its efficient and effective application in practice.

With regard to the study design that underpinned the mixed-methods approach, choosing the convergent parallel type was straight-forward; its selection, following appraisal, was based on it being the only typology to wholly accept and accommodate the research requirements. Ultimately, it proved a valuable tool to support research (comprising complementary parallel Research Strands) that facilitated the generation of quantitative and qualitative data that addressed connected aspects of the same research problem (Teddlie and Tashakkori, 2009). The convergent parallel design may be the most well-known of mixed-methods study types, but its main benefit stemmed from it allowing the two parallel Research Strands to remain independent of each other until after their respective analyses stages and thus encouraged the use of traditional data collection and analysis techniques. This meant that data collection and analysis methods were not over-complicated. Overall, the main observed strength of this design is that it was intuitive and efficient, and reaped the benefits of data triangulation to maximise research 'yield'.

Research yield refers to the meaningful, useful and complete knowledge and insight generated only through mixed-methods studies (O'Cathain *et al.*, 2007). It recognises that the conversation and connection between quantitative and qualitative elements in mixed-methods research is key to unlocking and accessing unique knowledge and understanding on the subject being studied. Without data integration, the research knowledge gained is only equivalent to outputs of independently-conducted qualitative and quantitative studies (Barbour, 1999).

In this instance, a clear rationale argued why both qualitative and quantitative research should be undertaken. Only by conducting both types of study could all aspects of the research problem be investigated thoroughly and the research questions answered fully. Inherent in convergent parallel studies is the design feature that allows data from separate research strands to remain independent of one another before merging them to offer an overall research interpretation that is greater than the sum of its component parts (O'Cathain *et al.*, 2010). Doing this generates different but complementary data on the same topic that really helps to understand more about the research problem under investigation (Creswell and Plano Clark, 2011; Morse, 1991).

Although mixing qualitative and quantitative data in this way is considered a robust approach to achieve true, triangulated, mixed-methods research outcomes (Keeney *et al.* 2011), this research project actually went beyond this in a number of ways. First, findings from both Research Strands were also triangulated with those of the original literature review. This method of triangulation – describing corroboration between two or more sets of findings – integrated data from different sources, enhanced validity and minimised risks of partial or inaccurate interpretation (Guest and Namey, 2015). Second, the overall research interpretation – obtained by integrating data from both Research Strands and corroborating this with literature review results – was validated, explored and evolved further through additional research stages in the form of a stakeholder workshop and case study interviews. This latter enhancement of the mixed-methods convergent parallel study design is all-important since it served to heighten research quality and credibility.

7.5.2 Research Strand 1's ecological study

A limitation of ecological studies generally is assuming that hazards, risks and outcomes are spread evenly across defined areas and populations. Since this study assessed air pollution, deprivation and health associations by using aggregated area-level data, the risk of the 'ecological fallacy' (Hart, 2011) – making inferences about individuals from area/population-level analyses – was minimised. Assumptions around homogeneity, and separate air pollutant analyses that did not account for pollutant synergies (Walton *et al.*, 2015) might have underestimated the strength of associations found. Further, causal inference cannot be drawn from findings.

This study's emphasis on exploring 'local' associations meant that, as with all small-area analyses, there were limitations of using high-resolution data. Limitations often include: numbers of health events over short periods may be small and give rise to health burden estimates affected by chance and random variation, measures of exposure are approximate, boundaries and populations may change over short time-frames, and allocating events to areas is difficult. In some instances the relatively small numbers of health events gave rise to some results that were not expected such as the significant negative associations between area-level PM status and cardiovascular disease mortality. However, in the main, selecting LSOAs as the geographical study unit, and linking all data at that level, made this study more robust. Data were aggregated based on matched area-level characteristics (air pollution and income-deprivation status) to avoid problems associated with small numbers, data for three years were used to smooth annual variations, and LSOA boundaries were consistent over the study period. Also, despite varying in size geographically, the limited population variation of LSOAs facilitated comparisons across small areas, compared with geographic units used in ecological analyses historically such as electoral 'wards'.

Modelled air pollution data were preferred over measured data from discrete monitoring points (where distances, and probability of pollution variation, between receptor and the nearest monitor can be significant) as they more accurately reflect area concentrations and population exposures (Krewski *et al.*, 2009; Jerrett *et al.*, 2005). The modelled data used in this study are validated annually against measured data from air pollution monitoring stations. While this increases confidence in area-level modelled air pollution data, it should be noted that such area-level estimates may not correspond exactly with actual personal exposure which is influenced by an individual's mobility, time spent indoors and outdoors, and activity patterns, levels and types. Given that this ecological study was concerned with area-level relationships only, it was inappropriate to attempt to estimate the exposure of individuals; this avoided bias from exposure misclassification.

Only one measure of deprivation – income deprivation – was used as an indicator for area-level multiple deprivation status. Doing so avoided 'double counting' health and air pollution measures, which might have occurred had the summary WIMD score been used, and skewing results (Fecht *et al.*, 2015; Richardson *et al.*, 2013; Goodman *et al.*, 2011).

It was not possible to account for *all* confounding factors. Smoking, for example, is a key risk factor for the health outcomes of interest in this study, but only local authority-level smoking prevalence data were available, based on self-reported survey responses from a sample of the Welsh population. Using these data (not specific to small areas) would have yielded little bias-reduction since large-area summary data are often grossly inadequate to ensure effective control (Greenland and Robins, 1994). Attempting to disaggregate these data would have introduced more uncertainty and bias. Other studies of air pollution, deprivation and health associations have confirmed that adjusting for smoking behaviour where available at larger geographies does not significantly attenuate results (Richardson *et al.*, 2011; Pearce *et al.*, 2011; Wheeler and Ben Schlomo, 2005). However, the use of chronic liver disease 'control' outcomes did aid the interpretation of results.

7.5.3 Research Strand 2's Delphi study

The strength of the Delphi approach is that it is underpinned by principles of anonymity and democratic participation, where all panellists have equal opportunity to influence the process (Day and Bobeva, 2005). However, some aspects are open to interpretation, and so it is important to reflect on the steps taken in this study to assure validity and reliability (or trustworthiness):

- <u>How many survey rounds</u>?
  To instil confidence and rigour, a general rule is for researchers to commit to provide feedback to panellists over at least two survey rounds (Day and Bobeva, 2005). This study had three rounds, and a 'classic' design was preferred to other Delphi variants because existing evidence was limited and a first idea-generation round was required.

- Who is an ‘expert’?

  Appropriate selection of panellists is a critical process; selection bias introduced by choosing the wrong experts can seriously affect study validity and reliability. To minimise bias here, only ‘professional’ experts were engaged (through a process of systematic identification and peer recommendation) who met pre-agreed eligibility criteria. Involving participants with diverse backgrounds avoided any ‘illusory expertise’ skewing results (Linstone and Turoff, 2002).

- What is the optimal number of Delphi panellists?

  Most panels comprise 10-50 experts (Keeney *et al*, 2011) but it is generally accepted that larger panels enhance study reliability and reduce error (Cochran, 1983). Panel make-up also influences decisions with homogeneous panels requiring fewer participants than heterogeneous panels (Paliwoda *et al*., 1983). The latter also needs homogeneous sub-panels comprising at least ten experts, to facilitate comparisons of different groups’ perspectives (Okali and Pawlowski 2004; Parente and Anderson-Parente, 1987). To maximise credibility here, a heterogeneous panel of experts was recruited, with each of the three homogeneous sub-panels having more than 10 experts.

  Delphi studies are sometimes criticised because findings from small numbers of experts are not considered representative (Yousuf, 2007). Such criticism is ill-informed. It is not appropriate, nor intended, to generalise findings given their derivation from an expert panel with unique characteristics. That said, this study’s panel size, diversity and response rates may mean that opinions *were* a valid representation of expert views on this particular subject.

Another possible criticism is that Delphi can achieve only quasi-anonymity as researchers know panel members and their responses. It is possible that experts knew each other too, but this was unavoidable. Perversely, this may have helped increase response rates – the perception of being in an elite expert ‘club’ may have motivated participation. This is important; Delphi’s effectiveness is dependent upon ongoing participation. Other factors likely helped improve response rates too, e.g. panellists’ interest in the research area, administering surveys electronically in non-holiday periods, regular communications, reiterating contribution importance, and setting a three-round study limit.

It is also important to acknowledge that participants' views may be influenced by group opinion. While this is the whole point of Delphi's iterative consensus-forming process interspersed with controlled feedback, unlike in alternative group research methods, participants are under no pressure to change their minds as the process evolves. This is because Delphi is based on democratic participation and anonymity. If participants wish to revise responses in light of group feedback, they can; but if they are not swayed by the group opinion statistical feedback presented, they need not change their mind. In this study, 47% of Round 2 responses were revised in Round 3. Interestingly, it was the public health experts that changed their minds the least (37%); while this group of experts probably knew relatively little about LAQM compared with others, this result may be explained by public health experts feeling more confident with their responses because the research problem under investigation was public health-focused.

Possible data collection and analysis-related limitations should also be acknowledged. For example, it is possible for data collection instruments to confuse panellists and, through the use of leading questions, compromise the collection of balanced responses. To avoid this, and to ensure surveys asked clear, concise and unambiguous questions, each round was piloted and refined accordingly.

In terms of qualitative data analysis, measures were taken to mitigate panellists' contributions not being captured or interpreted correctly, especially outlier responses. While the thematic analysis approach adopted in this study may not hold the same 'kudos' as full discourse analysis or grounded theory, it is no less credible, having been used successfully in other health research (Allen and Foulkes, 2011; Fade and Swift, 2011; Braun and Clarke, 2006). To minimise data misinterpretation risks, several recommended steps were taken: seeking brief explanations of opinions submitted, having different research team members independently review panellists' responses, and validating summary item lists directly back with panellists (Dubois and Graff, 2011; Linstone and Turoff, 2002).

As for quantitative data analysis, determining consensus is often the most controversial aspect of any Delphi study. Consensus is defined as "a condition of homogeneity or consistency of opinion among panellists" (Graham *et al*., 2003 p. 1152), but achieving it does not mean the correct answer has been found, rather panellists have reached agreement on something. Unhelpfully, because consensus measurement criteria are lacking, a variety of methods have been used previously e.g. aggregating response judgments, setting pre-determined consensus levels, applying measures of central tendency. Here, consensus assessment was based on the latter approach using objective statistical techniques and not the application of arbitrary levels of agreement. The combined use of data *median* and *inter-quartile range* measures is believed to be the most robust method for measuring consensus in Delphi studies (Murphy *et al*., 1998) and so was used here.

To further strengthen study reliability, consensus measurement was complemented by stability assessment using a statistical test recommended for use with not-normally-distributed ordinal data (Von der Gracht, 2012; Banks *et al*., 2009; Crisp *et al*., 1997). It is important to have regard for convergence or divergence of opinions over successive rounds (as a separate component to consensus) since the concept of stability indicates whether agreement was there always, developed through the Delphi process or changed between rounds (Dajani *et al*., 1979; Scheibe *et al*., 1975). Participants do change their views as the Delphi evolves; this is the value of the iterative process, but stability assessment makes sure this is not so significant that the response is rendered meaningless.

7.5.4 Data mixing, validation and evolution

The research update and development workshop's format worked well. An evaluation of the event confirmed it was positively received by participants (Appendix J).

Having confidence in workshop-generated evidence was justified. Participants were not only content to accept and validate the summary of research evidence presented to them at the outset of the workshop, but showed an eagerness to explore how Research Strand 2-suggested solutions (upon which enablers were based) could be achieved in practice. Workshop attendance and discipline representation was good too; 56 experts attended (65% of those invited), and the good balance of expertise achieved across 'public health', 'air quality management' and 'other' groups served to minimise bias and ensure opinions were representative of the whole multi-disciplinary group. With regards this latter point, it was deemed appropriate to continue to engage with members of the Delphi panel (from Research Strand 2) rather than establish new groups since they had been identified previously through a comprehensive *knowledge resource nomination* process and were known experts in the subject area under investigation. Their prior involvement in this research meant they were also more likely to understand both subject area and research context.

As for the case study interviews, the following robust approach and methods adopted meant the information generated through them was valid, reliable and of high quality:

- <u>Participant selection</u>
  Participant numbers were kept small deliberately to facilitate open, frank and fruitful discussion. The selection of participants was carried out independently (outside of the research team) by established all-Wales partnerships; the only stipulation made to guide their selection was that participants must have engaged previously in Research Strand 2's Delphi study. This approach was preferred over the research team selecting participants since it eliminated the potential to introduce bias by the research team selecting participants who, for example, they had good working relationships with or were known to have certain views on specific issues. The public health (n=8) and air quality management (n=10) experts participating in the four interviews offered a balanced, representative inter-disciplinary view on the conceptual framework.

- <u>Group discussion approach</u>
  All too often, the problem with group discussions is that they mean different things to different people (Guest and Namey, 2015). In this instance, confusion was minimised because participants had been part of this research since the Delphi study and had a sound knowledge and understanding of the subject and wider research context. Since maintaining anonymity at this stage of the research was not necessary, using the group discussion approach was appropriate; indeed, many participants had already worked together at the research update and development workshop and had started to develop good working relationships and an appreciation of professional roles and responsibilities.

- <u>Geographical focus</u>
  Holding case study discussions based on specific geographical areas ensured that due consideration was given to applying the LAQM conceptual framework in places with varied population, socio-economic status, air pollution concentrations, urban/rural characteristics, and LAQM implementation experience. The focus on health board areas was influenced by a suggested enabler to enhance LAQM by advocating to drop the 'L' (i.e. 'local') to encourage more-regional assessment, collaboration and management action.

- <u>Questions asked</u>

  The questions asked of participants provided a helpful framework to guide group discussions and make sure that all lines of enquiry were covered in each session. Questions were carefully thought through by members of the research team in advance to ensure they sought insights on ‘structure’, ‘process’ and ‘outcome’ aspects of the conceptual framework.

  Each group was asked to answer the same list of questions to facilitate, as far as possible given the subjective nature of group thinking, assessment of opinion convergence and divergence across groups. Also, questions were shared with participants in advance of the sessions, along with other relevant background information, so that they could consider their answers independently prior to contributing them to group discussions.

- <u>Participant attendance</u>

  All experts invited to the case study interviews, attended. Good uptake was likely influenced by regular, clear communications between researcher and participants in advance, as well as holding the sessions outside of traditional holiday months – during September and October 2017. Further, all four sessions took place while the research update and development workshop was fresh in participants’ minds, and also over a relatively tight time-scale so that participants’ opinions were not influenced by policy and/or practice developments over time.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Research overview and main findings

Air pollution is a significant, and growing, public health concern. Exposure to harmful pollutants like particulate matter and nitrogen dioxide reduces life expectancy by increasing morbidity and mortality risks from heart disease and strokes, respiratory diseases, lung cancer and other conditions. Effective collaboration and co-ordinated action are required to assess and reduce air pollution and health risks at the local level, as mandated by the LAQM regime. Despite LAQM's public health intentions and underpinning principles, the regime is disconnected from broader public health policy and practice; the contribution that public health bodies and specialists can and should make to LAQM has largely gone unrecognised and unrealised.

This research, focused on the situation in Wales, investigated this complex problem for the first time. Aiming to enhance LAQM to maximise public health awareness, integration, collaboration and impact, this research explored problems linked with disconnected policy and practice and disengaged public health specialists. It sought to generate evidence that could help increase the public health reach and impact of LAQM by making public health part of the solution to better-understood air quality and health problems.

A critique of available evidence identified several 'structure' and 'process' limitations that have likely contributed to LAQM's failure to deliver effective 'outcomes' to protect and improve health. Problems stemmed from two main shortfalls:

i. a prescribed risk assessment and management process which is too narrow in public health scope and which fails to encourage policy connection;
ii. a disengaged public health community resulting from poorly defined roles and expectations.

Informed by these evidence critique findings, it was hypothesised that enhancing the LAQM regime – by broadening the scope of the regime and clarifying the public health role therein – can maximise public health awareness, integration, collaboration and impact.

To test this hypothesis, these two main LAQM shortfalls were investigated via complementary Research Strands, framed by a mixed-methods approach and guided by a convergent parallel study design. Research Strand 1's ecological study sought to assess the value added from broadening the scope of LAQM risk assessment and management; Research Strand 2's Delphi study sought to define the role of public health bodies and specialists in LAQM, and explore and describe the value added from better public health awareness, integration and collaboration.

These two studies generated the following results:

- Research Strand 1 – an ecological data-linkage study – found that interactions between air pollution and deprivation status (the latter acting as a proxy for wider health determinants linked to socio-economic status) modified and compounded associations with important health outcomes such as all-cause and respiratory disease mortality. It provided Wales-specific evidence that demonstrated there is considerable merit in routinely assessing air pollution risks in the context of wider public health priorities, and *vice versa*. Further, the observed connectedness between air pollution and broader health-influencing factors made a compelling case for LAQM to adopt a new approach to managing risks. This should involve universal action to reduce risks for everyone, but which may be intensified and targeted in places with poor air quality (but where Air Quality Objectives need not be breached) *and* poor population health status (where populations may be more susceptible to air pollution effects), in order to narrow health inequalities gaps. This approach aligns with the principles of the 'prevention paradox' (where population health gain is maximised through mass remedies) and of 'proportionate universalism' (where the resourcing and delivery of universal services is at a scale and intensity proportionate to the degree of need).

- Research Strand 2 – a consensus-forming Delphi study – specified the role of public health in LAQM for the first time. Responsibilities for public health bodies and specialists include: supporting public health risk assessments, integrating action to reduce air pollution, risks and inequalities with the 'day job' to help address linked priorities and achieve co-benefits, undertaking research and evaluation, and appraising and interpreting evidence. Experts suggested that these functions, along with the application of other core public health skills such as effective and authoritative communications (to raise professional and public awareness), advocacy, leadership and change management can inform evidence-based LAQM policy and practice development and implementation. The value added from better public health awareness, integration and collaboration in LAQM was considered significant, and several opportunities were proposed to help achieve this including stakeholder commitments and ambitions to drive change and Wales' unique policy and legislative landscape. These opportunities were countered with a number of identified barriers that have the potential to hinder progress if not mitigated, but experts agreed that solutions exist to overcome these.

Following expert validation of outcomes from both Research Strand studies, the proposed solutions – intended to support better public health integration, interaction and collaboration in LAQM – were explored further through a stakeholder workshop to determine how they could achieve change in practice. Proposed practical enabling actions that could help achieve solutions included: advocating for air pollution to be regarded as a public health priority, influencing and developing policy to encourage the consideration of air pollution problems and solutions in a broad public health context, and aligning action with other public health work to reduce air pollution, risks and inequalities. Also, collaborating and co-ordinating actions across larger geographies and connecting LAQM with broader strategic health and wellbeing intentions could help, as could providing training to increase expertise, and improving communications to raise professional, political and public awareness.

All evidence generated through both Research Strands and the stakeholder workshop, was integrated. This facilitated its consideration and interpretation in the context of the broader research aim, and triangulation with original literature review results, and ensured an overall research outcome greater than the sum of its component parts. Synthesised findings were used to develop a public health-driven LAQM conceptual framework for Wales, which was scrutinised by experts through a series of case study interviews to test its local-level appropriateness, applicability and acceptability.

While the concepts proposed in this framework received overwhelming support, experts expressed concerns over the feasibility of overhauling the existing statutory LAQM regime. Acknowledging the urgency in requiring LAQM enhancement in the ways specified, and the difficulty of achieving major legislation change in the short-term, the need for a more pragmatic approach was recognised. Taking on board feedback received, to allow greater flexibility in local-level adoption, adaption and implementation, the conceptual framework was re-imagined and re-presented as a suite of evidence-based drivers (with linked recommended enabling practical actions). The resulting driver model intends to guide and support new ways of working in LAQM that are public health driven and integrated, and demonstrates how they can be achieved *within* the boundaries of the existing regime.

The principal driving forces behind the proposed public health-driven LAQM approach were agreed to be: LAQM risk assessment and management approaches of broader public health scope, better awareness and support from public health bodies and specialists, and full integration of LAQM with wider public health policy and practice. Although appearing as a relatively straight-forward task on paper, it is recognised that these primary drivers will not be easy to achieve in practice. This is because they are dependent on establishing several linked secondary drivers which are, in turn, influenced by multiple enablers. The final driver diagram captures this detail succinctly, yet also highlights the complexity of the matrix of influence that underpins the proposed enhanced LAQM ways of working that seek to maximise public health awareness, integration and collaboration.

8.2 Using evidence to enhance LAQM

Having a sound understanding of this matrix of influence is essential since it can help drive efficient actions that maximise potential for impact and achieving change in practice. To explain this, it is helpful to revisit the findings of the evidence critique undertaken at the outset of this research which were framed in the context of LAQM 'structures', 'processes' and 'outcomes'. These findings built a compelling case which hypothesised that concentrating efforts to address two main LAQM shortfalls could trigger chain reactions that simultaneously resolve a whole host of other inter-connected problems. For example:

- Enhancing LAQM 'structures'

  Defining the role of public health bodies and specialists in LAQM is a critical first-step in enhancing regime 'structures'. Doing so can help make air quality assessment and management activities more relevant to a broader public health audience. In turn, this can lead to other positive knock-on 'structure' impacts; it encourages and facilitates stronger public health engagement from a more aware and better trained public health workforce (which calls for investment in developing and delivering training and other support resources to professionals) and embeds public health as a core driving principle in LAQM. This latter development can act as a catalyst to help achieve the other essential step-change 'structure' enhancement i.e. broadening the scope of LAQM so that air pollution problems and solutions are routinely assessed and managed in the context of wider health determinants.

- Enhancing LAQM 'processes'

  Through stronger engagement and support, and with a broader, more comprehensive risk assessment and management approach adopted, better-prepared public health bodies and specialists will be able to influence LAQM 'processes'. The most important 'process' enhancements will be the consideration of air pollution problems and solutions in the broadest possible public health context, and acting to address them through a new management approach aligned with principles of the prevention paradox and proportionate universalism, where:

  - evidence-based universal action is taken to reduce risks for everyone,
  - evidence-based action is targeted to reduce air pollution in worst affected areas,
  - evidence-based action is targeted to reduce risks in most susceptible populations.

To assist, public health skills can be best used to identify and seize more opportunities to achieve change across larger populations and geographies through the collaborative implementation of ‘whole system’ solutions. This is where LAQM can be better integrated with the ‘day job’ for more public health specialists to realise co-benefits (e.g. reducing obesity and air pollution, risks and inequalities by increasing physical activity and active travel) and linked to relevant strategies and work plans in other disciplines, sectors and priority work areas. Being able to make better use of other core public health skills – such as data linkage, analysis and interpretation, epidemiology, surveillance and risk assessment, effective communications, advocacy, leadership and behaviour change management – will also enhance LAQM ‘processes’. Such skills will also be of use in supporting more research and intervention evaluations, where air pollution and health are never considered in isolation.

- <u>Enhancing LAQM ‘outcomes’</u>

  Through the inter-connected LAQM ‘structure’ and ‘process’ enhancements described, some significant output and ‘outcome’ improvements could be achieved.

  There is no doubt that there will be greater general awareness of the contribution that public health bodies and specialists can and should make in LAQM. Other stakeholders in the regime – not only air quality management specialists but other professionals such as transport and planning colleagues too – will have a good understanding of how public health can support their endeavours. This is reciprocal. Public health experts will be trained so they become more knowledgeable, confident and able to support LAQM.

  More comprehensive risk assessments will generate more accurate and robust information that can be used to inform LAQM strategy and work plan development. The new approach to managing identified air pollution and health-linked problems can also create efficiencies by aligning practice amongst air quality management and public health specialists for optimum effect to reduce air pollution and health risks. In turn, co-ordinated practice can promote and facilitate policy-related LAQM connection and integration with other local/regional shared strategic plans and systems (e.g. WFG Act Public Services Boards and Wellbeing Assessments) and encourage reporting to wider networks and establishing governance and accountability arrangements. It can also enhance connections with national and international air quality management policy.

Improving communications amongst partner agencies is key to unlocking the potential of LAQM to protect and improve health. With public health more involved, the NHS – a major employer and 'system' partner – will have recognised responsibilities to work more sustainably and be a better champion for LAQM policy and practice. Beyond public body agencies, communicating risks and solutions with the public will also be a key 'outcome' enhancement. Public health specialists can not only support more authoritative communications to raise awareness amongst different groups (in the most effective ways) but also use appropriate methods and networks to influence individual and population behaviour change.

Another important output development that can enhance LAQM 'outcomes' is more and better research and evaluation activities, where learning can be used in a cycle of continuous quality improvement to evolve evidence-based services and interventions.

While many of these possible LAQM enhancements were first proposed in the original literature review, this research project has consolidated evidence and corroborated their relevance and significance. More importantly, however, this research has evolved evidence; it has revealed new insights on, and improved understanding of, how enhancements can be achieved in practice (mindful of linked opportunities, barriers and solutions). This new evidence has helped answer the two specified research questions, namely:

i. Is there merit in assessing and managing local air pollution risks in a broader public health context (than that currently prescribed), and advocating for action beyond Air Quality Management Areas?
ii. How can a better-defined role for public health bodies and specialists in LAQM increase awareness, integration and collaboration, and add value to existing LAQM arrangements?

Moreover, this evidence has allowed the research hypothesis to be accepted i.e. that enhancing the LAQM regime by broadening its scope and specifying the public health role can maximise public health awareness, integration, collaboration and impact. By confirming that, and explaining how, multiple LAQM enhancements can result from focusing collective efforts on two feasible step-changes to LAQM 'structures', the implementation of the final driver model (Figure 30; Figure 31) is rendered a realistic, achievable ambition that is less daunting than the task appears at first sight.

Clearly, achieving each and every element of the driver diagram will require robust commitment amongst LAQM stakeholders – especially public health bodies and specialists – and a considerable investment in time and effort. However, this research suggests the value added from doing so would be significant. Not only would an enhanced, more efficient and effective LAQM regime result; the positive impacts associated with stronger LAQM and public health policy and practice connection have the potential to influence beyond LAQM to help tackle wider linked public health and wellbeing priorities such as physical inactivity and obesity.

The increasing professional, political and public appetites to improve air quality and protect health, together with a supportive legislative and policy landscape, offer unique opportunities for achieving sustainable change in Wales, the UK and internationally. Specifically in Wales, in 2018, a new cross-Welsh Government air quality programme board has been announced, set to steer and oversee several connected work streams including developing and implementing a Clean Air Plan for Wales, establishing a new national assessment, monitoring and research resource centre, and taking forward audience-tailored communication and behaviour change interventions. There have also been important advances from a public health perspective too; guidance setting out how NHS Wales' policy and practice should contribute to air quality management (through corporate responsibilities and collaboration beyond the NHS) is soon to be introduced, and formal long-term working arrangements have been agreed between Public Health Wales and Welsh Government to help embed public health in air quality policy development.

Applying the grounded 'theory-into-practice' evidence of this research project can help seize, and continue to build upon, these opportunities to make a real-world difference. The evidence-based driver model generated, and supporting practical enabling actions, provides all the information and impetus required to take forward co-ordinated action to achieve change. The added value that could result would be unprecedented in LAQM terms, with true enhancement brought about through the creation of an effective public health-driven LAQM regime in Wales, underpinned by better awareness, integration and collaboration.

8.3 Recommended 'next steps' to take this research forward

To commence the transition from research theory to action, and create a pathway to impact in Wales, the following practical next steps are proposed:

i. The evidence-based LAQM drivers for change are communicated widely, identifying them as solutions to the problem of LAQM and public health policy and practice disconnection;
ii. The role of public health bodies and specialists in LAQM is clearly defined and communicated, to encourage and influence revision of LAQM policy guidance and the development of other linked Welsh Government policy;
iii. An enhanced evidence-based approach to LAQM is described to require the routine consideration of air pollution problems and solutions in the broadest possible public health context, to influence LAQM policy and practice;
iv. Tailored training materials are developed and delivered to a broad audience (including public health and air quality management specialists) to raise awareness of roles, increase LAQM expertise, and strengthen confidence amongst partners to engage and collaborate;
v. Opportunities to advocate and lead change are seized by public health and air quality management specialists, to influence and drive LAQM and public health policy and practice developments, in line with evidence generated through this research;
vi. Supported by the preceding developments, the proposed public health-driven ways of working in LAQM are trialled in two or three different health board areas in Wales;
vii. Any pilots of the new public health-driven ways of working in LAQM should be subject to formal evaluation, in order to inform follow-up debate and decision around all-Wales roll-out;
viii. In the future, especially following piloting and evaluating the new ways of working, it is recommended that this research is repeated in Wales to assess evolution and connectedness of LAQM and public health policy and practice.

While this research is Wales-specific, findings are relevant across the UK where the same disconnect between LAQM and public health policy and practice has been recognised, or perhaps where it is an undiscovered problem. The evidence generated here will also be of use beyond the UK, especially in those countries operating collaborative local air quality management regimes similar to LAQM.

9. RECOMMENDATIONS FOR FURTHER RESEARCH

During the course of this research project, a number of interesting avenues for further research were identified. While some of these were investigated, and ultimately became part of this research, it was not possible to look into them all in detail. Therefore, to build on this research, and address the unexplored areas/issues that warrant further investigation, it is recommended that:

i. A mapping exercise is carried out to scope the extent of the relationships and overlaps between LAQM and other public health work (for example, promoting physical activity, changing behaviour and tackling inequalities) undertaken to tackle linked priorities;
ii. Research is undertaken to quantify the increase in number of people benefiting (i.e. having health protected and improved) by adopting a proportionate universalism LAQM approach in parallel with the current prescribed air pollution ‘hotspot’-targeted LAQM approach;
iii. Research is carried out to model and quantify the additional public health gain to be achieved by adopting a proportionate universalism LAQM approach in parallel with the current prescribed air pollution ‘hotspot’-targeted LAQM approach;
iv. This research is repeated in other parts of the UK (and in countries beyond, where appropriate) to determine how public health awareness, integration and collaboration can be achieved to enhance LAQM ways of working and impacts in the context of different local/regional characteristics and opportunities;
v. Further work is undertaken to link air pollution, health and other data to continue to develop understanding of relationships and associations between hazards and risks in a broad public health context; evolving and sharing evidence can inform air pollution and health risk assessment approaches as well as air quality management action;
vi. Further work is undertaken to summarise, evolve, interpret and communicate evidence of intervention effectiveness to encourage implementation of joint action (by public health and air quality management specialists) to reduce air pollution, risks and inequalities;
vii. Similar research methods are applied to explore, understand and enhance ways of working in LAQM with stakeholders other than public health and air quality management specialists e.g. planning, transport, regulation and environmental sustainability specialists.

For all these recommendations, it is essential for the findings and learning to be shared widely.

10. REFERENCES

Aarts MJ, Schuit AJ, van der Goor AM, van Oers AM (2011). Feasibility of multi-sector policy measures that create activity-friendly environments for children: results of a Delphi study. *Implementation Science*; 6: 128-138.

Ahn S, Burdine JN, Smith LN *et al*. (2011). Residential rurality and oral health disparities: influences of contextual and individual factors. *Journal of Primary Prevention*; 32(1): 29-41.

Allen C, Foulkes WD (2011). Qualitative thematic analysis of consent forms used in cancer genome sequencing. *BMC Med Ethics*; 12(1): 14222.

Amann M, Cofala J, Heyes C *et al.* (2004). RAINS Review 2004. *The RAINS model – documentation of the model approach; prepared for the RAINS Peer Review 2004.* IIASA: Laxenberg, Austria.

Argyrous G (2005). Statistics for research, 2nd edition. Sage: London, UK.

Armitage P, Berry G (1994). *Statistical methods in medical research* (3rd edn). 1994. Blackwell: Oxford, UK.

Bailey R, Longhurst JWS, Hayes ET *et al.* (2012). Exploring a city's potential low carbon futures using Delphi methods: some preliminary findings. *Journal of Environmental Planning and Management*; 55(8): 1022-1046.

Bannister D (2008). The sustainable mobility paradigm. *Transport Policy*; 15: 73-80.

Banks DE, Shi R, McLarty J, Cowl CT *et al*. (2009). American College of Chest Physicians Consensus Statement on the Respiratory Health Effects of Asbestos: results of a Delphi Study. *Chest*; 135(6): 1619-1627.

Barbour RS (1999). The case for combining qualitative and quantitative approaches in health services research. *Journal of Health Services Research Policy*; 4: 39-43.

Barnes JH, Hayes ET, Chatterton TJ, Longhurst JWS (2014). Air quality action planning: why do barriers to remediation in local air quality management remain? *Journal of Environmental Planning and Management*; 57(5): 660-681.

Barnes J, Chatterton T (2017). An environmental justice analysis of exposure to traffic-related pollutants in England and Wales. *Transactions on Ecology and the Environment*; 210 (12): 431-442.

Barnes J, Hayes E, Chatterton T, Longhurst J (2018). Policy disconnect: a critical review of UK air quality policy in relation to EU and LAQM responsibilities over the last 20 years. *Environmental Science and Policy*; 85: 28-39.

Barton H, Grant M (2006). A health map for the local human habitat. *Journal of the Royal Society for the Promotion of Health*; 126 (6): 252-253.

Barton H (2009). Land-use planning and health and wellbeing. *Land Use Policy*; 26: 115-123.

Barton H, Grant M (2010). *Shaping neighbourhoods for local health and global sustainability*. Routledge: London, UK.

Bateson TF, Schwartz JJ (2008). Children's response to air pollutants. *Toxicol Environ Health A*; 71: 238–43.

Beattie CI, Longhurst JWS, Woodfield NK (2000). Air quality management: challenges and solutions in delivering air quality action plans. *Energy and Environment*; 11(6):729-747.

Beattie CI, Longhurst JWS, Woodfield NK (2001). Air quality management: evolution of policy and practice in the UK as exemplified by the experience of English local government. *Atmospheric Environment*; 35: 1479-1490.

Becker GE, Roberts T (2009). Do we agree? Using a Delphi technique to develop consensus on skills of hand expression. *Journal Hum Lact*; 25(2): 220-225.

Beelen R, Raaschou-Nielsen O, Stafoggia M, *et al*. (2014). Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet*; 383: 785-795.

Bekker M, Putters K, Van der Grinten T. Evaluating the impact of HIA on urban reconstruction decision-making – who manages those risks? *Environment Impact Assessment and Review*; 25: 758-771.

Bell ML, Zanobetti A, Dominici F(2013). Evidence on vulnerability and susceptibility to health risks associated with short-term exposure to particulate matter: a systematic review and meta-analysis. *Am J Epidemiol*; 178: 865–76.

Benach J, Malmusi D, Yasui Y *et al*., (2012). A new typology of policies to tackle health inequalities and scenarios of impact based on Rose’s population approach. *Journal of Epidemiology and Community Health*; 67: 286-291.

Berger PL, Luckmann T (1966). *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*. Doubleday: Garden City, NY, US.

Bergman M (2008). Introduction: whether mixed methods? In M Bergman (Ed). *Advances in Mixed Methods Research*: 1-7. Sage: Thousand Oaks, CA, US.

Bloor M, Sampson H, Baker S, Dahlgren K (2015). Useful but no oracle: reflections on the use of a Delphi group in a multi-methods policy research study. *Qualitative Research*; 15(1): 57-70.

Bogdan RC, Biklen SK (1998). *Qualitative research in education: An introduction to theory and methods* (3rd edition). Allyn & Bacon: Needham Heights, MA, US.

Bond A, Cave B, Ballantyne R (2013). Who plans for health improvement? SEA, HIA and the separation of spatial planning and health planning. *Environmental Impact Assessment Review;* 42: 67-73.

Bondarouk E, Liefferink D (2017). Diversity in sub-national EU implementation: the application of the EU Ambient Air Quality directive in 13 municipalities in the Netherlands. *Journal of Environmental Policy and Planning*; 19(6): 733-753.

Bottle A, Hansell A, Aylin P (2002). Hospital episode statistics: time for clinicians to get involved? *Clinical Medicine*; 2(5): 483-484.

Boulkedid R, Abdoul H, Loustau M (2011). Using and reporting the Delphi method for selecting quality indicators: a systematic review. *PLOS One*; doi: 10.1371/journal.pone.0020476.

Bowen W (2002). An analytical review of environmental justice research: what do we really know? *Environmental Management*; 29(1): 3-15.

Braun V, Clarke V (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*; 3(2): 77-101.

Breslow NE, Day NE (1987). *Statistical methods in cancer research, volume II: The design and analysis of cohort studies*. 1987. International Agency for Research on Cancer, World Health Organization: Lyon, France.

Briggs D, Fecht D, De Hoogh K (2008). Environmental inequity in England: small area associations between socio-economic status and environmental pollution. *Soc Sci and Med*; 67: 1612-1629.

Brochu PJ, Yanosky JD, Paciorek *et al*. (2011). Particulate air pollution and socioeconomic position in rural and urban areas of northeastern United States. *Am Journal of Public Health*; 101(1): 224-230.

Brownson RC, Royer C, Ewin R *et al.* (2006). Researchers and policymakers: travellers in parallel universes. *Am J Prev Med*; 30: 164-172.

Brunekreef B, Holgate ST (2002). Air pollution and health. *The Lancet*; vol. 360: pp. 1233-1242.

Brunt H (2006). *An evaluation of the health and wellbeing aspects of the Swansea 'Positive Steps' exercise referral scheme, September 2004 to March 2006*. National Public Health Service Wales: Swansea, UK.

Brunt H, Barnes J, Longhurst JWS, Scally G, Hayes E (2016a). Local Air Quality Management policy and practice in the UK: the case for greater Public Health integration and engagement. *J Env Sci Policy*; 58: 52-60.

Brunt H, Barnes J, Jones SJ, Longhurst JWS, Scally G, Hayes E (2016b). Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. *J Public Health*; 39(3): 485-497.

Brunt H, Barnes J, Longhurst JWS, Scally G, Hayes E (2017). Enhancing Local Air Quality Management to maximise public health integration, collaboration and impact in Wales, UK: a Delphi study. *Journal of Environmental Science and Policy*; 80: 105-116.

Burstrom B, Marttila A, Kulane A *et al*., (2017). Practising proportionate universalism – a study protocol of an extended postnatal home visiting programme in a disadvantaged area in Stockholm, Sweden. *BMC Health Services Research*; 17: 91-98.

Busscher T, Zuidema C, Tillema C, Arts J (2014). Bridging gaps: governing conflicts between transport and environmental policies. *Environment and Planning A*; 46(3): 666-681.

Buzzelli M, Jerrett M (2007). Geographies of susceptibility and exposure in the city: environmental inequity of traffic-related air pollution in Toronto. *Can J Reg Sci*; 30: 195-210.

Cannibal G, Lemon M (2000). The strategic gap in air quality management. *Journal of Environmental Management*; 60(4): 289-300.

Carmichael L, Lambert C (2011). Governance, knowledge and sustainability: the implementation of EU directives on air quality in Southampton. *Local Environment*; 16(2):181-191.

Carmichael L, Barton H, Gray S *et al*. (2012). Integration of health into urban spatial planning through impact assessment: identifying governance and policy barriers and facilitators. *Environmental Impact Assessment Review*; 32: 187-194.

Carmichael L, Barton H, Gray S *et al.* (2013). Health-integrated planning at the local level in England: impediments and opportunities. *Land Use Policy*; 31: 259-266.

Carney O, McIntosh J, Worth A (1996). The use of the nominal group technique in research with community nurses. *Journal of Advanced Nursing*; 23(5): 1024-1029.

Cesaroni G, Forastiere F, Stafoggia M *et al*. (2014). Long-term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project. *BMJ;* 348:f7412.

Charles CM (1995). *Introduction to educational research (2nd edition)*. Longman: San Diego, CA, US.

Chatterton TJ, Woodfield NK, Beattie CI, Longhurst JWS (2004). Outcomes of the first round of local authority air quality Review and Assessments under the UK's air quality strategy. *Journal of Environmental Monitoring*; 6: 849-853.

Chatterton T, Longhurst J, Leksmono N *et al*. (2007). Ten years of Local Air Quality Management experience in the UK: an analysis of the process. *Clean Air and Environmental Quality*; 41(4): 26-31.

Chi GC, Hajat A, Bird CE *et al.* (2016). Individual and neighbourhood socioeconomic status and the association between air pollution and cardiovascular disease. *Environmental Health Perspectives*; 124: 1840-1847.

Clougherty JE (2011). A growing role for gender analysis in air pollution epidemiology. *Cien Saude Colet*; 16: 2221–38.

Cochran SW (1983). The Delphi method: formulating and refining group judgments. *Journal of Human Sciences*; 2(2): 111-117.

Committee on the Medical Effects of Air Pollution (COMEAP) (2010). *The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom*. COMEAP. Accessed: http://www.comeap.org.uk/documents/reports on 11th March 2014.

Committee on the Medical Effects of Air Pollution (COMEAP) (2015). *Interim statement on quantifying the association of long-term average concentrations of nitrogen dioxide and mortality*. COMEAP: London, UK.

Community Local Government (CLG) (2012). *National planning policy framework*. CLG: London, UK.

Craig L, Brook JR, Chiotti Q, Croes B, Gower S *et al*., (2008). Air pollution and public health: a guidance document for risk managers. *J Toxicology and Environmental Health, Part A*; 71: 588-698.

Creswell J and Plano Clark V (2011). *Designing and conducting mixed methods research (2nd ed.). Sage:* Thousand Oaks, CA, US.

Crisp J, Pelletier D, Duffield C *et al*. (1997). The Delphi method? *Nursing Research*; 46(2): 116-118.

Croft GP, Williams JG, Mann RY *et al.* (2007). Can hospital episode statistics support appraisal and revalidation? Randomised study of physician attitudes. *Clinical Medicine*; 7(4): 332-338.

Croucher K, Myers L, Jones R *et al*. (2007). *Health and the physical characteristics of urban neighbourhoods: a critical literature review.* Glasgow Centre for Population Health: Glasgow, UK.

Crouse DL, Ross NA, Goldberg MS (2009). Double burden of deprivation and high concentrations of ambient air pollution at the neighbourhood scale in Montreal, Canada. *Soc Sci Med*; 69(6): 971-981.

Crutzen R, de Nooijer J, Brouwer W *et al*. (2008). Internet-delivered interventions aimed at adolescents: a Delphi study on dissemination and exposure. *Health Education Research*; 23(3): 427-439.

Dahlgren G, Whitehead M (1991). *Policies and strategies to promote social equity in health.* Institute for Future Studies: Stockholm, Sweden.

Dajani JS, Sincoff MZ, Talley WK (1979). Stability and agreement criteria for the termination of Delphi studies. *Technological Forecasting and Social Change*; 13 : 83-90.

Dalkey NC (1972). The Delphi method: an experimental study of group opinion. In NC Dalkey, DL Rourke, R Lewis, D Snyder (Eds.). *Studies in the quality of life: Delphi and decision-making* (13-54). Lexington Books: Lexington, MA, US.

Day R (2007). Place and the experience of air quality. *Health and Place*; 13: 249-260.

Day J, Bobeva M (2005). A generic toolkit for the successful management of Delphi studies. *The Electronic Journal of Business Research Methodology*; 3(2): 103-116.

DeAngelis C (1990). *An introduction to clinical research*. Oxford University: Press New York, NY, US.

De Bruin-Kooistra M, Amelink-Verburg MP *et al*.(2012). Finding the right indicators for assessing quality midwifery care. *International Journal for Quality in Health Care*; DOI: http://dx.doi.org/10.1093/intqhc/mzs006

Deguen S, Zmirou-Navier D (2010). Social inequalities resulting from health risks related to ambient air quality – a European review. *European Journal of Public Health*; 20(1): 27-35.

De Meyrick J (2003). The Delphi method and health research. *Health Education Research*; 103(1): 7-16.

Denscombe M (2003). *The good research guide for small scale research projects (2nd edition)*. Open University Press: Buckingham, UK.

Department for Environment, Food and Rural Affairs (2006). *Air quality and social deprivation in the UK: an environmental inequalities analysis*. Netcen/AEAT: Didcot, Oxon, UK.

Department for Environment, Food and Rural Affairs (2007). *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (volumes 1 and 2)*. Defra: London, UK.

Department for Environment, Food and Rural Affairs (2013). *Local air quality management review – summary of responses and government reply*. Defra: London, UK.

Department for Environment, Food and Rural Affairs (2015). *Draft plans to improve air quality in the UK: tackling nitrogen dioxide in our towns and cities. UK overview document.* Defra: London, UK.

Department for Environment, Food and Rural Affairs (2016). *Local Air Quality Management Policy and Technical Guidance TG (16).* Defra: London, UK.

Department for Environment, Food and Rural Affairs (2017). *Air pollution in the UK 2016*. Defra: London, UK.

Department for Environment, Food and Rural Affairs (2018). *Summary AQMA data*. Accessed: http://uk-air.defra.gov.uk/aqma/summary 14/02/18.

Department for Transport (2012). *Road Transport Forecasts 2011*. London, UK: Department for Transport.

Department of the Environment, Transport and Regions, Scottish Executive, National Assembly for Wales, Department of Environment for Northern Ireland (2000). *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*. CM 4548. TSO: London, UK.

Department of the Environment (1997). *The United Kingdom National Air Quality Strategy*. TSO: London, UK.

D'Elia L, Bencardino M, Ciancarella L *et al*. (2009). Technical and non-technical measures for air pollution emission reduction: the intgegrated assessment of the regional Air Quality Management Plans through the Italian national model. *Atmospheric Environment*; 43: 6182-6189.

Devenish G, Pollard C, Kerr D (2012). *The Delphi process for public health policy development: five things you need to know.* Curtin University: Australia.

DeVet EJ, Brug J, De Nooijer J, Dijkstra A, De Vries NK (2005). Determinants of forward stage transitions: a Delphi study. *Health Education Research*; 20(2): 195-205.

Diez-Roux AV (2003). Residential environments and cardiovascular risk. *J Urban Health*; 80: pp. 569-589.

Dockery DW, Pope CA 3rd, Xu X, *et al*. (1993). An association between air pollution and mortality in six US cities. *New England Journal of Medicine*; 329: pp. 1753-1759.

Donabedian A (1980). *The definition of quality and approaches to its assessment*. Health Administration Press: Ann Arbor, US.

Donabedian A (2005). Evaluating the quality of medical care. *The Millbank Quarterly*; 83(4): 691-729.

Donaldson L, Scally G (2009). *Donaldson's Essential Public Health 3rd edition*. Radcliffe Press: London, UK.

Dorfman P, Gibbs DC, Leksmono NS *et al*. (2010). Exploring the context of consultation. Case of Local Air Quality Management. *Local Environment*; 15(1): 15-26.

Dubois RW, Graff JS (2011). Setting priorities for comparative effectiveness research: from assessing public health benefits to being open with the public. *Health Aff*; 30(12): 2235-2242.

Egan M, Kearns A, Katikireddi SV *et al*., (2016). Proporttionate universalism in practice? A quasi-experimental study (GoWell) of a UK neighbourhood renewal programme's impact on health inequalities. *Social Science and Medicine*; 152: 41-49.

European Commission (2016). *In-depth report 13: links between noise and air pollution and socioeconomic status*. Science for Environment Policy, University of West of England: Bristol, UK.

European Environment Agency (2006). *Assessment and management of urban air quality in Europe: EEA Monograph 5*. Monitoring and assessment Research Centre, King's College London: London, UK.

European Parliament (2008). *Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe*. European Parliament: Brussels, Belgium.

Everard M, Pontin B, Appleby T *et al*. (2013). Air as a Common Good. *Env Sci and Policy*; 33: 354-368.

Faculty of Public Health (2010). *What is Public Health practice?* Accessed: http://www.fph.org.uk/what_is_public_health 16/07/15.

Fade SA, Swift JA (2011). Qualitative research in nutrition and dietetics: data analysis issues. *J Hum Nutr Diet*; 24(2): 106-114.

Fang M, Chan CK, Yao X (2009). Managing air quality in a rapidly developing nation: China. *Atmospheric Environment*; 43: 79-86.

Fann N, Roman HA, Fulcher CM *et al*. (2011). Maximising health benefits and minimizing inequality: incorporating local-scale data in the design and evaluation of air quality policies. *Risk Analysis*; DOI:10.1111/j.1539-6924.2011.01629.x.

Farber HJ (2013). Public policy, air quality and protecting most vulnerable. *CHEST*; 144(4): 1093-1094.

Farmer MM, Rose DE, Ropelle D *et al*. (2011). Gender differences in smoking and smoking cessation treatment: an examination of the organizational features related to care. *Women's Health Issues*; 21(4): 182-189.

Faustini A, Rapp R, Forastiere F (2014). Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. *Eur Respir J*; 44(3): 744-753.

Fecht D, Fischer P, Fortunato L, Hoek G *et al*. (2015). Associations between air pollution and socioeconomic characteristics, ethnicity and age profile in neighbourhoods in England and the Netherlands. *Environmental Pollution*; 198: 201-210.

Fernandez-Somoano A, Hoek G, Tardon A (2013). Relationships between area-level socioeconomic characteristics and outdoor NO_2 concentrations in rural and urban areas of northern Spain. *BMC Public Health*; 13: 71-81.

Finkelstein MM, Jerrett M, Sears MR (2005). Environmental inequality and circulatory disease mortality gradients. *Journal of Epidemiology and Community Health*; 59: 481-487.

Forastiere F, Stafoggia M, Tasco C *et al.* (2007). Socioeconomic status, particulate air pollution, and daily mortality: differential exposure or differential susceptibility. *Am J Ind Med*; 50: 208-216.

Frewer LJ, Fischer ARH, Wentholt MTA *et al*. (2011). The use of Delphi methodology in agrifood policy development: some lessons learned. *Technological Forecasting and Social Change*; 78: 1514-1525.

Frohlich KL, Abel T (2014). Environmental justice and health practices: understanding how health inequalities arise at the local level. *Social Health and Illness*; 36(2): 199-212.

Frohlich KL, Potvin L (2008). The inequality paradox: the population approach and vulnerable populations. *American Journal of Public Health*; 98(2): 216-221.

Giles LV, Barn P, Kunzli N *et al.* (2011). From good intentions to proven interventions: effectiveness of actions to reduce the health impacts of air pollution. *Environ Health Perspectives*; 119(1): 29-36.

Gijsbers HJH, Lauret GJ, van Hofwegen A (2016). Development of quality indicators for physiotherapy for patients with PAOD in the Netherlands: a Delphi study. *Physiotherapy*; 102 (2): 196-201.

Glanz K, Sallis JF, Saelens BE *et al*. (2005). Healthy nutrition environments: concepts and measures. *American Journal of Health Promotion*; 19(5): 330-333.

Glaser BG, Strauss AL (1967). *The discovery of grounded theory: strategies for qualitative research*. Aldine: Chicago, IL, US.

Golofshani N (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report*; 8(4): 597-607.

Goodman A, Wilkinson P, Stafford M, Tonne C (2011). Characterising socioeconomic inequalities in exposure to air pollution: a comparison of socio-economic markers and scales of measurement. *Health & Place*;17:767-774.

Gordon TJ (2003). *The Delphi method*. In: JC Glenn, TJ Gordon (Eds.) Futures Research Methodology v 2.0. American Council for the United Nations University: Washington, US.

Gowers AM, Miller BG, Stedman JR (2014). *Estimating local mortality burdens associated with particulate air pollution.* Public Health England: London, UK.

Graham B, Regehr G, Wright JG (2003). Delphi as a method to establish consensus for diagnostic criteria. *Journal of Clinical Epidemiology*; 56: 1150-1156.

Graham H (2007). Unequal lives: health and socioeconomic inequalities. Open University Press: Buckingham, England UK.

Green L, Kreuter M (1999). Health promotion planning: an educational and environmental approach, 2nd ed. Mayfield Publishing: California, US.

Greene J (2007). *Mixed methods in social inquiry*. Jossey-Bass: San Francisco, CA, US.

Greenland S, Robins J (1994). Ecological studies – biases, misconceptions and counterexamples. *Am J Epidemiol*; 139(8): 747-60.

Guba EG, Lincoln YS (1994). Competing paradigms in qualitative research. In NK Denzin & YS Lincoln (Eds.); *Handbook of qualitative research* (pp. 105-117). Sage: London, UK.

Guest G, Namey EE (2015). *Public health research methods*. Sage: Thousand Oaks, CA, US.

Gulia S, Nagendra SMS, Khare M, Khanna I (2015). Urban air quality management – a review. *Atmospheric Pollution Research*; 6: 286-304.

Gulia S, Nagendra S, Barnes J, Khare M (2018). Urban local air quality management framework for non-attainment areas in Indian cities. *Science of the Total Environment*; 619-620: 1308-1318.

Hajat A, Hsia C, O'Neill MS (2015). Socioeconomic disparities and air pollution exposure: a global review. *Curr Environ Health Rep*; 2: 440-450.

Hall B, Howard K (2008). A synergistic approach: conducting mixed methods research with typological and systemic design considerations. *Journal of Mixed Methods Research*; 2(3): 248-269.

Halonen JI, Lanki T, Yli-Tuomi T, Tittanen P, Kulmala M, Pekkanen J (2009). Particulate air pollution and acute cardiorespiratory hospital admissions and mortality amongst the elderly. *Epidemiology*; 20: pp. 143-153.

Harrell JA, Baker EL (1994). Essential services of public health. *Leadership Public Health*; 3(3): 27-30.

Hart J (2011). On ecological studies: a short communication. *Dose Response*; 9(4): 497-501.

Havard S, Deguen S, Zmirou-Navier D *et al*. (2009). Traffic-related air pollution and socioeconomic status: a spatial autocorrelation study to assess environmental equity on a small-area scale. *Epidemiology*; 20: 223–230.

Hayes E, Chatterton T, Laxen D (2009). *Questionnaire survey of UK Local Authorities on the Local Air Quality Management Process*. UWE/AQC: Bristol, UK.

Health Effects Institute (2012). *Global health – air pollution is a global issue.* Accessed: https://www.healtheffects.org/global

HM Government (1995). *Environment Act 1995, Chapter 25 (part IV).* HMSO: London, UK.

HM Government (1997). *Air Quality Regulations, 1997, 3043*. HMSO: London, UK.

HM Government (2010). *Air Quality Standards Regulations*. HMSO: London, UK.

HM Government (2008). *Climate Change Act 2008*. HMSO: London, UK. Available at: http://www.legislation.gov.uk/ukpga/2008/27/pdfs/ukpga_20080027_en.pdf [accessed on 23rd November 2016].

Hoek G, Krishnan RM, Beelan R *et al*. (2013). Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environmental Health*; 12: pp. 43-57.

House of Commons Environmental Audit Committee(2009). *Memorandum submitted by LA Coordinators of Regulatory Services*. Accessed: http://publications.parliament.uk/pa/cm200910/cmselect/cmenvaud/229/229we16.htm, 16/07/15.

House of Commons Environmental Audit Committee (2010). *Fifth Report of Session 2009-10*. House of Commons: London, UK.

House of Commons Environmental Audit Committee (2014). *Action on Air Quality. Sixth report of session 2014-15*. TSO: London, UK.

Howe KR (1992). Getting over the quantitative-qualitative debate. *American Journal of Education*; 100: 236–257.

Hsueh SL (2015). Assessing the effectiveness of community-promoted environmental protection policy by using a Delphi-fuzzy method: a case study on solar power and plain afforestation in Taiwan. *Renewable and Sustainable Energy Reviews*; 49: 1286-1295.

Huang JV, Leung GM, Schooling CM (2017). The association of air pollution with birthweight and gestational age: evidence from Hong Kong's 'Children of 1997' birth cohort. *Journal of Public Health*; 39(3): 476-484.

Hutt P, Gilmour S (2010). *Tackling inequalities in General Practice*. The Kings Fund: London, UK.

In House Policy Consultants (IHPC) (2010). *Review of Local Air Quality Management: report to Defra and the Devolved Administrations*. Defra: London, UK.

Institute of Occupational Medicine (2006). *Comparing estimated risks for air pollution with risks for other health effects*. Accessed: http://www.iom-world.org/pubs/IOM_0601.pdf on 27th March 2014.

Jacobs JM (1996). *Essential assessment criteria for physical education teacher education programs: a Delphi study.* Unpublished doctoral dissertation. West Virginia University: Morgantown, West Virginia, US.

Janssen BG, Byun HM, Gyselaers W *et al*. (2015). Placental mitochondrial methylation and exposure to airborne particulate matter in the early life environment: An ENVIRONAGE birth cohort study. *Epigenetics*; 10: 536–44.

Jensen SS, Berkowicz R, Hansen HS, Hertel O (2001). A Danish decision-support GIS tool for management of urban air quality and human exposures. *Transportation Research;* 6: 229-241.

Jerrett M, Burnett R, Kanaroglou P, *et al.* (2001). A GIS-environmental justice analysis of particulate air pollution in Hamilton, Canada. *Environment and Planning A*; 33: 955-973.

Jerrett M , Burbett RT, Kanaroglou P, Eyles J *et al.* (2004). Do socioeconomic characteristics modify the short term association between air pollution and mortality? Evidence from a zonal time series in Hamilton, Canada. *Journal of Epidemiology and Community Health*; 58: 31-40.

Jerrett M, Burnett RT, Ma R *et al*. (2005). Spatial analysis of air pollution and mortality in Los Angeles*. Epidemiology*; 16: 727-736.

Jick TD (1979). Mixing qualitative and quantitative methods: triangulation in action. *Administrative Science Quarterly*; 24 (4): 603-611.

Johnson RB, Onwuegbuzie AJ (2004). Mixed methods research: a research paradigm whose time has come. *Educational Researcher*; 33: pp. 14-26.

Johnson RB, Onwuegbuzie AJ, Turner LA (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*; 1(2): 112-133.

Jones J, Hunter D (1995). Consensus methods for medical and health services research. *British Medical Journal*; 311: 376-380.

Kalaian SA, Kasim RM (2012). Terminating sequential Delphi survey data collection. *Practical Assessment and Evaluation*; 17)5): 1-10.

Keeney S, Hasson F, McKenna H (2011). *The Delphi technique in nursing and health research*. Wiley-Blackwell: Oxford, UK.

Kilbane-Dawe I (2012). Cost Effective Actions to Cut Central London Air Pollution. Par Hill Research Ltd: London, UK.

Kim JW, Park S, Lim CW *et al*. (2014). The role of air pollutants in initiating liver disease. *Toxicological Research*; 30(2): 65-70.

King K, Stedman J (2000). *Analysis of air pollution and social deprivation. A report produced for Department of the Environment, Transport and the Regions, The Scottish Executive, The National Assembly for Wales and Department of Environment for Northern Ireland*. AEA Technology: Abingdon, Oxfordshire, UK.

King's Fund (2015). *Has the government delivered a new era for public health?* King's Fund: London, UK. Accessed: https://www.kingsfund.org.uk/projects/verdict/has-government-delivered-new-era-public-health on 30th June 2018.

Knill C, Lenschow A (2004). Modes of regulation in the governance of the European Union: towards a comprehensive evaluation. In Jordana J and Levi-Faur D (Eds.), *The politics of regulation: institutions and regulatory reforms for the age of governance* (pp. 218-244). Edward Elgar Publishing: Cheltenham, UK.

Krewski D, Jerrett M, Burnett RT *et al.* (2009). Extended follow-up and spatial analysis of the American Cancver Society study linking particulate air pollution and mortality. *Res Rep Health Eff Inst*; 140: 5-114.

Kruize H, Driessen PPJ (2007). Environmental equity and the role of public policy: experiences in the Rijnmond region. *Environmental Management* 2007; 40: 578-595.

Lancet (2014). Clearing the air over Europe, and elsewhere. *The Lancet*; 383(9911): p. 1.

Landrigan PJ, Fuller R, Acosta NJR *et al*. (2017). The Lancet commission on pollution and health. *The Lancet*; http://dx.doi.org/10.1016/S0140-6736(17)32345-0

Laurian L, Funderberg R. Environmental justice in France? A spatio-temporal analysis of incinerator location. *Journal of Environmental Planning and Management*; 6: 1-23.

Laxen D, Beattie C, Dickie I (2014). *Health impacts of air pollution in Bristol*. Bristol: Air Quality Consultants.

Leksmono N, Dorfman P, Burnet F *et al.* (2010). Enhancing consultation practices in Air Quality Management in local authorities. *Journal of Env Planning and Management*; 53(5): 559-571.

Liberatos P, Link BG, Kelsey JL (1988). The measurement of social class in epidemiology. *Epidemiologic Reviews*; 10: 87-121.

Lim SS, Vos T, Flaxman AD *et al.*(2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*;380:2224-2260.

Lindley SJ, Longhurst JWS, Watson AFR, Conlan DE (1996). Procedures for estimation of regional scale atmospheric emissions-an example from NW region of England. *Atmos Env*; 30(17): 3079-3091.

Linstone HL, Turoff M (Eds) (2002). *The Delphi method: Techniques and Applications.* Addison-Wesley Publishing Company: Reading, MA, US.

Lipfert FW (2004). Air pollution and poverty: does the sword cut both ways? *J Epi Com Health*; 58: 2-3.

Local Government Association (2014). *Public health in local government – one year on*. Local Government Association: London, UK.

Longhurst JWS, Lindley SJ, Watson AFR, Conlan DE (1996). The introduction of local air quality management in the UK. A review and theoretical framework. *Atmospheric Env.*; 30 (23): 3975-3985.

Longhurst JWS, Beattie CI, Chatterton TJ *et al.* (2006). Local air quality management as a risk management process: Assessing, managing and remediating risk of exceeding an air quality objective in Great Britain. *Environment International*; 32: 934-947.

Longhurst JWS, Irwin JG, Chatterton TJ *et al*. (2009). The development of effects-based air quality management regimes. *Atmospheric Environment*; 43: 64-78.

Longhurst JWS, Olowoporoku AO, Barnes J *et al*. (2011). Exploring issues of process efficiency and outcome effectiveness in the UK's Local Air Quality Management regime. *International Journal of Sustainable Development and Planning*; 6(3): 286-298.

Maantay J (2002). Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. *Environmental Health Perspectives*; 110(2): pp. 161-171.

Major JM, Sargent JD, Graubard BI *et al*. (2014). Local geographic variation in chronic liver disease and hepatocellular carcinoma: contributions of socioeconomic deprivation, alcohol retail outlets and lifestyle. *Annals of Epidemiology*; 24: 104-110.

Makri A, Stilianakis NI (2008). Vulnerability to air pollution health effects. *Int J Hyg Environ Health*; 211: 326-36.

Marmot M (2010). *Fair Society, Healthy Lives: The Marmot Review*. UCL Institute of Health Equity: London, UK.

Matte TD, Cohen A, Dimmick F *et al*. (2009). Summary of the workshop on methodologies for environmental public health tracking air pollution effects. *Air Qual Atmos Health*; 2(4): 177-184.

Maxcy S (2003). Pragmatic threads in mixed methods research in the social sciences: the search for multiple modes of inquiry and the end of the philosophy of formalism. In *Handbook of Mixed Methods in Social & Behavioral Research,* Tashakkori A & Teddlie C (Eds.). Sage: California, US.

McDonald JS, Hession M, Rickard A *et al.* (2002). Air quality management in UK local authorities: public understanding and participation. *J Env Planning and Management*; 45(4): 571-590.

McKee M, Stuckler D (2011). The assault on universalism: how to destroy the welfare state. *BMJ*; 343, d7973.

McKenna H (1994). The Delphi technique: a worthwhile research approach for nursing? *Journal of Advanced Nursing*; 19(6): 1221-1225.

McLeod H, Langford IH, Jones AP *et al*. (2000). The relationships between socioeconomic indicators and air pollution in England and Wales: implications for environmental justice. *Reg Env Change*; 1(2): 18-26.

Miller LE (2006). *Determining what could/should be: the Delphi technique and its application*. Paper presented at the meeting of the 2006 annual meeting of the Mid-Western Educational Research Association: Columbus, Ohio, US.

Mitchell G, Dorling D (2003). An environmental justice analysis of British air quality. *Environment and Planning A*; 35: 909-929.

Mitchell R, Popham F (2008). Effect of exposure to natural environment on health inequalities and observational population study. *The Lancet*; 372: 1655-1660.

Morse JM (1991). Approaches to qualitative-quantitative methodological triangulation. *Nursing Research*; 40: 120-123.

Moynihan S, Paakkari L, Valimaa R *et al.* (2015). Teacher competencies in health education: results of a Delphi study. *PLOS One*; 10(12): 1-17.

Murphy MK, Sanderson CFB, Black NA *et al*. (1998). Consensus development methods and their use in clinical guideline development. *Health Technology Assessment*; 2: 5-83.

Nadin S, Cassell CM (2007). New deal for old? Exploring the psychological contract in the small firm environment. *International Small Business Journal*; 25(4): 417-443.

Naess O, Piro FN, Nafstad P, Smith GD *et al*. (2007). Air pollution, social deprivation and mortality: a multilevel cohort study. *Epidemiology*; 18: 686-694.

Naiker Y, Diab RD, Zunckel M, Hayes ET (2012). Introduction of local Air Quality Management in South Africa: overview and challenges. *Journal of Environmental Science and Policy; 17: 62-71.*

National Collaborating Centre for Determinants of Health (2013). *Let's talk: universal and targeted approaches to health equity.* National Collaborating Centre for Determinants of Health: Antigonish, NS.

National Health Service (2014). *NHS England – Five-year forward view*. Accessed: https://www.england.nhs.uk/wp-content/uploads/2014/10/5yfv-web.pdf, 16/07/15.

Neidell MJ (2004). Air pollution, health, and socio-economic status: the effect of outdoor air quality on childhood asthma. *Journal of Health Economics*; 23: 1209-1236.

Neidzwiedz C, Katikireddi SV, Pell JP, Mitchell R (2014). Socioeconomic inequalities in the quality of life of older Europeans in different welfare regimes. *European Journal of Public Health*; 24: 364-370.

Newcombe RG (2013). MOVER-R confidence intervals for ratios and products of two independently estimated quantities. *Statistical Methods in Medical Research*; 0(0): 1-5.

Newcombe RG, Bender R (2013). Implementing GRADE: calculating the risk difference from the baseline risk and the relative risk. *Evid Based Med*; 0(0):1-4.

Ng CWL, Ng KP (2013). Does practice size matter? Review of effects on quality of care in primary care. *British Journal of General Practice*. DOI:10.3399/bjgp13X671588.

NICE (2011). *The effectiveness of and cost effectiveness of health appraisal currently in use to address health and wellbeing during project appraisal*. NICE: London, UK.

Noble M, Wright G, Smith G, Dibben C (2006). Measuring multiple deprivation at the small-area level. *Environment and Planning A;* 38: 169–185.

O'Cathain A, Murphy E, Nicholl J (2007). Integration and publications as indicators of 'yield' from mixed methods studies. *Journal of Mixed Methods Research*; 1: 147-163.

O'Cathain A, Murphy E, Nicholl J (2010). Three techniques for integrating data in mixed methods studies. *BMJ*; 341: c4587.

Office for National Statistics (ONS (2011). *2011 Census geography products for England and Wales*. Accessed at: http://www.ons.gov.uk/ons/guide-method/geography/products/census/index.html on 6th November 2014.

Office for National Statistics (2015). *Lower Super Output Areas Population Estimates for Wales*. ONS: Newport, UK. http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates (12 May 2016, date last accessed).

Okali C, Pawlowski SD (2004). The Delphi method as a research tool: an example, design considerations and applications. *Information and Management*; 42: 15-29.

Olowoporoku AO, Hayes ET, Leksmono NS *et al*. (2010). A longitudinal study of links between LAQM and local transport planning policy processes in England. *Journal of Environmental Planning and Management*; 53(3): 385-403.

Olowoporoku AO, Hayes E, Longhurst J, Parkhurst G (2011). Improving road transport-related air quality in England through joint working between Environmental Health and Transport Planners. *Local Environment*; 16(3): 603-618.

Olowoporoku AO, Hayes E, Longhurst J, Parkhurst G (2012). Rhetoric and realities of integrating air quality into the local transport planning process in English local authorities. *J Env Mgt*; 101: 23-32.

O'Neill MS, Jerrett M, Kawachi *et al*. (2003). Health, wealth and air pollution: advancing theory and methods. *Environmental Health Perspectives*; 111(16): 1861-1870.

O'Neill MS, Kinney PL, Cohen AJ (2008). Environmental equity in air quality management: local and international implications for human health and climate change. *Journal of Toxicology and Environmental Health*; 71 (9-10), 570-577.

Padilla CM, Kihal-Talantikite W, Vieira VM *et al.* (2014). Air quality and social deprivation in French metropolitan areas – a localized spatiotemporal environmental inequality analysis. *Environ Res*; 134: 315-324.

Paliwoda SJ (1983). Predicting the future using Delphi. *Management and Decision*; 21(1): 31-38.

Parente FJ, Anderson-Parente JK (1987). *Delphi inquiry systems*. In: Wright G, Ayton P (Eds.) Judge Mental Forecasting. John Wiley: Chichester, UK.

Parkin RT, Balbus JM (2000). Variations in concepts of 'susceptibility' in risk assessment. *Risk Anal*; 20: 603–11.

Pearce J, Kingham S, Zawar-Reza P (2006). Every breath you take? Environmental justice and air pollution in Christchurch, New Zealand. *Environment and Planning A*; 38: 919-938.

Pearce J, Kingham S (2008). Environmental inequalities in New Zealand: a national study of air pollution and environmental justice. *Geoforum*; 39: 980-993.

Pearce JR, Richardson EA, Mitchell RJ, Shortt NK (2010). Environmental justice and health: the implications of the socio-spatial distribution of multiple environmental deprivation for health inequalities in the United Kingdom. *Trans Inst Br Geogr*; 35: 522-539.

Pearce JR, Richardson EA, Mitchell RJ *et al.* (2011). Environmental justice and health: a study of multiple environmental deprivation and geographical inequalities in health in New Zealand. *Soc Sci Med*; 73: 410-20.

Peng RD, Chang HH, Bell ML *et al*. (2008). Coarse particulate matter air pollution and hospital admissions for cardiovascular and respiratory diseases among Medicare patients. *JAMA*; 299: pp. 2172-2179.

Phillips AC, Lewis LK, McEvoy MP, *et al*. (2014). A Delphi study to determine how educational interventions for evidence-based practice should be reported: stage 2 of the development of a reporting guideline. *BMC Medical Education*; 14: 159.

Phillips G, Green J (2015). Working for the public health: politics, localism and epistemologies of practice. *Sociology of Health and Illness*; 37(4): 491-505.

Policy Exchange (2013). *Cleaning up road transport in London: the next steps to improve the capital's air quality.* Accessed: http://www.policyexchange.org.uk/images/publications/cleaning%20up%20road%20transport%20in%20london.pdf, 16/07/15.

Polit D, Beck C, Hungler B (2001). *Essential of nursing research – methods, appraisal and utilisation* (5th edition). JB Lippincott Company: Philadelphia, US.

Poortinga F, Dunstan FD, Fone D (2008). Neighbourhood deprivation and self-reported health: the role of perceptions of the neighbourhood and of housing problems. *Health & Place*; 14(3): 562-575.

Pope CA 3rd, Thun MJ, Namboodiri MM *et al.* (1995). Particulate air pollution as a predictor of mortality in a prospective study of US adults. *Am J Respir Crit Care Med*; 151: pp. 669-674.

Privitera GJ (2012). *Statistics for the Behvioral Sciences*. Sage Publications:

California, US.

Pruss-Ustun A, Wolf J, Corvalan C *et al.* (2017). Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health. *Journal of Public Health*; 39(3): 464-475.

Public Health Wales (2016), *Estimated mortality burden associated with air pollution exposure in Wales*. Public Health Wales: Cardiff, UK.

Pye S, Stedman J, Adams M, King K (2001). *Further analysis of NO2 and PM10 air pollution and social deprivation*. Department of Rural Affairs, the National Assembly for Wales and Department of the Environment in Northern Ireland. Defra: London, UK.

Radestad M, Jirwe M, Castren M *et al*. (2013). Essential key indicators for disaster medical response suggested to be included in a national uniform protocol for documentation of major incidents: a Delphi study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*; 21: 68-79.

Rao M, Barten F, Blackshaw N *et al.* (2011). Urban planning, development and non-communicable diseases. *Planning Practice and Research*; 26(4): 373-391.

Raskin MS (1994). The Delphi study in field instruction revisited: expert consensus on issues and research priorities. *Journal of Social Work and Education*; 30: 75-89.

Ratnapradipa D, Brown SL, Wodika AB (2011). Examining the breadth and depth of environmental health through a modifies Delphi technique. *American Journal of Health Education*; 42(1): 50-57.

Rauch W (1979). The decision Delphi. *Technological Forecasting and Social Change*; 15: 159-169.

Rayens MK, Hahn EJ (2000). Building consensus using the policy Delphi method. *Policy Polit Nurse Pract*; 1: 308-315.

Revilla MA, Saris WE, Krosnick JA (2014). Choosing the number of categories in agree-disagree scales. *Sociological Methods and Research*; 43(1): 73-97.

Richardson EA, Pearce J, Kingham S (2011). Is particulate air pollution associated with health and health inequalities in New Zealand? *Health Place*; 17: 1137-43.

Richardson EA, Pearce J, Tunstall H *et al*. (2013). Particulate air pollution and health inequalities: a Europe-wide ecological analysis. *International Journal of Health Geographics*; 12: 34-43.

Riley M, Wood RC, Clark E *et al.* (2000). *Researching and Writing Dissertations in Business and Management*. Thomson Learning: London, UK.

Riordan P (2015). *Improving the health of everyone in Wales-the Public Health challenge of prudent healthcare.* Accessed: http://www.prudenthealthcare.org.uk/wp-content/uploads/2014/10/Improving-the-health-of-everyone-in-Wales-%E2%80%93-the-public-health-challenge-of-prudent-healthcare.pdf, 07/10/15.

Romieu I, Castro-Giner F, Kunzli N, Sunyer J (2008). Air pollution, oxidative stress and dietary supplementation: a review. *Eur Respir J*; 31: 179–97.

Rose G (1981). Strategy of prevention: lessons from cardiovascular disease. *BMJ*; 282: 1847-51.

Royal Colleges of Physicians and Paediatrics Child Health (2016). *Every breath we take – the lifelong impact of air pollution*. London: Royal College of Physicians.

Rundle A, Hoepner L, Hassoun A *et al*. (2012). Association of childhood obesity with maternal exposure to ambient air polycyclic aromatic hydrocarbons during pregnancy. *Am J Epidemiol*; 175: 1163–72.

Salway R, Wakefield J (2008). A hybrid model for reducing ecological bias. *Biostatistics;* 9: 1-17.

Sallis JF, Burdett R, Frank LD *et al.* (2016). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. *The Lancet*; 388: 2936-2947.

Samet JM, White RH (2004). Urban air pollution, health and equity. *Journal of Epidemiology and Community Health*; 58: 3-5.

Saunders P, Saunders A, Middleton J (2015). Living in a 'fat swamp': exposure to multiple sources of accessible, cheap, energy-dense fast foods in a deprived community. *Br J Nutr*; 113: 1828–34.

Scheibe M, Skutsch M, Schofer J (1975). Experiments in Delphi methodology. In: HA Linstone, M Turoff (Eds.) The Delphi Method – techniques and applications (262-287). Addison-Wesley: Reading, US.

Schmidt K, Montgomery L, Bruene D, Kenny M (1997). Determining research priorities in pediatric nursing: a Delphi study. *Journal of Pediatric Nursing*; 12(4): 201-207.

Scottish Government (2015). *Cleaner air for Scotland – the road to a healthier future*. The Scottish Government: Edinburgh, UK.

Scottish Government (2016). *Local Air Quality Management Policy Guidance PG S 16*. Scottish Government: Edinburgh, UK

Secker J, Wimbush E, Watson J, Milburn K (1995). Qualitative methods in health promotion research: some criteria for quality. *Health Education Journal*; 54: pp. 74–87.

Seinfeld JH, Pandis S (2006). *Atmospheric chemistry and physics*. 2nd ed. John Wiley: Hoboken, New Jersey, US.

Shah ASV, Langrish JP *et al*. (2013). Global association of air pollution and heart failure: a systematic review and meta analysis. *The Lancet*; 382: pp. 1039-1048.

Sheen NJL, Fone D, Phillips CJ *et al*. (2009). Novel optometrist-led all-Wales primary eye-care services: evaluation of prospective case series. *British Journal of Ophthalmology*; 93(4): 435-438.

Sherriff G (2014). Drivers of and barriers to urban energy in the UK: a Delphi study. *Local Environment*; 19(5): 497-519.

Soret A, Jimenez-Guerrero P, Baldasano JM (2011). Comprehensive air quality monitoring for the Barcelona Metropolitan Area through traffic management. *Atmospheric Pollution Research*; 2: 255-266.

Stedman J, Bush T, Vincent KJ *et al.* (2003). *UK air quality modelling for annual reporting 2002 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC*. 2003. AEA Technology: Abingdon, UK:. https://uk-air.defra.gov.uk/assets/documents/reports/cat05/0402061100_dd12002mapsrep1-2.pdf (12 May 2016, date last accessed).

Stern N (2006). *Stern review: the economics of climate change*. Accessed: http://webarchive.nationalarchives.gov.uk/20130129110402/http://www.hm-treasury.gov.uk/stern_review_report.htm, 16/07/15.

Su JG, Larson T, Gould T *et al*. (2009). Transboundary air pollution and environmental justice: Vancouver and Seattle compared. *GeoJournal*; 75: 595-608.

Teddlie C, Tashakkori A (2009). *Foundations of mixed methods research: integrating quantitative and qualitative approaches in the social and behavioural sciences.* Sage: Thousand Oaks, CA, US.

Twedwr-Jones M (2011). *A review of the extent to which the spatial planning system supports the delivery of e Government's health, wellbeing and social care objectives.* Colin Buchanan and Partners: London, UK.

Thomas B, Dorling D, Smith GD (2010). Inequalities in premature mortality in Britain: observational study from 1921 to 2007. *BMJ*; 341.

Turoff M, Hiltz SR (1996). Computer-based Delphi process. In M Adler, E Ziglio (Eds). *Gazing into the oracle: the Delphi method and its application to social policy and public health* (56-88). Jessica Kingsley Publishers: London, UK.

USEPA (2013). Integrated science assessment for oxides of nitrogen – health criteria EPA/600/R-13/202. United States Environmental Protection Agency: Washington DC, US.

Villeneuve PJ, Burnett RT, Shi Y *et al*. (2003). A time-series study of air pollution, socioeconomic status and mortality in Vancouver, Canada. *J Exposure Analysis and Environmental Epidemiology*; 13: 427-435.

Von der Gracht (2012). Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technological Forecasting and Social Change*; 79: 1525-1536.

Wakefield J, Shaddick G (2006). Health-Exposure Modelling and the Ecological Fallacy. *Biostatistics*; 7(3): 438-455.

Walker AM, Selfe J (1996). The Delphi method: a useful tool for the allied health researcher. *British Journal of Therapy and Rehabilitation*; 3(12): 677-681.

Walker G, Fairburn J, Smith G, Mitchell G (2006). *Air quality and social deprivation in the UK: an environmental inequalities analysis*. Environment Agency: Bristol, UK.

Walton H, Dajnak D, Beevers S et al. (2015). *Understanding the health impacts of air pollution in London*. Kings College London: London, UK. https://www.kcl.ac.uk/lsm/research/divisions/aes/research/ERG/research-projects/ HIAinLondonKingsReport14072015final.pdf (Accessed: 12 May 2016).

Wang S, Hao J (2012). Air quality management in China: issues, challenges and options. *Journal of Environmental Sciences*; 24(1): 2-13.

Waterlander WE, Steenhuis IHM, de Vet E *et al*. (2009). Expert views on most suitable monetary incentives on food to stimulate healthy eating. *European Journal of Public Health*; 20(3): 325-331.

Welsh Government (2009). *Local Air Quality Management Policy Guidance for Wales*. WG: Cardiff, UK.

Welsh Government (2011). Welsh Index of Multiple deprivation: Guidance on Use. Welsh Government: Cardiff, UK. Accessed at: http://wales.gov.uk/docs/statistics/2011/110922wimd11guidanceen.pdf on 7th November 2014.

Welsh Government (2013). *Active Travel (Wales) Act 2013*. Welsh Government: Cardiff, UK. Available at: http://www.legislation.gov.uk/anaw/2013/7/contents [accessed on 23rd November 2016].

Welsh Government (2014). *Welsh Index of Multiple Deprivation 2014 (WIMD 2014) Technical Report*. Welsh Government: Cardiff, UK. http://gov.wales/statistics-and-research/welsh-index-multiple-deprivation/technical-information/?lang=en (18 May 2016, date last accessed).

Welsh Government (2014). *CMO Annual Report 2013/14.* Welsh Government: Cardiff, UK.

Welsh Government (2015). *CMO Annual Report 2014/15.* Welsh Government: Cardiff, UK.

Welsh Government (2015). *Wellbeing of Future Generations (Wales) Act 2015.* Welsh Government: Cardiff, UK. Available at: http://www.legislation.gov.uk/anaw/2015/2/contents/enacted [accessed on 23rd November 2016).

Welsh Government (2015). *Planning (Wales) Act 2015*. Welsh Government: Cardiff, UK. Available at: http://www.legislation.gov.uk/anaw/2015/4 [accessed on 23rd November 2016].

Welsh Government (2016). *Environment (Wales) Act 2016*. Welsh Government: Cardiff, UK. Available at: http://www.legislation.gov.uk/anaw/2016/3/contents/enacted [accessed 23rd November 2016].

Welsh Government (2016). *Welsh Index of Multiple Deprivation*. Welsh Government: Cardiff, UK. http://wimd.wales.gov.uk/ (12 May 2016, date last accessed).

Welsh Government (2017). *Local Air Quality Management Policy Guidance PG W 17*. Welsh Government: Cardiff, UK.

Welsh Government (2017). *Prosperity for All*. Welsh Government: Cardiff, UK.

Welsh Government (2017). *Public Health (Wales) Act 2017*. Welsh Government: Cardiff, UK.

Welsh Government (2018). *CMO annual report: Gambling with our health*. Welsh Government: Cardiff, UK.

Wheeler BW (2004). Health-related environmental indices and environmental equity in England and Wales. *Environment and Planning A*; 36: 803-822.

Wheeler BW, Ben-Schlomo Y (2005). Environmental equity, air quality, socioeconomic status, and respiratory health: a linkage analysis of routine data from the Health Survey for England. *Journal of Epidemiology and Community Health*; 59: 948-954.

Whitehead M, Dahlgren G (2006). *Concepts and principles for tackling social inequities in health: levelling up part 1*. World Health Organization: Geneva, Switzerland.

Wilkins ET (1954). Air pollution and the London fog of December, 1952. *Journal of the Royal Society for the Promotion of Health*; 74(1): 1-15.

Woodfield NK, Longhurst JWS, Beattie CI, Laxen DPH (2002). Designating Air Quality Management Areas in the UK: implications for securing UK Air Quality Objectives. *Water Air and Soil Pollution*; 2: 677-688.

Woodfield NK, Longhurst JWS, Beattie CI, Laxen DPH (2003). Critical evaluation of the role of scientific analysis in UK local authority AQMA decision-making. *Science Total Environment*; 311: 1-18.

Woodfield NK, Longhurst JWS, Beattie CI *et al*. (2006). Regional collaborative urban air quality management: case studies across Great Britain. *Environmental Modelling and Software*; 21: 595-599.

Wooten H (2010). Healthy planning in action. *Planning*; 76(2): 20-23.

World Health Organization (2000). *Quantification of the health effects of exposure to air pollution*. World Health Organization European Centre for Environment and Health: Bilthoven: Netherlands.

World Health Organization (2004). *Health aspects of air pollution: results from the WHO project "systematic review of aspects of air pollution in Europe".* WHO: Copenhagen, Denmark.

World Health Organization (2005). *Air quality guidelines global update*. WHO: Copenhagen, Denmark.

World Health Organization (2006). *Air quality guidelines global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. WHO: Geneva, Switzerland.

World Health Organization (2010). *Urban planning, environment and health – from evidence to policy action.* WHO Europe: Cpenhagen, Denmark.

World Health Organization (2013). *Review of evidence on health aspects of air pollution– REVIHAAP*. WHO: Copenhagen, Denmark.

World Health Organization (2015). Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth. WHO: Copenhagen, Denmark.

World Health Organization (2017). *Evolution of WHO air quality guidelines: past, present and future*. WHO: Copenhagen, Denmark.

World Health Organization IARC (2013). *Outdoor air pollution a leading environmental cause of cancer deaths*. Lyon, France: WHO International Agency for Research on Cancer.

Yanosky JD, Schwatrz J, Suh HH (2008). Associations between measures of socioeconomic position and chronic nitrogen dioxide exposure in Worcester, Massachusetts. *Journal of Toxicology and Environmental Health, Part A*; 71: 1593-1602.

Yousuf MI (2007). Using expert opinions through Delphi technique. *Pract Assess Res Eval*; 12(4): 1-8.

Zanini G, Pignatelli T, Monforti F *et al.* (2005). *The MINNI project: an integrated assessment modelling system for policy making* In: Proc. of MODSIM 2005 Int. Congress on modelling and simulation. Modelling and Simulation Society of Australia and New Zealand. ISBN 0-9758400-2-9 2005-2011.

Zeka A, Zanobetti A, Schwartz J (2006). Individual level modifiers and the effects of particulate matter on daily mortality. *Am J Epidemiol*; 163(9): 849-59.

Zhang K, Batterman S (2013). Air pollution and health risks due to vehicle traffic. *Science of the Total Environment*; 450-451: pp. 307-316.

Appendix A

Published papers, conference presentations and posters

Peer-review journal publications

- Evidence critique:

  Brunt H, Barnes J, Longhurst JWS, Scally G, Hayes E (2016). Local Air Quality Management policy and practice in the UK: the case for greater Public Health integration and engagement. *Journal of Environmental Science and Policy*; 58: 52-60.

  https://www.sciencedirect.com/science/article/pii/S1462901116300090

  UWE repository: http://eprints.uwe.ac.uk/28167/

- Research Strand 1's ecological study:

  Brunt H, Barnes J, Jones SJ, Longhurst JWS, Scally G, Hayes E (2016). Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. *J Public Health*; 39(3): 485-497.

  https://academic.oup.com/jpubhealth/article/39/3/485/3076806

  UWE repository: http://eprints.uwe.ac.uk/30133/

- Research Strand 2's Delphi study:

  Brunt H, Barnes J, Longhurst JWS, Scally G, Hayes E (2017). Enhancing Local Air Quality Management to maximise public health integration, collaboration and impact in Wales, UK: a Delphi study. *Journal of Environmental Science and Policy*; 80: 105-116.

  https://www.sciencedirect.com/science/article/pii/S1462901117302599

  UWE repository: http://eprints.uwe.ac.uk/34102/

Other publications, conference presentations and posters

- Wales Public Health conference, Cardiff, UK (December 2017) - poster
- UK Health Protection Society meeting, Cardiff, UK (April 2017) - presentation
- Huw Brunt, Jo Barnes, James Longhurst, Gabriel Scally, Enda Hayes (2017). Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact. *Environmental Scientist*; 26(2): 30-37. Accessed at: https://www.the-ies.org/sites/default/files/journals/es_clean_air_Apr_17.pdf on 19th March 2018 – journal article

- UK active travel conference, Bristol, UK (September 2016) - presentation
- UWE Doctoral Exchange event, Bristol, UK (May 2016) - presentation
- Wales Public Health conference, Cardiff, UK (November 2015) http://www.wales.nhs.uk/sitesplus/888/document/277455 - presentation
- Welsh Air Quality Forum annual seminar, Llandrindod Wells, UK (October 2015) http://www.welshairquality.co.uk/documents/seminars/494151028_WAQF_Seminar_Programme_2015-Final.pdf - presentation
- International Air Pollution conference, Valencia, Spain (June, 2015) http://www.wessex.ac.uk/conferences/2015/air-pollution-2015 - presentation
- ACT Travelwise road transport and air pollution conference, Birmingham, UK (December 2014) https://www.slideshare.net/act-travelwise/huw-brunt-42639876 - presentation
- UK Review Meeting on Outdoor and Indoor Air Pollution Research, Birmingham, UK (June 2014) - poster
- UWE Doctoral Exchange event, Bristol, UK (June 2014) – presentation

Appendix B Delphi study participant invite, information pack and consent form

Delphi study invite

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact

My name is Huw Brunt. I am a PhD researcher at the University of the West of England's Air Quality Management Resource Centre and Lead Consultant in Environmental Health Protection at Public Health Wales. I have a special interest in the public health aspects of air quality management.

I am writing to you as I would like to involve you in research I am carrying out to determine how best to enhance the *Local Air Quality Management* regime in Wales to maximise public health integration, collaboration and impact.

Through the work I have already undertaken as part of my studies, I have found that the public health role in *Local Air Quality Management* is poorly defined, that public health is disengaged from the process, and that the disconnect in policy and practice between these work areas is significant. To understand and help resolve these problems, I am carrying out a three-round Delphi survey to:

- clarify the role of public health in Local Air Quality Management;
- identify opportunities to improve public health integration and collaboration in Local Air Quality Management;
- identify the barriers to improving integration and collaboration; and
- explore what added value could result from improved integration and collaboration if barriers are overcome.

You have been identified as someone with considerable expertise and experience in the areas of local public health practice, local air quality management and/or environmental health. As such, your contribution to this study would be valued.

Please read the information contained in this participant information pack.

If you are interested in participating in this survey, please complete a consent form and return a scanned copy to huw3.brunt@uwe.ac.uk by 15th April 2016.

Should you have any queries, or require further information, please do not hesitate to contact me at the above e-mail address, or on my mobile: 07817 872577. Alternatively, you can write to me at: Air Quality Management Resource Centre, Faculty of Environment and Technology, University of West of England, Coldharbour Lane, Bristol BS16 1QY.

Huw Brunt (PhD Researcher)
Air Quality Management Resource Centre, University of West of England, Bristol

Delphi study participant information

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact

1. Invitation

You are being invited to participate in a research study. To inform your decision on whether to take part, please read this information as it will help you understand why the research is being carried out and what it will involve. Please do not hesitate to get in touch with us if you would like further information or clarification on any points.

2. What is this research trying to achieve?

Exposure to outdoor air pollution is known to adversely affect human health and reduce life expectancy. Whilst air quality, on the whole, has improved considerably in the UK, air pollution problems persist at the local level and pose increased public health risks.

Since 1997, through the *Local Air Quality Management* (LAQM) regime, Local Authority-led collaborative action has strived to protect health by identifying, defining and tackling local air pollution problems through a prescribed process of 'review and assessment' and 'action planning' and implementation. As a result, Local Authorities have successfully identified local air pollution 'hotspots' and developed a comprehensive understanding of local air quality across the areas they cover.

However, efforts to assess risks and solve problems have had little regard to public health. There is evidence to suggest that, although identified as an LAQM stakeholder, public health is disengaged from LAQM practice and that a disconnect exists between the two policy areas. Public health can make a significant contribution to LAQM. To facilitate this, and add value to existing arrangements and impacts, the role of public health in LAQM should to be clarified and defined, and opportunities to improve integration and collaboration should be seized.

LAQM remains the only mechanism through which to protect local public health from the impacts of air pollution exposure. In recognition of existing LAQM deficiencies, alongside compelling evidence of adverse health effects from air pollution exposure, acting to place public health at the heart of local air quality assessment and management efforts is now a real priority. This study therefore seeks to:

- clarify the role of public health in Local Air Quality Management;
- identify opportunities to improve public health integration and collaboration in LAQM;
- identify the barriers to improving integration and collaboration; and
- explore what added value could result from improved integration and collaboration.

3. What is the Local Air Quality Management regime?

For your information, the Local Air Quality Management (LAQM) process is briefly described here. Please note that you do not need to be an expert in LAQM to participate in this research.

The UK's Local Air Quality Management (LAQM) regime aims to protect public health from the effects of air pollution exposure. To facilitate this, Local Authorities are required to periodically assess local air pollution concentrations and compare them, through a prescribed risk assessment process, with health-based Air Quality Objectives (AQO) for key air pollutants such as particulate matter and nitrogen dioxide.

The concept of LAQM originated in the first version of the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (1997) and the Environment Act, Part IV (1995). It recognises that air pollution sources are best managed at the local level through proportionate, cost-effective, collaborative action that takes account of the local context. Health Authorities are identified as a stakeholder in LAQM.

Although changes are being made to the process, the regime's two-stage health effects-based approach (i.e. air quality assessment in the context of likely public exposure) comprises:

a) *Review and Assessment.* A phased risk-management approach to review air quality in locations where the public is likely to be regularly present and declare an *Air Quality Management Area* (AQMA) where required.
b) *Action Planning.* Following AQMA declaration, an *Air Quality Action Plan* (AQAP) of collaborative, proportionate, cost-effective time-bound mitigation and management measures is developed and implemented. Local Councils work to achieve AQOs.

4. Why have I been chosen?

You have been asked to participate because you have been identified as an expert in this area. This may be as a public/environmental health specialist, an air quality specialist, or both. You do not need a technical understanding of the LAQM regime to participate in this research but a brief overview is provided above for your information.

This study has the following inclusion criteria which we think you might meet:

- a minimum of five years experience of working in at least one of the following areas: local air quality assessment and management; environmental health; public health;
- work/worked in at least one of the following areas in Wales in the last five years: local air quality management; environmental health; public health;
- can offer insightful opinions and viewpoints;
- have the motivation to address an identified problem;
- interest, capacity and willingness to participate.

5. Must I take part?

You are not obliged to participate in this research study. If you decide to participate, you should keep this information. Please also complete and return a consent form. All participation details and instructions will be provided to you at in advance of you needing to do anything. You can withdraw at any time without giving a reason. However, the effectiveness and value of this research process is dependent upon ongoing participation (over a period of 6-8 months).

6. What if I decide to participate?

The research will use the Delphi survey method to facilitate structured communication and information gathering from experts. This method is based on the principle that feedback from a group of individuals is more valid and reliable than that from individuals. Delphi is a structured communication technique (with core characteristics of anonymity, iteration, controlled feedback and statistical group response) which relies on a panel of experts. Panelists answer questions in two or more iterative survey rounds which are interspersed with feedback. After each round, the researcher provides an anonymous summary of the experts' answers and reasoning from the previous round. Experts can revise their earlier answers in light of the replies of other Panel members. This process encourages the group to converge towards one answer.

In the first round, you will be asked to answer open-ended questions. Once responses from all participants have been received, they will be collated and summarised to inform the development of a second questionnaire. You will have the opportunity to review and revise your answers in subsequent survey rounds. There are no right or wrong answers to questions. The surveys seek your ideas and opinions. Each of the three survey rounds will take no more than 30 minutes.

After the Delphi process has stopped, you will be sent a summary of the findings/conclusions. These will be used to inform the development of an enhanced, public health-focused LAQM model. You will be invited to attend a workshop at a later date to validate the new framework.

The following points are important for you to remember:

- Your participation in this study, and subsequent validation workshop, is voluntary;
- If you agree to participate, you should complete and return a consent form. Despite there being three survey rounds and a validation workshop, you will only need to complete the form once as this implies ongoing consent;
- Your opinions will remain anonymous to other participants. You will be given a unique code. Your decision to participate, and responses, will be confidential to researchers;
- Confidentiality will remain when the results of the research are written up for any publication/dissemination purposes;
- All information will be handled and stored in accordance with the requirements of the University of the West of England and the Data Protection Act 1998. All information will be destroyed five years after completion of this research;

- You can decline or withdraw from the study at any time. However, as stated above, the effectiveness and value of this research process is dependent upon ongoing participation by participants. Since your opinions and feedback will be analysed and re-circulated, you have the opportunity to actively contribute to and shape the research process as it evolves and develops. As such, your continued participation will really help to make the study a success.

7. What are the benefits of participation?

We cannot guarantee that this study will help you as an individual. However, the data we obtain through this research should inform and facilitate the development of improved public health integration and collaboration in future LAQM policy and practice in Wales.

8. What if something goes wrong?

We are not aware of any complications or risks that could arise from you taking part in this study. If you decide to participate, and you have any complaints or difficulties with any aspect of the study, you should contact the principal researcher and/or another member of the Research Team:
Huw Brunt, Principle Researcher: huw3.brunt@uwe.ac.uk; 07817872577.
Dr Enda Hayes, Director of Studies: enda.hayes@uwe.ac.uk; 01173 283825.
Dr Jo Barnes, Second Supervisor: jo.barnes@uwe.ac.uk; 01173 283825.

9. What happens when the study stops?

After the Delphi process, you will be sent a summary of the findings/conclusions. These will be used to inform the development of an enhanced, public health-focused LAQM model. You will be invited to attend a workshop later, to validate the new framework.

10. Who is organising this study?

The principal researcher is Huw Brunt, a PhD researcher with the Air Quality Management Resource Centre, University of the West of England, Bristol. The Centre has extensive experience in air quality management-related research. The research is supported by Public Health Wales which is part of the NHS in Wales and has a remit of providing independent, specialist public health advice and support to a broad range of stakeholders.

11. Research ethics approval

This study has been approved by the University of West of England Faculty Research Ethics Committee (Ref FET/16/02/028).

12. Further information

If you wish to clarify any aspect of this research or speak to someone about it, please contact the principal researcher, Huw Brunt, on huw3.brunt@uwe.ac.uk or 07817872577; or another member of the Research Team (see 8. above).

Thank you for taking the time to read this information.
If you would like to participate, please complete and return the consent form by 15/04/16.

Delphi study consent form

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact

CONSENT

Mark all with 'X'

1	I confirm that I have read and understood the 'Delphi participant information sheet' for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
2	I am willing to participate in this Delphi study and the subsequent validation workshop.	☐
3	I understand that my participation is voluntary and that I can withdraw at any time, without giving any reason.	☐
4	I understand that I will remain anonymous to the other participants throughout this study and only the researchers will be able to identify my specific answers.	☐
5	I understand that the researcher will hold all information and data collected in a secure and confidential manner.	☐

Name

Signature

E-mail address

Date

When complete, please scan this form and email a copy to:
huw3.brunt@uwe.ac.uk by 15th April 2016

For Research Team use only:

Unique ID

Appendix C

Delphi study round 1 survey

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact

Thank you for returning your consent form and agreeing to participate in this three-round Delphi research study.

Survey completion instructions

This first survey consists of the following 4 open-ended questions:

1. What is the role of public health in Local Air Quality Management?

2. How can public health integration and collaboration in Local Air Quality Management be improved?

3. What are the barriers to improving public health integration and collaboration in Local Air Quality Management?

4. What added value could result if barriers are overcome?

For each question, you should answer by providing at least 3, but no more than 6, personal opinions and ideas. For each opinion or idea you give, please justify why you think it is important.

After the open-ended questions, you will be asked for some additional information that will allow the Research Team to identify you, who you work for and your levels of experience and expertise. The information you provide will remain anonymous to all other survey participants.

Please complete this survey by Friday 20th May 2016.

What happens after you've responded?

Once all responses have been received, the Research Team will summarise the data generated by this survey and send it back to you for validation. The second round survey will launch in June 2016, but you will be contacted again before this with updates and instructions. The third and final survey will lauch after the summer holidays in Autumn 2016.

Should you have any queries, require further information, or experience difficulties completing this survey, please contact Huw Brunt on huw3.brunt@uwe.ac.uk or 07817 872577.

Thank you.

1 / 9

1. In your opinion, what is the role of public health in Local Air Quality Management in Wales?

Please list a minimum of 3 different opinions and ideas in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important. If helpful, click the 'more info' option for a definition of public health.

More info

	Public Health role	Why important?
1		
2		
3		

1.a. If you wish to provide more opinions and ideas in response to this question, please do so in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Public Health role	Why important?
4		
5		
6		

2. In your opinion, what opportunities are there to improve public health integration and collaboration in Local Air Quality Management in Wales?

Please list a minimum of 3 different opinions and ideas in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Opportunity	Why important?
1		
2		
3		

2.a. If you wish to provide more opinions and ideas in response to this question, please do so in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Opportunity	Why important?
4		
5		
6		

3. **In your opinion, what barriers stand in the way of improving public health integration and collaboration in Local Air Quality Management in Wales?** Please list a minimum of 3 different opinions and ideas in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Barrier	Why important?
1		
2		
3		

3.a. If you wish to provide more opinions and ideas in response to this question, please do so in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Barrier	Why important?
4		
5		
6		

4. In your opinion, what added value could result from improving public health integration and collaboration in Local Air Quality Management in Wales?

Please list a minimum of 3 different opinions and ideas in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Added value	Why important?
1		
2		
3		

4.a. If you wish to provide more opinions and ideas in response to this question, please do so in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Added value	Why important?
4		
5		
6		

About you

5. Your name and contact details

	Please complete * Required
Name	
Confirm e-mail address	
Contact telephone number	

6. Your current role

	Please complete * Required
Job title	

6.a. Position * Required

6.a.i. If you selected Other, please specify:

6.b. Discipline * Required

6.b.i. If you selected Other, please specify:

6.c. Work in, or on behalf of agencies in, Wales... * Required

7. Your expertise and experience

	Please complete * Required
Highest relevant qualification	

7.a. Years of relevant experience * Required

7.b. Undertake air quality-related work * Required

7.c. Undertake public health-related work * Required

8. Your employer details

	Please complete * Required
Employer name	

8.a. Employer type * Required

8.a.i. If you selected Other, please specify:

Finish

Thank you for taking the time to complete this survey.

Your support and contributions are valued.

Key for selection options

6.a - Position
- Practitioner
- Manager
- Advisor
- Researcher
- Other

6.b - Discipline
- Air quality
- Environmental Health
- Public Health
- Regulation
- Policy
- Research
- Other

6.c - Work in, or on behalf of agencies in, Wales...
- Permanently
- Frequently
- Occasionally

7.a - Years of relevant experience
- 5-10
- 11-19
- 20-29
- 30+

7.b - Undertake air quality-related work
- Daily
- A few times per week
- A few times per month
- A few times per year
- Never

7.c - Undertake public health-related work
- Daily
- A few times per week
- A few times per month
- A few times per year
- Never

8.a - Employer type
- Local Government
- National Health Service
- Civil Service

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact (Round 2 survey)

Page 1

Dear Participant

Thank you for continuing to support this three-round Delphi research study.

Survey completion instructions

This second survey consists of four closed questions and one open-ended question; it should take 20-30 minutes to complete.

The closed questions ask you to rate your level of agreement with opinions generated from your feedback to the first round survey. Opinions are provided in the form of statements (items), of which there are 80 in total, 20 in each of four separate lists relating to:

1. the role of public health specialists (in Public Health Wales/Health Boards) in Local Air Quality Management

2. opportunities to increase public health integration and collaboration

3. added value of increased public health integration and collaboration

4. barriers to increasing public health integration and collaboration

The final open-ended question asks you to suggest solutions that can help overcome barriers. As in the first round, please answer this question by providing at least 3, but no more than 6, personal opinions/ideas.

If you need to complete the survey in stages, you can save your progress after answering each question i.e. select 'finish later'. This is also good practice to avoid losing work as you progress through the survey.

Please complete this survey by Friday 30th September 2016.

What happens next?

Once all responses have been received, the data will once again be collated and analysed.

In the third and final survey round, you will be asked to repeat the exercise of rating your level of agreement with statements that did not achieve consensus in the second survey round. To help infom the re-evaluation, and possible revision, of your agreement status with the statements that remain, you will be provided with some information about the thoughts of the Delphi panel as a whole as well as being reminded about the responses you provided in the second round survey.

The third survey will launch in November 2016.

Should you have any queries, require further information, or experience difficulties completing this survey, please contact Huw Brunt on huw3.brunt@uwe.ac.uk or 07817 872577.

Thank you.

Huw Brunt

1. **To what extent do you agree with the following statements on the roles of public health specialists (in Public Health Wales/Health Boards) in Local Air Quality Management?**

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. To help others assess air pollution risks in the broadest possible public health context	☐	☐	☐	☐	☐	Theme: risk assessment
2. To use expertise and resources to share, link and analyse data to assess risks and impacts	☐	☐	☐	☐	☐	Theme: risk assessment
3. To determine how air pollution-related risks vary between and within communities	☐	☐	☐	☐	☐	Theme: risk assessment
4. To interpret evidence, and use it to set shared priorities and inform others' decisions	☐	☐	☐	☐	☐	Theme: risk assessment
5. To advocate for, and support evidence reviews to, assess the effectiveness of interventions	☐	☐	☐	☐	☐	Theme: research and evaluation
6. To undertake new research to evaluate the air pollution and health impacts of action	☐	☐	☐	☐	☐	Theme: research and evaluation
7. To understand broader public health consequences of action to reduce air pollution/risks	☐	☐	☐	☐	☐	Theme: research and evaluation

8. To provide independent scrutiny of evidence-based and innovative action to reduce air pollution and linked health risks, and hold those implementing it to account	☐	☐	☐	☐	☐	Theme: risk management
9. To work with others to promote and facilitate active-travel for all	☐	☐	☐	☐	☐	Theme: risk management
10. To work with others through all appropriate partnership networks to improve public health generally to reduce individual and population-level susceptibility to air pollution exposure	☐	☐	☐	☐	☐	Theme: risk management
11. To champion the principles of environmental sustainability; lead by example by reducing the local air quality impacts from NHS services and estate	☐	☐	☐	☐	☐	Theme: risk management
12. To raise the profile of air pollution as a local public health priority through effective authoritative communications with partners and the public	☐	☐	☐	☐	☐	Theme: communications
13. To let people know 'what works' to reduce air pollution and associated risks	☐	☐	☐	☐	☐	Theme: communications

14. To work with others to provide timely advice to the public on how to minimise risks						Theme: communications
15. To lead, and support others across relevant sectors, to develop and implement long-term, prevention-focused air pollution, health risk and inequality reduction policy and practice						Theme: change leadership
16. To use local-level learning to inform policy development at the national level						Theme: change leadership
17. To connect local air quality management policy and practice with other public health priority work areas e.g. respiratory and heart diseases, obesity, injuries, diabetes						Theme: change leadership
18. To advocate for, and support, evidence-based action to reduce air pollution-related health risks for all i.e. extending efforts beyond localised air pollution 'hot-spots						Theme: change leadership
19. To advocate for, and support, targeted evidence-based action in 'at risk' areas/populations to reduce air pollution and health-related inequalities, as appropriate						Theme: change leadership

20. To help shape others' policy and practice to reduce air pollution and associated health risks e.g. environmental health, transport, land-use planning, environmental sustainability	☐	☐	☐	☐	☐	Theme: change leadership

2. **To what extent do you agree with the following statements on the opportunities to increase public health integration and collaboration in Local Air Quality Management?**

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. There is a need to capitalise on the availability of stronger evidence and raised political, media and public interest in air pollution as a public health priority	☐	☐	☐	☐	☐	Theme: profile and understanding
2. Given that key pollutants have no 'safe' level of exposure, acting to reduce local air pollution and risks must extend beyond localised air pollution 'hotspots'	☐	☐	☐	☐	☐	Theme: profile and understanding
3. A better understanding of links between air pollution and health determinants calls for problems and solutions to be considered in a broad public health context	☐	☐	☐	☐	☐	Theme: profile and understanding

4. LAQM responsibilities are a devolved responsibility; opportunities exist to enhance the regime to render it fit-for-purpose in Wales						Theme: policy development
5. Welsh Government is committed to review existing LAQM arrangements so there are good opportunities to influence its development						Theme: policy development
6. The Wellbeing of Future Generations (Wales) Act 2015 calls for sustainable action that can enhance LAQM developments						Theme: policy development
7. Public bodies must act to prevent environmental and health/wellbeing problems (including inequalities); 'treating' effects rather than causes is not acceptable						Theme: policy development
8. Wales' national air quality indicator can help inform local action and evaluations						Theme: policy development
9. Public Health Wales is well-placed to encourage action across the wider NHS						Theme: policy development

10. Good relationships with Welsh Government can facilitate evidence-based change	☐	☐	☐	☐	☐	Theme: collaboration and communication
11. The Welsh Air Quality Forum offers good opportunities to increase collaboration and action to enhance LAQM	☐	☐	☐	☐	☐	Theme: collaboration and communication
12. Public Service Boards must work together to agree and address joint priorities	☐	☐	☐	☐	☐	Theme: collaboration and communication
13. To reduce air pollution risks for all, public bodies are encouraged to work together regionally and nationally to plan action for local, consistent implementation	☐	☐	☐	☐	☐	Theme: collaboration and communication
14. Understanding links between air pollution risks and wider health determinants can help align broader public health with LAQM action	☐	☐	☐	☐	☐	Theme: collaboration and communication

15. Increasing collaboration between public health professionals, academics and Local Authorities can create opportunities for multi-disciplinary research and evaluation	☐	☐	☐	☐	☐	Theme: collaboration and communication
16. Communicating air pollution messages in a broad public health context is likely to have more influence amongst partners, policy-makers, politicians and the public	☐	☐	☐	☐	☐	Theme: collaboration and communication
17. Good communications with a broader audience can help make air pollution a less specialist subject so more people understand it and engage	☐	☐	☐	☐	☐	Theme: collaboration and communication
18. Good quality local-level data can inform risk assessments, surveillance and action	☐	☐	☐	☐	☐	Theme: risk assessment
19. There is an increasing willingness to share data, intelligence and expertise	☐	☐	☐	☐	☐	Theme: risk assessment

20. Public health expertise can help support Local Authority-led risk assessments	☐	☐	☐	☐	☐	Theme: risk assessment

3. **To what extent do you agree with the following statements on the added value that could result from increasing public health integration and collaboration in Local Air Quality Management?**

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. Defining the role of, and training, public health professionals in air quality management can raise awareness, understanding, confidence, expertise and collaboration	☐	☐	☐	☐	☐	Theme: collaboration
2. Greater public health support for Local Authorities can help increase capacity	☐	☐	☐	☐	☐	Theme: collaboration
3. A public health-focused and supported LAQM regime can facilitate broader air pollution risk assessment and management (by data sharing, linking, analysis)	☐	☐	☐	☐	☐	Theme: risk assessment and communications

4. A better understanding of risks can inform communications that reach out to, and secure support from, broader audiences e.g. health, planners, transport, academics, public	☐	☐	☐	☐	☐	Theme: risk assessment and communications
5. 'Big picture' evidence can justify linking air pollution with other local public health priorities	☐	☐	☐	☐	☐	Theme: risk assessment and communications
6. A broader outlook on air pollution problems and solutions can help public health professionals integrate LAQM with 'the day job'	☐	☐	☐	☐	☐	Theme: policy connection
7. A broader outlook on LAQM can help connect it with 'prevention-focused' policy and practice (supported by the Wellbeing of Future Generations Act)	☐	☐	☐	☐	☐	Theme: policy connection
8. Connecting policy and practice can create more efficient and effective ways of working	☐	☐	☐	☐	☐	Theme: policy connection

9. A better understanding of risks and more joined-up working can inform joint priority-setting and action based on agreed short, medium and long-term sustainable objectives	☐	☐	☐	☐	☐	Theme: risk management
10. Integrated action planning and delivery can embrace a dual approach to maximise impacts by reducing risks for all and targeting action in 'at risk' areas to reduce inequalities	☐	☐	☐	☐	☐	Theme: risk management
11. Greater collaboration can lead to more creative and innovative solutions to problems	☐	☐	☐	☐	☐	Theme: risk management
12. Informing, educating and empowering others can help reduce air pollution and linked health problems e.g. facilitating active travel by planning for healthy communities	☐	☐	☐	☐	☐	Theme: risk management

13. LAQM can help achieve multiple co-benefits e.g. active travel can reduce air pollution, physical inactivity and obesity and improve physical and mental health	◻	◻	◻	◻	◻	Theme: risk management
14. Improving population health through LAQM can make people less susceptible to the effects of air pollution and less reliant on NHS services	◻	◻	◻	◻	◻	Theme: risk management
15. Close working between public health, academics and Local Authorities can create more opportunities for evidence reviews, evaluations and new research	◻	◻	◻	◻	◻	Theme: research and evaluation
16. New research in Wales can add to the evidence-base on intervention [cost] effectiveness	◻	◻	◻	◻	◻	Theme: research and evaluation
17. Being able to demonstrate positive LAQM impacts can encourage more sustainable 'prevention-focused' services and investment in the future	◻	◻	◻	◻	◻	Theme: prevention, not reaction

18. Improving public health involvement can increase LAQM inclusiveness and transparency	☐	☐	☐	☐	☐	Theme: prevention, not reaction
19. A public health-focused and supported LAQM regime can ensure that future decisions and policy development do not ignore air pollution and public health	☐	☐	☐	☐	☐	Theme: applying learning elsewhere
20. Enhancing LAQM can act as an exemplar for evolving policy and practice in other public health priority areas	☐	☐	☐	☐	☐	Theme: applying learning elsewhere

4. **To what extent do you agree with the following statements on barriers to increasing public health integration and collaboration in Local Air Quality Management?**

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. Despite increasing media and public interest, air pollution and health risks currently have a relatively low profile, especially in Local Authorities and the NHS in Wales	☐	☐	☐	☐	☐	Theme: profile
2. As a result of poor communications, most people - especially politicians and the public - are unaware of the scope of problems and what they can do to help address them	☐	☐	☐	☐	☐	Theme: profile
3. The NHS in Wales lacks commitment to reduce air pollution and risks; there is often a perception (not helped by role uncertainties) that air pollution is 'someone else's problem'	☐	☐	☐	☐	☐	Theme: profile

4. Air pollution is seen as a stand-alone concern; its relationships with wider health determinants are rarely recognised or understood	☐	☐	☐	☐	☐	Theme: profile
5. Air pollution is a technical subject; many lack the understanding and confidence to engage	☐	☐	☐	☐	☐	Theme: profile
6. LAQM is disconnected from many relevant aspects of public health policy and practice	☐	☐	☐	☐	☐	Theme: policy
7. LAQM is only concerned with taking action in areas which breach Air Quality Objectives; to reduce air pollution and health risks for all, action should not be restricted to these areas	☐	☐	☐	☐	☐	Theme: policy
8. The current LAQM process is too reactive; proactive approaches that reduce air pollution and health risks (linked to broader public health work) are not encouraged	☐	☐	☐	☐	☐	Theme: policy

9. Despite some streamlining, the LAQM risk assessment and action planning processes remain cumbersome and confusing to many	☐	☐	☐	☐	☐	Theme: policy
10. There is a lack of guidance on undertaking comprehensive air quality public health risk assessments; stakeholders do not know what to do and how to do it	☐	☐	☐	☐	☐	Theme: risk assessment
11. Information governance and IT data systems/policies may discourage data sharing/linking	☐	☐	☐	☐	☐	Theme: risk assessment
12. There is a lack of information on air pollution and health intervention [cost] effectiveness	☐	☐	☐	☐	☐	Theme: risk management
13. There is no 'one size fits all' answer to reduce air pollution problems, risks and inequalities; solutions are often considered too difficult, prohibitively costly and take too long to deliver	☐	☐	☐	☐	☐	Theme: risk management

14. There is a perception that little can be done to reduce air pollution locally; there is an over-reliance on achieving local improvements through national policy and technology advances	☐	☐	☐	☐	☐	Theme: risk management
15. LAQM is focused on reducing air pollution concentrations to protect health; reducing risks by other means are rarely considered (e.g. improving health to reduce susceptibility)	☐	☐	☐	☐	☐	Theme: risk management
16. Local Authorities now have less LAQM-dedicated resource; as a result, co-ordinating and securing 'buy-in' from all necessary stakeholders is becoming more difficult	☐	☐	☐	☐	☐	Theme: collaboration
17. Public health professionals are disengaged from LAQM; their role and expected contribution is not defined and air pollution is not regarded as a priority for action	☐	☐	☐	☐	☐	Theme: collaboration

18. There is a general lack of understanding about air pollution issues amongst public health professionals as training and information resources have not been made available to date	☐	☐	☐	☐	☐	Theme: collaboration
19. Public health professionals usually have no formal position in Local Authorities; this could act as a barrier to effective LAQM risk assessment, action planning and implementation	☐	☐	☐	☐	☐	Theme: collaboration
20. Local Authorities tend not to engage with public health professionals and academics on air pollution and health research and evaluation projects	☐	☐	☐	☐	☐	Theme: collaboration

5. **In your opinion, what solutions could help overcome the barriers identified in Q4?** Please list a minimum of 3 different opinions and ideas in the grid below that could help enhance Local Air Quality Management to maximise public health integration, collaboration and impact. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important. To remind you of the barriers listed in Q4, please click the 'more info' option.

More info

	Solution to barriers * Required	Why important?
1		
2		
3		

5.a. If you wish to provide more opinions and ideas in response to this question, please do so in the grid below. For each opinion or idea you provide, in one or two sentences, please explain why you consider it important.

	Solution to barriers	Why important?
4		
5		
6		

Enhancing Local Air Quality Management in Wales to maximise public health integration, collaboration and impact (Round 3 survey)

Page 1

Dear Participant

This is the third and final survey round of the Delphi study.

Thank you for continuing to support it.

Survey completion instructions

This survey consists of 4 closed questions and should take less than 20 minutes to complete.

As before, the questions ask you to rate your level of agreement with statements. Some statements you will have seen before, but are offered here again as they did not reach consensus opinion in the last survey round. There are also some new statements around 'solutions' that you and other participants proposed in the last survey round.

For the statements you are seeing for a second time, you are asked to re-evaluate your agreement status. You may decide that you are content with your original response but if you wish, you can revise it. To help inform your re-evaluation, you should refer to the summary of the collective Panel response to each statement as well as your original answers to the Round 2 survey (sent to you in a separate email from me).

As before, if you need to complete the survey in stages, you can save your progress after answering each question i.e. select 'finish later'. This is also good

practice to avoid losing work as you progress through the survey.

Please complete this survey by 5pm on Friday 25th November 2016.

What happens next?

Once all responses have been received, the data will be analysed. A final Delphi study report will be written and shared with you early next year.

To maintain anonymity amongst Panel members, I will not be bringing all participants together but will look to provide updates through other avenues e.g. meetings, workshops and conferences. I will also be contacting some of you to request a brief interview to scope the feasibility of taking action in respect of the findings of this research.

If you have any queries, require further information, or experience difficulties completing this survey, please contact me on huw3.brunt@uwe.ac.uk or 07817 872577.

Thank you once again for all your support.

Huw Brunt

1. To what extent do you agree with the following statements on the roles of NHS Public Health specialists in Local Air Quality Management?

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
6. To undertake new research to evaluate the air pollution and health impacts of action	☐	☐	☐	☐	☐	Theme: research and evaluation
8. To provide independent scrutiny of evidence-based and innovative action to reduce air pollution and linked health risks, and hold those implementing it to account	☐	☐	☐	☐	☐	Theme: risk management

11. To champion the principles of environmental sustainability; lead by example by reducing the local air quality impacts from NHS services and estate	☐	☐	☐	☐	☐	Theme: risk management

2. To what extent do you agree with the following statements on the opportunities to increase public health integration and collaboration in Local Air Quality Management?

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
4. LAQM responsibilities are a devolved responsibility; opportunities exist to enhance the regime to render it fit-for-purpose in Wales	☐	☐	☐	☐	☐	Theme: policy development
6. The Wellbeing of Future Generations (Wales) Act 2015 calls for sustainable action that can enhance LAQM developments	☐	☐	☐	☐	☐	Theme: policy development

9. Public Health Wales is well-placed to encourage action across the wider NHS	☐	☐	☐	☐	☐	Theme: policy development
11. The Welsh Air Quality Forum offers good opportunities to increase collaboration and action to enhance LAQM	☐	☐	☐	☐	☐	Theme: collaboration and communication
19. There is an increasing willingness to share data, intelligence and expertise	☐	☐	☐	☐	☐	Theme: risk assessment

3. **To what extent do you agree with the following statements on the added value that could result from increasing public health integration and collaboration in Local Air Quality Management?**

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. Defining the role of, and training, NHS Public Health specialists in air quality management can raise awareness, understanding, confidence, expertise and collaboration	☐	☐	☐	☐	☐	Theme: collaboration
2. Greater public health support for Local Authorities can help increase capacity	☐	☐	☐	☐	☐	Theme: collaboration

8. Connecting policy and practice can create more efficient and effective ways of working	☐	☐	☐	☐	☐	Theme: policy connection
10. Integrated action planning and delivery can embrace a dual approach to maximise impacts by reducing risks for all and targeting action in 'at risk' areas to reduce inequalities	☐	☐	☐	☐	☐	Theme: risk management
14. Improving population health through LAQM can make people less susceptible to the effects of air pollution and less reliant on NHS services	☐	☐	☐	☐	☐	Theme: risk management

20. Enhancing LAQM can act as an exemplar for evolving policy and practice in other public health priority areas	☐	☐	☐	☐	☐	Theme: applying learning elsewhere

4. To what extent do you agree with the following statements on barriers to increasing public health integration and collaboration in Local Air Quality Management?

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
3. The NHS in Wales lacks commitment to reduce air pollution and risks; there is often a perception (not helped by role uncertainties) that air pollution is 'someone else's problem'	☐	☐	☐	☐	☐	Theme: profile
4. Air pollution is seen as a stand-alone concern; its relationships with wider health determinants are rarely recognised or understood	☐	☐	☐	☐	☐	Theme: profile

10 / 22

5. Air pollution is a technical subject; many lack the understanding and confidence to engage						Theme: profile
6. LAQM is disconnected from many relevant aspects of public health policy and practice						Theme: policy
9. Despite some streamlining, the LAQM risk assessment and action planning processes remain cumbersome and confusing to many						Theme: policy
11. Information governance and IT data systems/policies may discourage data sharing/linking						Theme: risk assessment

13. There is no 'one size fits all' answer to reduce air pollution problems, risks and inequalities; solutions are often considered too difficult, prohibitively costly and take too long to deliver	☐	☐	☐	☐	☐	Theme: risk management
16. Local Authorities now have less LAQM-dedicated resource; as a result, co-ordinating and securing 'buy-in' from all necessary stakeholders is becoming more difficult	☐	☐	☐	☐	☐	Theme: collaboration

18. There is a general lack of understanding about air pollution issues amongst public health professionals as training and information resources have not been made available to date	☐	☐	☐	☐	☐	Theme: collaboration
19. NHS Public Health specialists usually have no formal position in Local Authorities; this could act as a barrier to effective LAQM risk assessment, action planning and implementation	☐	☐	☐	☐	☐	Theme: collaboration
20. Local Authorities tend not to engage with NHS Public Health specialists and academics on air pollution and health research and evaluation projects	☐	☐	☐	☐	☐	Theme: collaboration

5. To what extent do you agree with the following statements on solutions to increase public health integration and collaboration in Local Air Quality Management?

	Strongly disagree	Disagree	Indifferent or undecided	Agree	Strongly agree	
1. Extend the scope of LAQM to tackle localised air pollution problems (based on Air Quality Objective non-compliance) and reduce air pollution risks for all.	☐	☐	☐	☐	☐	Theme: LAQM development

2. Shift LAQM accountability to Public Services Boards (from Local Authorities) to increase collective commitment, long-term planning, resource sharing and collaborative action.	☐	☐	☐	☐	☐	Theme: LAQM development
3. Statutorily require Public Health Wales and Health Boards to support all stages of LAQM, including risk assessment, action planning and implementation, and evaluation.	☐	☐	☐	☐	☐	Theme: LAQM development
4. Specify the LAQM role of NHS Public Health specialists (across all disciplines) in new guidance.	☐	☐	☐	☐	☐	Theme: LAQM development

5. Specify a new LAQM risk assessment approach to measure, and help prioritise, air pollution risks and impacts in a broader public health context and stimulate NHS interest and action.	☐	☐	☐	☐	☐	Theme: LAQM development
6. Promote the integration of LAQM with the 'day job' amongst NHS Public Health specialists (across disciplines) to help co-ordinate action to reduce air pollution and risks e.g. behaviour change initiatives, active travel, planning, incident response, environmental sustainability.	☐	☐	☐	☐	☐	Theme: LAQM development

7. Target action in both 'high risk' air pollution and poor health areas to reduce inequalities.						Theme: LAQM development
8. Fully integrate Health Impact Assessment principles with LAQM.						Theme: LAQM development
9. Tighten Air Quality Objectives to support the delivery an extended LAQM regime.						Theme: LAQM development
10. Create environmental sustainability expert groups (supported by a network of local and national NHS Public Health specialists) to assist Public Services Boards' LAQM delivery.						Theme: Enabling developments

11. Raise the profile of LAQM in and across Welsh Government to improve cross-department working, and facilitate better integration and collaboration amongst other public bodies.	☐	☐	☐	☐	☐	Theme: Enabling developments
12. Capitalise on the independent role of NHS Public Health specialists to add value to, and advocate for change in, LAQM.	☐	☐	☐	☐	☐	Theme: Enabling developments
13. Invest in technology (e.g. monitoring networks, real-time information dashboards, smart apps) to make it easier to 'see' air pollution problems and stimulate interest and action.	☐	☐	☐	☐	☐	Theme: Enabling developments

14. Make a ring-fenced recurring environmental sustainability funding stream available to Public Services Boards to support LAQM implementation in a broader context.	☐	☐	☐	☐	☐	Theme: Enabling developments
15. Make Public Health Wales and Health Boards statutory consultees in the planning process.	☐	☐	☐	☐	☐	Theme: Enabling developments
16. Determine 'what works' to reduce air pollution, risks and inequalities and share knowledge to promote evidence-based action, while also encouraging innovation (with evaluation).	☐	☐	☐	☐	☐	Theme: Research

17. Seize opportunities offered by existing community initiatives to increase public awareness and action around LAQM, and undertake 'citizen science'-based research and evaluation.	☐	☐	☐	☐	☐	Theme: Research
18. Train all NHS Public Health specialists (including those in training) on air pollution epidemiology, and LAQM risk assessment, management and evaluation.	☐	☐	☐	☐	☐	Theme: Training and education

19. Develop and implement a multi-faceted communications strategy to inform public bodies, policy-makers, politicians and public about air pollutions risks and offer practical advice.	☐	☐	☐	☐	☐	Theme: Training and education
20. Introduce formal arrangements to support LAQM-related placements or projects across public bodies to increase stakeholder synergy, experience, expertise and capacity.	☐	☐	☐	☐	☐	Theme: Training and education

Appendix F Delphi study – UWE Faculty Research Ethics Committee approval

University of the West of England
BRISTOL

Faculty of Environment
& Technology
Frenchay Campus
Coldharbour Lane
Bristol
BS16 1QY

UWE REC REF No: FET/16/02/028

29th February 2016

Dear Huw

Application title: Enhancing the Local Air Quality Management regime in Wales to maximise Public Health integration, collaboration and impact

Your ethics application was considered by the Faculty Research Ethics Committee and reviewed by at least two of its members. Based on the information provided, your application has been given ethical approval to proceed subject to satisfying the following conditions:

1. The application states that all data will be destroyed within 5 years. However, it might be worth checking there is no open access requirement / requirement from Public Health Wales which conflicts with this. Please check and then confirm or revise.

2. Please justify asking a non-consenter to tick the statement "I am NOT willing to participate in this study". Suppose they refuse to tick it? Could it make them uneasy at not consenting and be seen as a form of pressure to consent – if so, then it should be deleted from the consent form.

The reviewers also made the following comments that you may wish to consider and act upon, but which are not conditions for approval.

1. The Delphi method requires high levels of commitment from participants and drop-put levels are can be high. This is acknowledged by the applicant, but it can be critical to the technique. The success of this technique is often therefore dependent on the expertise of the coordinator to sustain the process. If the student doesn't possess this expertise he may find himself critically exposed.

You must not proceed with your research until you have responded to these conditions and have received full unconditional approval from the committee.

You must notify the committee in advance if you wish to make any significant amendments to the original application using the amendment form at http://www1.uwe.ac.uk/research/researchethics/applyingforapproval.aspx.

Please also note that any information sheets and consent forms should have the UWE logo. Further guidance about the UWE logo is available at: http://www1.uwe.ac.uk/aboutus/departmentsandservices/professionalservices/marketingandcommunications/resources.aspx

The following standard conditions also apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee.

2. You must notify the University Research Ethics Committee (UREC) if you terminate your research before completion;

3. You must notify the University Research Ethics Committee (UREC) if there are any serious events or developments in the research that have an ethical dimension;

4. Any changes to the study protocol, which have an ethical dimension, will need to be approved by the relevant UWE Research Ethics Committee. You should send details of any such amendments to the relevant committee with an explanation of the reason for the proposed changes. Any changes approved by an external research ethics committee must also be communicated to the relevant UWE Research Ethics Committee.

Please note: The UREC is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the UREC and its committees.

We wish you well with your research.

Yours sincerely

Alistair Clark

Dr Alistair Clark

Chair, Faculty Research Ethics Committee

c.c *Enda Hayes*

Q1. What is the role of public health bodies and specialists in LAQM?			Delphi round 2 survey								Delphi round 3 survey							
Theme	Ref	Statement (item)	Median				IQR				Median				IQR			
			P	PH	EH	O	P	PH	EH	O	P	PH	EH	O	P	PH	EH	O
Risk assessment	1.1	To help others assess air pollution risks in the broadest possible public health context	5.0	5.0	5.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.2	To use expertise and resources to share, link and analyse data to assess risks and impacts	5.0	5.0	5.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.3	To determine how air pollution-related risks vary *between* and *within* communities	4.0	5.0	4.0	4.0	1.0	1.0	1.0	0.0	-	-	-	-	-	-	-	-
	1.4	To interpret evidence, and use it to set shared priorities and inform others' decisions	5.0	5.0	5.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
Research and evaluation	1.5	To advocate for, and support evidence reviews to, assess the effectiveness of interventions	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.6	To undertake new research to evaluate the air pollution *and* health impacts of action	4.0	4.0	5.0	4.0	2.0	2.0	1.0	1.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
	1.7	To understand broader public health consequences of action to reduce air pollution/risks	5.0	5.0	5.0	4.0	1.0	0.5	1.0	1.0	-	-	-	-	-	-	-	-
Risk management	1.8	To provide independent scrutiny of evidence-based and innovative action to reduce air pollution and linked health risks, and hold those implementing it to account	4.0	4.0	4.0	4.0	2.0	1.5	1.0	1.0	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0
	1.9	To work with others to promote and facilitate active-travel for all	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.10	To work with others through all appropriate partnership networks to improve public health generally to reduce individual and population-level susceptibility to air pollution exposure	5.0	5.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.11	To champion the principles of environmental sustainability; lead by example by reducing the local air quality impacts from NHS services and estate	4.0	4.0	4.0	4.0	1.0	1.0	1.0	2.0	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0
Communication	1.12	To raise the profile of air pollution as a local public health priority through effective authoritative communications with partners and the public	5.0	5.0	5.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.13	To let people know 'what works' to reduce air pollution and associated risks	4.0	5.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.14	To work with others to provide timely advice to the public on how to minimise risks	5.0	5.0	5.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
Change leadership	1.15	To lead, and support others across relevant sectors, to develop and implement long-term, prevention-focused air pollution, health risk and inequality reduction policy and practice	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	1.16	To use local-level learning to inform policy development at the national level	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.17	To connect local air quality management policy and practice with other public health priority work areas e.g. respiratory and heart diseases, obesity, injuries, diabetes	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.18	To advocate for, and support, evidence-based action to reduce air pollution-related health risks for all i.e. extending efforts beyond localised air pollution 'hot-spots	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.19	To advocate for, and support, targeted evidence-based action in 'at risk' areas/populations to reduce air pollution and health-related inequalities, as appropriate	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	1.20	To help shape others' policy and practice to reduce air pollution and associated health risks e.g. environmental health, transport, land-use planning, environmental sustainability	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-

Legend:

P	consensus opinion of entire Delphi panel
PH	consensus opinion of 'public health' sub-panel
EH	consensus opinion of 'environmental health' sub-panel
O	consensus opinion of 'other' sub-panel
Median	the 50th percentile or the middle value in a range of values; answer range is from 1.0 (strongly disagree) to 5.0 (strongly agree) e.g. for question 1.5, the mid-point of the range of responses received from all Delphi panel experts was 4.0 i.e. the consensus opinion of the entire Delphi Panel is to 'agree' with the statement
IQR	a measure of dispersion for the median that represents the middle 50% of all participant responses; If IQR >1, consensus not achieved (shaded red); if IQR = 1, good consensus achieved (shaded purple); if IQR <1, very good consensus achieved (shaded green)

Q2. What are the opportunities to increase public health integration and collaboration in LAQM			Delphi round 2 survey								Delphi round 3 survey							
Theme	Ref	Statement (item)	Median				IQR				Median				IQR			
			P	PH	EH	O	P	PH	EH	O	P	PH	EH	O	P	PH	EH	O
Profile and understanding	2.1	There is a need to capitalise on the availability of stronger evidence and raised political, media and public interest in air pollution as a public health priority	4.0	4.0	5.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.2	Given that key pollutants have no 'safe' level of exposure, acting to reduce local air pollution and risks must extend beyond localised air pollution 'hotspots'	4.0	4.0	5.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.3	A better understanding of links between air pollution and health determinants calls for problems and solutions to be considered in a broad public health context	4.0	5.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
Policy development	2.4	LAQM responsibilities are devolved; opportunities exist to enhance the regime to render it fit-for-purpose in Wales	4.0	4.0	4.0	4.0	2.0	1.0	1.0	2.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.5
	2.5	Welsh Government is committed to review existing LAQM arrangements so there are good opportunities to influence its development	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.6	The Wellbeing of Future Generations (Wales) Act 2015 calls for sustainable action that can enhance LAQM developments	4.0	5.0	4.0	4.0	1.0	1.0	1.0	2.0	5.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0
	2.7	Public bodies must act to prevent environmental and health/wellbeing problems (including inequalities); 'treating' effects rather than causes is not acceptable	5.0	5.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.8	Wales' national air quality indicator can help inform local action and evaluations	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.9	Public Health Wales is well-placed to encourage action across the wider NHS	4.0	4.0	4.0	4.0	1.0	1.0	0.0	2.0	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0
Collaboration and communication	2.10	Good relationships with Welsh Government can facilitate evidence-based change	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.11	The Welsh Air Quality Forum offers good opportunities to increase collaboration and action to enhance LAQM	4.0	4.0	5.0	4.0	2.0	1.5	1.0	1.0	4.0	4.0	4.0	4.0	2.0	2.0	1.0	1.0
	2.12	Public Service Boards must work together to agree and address joint priorities	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.13	To reduce air pollution risks for all, public bodies are encouraged to work together regionally and nationally to plan action for local, consistent implementation	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.14	Understanding links between air pollution risks and wider health determinants can help align broader public health with LAQM action	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.15	Increasing collaboration between public health professionals, academics and Local Authorities can create opportunities for multi-disciplinary research and evaluation	5.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.16	Communicating air pollution messages in a broad public health context is likely to have more influence amongst partners, policy-makers, politicians and the public	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.17	Good communications with a broader audience can help make air pollution a less specialist subject so more people understand it and engage	4.0	4.0	4.0	4.0	1.0	1.0	0.0	0.0	-	-	-	-	-	-	-	-
Risk assessment	2.18	Good quality local-level data can inform risk assessments, surveillance and action	5.0	4.0	5.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	2.19	There is an increasing willingness to share data, intelligence and expertise	4.0	4.0	4.0	3.0	1.0	1.0	1.0	1.0	4.0	3.0	4.0	4.0	1.0	1.0	2.0	1.0
	2.20	Public health expertise can help support Local Authority-led risk assessments	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-

Legend as for "Role of public health bodies and specialists in LAQM' table.

Median values shaded yellow indicate that consensus is achieved but the response opinion is 'indifferent or undecided'.

Q3. What is the added value of increased public health integration and collaboration in LAQM?			Delphi round 2 survey								Delphi round 3 survey							
Theme	**Ref**	**Statement (item)**	**Median**				**IQR**				**Median**				**IQR**			
			P	**PH**	**EH**	**O**	**P**	**PH**	**EH**	**O**	**P**	**PH**	**EH**	**O**	**P**	**PH**	**EH**	**O**
Collaboration	3.1	Defining the role of, and training, public health professionals in air quality management can raise awareness, understanding, confidence, expertise and collaboration	4.0	4.0	4.0	4.0	1.0	1.0	2.0	0.0	4.0	4.0	4.0	4.0	1.0	1.0	0.0	0.0
	3.2	Greater public health support for Local Authorities can help increase capacity	4.0	4.0	4.0	4.0	2.0	2.0	1.0	1.0	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0
Risk assessment and communication	3.3	A public health-focused and supported LAQM regime can facilitate broader air pollution risk assessment and management (by data sharing, linking, analysis)	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.4	A better understanding of risks can inform communications that reach out to, and secure support from, broader audiences e.g. health, planners, transport, academics, public	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.5	'Big picture' evidence can justify linking air pollution with other local public health priorities	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
Policy connection	3.6	A broader outlook on air pollution problems and solutions can help public health professionals integrate LAQM with 'the day job'	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	3.7	A broader outlook on LAQM can help connect it with 'prevention-focused' policy and practice (supported by the Wellbeing of Future Generations Act)	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.8	Connecting policy and practice can create more efficient and effective ways of working	4.0	4.0	4.0	4.0	1.0	1.5	1.0	1.0	4.0	5.0	4.0	4.0	1.0	1.0	1.0	1.0
Risk management	3.9	A better understanding of risks and more joined-up working can inform joint priority-setting and action based on agreed short, medium and long-term sustainable objectives	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	3.10	Integrated action planning and delivery can embrace a dual approach to maximise impacts by reducing risks for all *and* targeting action in 'at risk' areas to reduce inequalities	4.0	4.0	4.0	4.0	1.0	1.0	0.0	2.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
	3.11	Greater collaboration can lead to more creative and innovative solutions to problems	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.12	Informing, educating and empowering others can help reduce air pollution and linked health problems e.g. facilitating active travel by planning for healthy communities	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.13	LAQM can help achieve multiple co-benefits e.g. active travel can reduce air pollution, physical inactivity and obesity and improve physical and mental health	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.14	Improving population health through LAQM can make people less susceptible to the effects of air pollution and less reliant on NHS services	4.0	4.0	4.0	4.0	1.0	1.0	1.0	2.0	5.0	5.0	5.0	4.0	1.0	1.0	1.0	0.5
Research and evaluation	3.15	Close working between public health, academics and Local Authorities can create more opportunities for evidence reviews, evaluations and new research	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.16	New research in Wales can add to the evidence-base on intervention [cost] effectiveness	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
Prevention, not reaction	3.17	Being able to demonstrate positive LAQM impacts can encourage more sustainable 'prevention-focused' services and investment in the future	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.18	Improving public health involvement can increase LAQM inclusiveness and transparency	4.0	4.0	4.0	4.0	1.0	1.0	0.0	0.0	-	-	-	-	-	-	-	-
Applying learning elsewhere	3.19	A public health-focused and supported LAQM regime can ensure that future decisions and policy development do not ignore air pollution and public health	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	3.20	Enhancing LAQM can act as an exemplar for evolving policy and practice in other public health priority areas	4.0	4.0	4.0	4.0	1.0	1.5	0.0	0.0	4.0	4.0	4.0	4.0	0.0	0.0	1.0	0.0

Legend as for "Role of public health bodies and specialists in LAQM' table.

Q4. What are the barriers to increasing public health integration and collaboration in LAQM			Delphi round 2 survey								Delphi round 3 survey							
Theme	Ref	Statement (item)	Median				IQR				Median				IQR			
			P	PH	EH	O	P	PH	EH	O	P	PH	EH	O	P	PH	EH	O
Profile and understanding	4.1	Despite increasing media and public interest, air pollution and health risks currently have a relatively low profile, especially in Local Authorities and the NHS in Wales	4.0	4.0	4.0	4.0	1.0	0.5	0.0	1.0	-	-	-	-	-	-	-	-
	4.2	As a result of poor communications, most people - especially politicians and the public - are unaware of the scope of problems and what they can do to help address them	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	4.3	The NHS in Wales lacks commitment to reduce air pollution and risks; there is often a perception (not helped by role uncertainties) that air pollution is 'someone else's problem'	4.0	4.0	4.0	3.0	2.0	1.0	2.0	1.0	4.0	4.0	4.0	4.0	2.0	1.0	1.0	1.0
	4.4	Air pollution is seen as a stand-alone concern; its relationships with wider health determinants are rarely recognised or understood	4.0	4.0	4.0	4.0	1.0	1.0	1.0	2.0	4.0	4.0	4.0	4.0	2.0	1.0	0.0	2.0
	4.5	Air pollution is a technical subject; many lack the understanding and confidence to engage	4.0	4.0	4.0	3.0	1.0	0.5	1.0	2.0	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0
Policy development	4.6	LAQM is disconnected from many relevant aspects of public health policy and practice	4.0	4.0	4.0	4.0	2.0	1.0	2.0	1.0	4.0	4.0	4.0	4.0	0.0	1.0	1.0	0.0
	4.7	LAQM is only concerned with taking action in areas which breach Air Quality Objectives; to reduce air pollution and health risks for all, action should not be restricted to these areas	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	4.8	The current LAQM process is too reactive; proactive approaches that reduce air pollution and health risks (linked to broader public health work) are not encouraged	4.0	4.0	4.0	4.0	0.0	0.5	0.0	0.0	-	-	-	-	-	-	-	-
	4.9	Despite some streamlining, the LAQM risk assessment and action planning processes remain cumbersome and confusing to many	4.0	4.0	4.0	3.0	1.0	1.0	1.0	1.0	4.0	4.0	4.0	3.0	1.0	1.0	0.0	1.0
Risk assessment	4.10	There is a lack of guidance on undertaking comprehensive air quality public health risk assessments; stakeholders do not know what to do and how to do it	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	4.11	Information governance and IT data systems/policies may discourage data sharing/linking	4.0	4.0	4.0	3.0	1.0	2.0	1.0	1.0	4.0	4.0	3.0	3.0	1.0	0.0	1.0	1.0
Risk management	4.12	There is a lack of information on air pollution and health intervention [cost] effectiveness	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	4.13	There is no 'one size fits all' answer to reduce air pollution problems, risks and inequalities; solutions are often considered too difficult, prohibitively costly and take too long to deliver	4.0	4.0	4.0	5.0	1.0	2.0	1.0	1.0	4.0	4.0	5.0	4.0	1.0	1.0	1.0	1.0
	4.14	There is a perception that little can be done to reduce air pollution locally; there is an over-reliance on achieving local improvements through national policy and technology advances	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	-	-	-	-	-	-	-	-
	4.15	LAQM is focused on reducing air pollution concentrations to protect health; reducing risks by other means are rarely considered (e.g. improving health to reduce susceptibility)	4.0	4.0	4.0	4.0	1.0	1.0	1.0	0.0	-	-	-	-	-	-	-	-
Collaboration and communication	4.16	Local Authorities now have less LAQM-dedicated resource; as a result, co-ordinating and securing 'buy-in' from all necessary stakeholders is becoming more difficult	4.0	4.0	4.0	4.0	2.0	1.5	1.0	2.0	4.0	4.0	4.0	4.0	1.0	2.0	1.0	1.0
	4.17	Public health professionals are disengaged from LAQM; their role and expected contribution is not defined and air pollution is not regarded as a priority for action	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-
	4.18	There is a general lack of understanding about air pollution issues amongst public health professionals as training and information resources have not been made available to date	4.0	4.0	3.0	4.0	1.0	1.0	2.0	2.0	4.0	4.0	3.0	3.0	1.0	0.0	1.0	1.0
	4.19	Public health professionals usually have no formal position in Local Authorities; this could act as a barrier to effective LAQM risk assessment, action planning and implementation	4.0	3.0	3.0	4.0	1.0	1.5	2.0	2.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
	4.20	Local Authorities tend not to engage with public health professionals and academics on air pollution and health research and evaluation projects	3.0	3.0	3.0	4.0	1.0	1.0	2.0	1.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	1.0

Legend as for "Role of public health bodies and specialists in LAQM' table.

Q5. What are the solutions to increased public health integration and collaboration in LAQM			Round 3							
Theme	**Ref**	**Statement (item)**	**Median**				**IQR**			
			P	**PH**	**EH**	**O**	**P**	**PH**	**EH**	**O**
LAQM developments	5.1	Extend the scope of LAQM to tackle localised air pollution problems (based on Air Quality Objective non-compliance) *and* reduce air pollution risks for all.	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.5
	5.2	Shift LAQM accountability to Public Services Boards (from Local Authorities) to increase collective commitment, long-term planning, resource sharing and collaborative action.	4.0	4.0	2.0	4.0	2.0	1.0	1.0	1.0
	5.3	Statutorily require Public Health Wales and Health Boards to support all stages of LAQM, including risk assessment, action planning and implementation, and evaluation.	4.0	4.0	4.0	4.0	2.0	2.0	0.0	2.0
	5.4	Specify the LAQM role of NHS Public Health specialists (across all disciplines) in new guidance.	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0
	5.5	Specify a new LAQM risk assessment approach to measure, and help prioritise, air pollution risks and impacts in a broader public health context and stimulate NHS interest and action.	4.0	4.0	4.0	4.0	0.0	0.0	0.0	1.0
	5.6	Promote the integration of LAQM with the 'day job' amongst NHS Public Health specialists (across disciplines) to help co-ordinate action to reduce air pollution risks e.g. behaviour change initiatives, active travel, planning, incident response, environmental sustainability.	4.0	4.0	4.0	4.0	0.0	1.0	0.0	0.0
	5.7	Target action in both 'high risk' air pollution *and poor* health areas to reduce inequalities.	4.0	4.0	4.0	5.0	1.0	1.0	1.0	1.0
	5.8	Fully integrate Health Impact Assessment principles with LAQM.	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0
	5.9	Tighten Air Quality Objectives to support the delivery an extended LAQM regime.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
Enabling developments	5.10	Create environmental sustainability expert groups (supported by a network of local and national NHS Public Health specialists) to assist Public Services Boards' LAQM delivery.	4.0	4.0	3.0	4.0	1.0	1.0	1.0	1.0
	5.11	Raise the profile of LAQM in and across Welsh Government to improve cross-department working, and facilitate better integration and collaboration amongst other public bodies.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	0.0
	5.12	Capitalise on the independent role of NHS Public Health specialists to add value to, and advocate for change in, LAQM.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	0.0
	5.13	Invest in technology (e.g. monitoring networks, real-time information dashboards, smart apps) to make it easier to 'see' air pollution problems and stimulate interest and action.	4.0	4.0	5.0	4.0	1.0	1.0	1.0	2.0
	5.14	Make a ring-fenced recurring environmental sustainability funding stream available to Public Services Boards to support LAQM implementation in a broader context.	4.0	4.0	4.0	4.0	2.0	1.0	1.0	0.5
	5.15	Make Public Health Wales and Health Boards statutory consultees in the planning process.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	2.0
Research	5.16	Determine 'what works' to reduce air pollution, risks and inequalities and share knowledge to promote evidence-based action, while also encouraging innovation (with evaluation).	5.0	5.0	4.0	5.0	1.0	1.0	1.0	0.5
	5.17	Seize opportunities offered by existing community initiatives to increase public awareness and action around LAQM, and undertake 'citizen science'-based research and evaluation.	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0
Training and education	5.18	Train all NHS Public Health specialists (including those in training) on air pollution epidemiology, and LAQM risk assessment, management and evaluation.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.5
	5.19	Develop and implement a multi-faceted communications strategy to inform public bodies, policy-makers, politicians and public about air pollutions risks and offer practical advice.	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
	5.20	Introduce formal arrangements to support LAQM-related placements or projects across public bodies to increase stakeholder synergy, experience, expertise and capacity.	4.0	4.0	4.0	4.0	1.0	1.0	0.0	1.5

Legend as for "Role of public health bodies and specialists in LAQM' table.

Solution	Enabler (refer to Table 13)	Importance (1=low; 5=high)	Cost (1=high; 5=low)	Feasibility (1=low; 5=high)	Impact (1=low; 5=high)	Score (sum)	Stakeholder additional comments
1. *Specify and communicate the public health role in LAQM*	a)	4	4	3	3	14	'How to' and context setting guide required. Impact may change depending on uptake.
	b)	5	5	3	4	17	Examples of good practice exist. Need to embrace and share these and develop routes into PSBs.
	c)	5	5	5	5	20	Achieve change gradually through communications and air quality community agreement.
2. *Prescribe broader LAQM approach to stimulate interest, integration, interaction*	a)	4	4	3	4	15	
	b)	4	4	3	4	15	
	c)	5	4	5	3	17	Impact will depend on clarity of message promoted, communication effectiveness and uptake
3. *Extend LAQM scope to encourage targeted and universal risk reduction action*	a)	5	4	3	2	14	Score could be higher if strategy is effectively implemented
	b)	5	5	3	5	18	If this does not get taken forward then score would be lower
	c)	5	3	3	2	13	If evidence is used to inform LAQM enhancement, the health gains could be greater
4. *Integrate LAQM with the 'day job' for public health specialists (all disciplines)*	a)	4	4	5	4	17	
	b)	4	5	3	4	16	
	c)	4	5	2	4	15	
	d)	5	5	4	5	19	
	e)	4	5	3	5	17	Score only holds if successful
5. *Focus on reducing air pollution inequities and health inequalities*	a)	5	4	4	5	18	
	b)	5	4	4	4	17	
	c)	4	5	4	4	17	
6. *Integrate Health Impact Assessment principles into LAQM process*	a)	5	5	4	3	17	Could be achieved if LAQM included in the list of strategies to consider when undertaking HIA
	b)	5	3	4	5	17	Cost to applicant would be high; other costs low but will depend on capacity to review and interpret. Positive impacts of approach have potential to far outweigh associated costs.
	c)	3	3	5	5	16	Need to do this to demonstrate wider public health links and benefits (and disbenefits), but care needed in interpretation as some impacts will be intangible
7. *Create multi-sector local or regional LAQM expert groups*	a)	5	2	5	5	17	Feasible only if regional reports are formally commissioned
	b)	5	5	5	5	20	Seek funding from Welsh Government
	c)	5	2	3	5	15	
8. *Interpret and communicate evidence; encourage*	a)	5	3	4	5	17	Needs careful evidence interpretation and will require significant resources to implement
	b)	5	1	4	5	15	
	c)	5	3	4	5	17	

research and evaluation							
9. ***Raise awareness amongst public bodies, policy-makers, politicians and public***	**a)**	**5**	**4**	**5**	**3**	**17**	**If evidence affects behaviour then score could be higher**
	b)	4	3	5	3	15	If evidence affects behaviour then score could be higher
	C)	5	4	3	2	14	Score could be higher if strategy implemented
10. ***Raise profile of LAQM in/across Welsh Govt departments to facilitate cross-sector working***	**a)**	5	3	3	5	16	Wellbeing of Future Generations Act supports approach in theory, but not quick and simple to achieve.
	b)	**5**	**4**	**5**	**5**	**19**	**Need to describe exactly what this could look like; also, is there an opportunity cost?**
	c)	5	4	3	5	17	Need to use evidence to support engagement, but establishing evidence base takes time. Efforts needed to ensure no duplication as resources are scarce.
11. ***Use public health independence to advocate for LAQM change, as necessary***	**a)**	5	3	2	4	14	Feasibility depends on 'buy in'. Important for there to be demonstrable action and not just information.
	b)	5	5	2	4	16	
	c)	**5**	**5**	**5**	**4**	**19**	**Extends beyond the UK. Although uncertain at present, what about EU implications?**
	d)	5	5	1	3	14	Independent and respected voice of public health specialists should not be underestimated.
12. ***Establish funding to support collaborative air quality improvement action***	**a)**	5	5	2	3	15	Depends on scale of budget
	b)	2	5	1	2	10	Depends on scale of budget
	c)	5	5	2	5	17	Depends on scale of budget
	d)	**5**	**5**	**4**	**5**	**19**	**May be too difficult currently**
	e)	5	5	1	5	16	Too difficult currently
	f)	5	5	3	4	17	Too difficult currently
13. ***Work with communities: raise awareness, change behaviour***	**a)**	4	3	3	5	15	Although enabler does not improve air quality it can alter behaviour so people are more able to react. Need to understand local/regional plans before investing in national alert system.
	b)	5	4	4	4	17	
	c)	**5**	**4**	**5**	**5**	**19**	**Feasible only if formally commissioned**
14. ***Train public health specialists on all aspects of LAQM***	**a)**	5	5	5	3	18	
	b)	**5**	**4**	**5**	**5**	**19**	
	c)	5	5	3	4	17	Effective communications strategy required to sit alongside this enabler.
	d)	5	5	4	4	18	Feasibility score will be lower for formal curriculum changes as these are infrequent and there are likely many other competing priorities for change.
15. ***Create and support work placement and air pollution/health project options***	**a)**	**5**	**5**	**5**	**3**	**18**	**Either broaden the remit of LAQM or create a new mechanism**
	b)	4	5	5	2	16	Could be facilitated through Welsh Air Quality Forum
	c)	4	4	5	1	14	

Top scoring enablers are marked in bold red text in the table.

Appendix I Case study interviews – feedback on the conceptual LAQM framework

Case study interview #1

Feedback on the conceptual LAQM framework for Wales:

1. *How easy is it to understand and follow?*
   - In the main, it is easy to understand and follow. Some aspects could be improved.
   - The framework needs a new title that is easier to understand.
   - The read-across from the 'enhanced ways of working' column (right-hand of the page) to the different components of the LAQM framework (left-hand of the page) should be made clearer. Perhaps use faint dotted lines to break-up the framework by stage and linked text?
   - Use of the word 'link' in the context of aligning air quality strategies with Public Services Board Wellbeing Assessments and plans is vague. The term should be defined.
   - It would be useful if the framework indicated approximate timescales for implementation. For example, if local or regional air quality strategies are aligned with Public Services Board plans, then the former would need to adopt a five year cycle to coincide with the latter.
   - It is unclear whether air quality management action plans must deliver against all, or just some of the, three risk reduction actions marked i.e. targeted action in poor health areas to reduce air pollution health effects and inequalities; targeted action in areas with poor air quality to reduce risks in affected populations; and universal action to reduce air pollution and associated health risks for everyone. The framework should be revised to clarify this.
   - The framework suggests the flow of LAQM stages – from 'air quality strategies', through 'review and assessment' and 'action planning', to 'annul progress reporting' – is linear and that those implementing them must go through each in turn. This is misleading. Editing is required to clearly show that strategies offer the overarching local air quality management-related aim and objectives, and that delivery against these strategic intentions comprises three main components: 'review and assessment', 'action planning' and 'progress reporting'.

2. *Would you be happy to adopt the new way of working in your area?*
   - Yes.

- First impressions suggest that the conceptual framework's extra stages (compared with the existing framework) could mean more work and be more onerous. The current lack of resources to support LAQM delivery – particularly in local authorities – makes this a potential concern and barrier to adopting the framework. However, when greater consideration is given to the proposed new ways of working, it is clear that the framework is describing how LAQM delivery can become a more collaborative and efficient (and less burdensome) endeavour that is better integrated with and supported by public health professionals.
- Prior to any local adoption, the term 'mandatory' – used in the context of local or regional air quality strategies should be changed since it has the potential to confuse; it may mean 'enforcement' amongst local authority staff but something different amongst public health professionals. This aspect of the framework should be more carefully thought through. It may not actually be necessary to mandate the development of local/regional air quality strategies; it might be more appropriate to simply set this as an expectation of senior Welsh Government officials such as Ministers or the Future Generations Commissioner.

3. *Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?*
    - Yes.
    - The requirement to consider air pollution in a broader public health context means that LAQM would be relevant to a wider range of public health professionals. This, together with tailored training, would facilitate better public health integration and collaboration.
    - The proposed local or regional air quality management groups are a critical development in supporting implementation of this new enhanced approach to LAQM. Local authorities are already 'knocking at the door' of [internal] stakeholders such as transport and planning departments to engage them in LAQM action. This conceptual framework positions public health as another such department, albeit beyond the local authority structure. Joint training opportunities, and having public health professionals engage at all stages of the LAQM process, would increase public health engagement and impact.

4. *Given your engagement in this research, would you add or change anything about it?*
    - Overall, the framework is an accurate reflection of research outcomes. However, some aspects could be improved.

- For example, a more detailed description of the ‘review and assessment’ stage is needed. It should be more clearly indicated that this amended step calls for the implementation of a much more comprehensive risk assessment process that goes beyond air pollution risk assessment to require risks to be considered in the context of wider health determinants. As presented in the framework, this extra risk assessment dimension is not obvious and initially appears to be just one more thing that local authorities must do. However, it should be explained that this new requirement need not be more onerous for local authorities but rather a new opportunity for public health to engage and support LAQM action (and to draw upon existing data and resources to add value to air quality risk assessment).
- The reference to Health Impact Assessment is entirely appropriate, but it appears in the wrong place in the framework. Such assessments are most useful to inform decision-making around a new policy or development; as such, it should feature in the ‘action planning’ stage of the LAQM conceptual framework and not the ‘review and assessment’ stage as it currently does. (This point was discussed in some detail be applying it, theoretically, to examples: ongoing debate concerning a proposed bus exchange development on land adjacent to an existing Air Quality Management Area in Penarth that the local authority is seeking to revoke, and a proposal to de-pedestrianise Bridgend town centre where local air quality management specialists have not been engaged.
- In addition to previous comments about ‘action planning’ components, the framework needs amending to show that one of the three components – target action in areas with poor air quality is not a ‘new’ step in the LAQM process. It is consistent with existing arrangements. Further, clarification is needed around the application of another of the three components – target action in poor health areas... to reduce inequalities – since doing so all the time may not be appropriate. For example, it would not be necessary to target action in a deprived rural community with good air quality where known health inequalities are the result of poor service and amenity access only. Targeting action in poor health areas should more appropriately apply in areas where health profiles are poor and where air quality is too but not to the extent that an Air Quality Management Area is warranted. In such areas, potential health gains should outweigh the cost of action.

5. *What do you think the most challenging aspects are to secure buy-in for and implement?*
    - The framework makes a strong and evidence-based case for an enhanced way of working to support LAQM action; it provides succinct descriptions of the steps needed to achieve policy and practice change, and practical advice on how to go about this.
    - Establishing ownership of the local/regional air quality strategies poses problems, however. Based on existing LAQM requirements, it might be assumed that local authorities will take on this role. However, other stakeholders – such as public health – could lead. If the strategy becomes part of a suite of strategic intentions 'owned' by local Public Services Board then this might solve a number of problems around ownership, accountability and progress-reporting. The framework should be flexible on this point; so long as the policy principle is clear and accepted, it is most appropriate to let each locality decide what works best for them (taking into account local circumstances and structures). It also offers each area opportunities to define what is 'local' or 'regional'. This is especially important in some areas; for example, the Cardiff, Vale and Bridgend local authority Shared Regulatory Service (which has LAQM delivery responsibilities) spans three local authority areas, three Public Services Board areas and two Health Board areas.

6. *Do you think it will make a difference in practice in your area?*
    - Yes. It has the potential to evolve LAQM into a public health-driven tool that can help air quality management specialists relate it to broader public health work, and *vice versa*.
    - It asks for more to be done, but justifies why. It describes how, through better public health engagement and synergies – extra work burdens can be shared so action becomes efficient.
    - Importantly, the framework seeks to change mindsets and encourage ways of working that ensure action is focused on long-term environmental health protection and improvement.

7. *What should happen next to turn theory into reality?*
    - There are good opportunities on the horizon to make the case for this new, evidence-based way of working. It is appropriate to refer to this conceptual LAQM framework in relevant consultation responses in order to influence policy and practice development (e.g. the forthcoming Welsh Government consultation on a framework for Clean Air Zones in Wales).

- Guidance is needed to support implementation of this new way of working; it would be useful to integrate this with the next iteration of LAQM policy guidance. Also, it should be reflected in other relevant policies, especially across linked areas of public health practice.
- The framework should be piloted in a part of Wales. Quick wins would demonstrate the added value of adopting the approach. Successful evaluation may lead to all-Wales roll out ultimately.
- It is important to commence awareness-raising and training to support practical delivery of the framework. It would be a missed opportunity to train public health professionals in isolation. The added value of training public health professionals alongside other LAQM stakeholders would be substantial. The framework should encourage this.

Case study interview #2

Feedback on the conceptual LAQM framework for Wales:

1. *How easy is it to understand and follow?*
   - The conceptual framework is relatively easy to understand and follow.
   - It is clear that the 'enhanced ways of working' text on the right-hand side of the framework links across to the LAQM framework steps presented on the left-hand side.
   - The conceptual framework demonstrates how the Welsh Air Quality Forum can add value to existing LAQM arrangements by evolving its membership (to include public health specialists as well as transport and planning colleagues), adopting a broader public health-focused outlook, and driving change through evidence-informed strategic leadership.
   - The framework also places emphasis on the need for good links across local authorities, public health and academia to support LAQM action, research and evaluation.
   - The specified step of acting to reduce air pollution and risks for everyone, running in parallel with targeted action to reduce inequalities, is easy to understand in context.
   - It may be worth giving some consideration to the use of alternative methods to present the new ways of working e.g. a driver diagram or logic model approach. Both approaches would serve to highlight the importance of linking LAQM with, and helping to achieve the requirements and objectives of, 'bigger picture' legislation and policy.

2. *Would you be happy to adopt the new way of working in your area?*
   - Yes.

- While it is recognised that local or regional air quality management groups are needed to drive and support LAQM-related work, convening an entirely new group of relevant stakeholders may not always be necessary. For example, in the Swansea area, an Environment Forum already exists to lead the implementation of a range of different environmental sustainability work streams under the auspices of the 'Healthy Cities' project. If groups like this exist, they should be used as an established vehicle to deliver LAQM objectives (linked with broader public health and wellbeing goals) since it is important to minimise any extra burden on people's precious time. Integrating LAQM with the work of existing groups will likely be more productive because joint priorities, overlapping work plans and collaborative working opportunities will have been identified already. It should be acknowledged, however, that such groups do not always exist (as highlighted by colleagues from Carmarthenshire in this case study discussion) and so it may not be possible to seize opportunities to 'piggy back' on existing structures. The framework should show that this LAQM step of creating local and/or regional LAQM oversight groups, although necessary, is best implemented through flexible application based on local situations and needs.
- There is no doubt that LAQM needs strategic direction, leadership and support locally. However, in line with the preceding point, it may not be necessary to set this all out in a new standalone local or regional air quality strategy. Since the LAQM framework originates in legislation, like other linked public health functions, producing a new local air quality strategy may be an unnecessary additional step in the new conceptual framework way of working. A more efficient way forward may be to take the strategic direction, prescribed processes, and requirements to work across policy areas in more sustainable ways and use these to inform other local policies e.g. Wellbeing Assessment and Plans.
- The goal to improve air quality everywhere and not just tackle isolated problems in pollution hotspots, is welcomed.

3. *Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?*
    - Yes.
    - Years ago, in mid and west Wales, local public health and environmental health specialists used to meet regularly. Relationships were good. However, changes in organisation structures and staff over the years have meant that these meetings almost never happen now (unless in reaction to problems) and the strong links between the two professions

locally have been eroded. The new ways of working proposed would help restore these important links by encouraging public health and local authority colleagues to work to a common goal: to reduce air pollution, risks and inequalities. Given the interactions of air pollution with wider public health determinants. of air pollution, collaborative work in this area can deliver health and wellbeing co-benefits.

4. *Given your engagement in this research, would you add or change anything about it?*
   - The framework does a good job of succinctly capturing research outcomes.
   - As described above, it could be argued that the 'mandatory air quality strategy' step is unnecessary if LAQM is prescribed and driven by national legislation and policy and incorporated and considered (alongside other public health priorities) in broader local plans e.g. wellbeing plans, physical activity/active travel plans, transport plans, planning strategies.
   - The flow of some parts of the framework could be made clearer. It would offer greater clarity if the three actions currently linked to the 'action plan' stage (i.e. for universal action, for targeted action in poor air quality areas, and for targeted action in poor health areas) were assigned to the 'review and assessment' stage instead. The latter is the part of LAQM that needs the most attention; it is important that the risk assessment process considers air pollution problems and solutions in the broadest possible public health context. Only after undertaking enhanced risk assessments can an informed action plan be developed. Further, the risk assessment process may identify other actions not traditionally incorporated into action plans such as longer-term research priorities and enhanced monitoring needs. This should be reflected in the framework too.

5. *What do you think the most challenging aspects are to secure buy-in for and implement?*
   - Without a doubt, the risk assessment approach and the need for this step to be underpinned by strong arrangements to share and link data and analytical expertise. This comment links with the preceding point. The framework should emphasise the point that the introduction of an enhanced risk assessment process is not intended to be more onerous for local authority air quality management specialists. Rather, it should clearly show that this responsibility should be a joint effort that is helped and made more efficient through greater support from public health specialists contributing their expertise around routine (and new) data sharing, linking and analysis (linked with academic partners).

- It remains a challenge to produce so many LAQM-related reports. To secure buy-in from all stakeholders, it would be good to see the new way of working offer a more streamlined approach to LAQM reporting i.e. through just <u>one</u> (albeit more comprehensive) review and assessment report that also specifies informed action - covering universal and targeted risk reduction action - and any other work that can improve understanding of new and emerging problems. This can be updated annually. The need to produce standalone plans for each Air Quality Management Area is short-sighted, overly bureaucratic and a waste of scarce time and other resources across already heavily-burdened air quality management and public health specialists. A separate brief progress report (just a couple of sides of A4) that presents an overview of progress made over the previous year should be all that is required to continue to inform the work of relevant local and regional partnerships.

6. *Do you think it will make a difference in practice in your area?*
   - Yes, especially if partners are able to embed the new ways of working in broader policy and practice (through relevant local and regional partnerships).

7. *What should happen next to turn theory into reality?*
   - A recent communication from the Welsh Government Future Generations Commissioner's office states that every local Public Services Board in Wales must have regard to local air quality reviews and assessments. This requirement can help ensure that LAQM is prioritised at the local and regional levels across multiple public sector bodies and reflected in individual organisations' workplans. Further, it presents opportunities to highlight that air pollution is everyone's business, that action is needed everywhere (not just in small Air Quality Management Areas), and that added value can result from making links with other public health interventions to tackle wider determinants of health. The new ways of working as outlined in this LAQM conceptual framework should be highlighted to Public Services Boards to help them respond to the Future Generations Commssioner's call to action.
   - Other opportunities exist to develop formal arrangements to implement this new LAQM framework e.g. a consultation will soon take place to develop new LAQM reporting templates. It will be important to consider this conceptual framework when responding to calls to design new reporting mechanisms and tools. As such, raising greater awareness of this approach amongst policy officials is a priority.

- Finally, good communications remain essential to get this new ways of working off the ground. These communications should not just seek to continue to raise awareness around air pollution-related risks but, equally importantly, what can be done to address them from both public and professional perspectives. This conceptual framework can help support news ways of working across both approaches.

Case study interview #3

Feedback on the conceptual LAQM framework for Wales:

1. *How easy is it to understand and follow?*
   - The flow of the conceptual framework is logical, but some aspects would benefit from simpler presentation and more detailed associated text/description.
   - It is helpful to frame this new way of working for LAQM in a broader policy context, but doing so makes it quite confusing to understand exactly which components are LAQM-specific and which are beyond the boundary of LAQM. Consideration should be given to making this distinction using a clearer presentation.

2. *Would you be happy to adopt the new way of working in your area?*
   - Yes. The Cwm Taf Public Services Board would support developments of this kind. The underpinning principles of, and approach outlined in, this new way of LAQM working meets Wellbeing of Future Generations Act requirements. However, it is important to specify what the added value of implementing the framework will be for Public Services Boards.
   - This way of working would be accepted in this area; there would be appetite to trial it as a new way of working (and evaluate its success and impact).

3. *Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?*
   - Yes. Through closer working with public health professionals, LAQM delivery can become more holistic in its approach. It makes complete sense to think of air pollution as a public health priority rather than just an isolated problem; it is important to act to reduce air pollution *and* associated population-level risks (linked to wider health determinants). Working to reduce air pollution concentrations to achieve legislation compliance is a small part of a much bigger picture; if the wider context is not considered, it is likely that the

task of tackling problems will be more difficult, and unintended adverse consequences could result from ill-informed decisions and actions. The Church Village bypass development was offered as an example to illustrate this point - while the bypass has reduced air pollution concentrations in several communities (previously affected by pollution from congested traffic), but has also made travelling easier, increased the number of vehicles in the area, and raised pollution concentrations in areas that previously enjoyed good air quality.

4. *Given your engagement in this research, would you add or change anything about it?*
   - Research outcomes are well considered and represented in the conceptual framework, but some suggested changes may improve process flow and overall presentation.
   - The arrow linking 'national legislation, policy and guidance' and 'Welsh Air Quality Forum' should be double-ended to illustrate their reciprocal influence.
   - More detail should be provided on the role of the Welsh Air Quality Forum (as a national body to coordinate communications, lobby and advocate for change and influence policy) and its membership (e.g. to include public health, planning, transport, education colleagues).
   - Having local or regional air quality management groups would facilitate public health engagement and most certainly add value to LAQM work and reach, but only if the purpose and remit of these groups are specified. The framework should describe: whether groups should just focus on LAQM implementation, whether they endeavour to link LAQM with 'bigger picture' public health priorities, policy and practice, whether they hold stakeholders accountable for action or whether they do all these and more?
   - It is appropriate for the 'review and assessment' step to consider air pollution risks in a broader public health context through better data sharing, linkage and analysis. Targeted action prioritised as a result of this assessment should seek to reduce both air pollution and associated health risks in worst affected areas. However, the universal action to reduce risks for everyone may not need to form part of the same risk assessment; action may be based on a suite of principles and interventions agreed at the local, regional and/or national level. This part of the framework should be revised to reflect this; there is also merit in linking the universal action with broader Public Services Boards-led public health and wellbeing work.
   - The framework does a good job of stressing that the 'action plan' element of LAQM should frame a broader and more coherent LAQM approach with prioritised action based

on a review and assessment of air pollution in the context of wider health determinants. However, the ‘action plan’ part of the framework should be informed by the ‘risk assessment’ component (which includes consideration of the three action work streams). The conceptual framework has this the wrong way round at the moment.

5. *What do you think the most challenging aspects are to secure buy-in for and implement?*
   - It should be made clear that the proposed new way of working seeks to add value to the existing LAQM framework through greater public health engagement and support, considering air pollution risks and solutions in a broader context and acting to reduce risks through targeted and universal action. There will likely be some opposition from local authorities if they perceive the framework will do this by weakening or eroding their statutory role/function in LAQM delivery. This is not the case, but it is something that needs to be made clearer in the framework.
   - The suggested approach of assessing air pollution risks in a broader public health context, and acting to reduce risks for everyone will only happen if made a formal requirement of the LAQM process and supported by policy and guidance.

6. *Do you think it will make a difference in practice in your area?*
   - Yes, it has the potential to improve public health integration and collaboration in LAQM and strengthen relationships with local authority stakeholders, especially environmental health professionals. For example, rather than public health specialists being consulted on local review and assessment reports by local authority environmental health professionals after they are drafted, both should be coming together at the outset of the process to collaboratively assess risks (from both air pollution and public health perspectives), agree actions and develop reports.
   - There are a number of opportunities where this new way of working (linking air pollution with other public health priorities) could add value. For example, discussions and actions amongst public bodies concerning City Deal and Metro developments (including electrification of trains), that seek to introduce more sustainable transport infrastructure connecting parts of Cwm Taf Health Board area and Cardiff, would really benefit from being influenced by a more informed and public health-driven LAQM process. There are other opportunities too e.g. incorporating LAQM with sustainable infrastructure developments and ‘green tourism’ ventures such as the Bike Park Wales attraction in this area.

- It is also possible that greater collaboration and engagement will create opportunities to access more funding streams to support action.

7. *What should happen next to turn theory into reality?*
    - Draft a briefing for the Cwm Taf Public Services Board seeking to secure senior-level commitment to trial this new way of working for LAQM in the area. Its sustainable approach, policy connections and potential added value should be highlighted. It will be easier to do this in Cwm Taf than other parts of Wales because it is the only area where one Public Services Board spans two local authority areas and the Health Board.

Case study interview #4

Feedback on the conceptual LAQM framework for Wales:

1. *How easy is it to understand and follow?*
    - In the main, it is easy to understand and follow.
    - It is not clear that the text on the right of the page links to the LAQM steps on the left.
    - The title is confusing; stating that the proposed way of working is 'public health-driven' implies [incorrectly] that LAQM is led and delivered by public health bodies/specialists. The term 'public health-driven' should refer to public health as a subject, not as an organisation.
    - The 'review and assessment'-related text refers to "wider health determinants population vulnerability profiles". It is not clear what this means.
    - It may be beneficial to entitle the 'enhanced ways of working' text column as 'working in more sustainable ways' as this links directly to the principles and requirements of the Wellbeing of Future Generations (Wales) Act 2015 and will help a broader audience relate to this new way of working for LAQM.

2. *Would you be happy to adopt the new way of working in your area?*
    - Yes. The proposed new ways of working has the potential to bring air quality management and public health specialists closer together to pursue shared goals to reduce risks and inequalities. However, because this approach has not been evaluated, it would be sensible to pilot it in a few areas across Wales and assess its impact through robust evaluation.

- An aspect of the conceptual framework that would benefit from more explanation is the additional burden associated with extra work around risk assessments. It is easy to direct stakeholders to share and link relevant data sources but clear guidance would be needed on how this should be done correctly, and by whom. Local Authorities do not have the expertise or capacity to undertake comprehensive public health risk assessments; greater support would be needed from public health specialists. It should be made clear that this extra burden would not fall to local authority air quality management specialists alone, but would be shared with public health specialists through collaborative working.

3. *Do you think it would improve public health integration and collaboration in LAQM and add value to existing arrangements in your area?*
    - Yes. In north Wales, a collaborative has already been established around LAQM (and noise) activity. This is a similar approach to that proposed in the conceptual model, but at present joint working at the regional level is amongst local authorities (Environmental Health) only. As justified by this new way of working in LAQM, it is sensible to extend this collaboration to facilitate engagement with public health specialists as well as other key stakeholders.
    - Building on the preceding point, it is important to broaden the role and membership of the Welsh Air Quality Forum at an all-Wales level so that more public health specialists are involved. The more public health specialists know about air quality, the more informed they will be to make the links between it and their 'day job'. Further, if the Welsh Air Quality Forum can become a leadership group (involving all key stakeholders) then there is more chance of it setting shared priorities for action and research that link with broader public health and wellbeing strategic plans.
    - The conceptual framework does a good job of stressing the importance of assessing risks and taking action to reduce risks in those areas where air pollution is having adverse impacts on public health but is not at concentrations that breach air quality standards and where Air Quality Management Areas should be declared. The approach advocated by the conceptual framework – i.e. universal action to minimise risks for everyone, running in parallel with targeted air pollution reduction action – is key to reaching out to and engaging a wider public health audience. It relates to broader public health work (e.g. physical inactivity initiative) seeking to reduce health inequalities.

4. *Given your engagement in this research, would you add or change anything about it?*
    - The conceptual framework captures research findings well.
    - More emphasis should be placed on the role of Health Impact Assessment in LAQM, particularly how it can facilitate links with both reactive and proactive strategic planning e.g. Local Development Plans, carbon management plans and green travel plans. It would also be worth highlighting how the approach might support broader air quality risk assessments, decision-making and impact evaluations.
    - The role of (and communication with) the public is currently given only limited consideration in this conceptual framework despite this being a recommendation in existing LAQM policy guidance. Similarly, there is no mention of third sector partners and how improved collaboration with that sector can support delivery of a public health-driven model.

5. *What do you think the most challenging aspects are to secure buy-in for and implement?*
    - For many, especially public health specialists, air quality management is a daunting subject; the perception that it is a very technical specialty puts many practitioners off engaging. In order to secure buy-in at the local and regional levels, the conceptual framework must be kept simple so that as many people as possible can understand it and relate to it, and join in.
    - It will be a challenge in most places to establish a new multi-agency LAQM group if one does not already exist. There is no doubt that a group of this kind is needed locally and/or regionally, however, to drive LAQM implementation because it will be required to link across to local strategic planning partnerships (e.g. Public Services Boards) and nationally too (e.g. with Welsh Air Quality Forum). This group will be essential in supporting effective LAQM delivery but creating it will be difficult. A rationale or business case will be needed locally to convince stakeholders of the added value that could be achieved through such as group.
    - It is not clear whether a standalone LAQM strategy would be preferable to incorporating LAQM into other strategic plans. There would be no harm in having both but it would be a missed opportunity if partners did not document LAQM strategic intentions and share them.
    - It is likely that the new approach - of assessing risks and targeting action in poor air quality and health status areas, to prevent problems occurring and reduce inequalities - will need to be underpinned by some sort of memorandum of understanding that

relevant partners sign-up to. Again, a rationale describing why this approach is warranted will be needed to encourage partner buy-in.

6. *Do you think it will make a difference in practice in your area?*
    - Yes, it is essential that LAQM efforts are organised to tackle emerging problems as well as existing ones. This prevention-focused approach is in-keeping with the requirements of the Wellbeing of Future Generations Act sustainable ways of working. It is entirely appropriate to consider air pollution in a broader public health context - linked to wider health determinants - in order to identify those areas where targeted action is needed to tackle combinations of poor air quality (but not necessary air quality standard breaches) and poor population health status.
    - Links should be made with Public Health Wales' Policy Directorate to increase opportunities to access new funding to support partnership work in this area. A funding requirement is that projects are evaluated to determine what difference they have made to public health.

7. *What should happen next to turn theory into reality?*
    - This new way of working should be piloted and subject to formal evaluation.
    - The role and membership of the Welsh Air Quality Forum should be reviewed and revised.
    - Connect LAQM work to Public Health Wales' research priorities to raise the profile across all public health specialties and increase chances of securing funding to support research projects and cross-organisation work placements.

Appendix J Research update and development workshop evaluation

The research update and development session was well received by attendees. A balanced selection of delegate feedback is presented below rather than a reproduction of every comment made. The selection is intended to be representative and give an overall impression of what people thought of the session.

1. What went well?

Attendees commented:

- *"Lots of enthusiasm and agreement regards which areas to progress and how to do this; scoring system worked well and reflected what was discussed around the table."* [Public Health specialist]
- *"Very well presented and organised. Good communications and involvement with north Wales. Good to meet with PH and air quality colleagues who we don't see that often now."* [Air Quality Management specialist]
- *"Opportunity to meet practitioners in this area of work which I would not normally have the opportunity to do. Feedback provided on the outcomes of the Delphi consultation process."* [Public Health specialist]
- *"Interesting session and good to have a mix of professionals with different perspectives to feed into the discussions."* [Public Health specialist]

2. What did not go well?

Attendees commented:

- *"Assumption that participants are all up to speed with acronyms etc." [Public Health specialist]*
- *"I've been involved in a number of these types of events. The challenge is to show actual positive actions or outcomes that arise from them i.e. what did the meeting achieve? e.g. did it lead to the production of information, advice or guidance?"* [Air Quality Management specialist]
- *"Perhaps more time needed to fully complete the tasks to the level of detail required."* [Public Health specialist]

- *“Scoring for the prioritisation exercise was difficult for some actions e.g. impact could be high, but where the action/impact relied upon something else, impact could be low due to the low probability of the other thing occurring.”* [Public Health specialist]
- *“On my table I think we sometimes found it difficult to address all the workshop questions as we tended to want to discuss issues in greater depth. There is also a risk with this type of approach that the views of the most vocal carry undue weight and that the facilitators do not capture the full breadth of discussion in feedback. I have no evidence that this happened in this case, but it always needs to be considered.”* [Public Health specialist]

3. What did you learn?

Attendees commented:

- *“That there is a lot to learn! Seriously, I learnt that I have training needs that should be met in order to have further involvement in this field and also that there should be a requirement for us to support clean air/AQMA strategic developments at a local level.”* [Public Health specialist]
- *“It reiterated for me the links between air quality and health improvement, how it could be fed into Wellbeing of Future Generations plans and how air quality can be tackled on many different levels by a range of professionals and community members.”* [Public Health specialist]
- *“I’m not the only person thinking we need a different approach and we need to generate evidence of what works to be able to gain greater influence for improvements.”* [Air Quality Management specialist]
- *“It is always useful to discuss different proposed approaches with different sectors working in the area. It gives a wider perspective on the challenges that need to be addressed.”* [‘Other’ expert]
- *“There was a lot of common thinking across the tables based on the feedback and some realistic solutions suggested. I think one common theme is that we were preaching to the converted – the big challenge is getting others to look beyond their area of work and recognise the long-term, cross-sector benefits of investing in some of these solutions.”* [‘Other’ expert]

4. What will you do differently now?

Attendees commented:

- *"Lobby for training on this issue. Explore support for developing local strategies and responses in my area."* [Public Health specialist]
- *"Ensure air quality is featured in Public Services Boards and local Wellbeing of Future Generations plans."* ['Other' expert]
- *"Seek to work more collaboratively on a wider scale and engage like-minded colleagues to hopefully help deliver the prospect of real public health improvements from our interventions."* [Air Quality Management specialist]
- *"The session emphasised to me the need to think more creatively about engaging with professionals and the public to address these challenges."* [Public Health specialist]