2018

AIR QUALITY MANAGEMENT REVIEW: SYSTEMATIC LITERATURE REVIEW AND CASE STUDY OF LOCAL AIR QUALITY MANAGEMENT IN THE UNITED KINGDOM (UK)

Shenton, Amanda

Student Number: 10120981

AIR QUALITY MANAGEMENT REVIEW: SYSTEMATIC LITERATURE REVIEW AND CASE STUDY OF LOCAL AIR QUALITY MANAGEMENT IN THE UNITED KINGDOM (UK)

By

AMANDA SHENTON

A thesis submitted to the University of Plymouth in partial fulfilment for the degree of

Research Masters through the School of Nursing & Midwifery

May 2018

Student Number: 10120981

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere thanks to my supervisors Professor Janet Richardson, Doctor John Rieuwerts and the University of Plymouth, without their understanding, continued support and wealth of knowledge this paper wouldn't have ever been finished.

I owe a debt of gratitude to the Chartered Institute of Environmental Health in supporting this research project and NBCUniversal in encouraging my further education, most pertinently Lee Dunworth.

To my Mum and Dad, thank you for letting me talk at you and your unbreakable belief in my abilities. Daniel Wall, thank you for ensuring I ate and solving all life's problems along the way.

Student Number: 10120981

AURTHOR'S DECLARATION

At no time during the registration for the degree of Research Masters through the School of Nursing and Midwifery has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

This study was financed with the aid of a studentship from the Chartered Institute of Environmental Health.

Word count of main body of thesis: 23,761

Author's signature: 

Date: 22/06/2018

Student Number: 10120981

ABSTRACT

Shenton. A

AIR QUALITY MANAGEMENT REVIEW: SYSTEMATIC LITERATURE REVIEW AND CASE STUDY OF LOCAL AIR QUALITY MANAGEMENT IN THE UNITED KINGDOM (UK)

Advancements in the scientific understanding in the associated health implications of air pollution, coupled with raised public awareness and media coverage has brought this ever evolving public and environmental health issue into the forefront of society's agenda, within the UK.

The purpose of this study is to evaluate the impact the current Local Air Quality Management framework has had at reducing air pollution. The research project was designed in two phases: The initial structured literature search and review appraised the current body of knowledge in this area, developed an understanding of the known successes and shortfalls of Local Air Quality Management and highlighted areas were further understanding was required.

The second phases built upon the established comprehension of Local Air Quality Management by apprising generalised theories against a local authority's implementation, highlighting unseen influential factors and providing a quantitative analysis of empirical data to evaluate the impact this management system has had upon air pollution.

The conclusion outlines key factors for consideration moving forward in the changing political climate and mounting public health burden this intangible toxin presents to the UK's future wellbeing.

LIST OF CONTENT

Contents

LIST OF TABLES

LIST OF FIGURES

Glossary of Terms

AQMA – Air Quality Management Area

AQO(s) – Air Quality Objective(s)

AQS(s) – Air Quality Standard(s)

C_6H_6 – Benzene

EPAQS – Expert Panel on Air Quality Standards

COMEAP – Committee on the Medical Effects of Air Pollution

LAQM – Local Air Quality Management

LTP – Local Transport Plan

NO_2 – Nitrogen Dioxide

O_3 – Ozone

Pb – Lead

PM – Particulate Matter

Chapter 1

Air Quality

& Local Air Quality Management in Context

1.0. Context

Air pollution as defined by the English Oxford Dictionary (2016) is the presence of any substance in the air which has harmful or poisonous effects on public and environmental health. Notably it is the environmental factor with the greatest impact on health in Europe (Doherty *et al*., 2009, p. 2). Air pollution is linked to a range of health implications and was attributed to an estimated 29,000 deaths within the UK in 2008 by the Committee on the Medical Effects of Air Pollution (COMEAP) (2010, p. 13). However, further research has indicated the associated deaths may be much higher for example, in 2014 Public Health England accredit particulate matter (PM) alone to 28,969 deaths in 2010 of persons 25 years-plus, within the UK (Gowers *et al*., 2014, p. 22). Please see *Appendix 1* for a summary of the main air pollutants including sources and the associated health effects (Department for Environment, Food and Rural Affairs, 2011).

The evolution of regulatory restrictions on the production of air pollution and thus the improvement of air quality in the UK has established several key moments throughout recent history. For instance, the ‘Great Smog’ of 1952 with an attributable death toll of 12,000, resulting in the *Clean Air Act 1956 – last amended in 1993* (Davis *et al*, 2001). The once perceived acute and chronic health implications of Lead (Pb) in ambient air, gained sufficient epidemiological weight to lead to the *Motor Fuel Composition and Content Regulations 1999*, banning Pb from petrol

(Caparino and Togna, 1998; Elwood and Gallacher, 1984). Furthermore, the continued development of legislation limiting the emittance of ‘dark smoke’ from industrial sources provides an illustration, in the present day of our societies’ understanding and progression in this area (*Clean Air Act 1993*).

In local authorities, the management of air pollution has advanced from a non-unified monitoring programme, based on individual authority resources, and management on an ad hoc and pollution source basis until 1997; whereupon the Local Air Quality Management (LAQM) framework was introduced (Woodfield *et al*, 2003). The LAQM initiative works on a risk-based management strategy, in this context risk is defined as the probability multiplied by the magnitude of a particular adverse event occurring in a stated period of time, or as a result of specified challenges supported by sound scientific evidence and reasoning (Morgan, 1993; Pencheon *et al*, 2001).

This development in air quality management was brought forward through Part IV of the *Environment Act 1995*. The Act places a duty on local authorities to review current levels of air pollution and estimate future pollution levels in their districts, against the Air Quality Standards (AQSs). Air Quality Standards, often referred to as limits, values, or targets, are concentration levels considered acceptable in ambient air by a government-commissioned Expert Panel on Air Quality Standards (EPAQS), dissolved as of 2010 (Department for Environment, Food and Rural Affairs, 2010). The remaining Air Quality Expert group are stated to not inform ‘*health impacts or Air Quality Standards*’ but instead provide a consolidation of level recordings, source and characteristics. Theoretically providing less information on their subject area than a chemical safety data sheet (Department for Environment, Food and Rural

Affairs, 2016; European Chemical Agency, 2015). This raises questions about standardised levels, a '*one size fits all*' scenario, of air pollution tolerable toxicity to all persons. Furthermore, the governance over of AQSs is further deliberated by the efficiency of departmentalised: committees, agencies (Public Health England) and groups to inform on the subject; combined with the seeming reluctance in the UK to review local AQSs. See *Table 1* for AQSs under column *Objectives*.

Differentiating from AQSs and Air Quality Objectives (AQOs), AQSs as mentioned above provide parameter thresholds for air pollution levels and inform LAQM targets. Whereas, objectives are target dates, exceedances of AQSs must not exceed a specified number, refer to *Objectives Table 1* (Department for Environment, Food and Rural Affairs, 2016). The responsibility for achieving these objectives rest with central government. AQOs as seen in *Table 1* shows the pollutant ozone (O_3). However, it is important to note and will be touched upon later in this chapter, that local authorities do not have legal responsibilities in relation to this air pollutant (Beattie *et al*, 2006). Furthermore, Particulate Matter 2.5 and Polycyclic aromatic hydrocarbons were late additions to the AQOs and there is a pending proposed amendment at the time when writing this chapter to remove 1-3 Butadiene, benzene (C_6H_6), carbon monoxide, and Pb from the objectives (Department for Environment, Food and Rural Affairs, 2015). Following the removal of Pb from petrol the proposed air pollutants to be removed from the AQOs have not been perceived to present any significant air pollution risk in recent years, within the UK and have been in place due to EU decree (*ibid*). This is an example of action in the UK to review AQO but rather to reduce paper work than build upon past success. See *Table 1* for UK and EU objective deadlines.

As a consequence, local authorities hold a responsibility for AQOs and therefore, the assessment of current and future air quality in their district. Local authorities are to evaluate air quality and if possible exceedances of an AQS are indicted an Air Quality Management Area (AQMA) is to be declared. The AQMA is a zone within a local authority's jurisdiction in which the scientific evidence shows AQSs has or will breach accepted levels. Subsequently, an Air Quality Action Plan is required to provide a strategy to improve air quality and achieve AQOs (Department for Environment, Food and Rural Affair, 2016a). From a public health perspective Longhurst's *et al* (2006) clearly summaries the purpose of this legislation, which is as poignant today:

"Clean air is an essential ingredient of a good quality of life. People have the right to expect that the air that they breathe will not harm them." The primary objective of National Air Quality Strategy is "to make sure everyone can enjoy a level of ambient air quality in public places which poses no significant risk to health or quality of life".

In 1999 following the introduction of the Local Air Quality Management and the looming 2005 European Union (EU) AQOs, a UK White Paper on *Quality of Life Indicators* noted that "on 10% of days' air pollution exceeded the no harm levels… based on human health" (Her Majesty's Government, 1999: p. 17; cited in Walton *et al*, 2010). As an analogy of equal visual transparency and for the widely-known health implications, this could be equated to the UK population being subjected to harmful levels of man-made ionising radiation for over one month each year. However, there is a distinct difference in the control of man-made ionising radiation

to the equivalent air pollution, as any person subjected to x-rays is required to provide written/verbal consent (Health and Safety Executive, 2016; Health and Safety Executive, 2016a). Almost two decades on from the *Quality of Life Indicators* statement, following the 2010/15 and now the impending 2020 AQOs the current air pollution exceedances are depicted irrespective of area size, by the 809 AQMAs currently in place in the UK (Department for Environment, Food and Rural Affairs, 2016b).

The purpose of the following research is to determine the impact LAQM has had upon air quality by consolidating the established body of work on the management of local air quality through a systematic review and the appraisal of an indifferent local authority's implementation of this management system and the impact on air pollution.

Table 1. National air quality objectives (Department for Environment, Food and Rural Affairs, 2012)

National air quality objectives and European Directive limit and target values for the protection of human health							
Pollutant	**Applies**	**Objective**	**Concentration measured as[10]**	**Date to be achieved by and maintained thereafter**	**European obligations**	**Date to be achieved by and maintained thereafter**	**New or existing**
Particles (PM_{10})	UK	50µg.m^{-3} not to be exceeded more than 35 times a year	24 hour mean	31 December 2004	50µg.m^{-3} not to be exceeded more than 35 times a year	1 January 2005	Retain existing
	UK	40µg.m^{-3}	annual mean	31 December 2004	40µg.m^{-3}	1 January 2005	
	Indicative 2010 objectives for PM_{10} (from the 2000 Strategy and 2003 Addendum) have been replaced by an exposure reduction approach for $PM_{2.5}$ (except in Scotland – see below)						
	Scotland	50µg.m^{-3} not to be exceeded more than 7 times a year	24 hour mean	31 December 2010			Retain existing
	Scotland	18µg.m^{-3}	annual mean	31 December 2010			
Particles ($PM_{2.5}$) Exposure Reduction	UK (except Scotland)	25µg.m^{-3}	annual mean	2020	Target value 25µg.m^{-3} [12]	2010	New (European obligations still under negotiation)
	Scotland	12µg.m^{-3}		2020	Limit value 25µg.m^{-3}	2015	
	UK urban areas	Target of 15% reduction in concentrations at urban background[11]		Between 2010 and 2020	Target of 20% reduction in concentrations at urban background	Between 2010 and 2020	
Nitrogen dioxide	UK	200µg.m^{-3} not to be exceeded more than 18 times a year	1 hour mean	31 December 2005	200µg.m^{-3} not to be exceeded more than 18 times a year	1 January 2010	Retain existing
	UK	40µg.m^{-3}	annual mean	31 December 2005	40µg.m^{-3}	1 January 2010	
Ozone	UK	100µg.m^{-3} not to be exceeded more than 10 times a year	8 hour mean	31 December 2005	Target of 120µg.m^{-3} not to be exceeded more than 25 times a year averaged over 3 years	31 December 2010	Retain existing

Sulphur dioxide	UK	266µg.m^{-3} not to be exceeded more than 35 times a year	15 minute mean	31 December 2005			Retain existing
	UK	350µg.m^{-3} not to be exceeded more than 24 times a year	1 hour mean	31 December 2004	350µg.m^{-3} not to be exceeded more than 24 times a year	1 January 2005	
	UK	125µg.m^{-3} not to be exceeded more than 3 times a year	24 hour mean	31 December 2004	125µg.m^{-3} not to be exceeded more than 3 times a year	1 January 2005	
Polycyclic aromatic hydrocarbons	UK	0.25ng.m^{-3} B[a]P	as annual average	31 December 2010	Target of 1ng.m^{-3}	31 December 2012	Retain existing
Benzene	UK	16.25µg.m^{-3}	running annual mean	31 December 2003			Retain existing
	England and Wales	5µg.m^{-3}	annual average	31 December 2010	5µg.m^{-3}	1 January 2010	
	Scotland, Northern Ireland	3.25µg.m^{-3}	running annual mean	31 December 2010			
1,3- butadiene	UK	2.25µg.m^{-3}	running annual mean	31 December 2003			Retain existing
Carbon monoxide	UK	10mg.m^{-3}	maximum daily running 8 hour mean/in Scotland as running 8 hour mean	31 December 2003	10mg.m^{-3}	1 January 2005	Retain existing
Lead	UK	0.5µg.m^{-3}	annual mean	31 December 2004	0.5µg.m^{-3}	1 January 2005	Retain existing
		0.25µg.m^{-3}	annual mean	31 December 2008			

Nitrogen oxides	UK	30µg.m^{-3}	annual mean	31 December 2000	30µg.m^{-3}	19 July 2001	Retain existing in accordance with 1st Daughter Directive
Sulphur dioxide	UK	20µg.m^{-3}	annual mean	31 December 2000	20µg.m^{-3}	19 July 2001	Retain existing in accordance with 1st Daughter Directive
	UK	20µg.m^{-3}	winter average	31 December 2000	20µg.m^{-3}	19 July 2001	
Ozone: protection of vegetation & ecosystems	UK	Target value of 18,000µg m^{-3} based on AOT40 to be calculated from 1 hour values from May to July, and to be achieved, so far as possible, by 2010	Average over 5 years	1 January 2010	Target value of 18,000µg m^{-3} based on AOT40 to be calculated from 1 hour values from May to July, and to be achieved, so far as possible, by 2010	1 January 2010	New EU target

Chapter 2

Air Quality Management review: Systematic Literature Review of Local Air Quality Management in the United Kingdom (UK)

2.0. Aim

This review evaluates evidence, from published papers, on LAQM relating to '*the major threat to clean air*', '*that is significantly growing*', with transport emission contributing to over a third of the production of nitrogen oxides (Department for Environment, Food and Rural Affairs, 2016a; World Health Organisation, 2017; Department for Environment, Food and Rural Affairs 2016c, p14). Air pollution itself presents a vast scope, therefore, this literature review aims to focus on the potential leading cause of air pollution in the UK and a prominent management system currently in place. The relevance of each publication was appraised against the relevance to the air quality management system applicable to the UK and relating to transportation emissions. The impact of AQMAs in addressing this source of air pollution is discussed with suggestions for potential improvements and future research.

2.1. Search and Appraisal Methods

A systematic search was carried out using the following: AMED, Business Source Complete, CINAHL, Cochrane, EMBASE: (Ovid), JBI, MEDLINE, PsycINFO, PubMED, SocINDEX, and Wed of Science. During the period between February - May 2016.

2.2. Search Terms

"Air quality management areas" or "air quality management area*" or "air quality management*" and "emissions" or "air quality" and/or "emissions".

2.3. Additional search

A search of the National Research Register (United Kingdom) (renamed the UK Clinical Trials Gateway) was conducted during the same period to identify potential relevant unpublished and ongoing research. This avenue was considered due to the public health aspect of AQMAs. However, no studies were identified. A search of the Air Quality Management Resource Centre was conducted to consider current research projects, the results are supplied in *Table 2*.

2.4. Filtering

Potential papers were noted for their relevance to air quality management and transportation emissions against a flow-chart system developed for this review depicted in *Figure 1* and *2*. The basic study type categories included: publication after 1997 to account for the implementation of LAQM, publication referencing the UK's approach to air quality management and public health implications related to air quality management. Environmental and animal inference was not included in the categorisation process. The author carried out this process independently.

2.5. Inclusion Criteria

2.5.1. Type of study attributes: Reference to UK air quality management, transportation emissions, air quality management in the UK and public health relations to air quality management of emissions.

2.5.2. Type of study (exclusion) criteria: Published in English for translation purposes and referencing the UK air quality management process. Listed on a public health database for relevance, as public health protection is the proposed purpose of LAQM. Journals were required to be peer reviewed for credibility and published after 1997 to take account for the implementation of LAQM.

2.6. Findings

The search results from each database is represented in the '*Figure 1*. *Chart of databases searched and journals sourced'* and '*Figure 2. PRISMA* (Preferred Reporting Items for Systematic reviews and Meta-Analyses) *Flow Diagram*'.

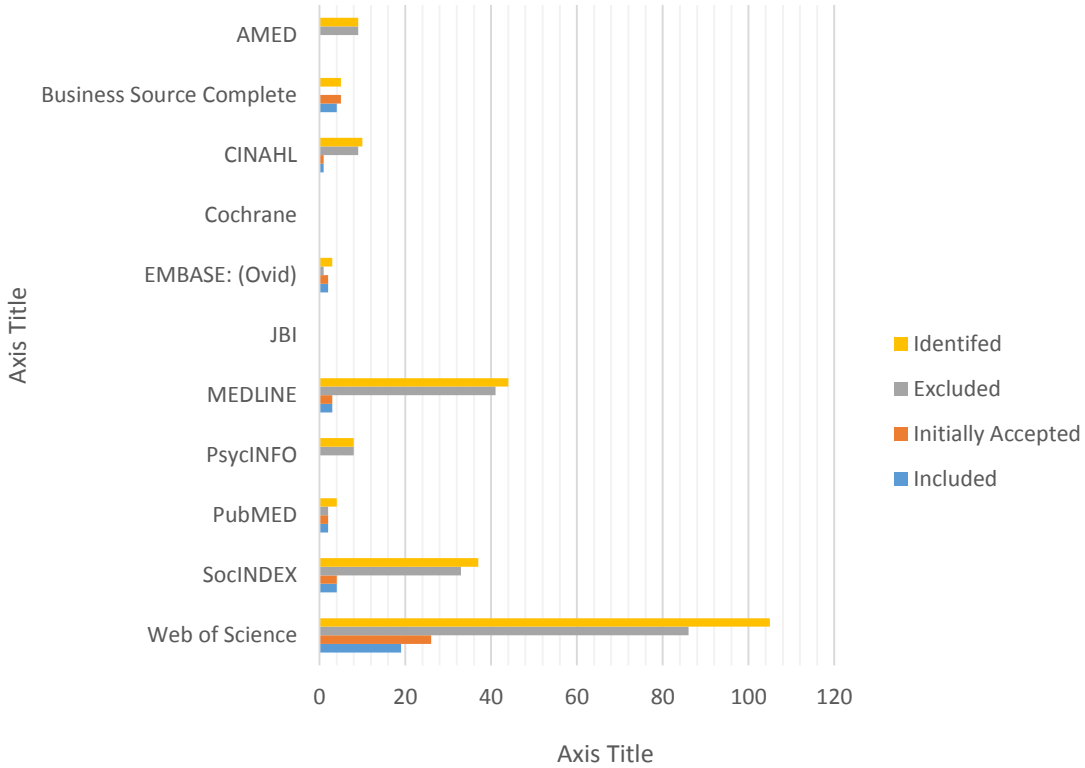

Figure 1. Chart of databases searched and number of journals sourced

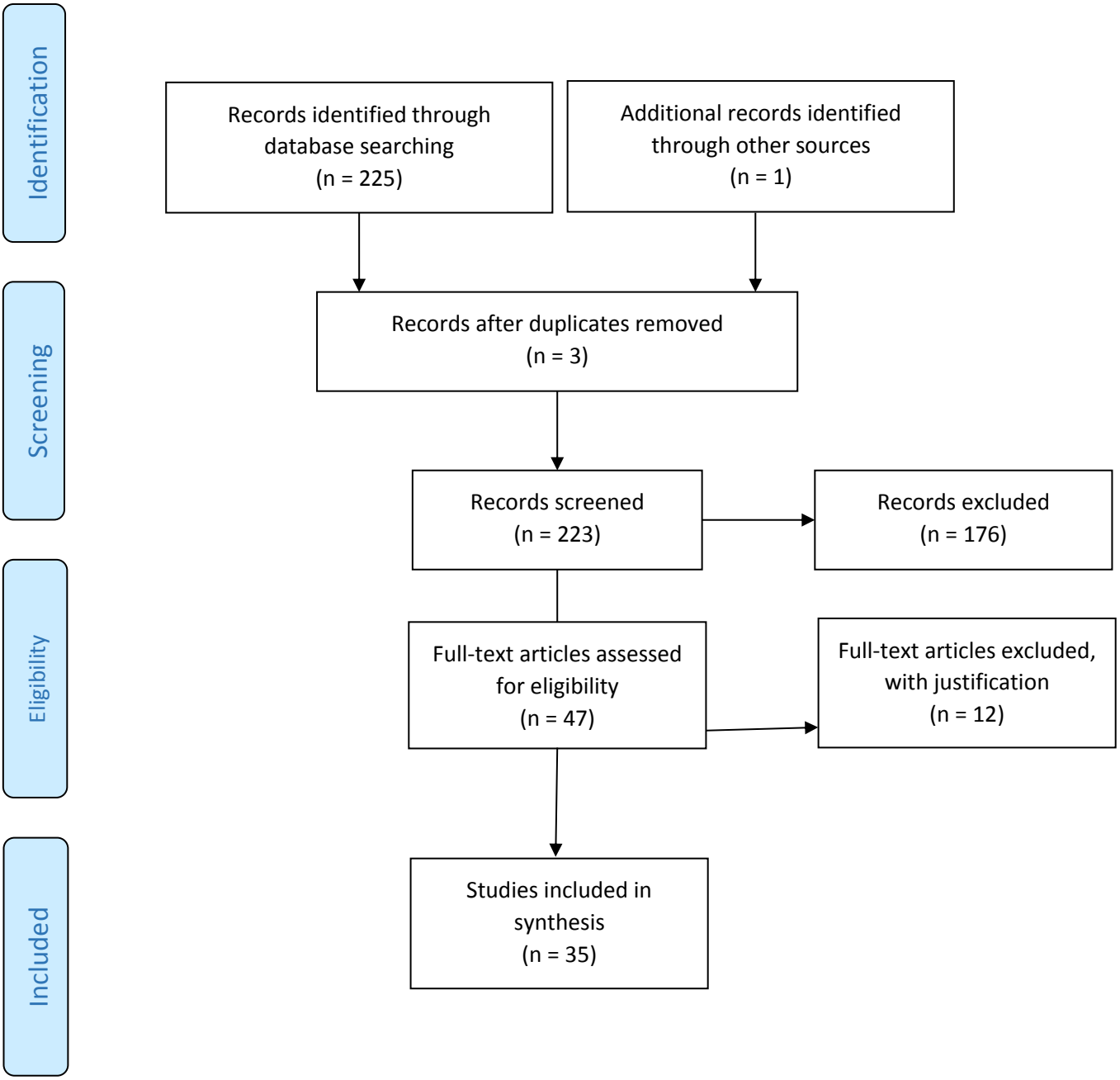

Figure 2. PRISMA Flow Diagram

The above *Figure 1,* Chart and *Figure 2,* PRISMA provide graphical representation of the flow of citations reviewed in the course of this systematic review. The PRISMA provides a four stage flow diagram depicting the filtering process. The initial search strategy identified 221 studies for potential inclusion in the review. The screening of journals against inclusion criteria, removal of duplications and non-eligible full text documents resulted in 35 studies incorporated into the systemic review for transparent reporting. The 12 studies that were excluded after the search criteria was applied are shown in *Appendix 2*, *Table 4* and *Table 5* alongside the reason for exclusion.

Table 2. Air Quality Research Centre – Current Research.

Research Area	Author	Title	Study Type	Subject	Reason for Exclusion	Expected Completion
EU research projects at AQMRC.	Hayes.	EU Air Quality Policies Framework contract.	Unknown.	An assessment of current and future air quality management policies.	Waiting to include the pending paper would delay progression of this research.	Sept 2017.

Table 3. Included studies

Reference	Author	Criteria	Study Type	Summary of Content
1.	Beattie et al, 1998.	Regional developments in Air Quality Management (AQM) in the United Kingdom - evidence from a study of South West England.	- Comparative, secondary data analysis	- The article highlights since 1998 air pollution was to be considered in land use planning and traffic management. The paper furthermore shows Plymouth's absences from submission of survey data for the research. Further issues are indicated in relation to LAQM integration, funding and public influence

2.	Beattie et al, 2000.	Air quality management in urban areas of England: the changing role of transport planning	- Analytical review through secondary data analysis	- The paper justifies the incorporation of multi-local authority departments in addressing LAQM. Furthermore, the communication of the importance of addressing air pollution is highlighted along with foreseen issues in local authority timescales
3.	Beattie and Longhurst, 2001.	Progress with implementing local air-quality management in rural areas of England.	- Comparative, primary data analysis	- A comparison between urban and rural air quality management. The hindrances facing rural air quality management such as,

				experience, expertise and practicality are presented
4.	Beattie et al, 2001.	Urban air quality: a comparison of the air pollution dilemmas facing urban and rural local authorities and approaches to managing them.	- Comparative, secondary data analysis	- A comparison of urban and rural challenges in relation to air pollution. The reliance on the perception of environmental health practitioners/officers in the LAQM. The publicity of LAQM if considered along with funding and staff time dedicated to the task of LAQM

5.	Beattie et al, 2002.	A Comparative Analysis of the Air Quality Management Challenges and Capabilities in Urban and Rural English Local Authorities.	- Comparative, secondary data analysis	- An analysis of the legal duty and process accompanying the LAQM framework. The 2001 local authority review findings are assessed to highlight current and future issues. Attention is drawn to the pollutants PM_{10}[1] and **Nitrogen Dioxide (NO_2)** with geological issues which exacerbate pollution concentrations indicated

[1] PM_{10} refers to particulate matter with a diameter less than 10 microns.

6.	Beattie et al, 2006.	Air Quality Action Plans in the UK: an overview and evaluation of process and practice.	- Analytical review through secondary data analysis	- The article looks at the integration of transport planning and the limitations on local authorities through bureaucracy and funding to tackle certain issues such as retro fitting buses to reduce emissions. The impact of national and local strategy on overall air pollution is considered along with the EU's contribution and other funding related determinants

7.	Chatterton et al, 2006.	Managing air quality - are we doing enough?	- Analytical review through secondary data analysis	- The review questions government support and powers/tools granted to local authorities to tackle air pollution. The EU's input on the reduction of air pollution in the UK is highlighted along with the benefits of AQMAs and a need for source control. The source control argument is further validated by the increase in vehicle yet decline in pollution
8.	Conlan et al, 1997.	The role of local authorities in developing		- The article draws attention to the health implication and therefore

		Air Quality Management in the UK.	- Analytical review through secondary data analysis	perceived benefits for the remediation of air pollution prior to the move of public health into local authority. Predicted decreases in air pollution draw upon catalyst conversion equipment in auto-vehicles. The paper also highlights points of interest such as, weather influences, O_3 and background levels. Predictions for C_6H_6 are poignant to proposed paper
9.	Doherty et al, 2009.	Current and future climate- and air pollution-		- The paper looks at the implication of weather patterns on air

		mediated impacts on human health.	- Cause and effect, secondary data analysis	pollution. O_3: causes, health burden and death toll regionally are provided. External factors on pollution levels are also highlighted (Other countries). Furthermore, future predictions of air quality of forecast with all scenarios presenting an increased health burden
10.	Dorfman. *et al*, 2005.	Consultation for local air quality management in the UK: opportunities for and barriers to successful science communication.	- Analytical review through secondary data analysis	- Trends in local authority are indicated and communication in and out of local authority if reviewed. Communication is suggested to be key to resolving

				some issues with LAQM. Improvements are suggested in guidance on the consultation process, with the benefits of public input outlined and elaboration of scientific information to enable general understanding
11.	Dorfman *et al*, 2006.	A preliminary review of local Air Quality Management consultation practices in England.	- Analytical review through primary data analysis	- The paper draws attention to the perceived impact of stakeholders can have upon air quality. The pros and cons of involving the public and Sheffield is presented as a best practice system for

				addressing stakeholders and thus air pollution in the area (Champions). Plymouth provided as an example. However, information states there to be no AQMA declaration in 2006 which is incorrect
12.	Elsom, 1999.	Development and implementation of strategic frameworks for Air Quality Management in the UK and European Community.	- Analytical review through secondary data analysis	- A detailed analysis on of the initial installation of Air Quality Management into local authority is provided. Disconnection between the European Community framework and the UK are made apparent with

				measurements of pollutions level at this time provided
13.	Elsom and Longhurst, 1997.	Assessment of the first phase of the UK National Air Quality Strategy.	- Analytical review through secondary data analysis	- The paper looks at: the legal standing that brought about LAQM, the absence of initial technical guidance, the lack of deadlines and absence of historical reprisal for failure to achieve AQO. Furthermore, the 2005 objectives are foreseen to be unattainable and issues in respect of funding, time limits and legal tools are highlighted

14.	Gegisian, *et al*, 2008.	Potential contribution of local air quality management to environmental justice in England.	- Analytical review through secondary data analysis	- The paper provides a review of AQAPs stating many remedial measures are not specific to air pollution. O_3 and public consultations are also highlighted. Additionally, the paper provides examples of the effectiveness of implemented remediation air pollution measures (congestion charges) and the limited impact
15.	Hassan, *et al*, 2006.	Local air quality management process in Great Britain in its second	- Analytical review through secondary data analysis	- Prescriptive guidance is promoted. Proposed issues with PM_{10} are highlighted (2006) as a

		round of review and assessment: efficiency vs. effectiveness.		cause for concern. However, not all local authorities were monitoring this pollutant at the time such as locality A. Further, suggestions are made based on percentages in relation to monitoring equipment do not consider alternative possibilities such as consultants
16.	Hayes, *et al*, 2006.	Integrating climate change management into the local air quality management process at a local and regional governance level in the UK.	- Analytical review through secondary data analysis	- The paper considers limitation in the progressive reduction of air pollution for example, the policy arena, separate of local authority and climate change, and human behavior. The benefits of access

				to environmental information and the limitation of providing information alone are touched upon. Uptake of the Nottingham declaration is provided and the cynicism and futility of local authority action highlighted
17.	Leksmono et al, 2010	Enhancing consultation practices on Air Quality Management in local authorities	- Analytical review through primary data analysis.	- The paper looks the communication aspect of air quality management. Providing a review of communication techniques adopted by for example local authorities, and the

				extent and variation of stockholder involvement.
18.	Lindley and Crabbe, 2004.	What lies beneath? - Issues in the representation of air quality management data for public consumption.	- Cause and effect, secondary data analysis	- The paper considers the benefit of public knowledge, provides information on identifying area that may form a potential risk to air quality. These criteria raise questions for the proposed paper, in relation to the possibility of businesses/industries being excluded from compliance of AQOs due to the financial reason in locality A

19.	Mediavilla-Sahagun and Simon, 2003.	Urban scale integrated assessment for London: Which emission reduction strategies are more effective in attaining prescribed PM10 air quality standards by 2005?	- Comparative, secondary data analysis	- The paper uses a detailed mapping system of air pollution sources to determine and predict future trends. The system is proposed to enable sufficient evidence to govern the effectiveness of proposed remediation measures
20.	Mindell and Joffe, 2004.	Predicted health impacts of urban air quality management.	- Cause and effect, primary data analysis	- The paper proposes future lower air quality objectives and presents benefit in a lives saved figure. A brief review of health outcome from air pollution is proposed with

				seasonal variations impact on air pollution highlighted and policy implications addressing air pollution considered
21.	Longhurst, *et al*, 2006.	Local air quality management as a risk management process: Assessing, managing and remediating the risk of exceeding an air quality objective in Great Britain.	- Comparative, secondary data analysis	- The paper provides definitions elaborating on the LAQM system. Areas of interest in the paper include for example, location of monitoring sites (15-minute rule), topography considerations and local authority equipment/resources. The paper also highlights the supply of information to the

				public. The power of public opinion of air pollution and how action has focused on dispersal rather than reduction (effects rather than cause)
22.	Longhurst et al, 2010.	Recalibrating the United Kingdom's local air quality management regime to deliver desired goals.	- Analytical review through secondary data analysis	- A historical overview of LAQM is provided alongside a summary of development of the AQMA process. The EU's contribution to air quality is highlighted along with local authority collaboration and shortfalls in AQAPs. The paper also states achievements in air quality and

				what improvements are still needed with justifications
23.	Walton et al, 2001.	Local Air Pollution Control in the USA: Potential Lessons for the Introduction of Air Quality Management Areas and Action Plans in the UK.	- Analytical review through secondary data analysis	- The paper provides insight into air pollution reform prior to the introduction of LAQM. Continued variation in modeling, identification and criteria highlighted, along with the term 'zones of uncertainty' being coined
24.	Woodfield *et al,* 2001.	Emerging political and collaborative decision-		- The journal compares UK LAQM to the USA system and reviews

		making frameworks for designating Air Quality Management Areas (AQMAs) in the UK: implications for future air quality action plans (AQAPs).	- Comparative, secondary data analysis	the efficiency that legal powers could have with tackling air pollution. Current sanctions in failing to achieve air quality objective are highlighted alongside the politics surrounding air quality and there being no safe level of toxic substances. The scrutiny of AQAPs is also reviewed
25.	Woodfield *et al,* 2002.	A review of air quality management areas in Great Britain: implications for land-use planning.	- Analytical review through secondary data analysis	- The paper highlights the high percentage of AQMA related to traffic, variations in AQMA boundaries and political

				influences. The number of homes encompassed within AQMAs are shown (Results only shown local authorities with two or more AQMAs)
26.	Woodfield *et al*, 2002.	Designating Air Quality Management Areas (AQMAs) in the UK: Implications for securing UK air quality objectives.	- Analytical review through of primary and secondary data	- A review of implications in declaring AQMs such as property blight, use of a precautionary approach when defining AQMA boundaries and consideration of influential factors when designating AQMAs

27.	Woodfield *et al,* 2003.	Critical evaluation of the role of scientific analysis in UK local authority AQMA decision-making: Method development and preliminary results.	- Analytical review of primary data	- The paper considers the use of different modeling and predictions tools that result in alternative outcomes. The need for stake holder engagement is highlighted alongside differing perceptions of local authority general engagement in LAQM
28.	Woodfield *et al,* 2003.	Regional collaborative urban air quality management: Case studies across Great Britain.	- Comparative, secondary data analysis	- The variation in air quality modeling methods and approaches to AQMA proposals are indicated with the potential implication on AQOs considered

29.	Woodfield *et al,* 2003.	Regional Variations in the Implementation of the Local Air Quality Management Process within Great Britain.	- A comparative, secondary data analysis	- A review of Local Air Quality Management processes and function. Highlighting the main source (Traffic) and the currents systems approach to address symptoms rather than cause. Drawing on points such as balancing cost against detrimental impact, political influences and quantity/distribution of AQMAs

30.	Woodfield *et al,* 2003.	The application of scientific uncertainty and error in the designated AQMAs of GB: implications for further air quality assessments.	- Cause and effect, secondary data analysis	- This paper looks at the use of consultants in LAQM, variations/errors in modeling and predictions, highlights the 3 main pollutants of concern and the high variation between local authorities on the consultation element of LAQM. The paper also seeks to amend technical guidance at that time

31.	Woodfield *et al*, 2006.	Emerging scientific decision-making for designating Air Quality Management Areas (AQMAs) in the United Kingdom.	- Analytical review of primary data	- A review of inconsistences in LAQM calling for collaboration between local authorities to increase understanding and consolidate practices
32.	Weitkamp and Longhurst, 2011.	Mediating consultation: insights from private sector consultations involved in air quality consultations.	- Mixed method review of primary data	- The paper examines local authorities use of third party consultant firms to fulfill the requirement to consultant key stakeholders – the public

33.	Olowoporoku, *et al*, 2012	The rhetoric and realities of integrating air quality into the local transport planning process in English local authorities.	- Systematic review, questionnaire and case study interviews	- This mixed method research project sought to understand potential reasons why the LAQM framework has not been effective in reducing traffic related air pollution – noting the local authorities working in silos and addressing 'hotspots' rather than looking at the bigger picture as critical limitations
34.	Barnes *et al*, 2013	Air quality action planning: why do barriers to remediation in local air quality management remain?	- A review of primary and secondary date	- This multi data source review notes the lack of funding, resources and powers to impacted the efficiency of LAQM to achieve AQOs but also local authority internal bureaucracy to

				have been equally critical to the shortcomings of LAQM
35.	Burnt *et al,* 2016.	**Local Air Quality Management policy and practice in the UK: The case for greater Public Health integration and engagement.**	- Systematic review of secondary text	- An appraisal of existing documentation presenting potential limitations and shortfalls of local authority in achieving AQOs

The main points of interest drawn from the papers in this review are grouped under the following headings: Management; Politics: Conflicts and Competing Interests; Air Quality Objectives/Standards; Consultation Process; Intergovernmental communication; Public Communication; Ozone (O_3)/Climate Change; Air Quality Action Plans; and European Union (EU). The purpose of which is to provide structure and coherency in order to identify the successes and shortfalls of these diverse and complex elements.

3.0. Management

Following the introduction in 1997 of the current LAQM system for local authorities, Elsom and Longhurst (1997) highlighted numerous potential issues surrounding the new management system for air quality. Decades on these issues are still pertinent, and perhaps establish the precursors for our present-day air pollution issues. The paper '*Assessment of the first phase of UK national Air Quality Strategy*' (Elsom and Longhurst, 1997) notes The National Air Quality Strategy recognised national policy instruments alone were ill equipped or a financially efficient means to deliver air quality objectives by 2005. Evidently, in hindsight, The National Air Quality Strategy may have been hindered by a succession of political evolutionary pitfalls.

Elsom and Longhurst suggested in 1997 and again in 1999 that the introduction of the LAQM system variations and inconsistencies in method and implementation occurred because of the absence of LAQM guidance. This further overflowed into the transport plans as Beattie *et al* (2000), established transport plans had not quantified future air

pollution trends with few counties including significant monitoring data. Subsequent developments in this area over time have provided an array of information provisions to local authorities for example, specific guidance documents, web-based information, telephone and email helpdesk supplied by the Department for Environment, Food and Rural Affairs (Hayes *et al*, 2006). Furthermore, initial and perhaps continued concerns with the management of air quality within local authorities centred around the delegation of responsibility from a central government without appropriate resources, consistent policy/direction, and absence of legal powers to feasibly communicate and address the cause or effects (Elsom, 1999; Beattie *et al*, 1998; Beattie *et al*, 2000; Brunt *et al,* 2016); along with external factors impacting success such as, weather changes, transboundary influences and public support (Conlan *et al*, 1997; Beattie *et al,* 1998).

Beattie *et al,* (1998) also noted the dependency of successful bids for funds to establish monitoring equipment and implement initiatives (Hassan *et al,* 2006). However, if authorities are required to compete for funding, the air pollution issues for those that are unsuccessful are likely to continue. Furthermore, a future point to be taken into consideration is the suggestion that rural Environmental Health Practitioners spend a fraction of their time devoted to air quality issues (Beattie *et al*, 2001; Beattie and Longhurst, 2010) in comparison to authorities with dedicated experts. Although, the risk maybe different this indicates a potential imbalanced system in operation in obtaining funding for air quality purposes.

Longhurst *et al* (2006) noted that the introduction of LAQM in 1997 saw the movement from point sources management to effects based control, due to the diversity of sources and pollutants in occurrence. This methodology would be logical if the source was being addressed by central government or the manufacturer. However, the emissions scandal is evidence to the contrary (Harvey, 2016). Transport has been noted as a major contributor to pollutants such as NO_2 (Beattie *et al,* 1998; Chatteron *et al,* 2006; Leksmono *et al*, 2010). When considering the justification for treatment of effects rather than addressing the cause, the management system seems illogical. This is not to say the mitigation of effects as a method of control is unorthodox, it undoubtedly has a place in the management of air pollution, but perhaps supplementary rather an unaided system or utilised to address sources beyond the control of central government or where the source is yet defined.

There has been clear progress in relation to reducing duplication and creating co-operation between local governmental departments, for instance, initially the AQAP was a standalone document (Beattie *et al*, 2000). However, developments in LAQM have seen central government permit local authorities to include AQAP actions within their transport plans, rather than producing separate documents, further highlighting the co-dependency of these issues (Beattie *et* al, 2006). This cohesive approach would perhaps, as cited by Longhurst *et al* (2010) and Van Vuuren (cited in Hayes *et al,* 2006) create greater funding portals, promote media attention and heed LAQM tangibility to those in power. However, these preserved benefits may have been hindered by the

noted issues with inter-governmental co-operation and co-ordination in Barnes *et al* review of air quality management (2013).

LAQM is perceivably based on sound scientific knowledge, however, disparities have been found across local authorities' in implementation. For example, the identification of areas of predicted exceedances, consultation and monitoring approaches, and lack of consistency, hint at possible misuse of the system. Furthermore, background levels records, modelling predictions, techniques, interpretation, consideration of uncertainty, areas of public exposure, boundaries of exposure, proposals for AQMAs, and declarations present additional variations (Pencheon *et al*, 2001; Woodfield *et* al, 2001, 2002, 2002a, 2003, 2003a; Mediavilla-Sahagun & ApSimon; 2004; Lindley and Crabbe*,* 2004). Theses inconsistencies create a post code lottery, as to the efficiency of LAQM.

The majority of studies reviewing LAQM have based their findings on the perceptions of practice from those in local authorities for example, Dorfman *et al* (2006); Woodfield *et al* (2006) and Leksmono *et al* (2010). Although, perception provides an insight, it should not be misconstrued as fact. This is not to discredit research based on perception but to merely highlight, that if possible empirical data should be utilised for triangulation or to broaden perspectives. Perception alone provides a limited insight. This is evident in an extract of Beattie, *et al* (2000) paper, stating 86% of transport planners surveyed in 1999 were aware of an air quality policy; their perceived comprehension provides little acuity as to the success with which LAQM was implemented.

In 2010 Walton *et al*, stated the EPAQS placed the greatest emphasis of scope on technological solutions. This would align to treating the cause rather than the symptoms, a contradictory statement to that of the perceived function of LAQM mentioned previously by Longhurst *et al* (2006). The EPAQS stance is evident in practises such as '*scrappage schemes'* aiding the removal of old technology and uptake of new. However, such schemes may have been hindered by the '*emissions rigging'* and by failures to prescribe any corrective action measures (*ibid*). Chatterton *et al* (2006) and Hayes *et al* (2006), reviewed hard and soft measures for instance, PM_{10} filters and behaviours changes but noted the absence of legal powers in the implementation. Leksmono *et al* (2010) and Longhurst e*t al* (2010), stated there are numerous contributing factors, with many solutions requiring more than a singular technological development, but rather a shared ownership between the government and the public.

3.1. Politics: Conflicts and Competing Interests

Since the introduction of LAQM, central and local government policies have had the potential to have profound influence on air quality. However, Chatterton *et al* (2006) illustrated how the government revised the 10-year transport plan, removing the commitment to reduce traffic and instead committed itself to planning for a considerable increase in traffic. As previously noted, traffic is identified as being a leading source of air pollution (Lsmono *et al*, 2010). Therefore, this move seems a trade-off for socio-

economic development at the expense of public health, sustainability, and environmental health. Further validating Olowoporoku *et al* (2012: p30) statement that 'the importance given to air quality in the decision-making process is very low'.

LAQM is perceivably based upon sound scientific information (Woodfield *et al*, 2003). However, the local decision making process is influenced by: sub-regional collaboration, the potential for property and planning blight, vested interest in relation to AQMA boundaries and manipulation of scientific assessment methods utilised (Woodfield *et al*, 2002, 2002a; 2003). Therefore, as stated by Woodfield *et al* (2002a), the LAQM framework is '*not… a wholly consistent approach*' to air pollution but rather a popularity contest; it is therefore, with pragmatic optimism we await to see if the movement of public health into local authority changed this mentality; notably still absent from LAQM in 2015 by Brunt *et al* (2016) (Department of Health, 2011).

3.2. Air Quality Objectives/Standards

The historic objectives "*represent the Government's present judgment of achievable air quality by the year 2005 of costs and benefits and technical feasibility*" (Department of the Environment, 1996 cited in Elsom and Longhurst, 1997). An achievement still not obtained at the time of writing this paper. Furthermore, the technical feasibility would have related to advancements in technology including, for example, predictions based on catalytic conversion equipment as per Conlan *et al* (1997); now evidently a

misguided prediction reliant of the moral compass of the automobile industry (Harvey, 2016).

Elsom and Longhurst (1997) queried the now dissolved EPAQS recommendations to relax the limits on some air pollutant such as NO_2 and PM_{10}. A query supported by Mindell and Joffe (2004) who call for a reduction in targets for short and long term health gains. A statement again issued by Brunt *et* al (2016) citing the AQSs insufficient to protect public health. The original NO_2 1-hour standard was based on a study from 1976, not since replicated. The standing for the decision EPQAS is questionable when considering the chemical structure NO_2 had not changed, nor was there any evidence falsifying the toxicity in the 1976 report. Furthermore, the limit value of PM_{10} was also relaxed from 99.5 to 99.9 per percentile. Elsom and Longhurst (1997) stated 'such a change to the objectives implies a permitted exceedance of four days rather than two days'. $PM_{2.5}$[2] was not included in the 1997 AQOs although it was expected in the near future due to mounting pressure in light of the 1996 United States of America (USA) standard. These points add weight to the previous concerns over governance in the UK of AQSs.

Elsom and Longhurst in 1997, Barnes *et al* in 2013 and Burnt *et al* in 2016 - noted the absence of any legal obligation on local authorities to achieve AQSs. Walton *et al* (2010), compared the UK's LAQM system to that of the USA, where failure to achieve objectives presumably results in sanctions and withdrawal of funding. However, Walton

[2] $PM_{2.5}$ refers to particulate matter with a diameter less than 2.5 microns.

et al (2010) noted the '*in house*' governing body in the USA tended to back down in sanctions on non-attainment. In 2006 Woodfield *et al* again highlighted the absence of implications on local authorities to achieve targets, which has transcended into the present day. This absence of legal measures to support and provide implications for failing to meet AQSs at a local level may have contributed to the continuation of this environmental and public health issue. Furthermore, the USA's '*in house*' shortcomings could set an example for the future of air quality in the UK, pending the exit from the EU.

3.3. Consultation Process

Beattie *et al* (1998) noted a critical deficiency in LAQM relating to stakeholder involvement and contribution. The *Environment Act 1995* stated the requirement for consultation, although in true non-prescriptive form it does not specify with whom. However, consultation with the public, if done effectively would enable for instance, the fulfilment of legal requirements to incorporate key stakeholders, enhance skillsets and outcomes, as well as developing '*good practice*' within the consultation parameters (Lindley and Crabbe, 2004; Leksmono *et al*, 2010). The legal loop-hole and initial issues with guidance may have led to initial scenarios such as, the '*idler public*' not being consulted until after AQMAs have been declared and action plans were underway (Dorfman *et al*, 2005; Woodfield *et al*, 2001). Although, subsequent guidance promotes public consultation as elective therefore perhaps why Woodfield *et al* (2001 & 2003) found the consultation processes highly variable across local authorities; by 2008 Gegisian *et al* notes public consultation is '*widely*' undertaken, although, to what extent is unknown. In 2011 Weitkamp and Longhurst highlighted the adoption of private sector consultants to carryout

air quality consultations but note them to be ‘tokenistic’; enabling local authority to tick a box rather than truly seeking public engagement.

As we move forward there are further issues highlighted such as, the translation of information to non-expert stakeholders, community response and take up. The local authorities’ ability to translate community knowledge and most unnervingly local authorities not favouring public participation, the very persons they represent and whose interest they are to promote (Dorfman *et al*, 2006; Leksmono, *et al*, 2010). However, Leksmono *et al*, 2010 suggests the critical deficiency perceived to be in place in 1998 is no longer the case as their study shows a more up-to-date and positive picture of perceptions of the consultation process. However, as discussed elsewhere in this research project, perception should not be misinterpreted as a true reflection of practise.

3.4. Intergovernmental Communication

Beattie *et al*, (1998) established that one of the primary aims for LAQM is to integrate air quality considerations into the decision-making processes of for example, land use planning and traffic management. However, local authority multiple tier structures were suggested to hinder the transfer of information into other governmental departments. Furthermore, the survey data suggested co-operation between local authorities was seen as the greatest obstacle, but critical to the success of LAQM (Beattie *et al*, 1998). Again, noted internal management failings highlighted again in 2012 by Barnes *et al* to the detriment of LAQM.

The results from research carried out by Beattie *et al* (2002) showed that in 1999, 86% of transport planners surveyed had a specific policy in place to address air quality in comparison to 66% of planning officers and 20% of economic development officers. These findings established a perceived comprehension of the importance of air quality in local transport planning following the introduction of the LAQM and an understanding in other compounding local authority departments that presumably would have been built upon as LAQM developed. However, these policies seemingly did not carry much weight because following the failure of the 2005 and 2010 AQOs for pollutants such as NO_2, in 2010 local transport planning decided to remove air quality as a priority for action (Longhurst *et al,* 2010).

Longhurst *et al* (2010) credits air pollutions lack of visible tangibility to the drop in priority. That is, the visual transparency of the issue, the absence of precautionary measures imposed on day to day life and the associated death rate; may certainly cloud judgement. However, perhaps if effective '*two-way*' communication and co-operation was in process between local governmental departments and the agendas of local and central government were aligned, the removal of air quality as a priority of action would not have occurred.

3.5. Public Communication

The 1998 and 2001 surveys carried-out by Beattie *et al* found that dissemination of information varied across local authorities with a predominant use of '*one way'* communication; the paper illustrates how the success of the LAQM regime is dependent upon the communication of information to the public and other governmental bodies. At this early stage in the development of LAQM there was a clear public distribution of material that presumably could have been built upon to inform and educate the public in later years. However, subsequent studies show further disparities in legislative drivers have failed to support this critical component to the detriment of LAQMs success (Longhurst *et al*, 2010; Woodfield *et al*, 2003).

As LAQM has developed there have been further papers advocating adequate communication with the public to, for example, maximise positive impacts, avoid misinterpretation, education, raising awareness and foster transparency; which is in increasing demand and provide tangible support and champions to the cause (Lindley and Crabbe, 2004; Dorfman *et al* 2005; Leksmono *et al*, 2010). This relates to all aspects of the LAQM and not merely the production and availability of locally specific information as it would be careless to assume this would motivate any form of action (Hayes *et al*, 2006). 'Adequate' is depicted as '*two-way'* communication with stakeholders' involvement rather than a spectatorship. However, these sentiments did not find any support with Plymouth City Council who limit the release of air quality monitoring data and statistics with only the AURN data readily available (Department for Environment, Food and Rural Affairs, 2013) (Department for Environment, Food and Rural Affairs, 2013).

3.6. Air Quality Action Plans

Walton *et al* (2010) noted that under section 82 of the *Environmental Act* 1995, local authorities are required to implement appropriate remedial measures. However, the value of this legislation was and still is highly dependent upon the effectiveness of the remedial measures local government have at their disposal and their willingness to use them. Longhurst *et al* (2010) suggested local authorities' inability to implement AQAPs, has been a result of their poor construction and their imprecise calibration to the problem. This issue was noted by Walton *et al* in 2010, where recommendations were made to same subject AQAPs to the scrutiny and validation of independent external bodies in much the same way as structure and transport plans. The absence of this external analysis has perhaps contributed to present-day legal proceedings for failures relating to NO_2, evident in the reports by Carrington (2016) and Nierynck (2016).

Issues with AQAP were noted back in 2006, nearly a decade on from the introduction on LAQM and subsequently since. Many plans were seen as being '*not specific to the issue*' and rather '*statements of non-air quality impacts*, *perceptions of cost and feasibility'*, rather than initiatives to reduce air pollution (Hayes *et al*, 2006; Gegisian *et al*, 2008). Furthermore, Hassan *et al* (2006) stated LAQM '*fails to remediate and therefore cannot be considered wholly effective*'; a sentiment that presumably has not been rectified due to the present day AQO failings, central government law suits and revised Air Quality Plans (Carrington, 2016; Nierynck, 2016). The shortcomings of AQAPs and the request of local authority for prescriptive guidance seemingly would be rectified by a system such as, Mediavilla-Sahagun & ApSimon's (2004) Urban Scale

Integrated Assessment Modelling system (Woodfield *et al*, 2003). The system provides: rapid assessment for a number scenarios and ranks identified solutions by cost and improvement to air quality, a tool seemingly not utilised by local authorities for perhaps either funding, publicity or perceived capability. A tool such as this, if readily available to all local authorities, could perceivably only benefit AQAP and have a positive effect on LAQM.

3.7. Ozone (O_3) - Climate Change

Conlan *et al* (1997) and Elsom and Longhurst (1997), as do the majority of persons reporting on LAQM, note the absence of O_3, as a secondary pollutant from local authority jurisdiction, through the decades along with for instance, Woodfield *et al* (2003), and Beattie *et al* (2006) Doherty *et al* (2009). The absence of O_3 from local authority consideration, is clearly stated as a result of O_3 being a national issue (Beattie *et al*, 2006). However, on reflection of this decision whilst drawing on the information from the LAQM monitoring networks it is apparent NO_2 a predominantly primary pollutant, is a national issue (*ibid*). Undoubtedly, time has provided this insight into the extent of the problem. Although, the presumed failure to react to this knowledge has subsequently left central government open to multiple law suits (Carrington, 2016).

The enlightened understanding of the extent of NO_2 in the UK, a precursor to O_3 known to regularly exceed the AQO combined with the prediction of growth in average temperatures. A contributing factor to the formation of O_3 and an absence of local

authority duty to the pollutant; raises concerns over the future responses to this highly toxic pollutant (Conlan *et al*, 1997; Doherty *et al*, 2009).

Moreover, Hayes *et al* (2006) highlights how local air quality and climate change are perceived within government as separate issues irrespective of their interwoven impacts upon: health, safety, property, quality of life; with both resulting from the burning of fossil fuels. Furthermore, this current separation potentially enables a trade-off in local government for local air quality over climate change rather than a co-beneficial Air Quality Plan. Van Vuuren (cited in Hayes *et al,* 2006) concluded '*combing the two could harvest considerable ancillary benefits in term of environmental impact and cost*'. However, increased responsibility to an already deemed inconsistent management system, without rectification of shortcomings seems paradoxical. Conversely, an Air Quality Plan that fails to consider local, national and international impacts, to the detriment of public and environmental health; is '*tunnel vision*' seen in practise.

3.8. European Union (EU)

LAQM pre-dates the EU legislation relating to '*Ambient Air Quality 96/62/EC'* and could be construed as clear evidence of central government being proactive in the management of air quality (Chatterton *et al*, 2006). However, subsequent inconsistencies and un-attainment of AQOs has caused numerous protests, legal battles between the '*idler public*' and central Government with financial penalties imposed by the European Commission (Nierynck, 2016; Vidal, 2016; Johnston, 2014).

This seemingly reactive rather than proactive culture yields concern over future action in the absence of an external governing body, imposing financial deterrents on central government and AQO/AQS.

Beattie *et al*, 2002 notes that European strategy and policy largely underpins the strategies for delivering environmental protection in the UK, with directives such as the '*Ambient Air Quality Framework'* influencing the UK's air quality policy approach. These and other developments in European Legislation, technological and scientific advancements have improved air pollution modelling techniques, increased understanding of economic and implementation of effective AQAPs (Beattie *et al,* 2006; Longhurst *et al,* 2010).

The now impending exit of the UK from the EU leaves the future of air quality uncertain. Furthermore, communication between all parties involved has always been seen as critical to positive improvements in air quality (Beattie *et al,* 2000; Longhurst *et* al, 2006; Leksmono *et al*, 2010). The UK Government is likely to be excluded from EU discussions and will no-longer be privy to certain information, developments or accountability but reliant upon external environmental programme and health organisations; with potential ramification relating to imported air quality issues from the continent (Doherty *et al*, 2009).

4.0. Discussion

The findings of this review suggest that although guidance and administrative provision to support the introduction of LAQM, many of the previously recognised limitations have not been addressed such as fundamental prescription relating to corrective measures are absent. The system itself while proclaiming to be based on sound scientific knowledge is swayed by numerous external factors. This has lead to a '*postcode lottery*' of local authority provisions to address air quality, in the absence of legal powers and obligations, potentially compounding the issue along with disparities in legislative drivers. However, evidence suggests the majority of local authorities may have inadvertently stalled progression, through a seemingly reluctance to include the public effectively into the LAQM process. Throughout this literature review communication, funding and legal powers have been presented as the critical road blocks to the success of LAQM. Critical factors that will each potentially be further hindered by the impending exit of the UK from the EU.

Based on this literature it is evident that perceptions of those working in local authority and objective opinions have been predominantly utilised to disseminate the workings of the LAQM process, as detailed under '*Management*', rather than actual data measuring the what impact LQAM has had upon air pollution. Therefore, what is required is a detailed analysis of data measuring the impact of LAQM in a particular area. This would provide a transparent account of the impact LAQM, has had on air pollution. What is required is a case study of a localised area that is neither an example of best practise, worse or inherently different to other localities in the UK. This would aid in providing a more accurate account of the LAQM situation for the majority of local authorities.

5.0. Recommendations

- The use of empirical data in research relating the LAQM to determine the impact this management system has had upon air quality

6.0. Future Research

- A study to examine the impact of LAQM including AQMAs and AQAPs on a specific geographical location is needed. This information would provide evidence of the effect this management system alone has had on air pollution

Chapter 3

Case Study of Local Air Quality Management (LAQM) in the United Kingdom

7.0. Introduction

The findings from the systematic literature review reported in *Chapter 2* provided an overview on LAQM. This indicated the need for further research at a localised level to enable the evaluation of implementation and impact of the air quality management framework. Furthermore, the literature review highlighted the deficit of empirical data with which to appraise LAQM. Therefore, the following research aims to build upon the recommendations for future research in the literature review and provide an in-depth analysis through the use of a case study. The case study reviews LAQM documentation produced by Plymouth City Council from 2004 – 2014 with traffic volume and weather conditions during this time, appraised alongside pollution readings to account for external variables. The justification for the use of this research method against others is elaborated upon under section 8.4.

Please note substantial improvement in air quality requires large scale changes in infrastructure and culture, which are only deliverable by central government. Furthermore, this analysis reviews only local governmental documentation and the parameters of the research do not permit speculation over potential bureaucratic or resource hindrances.

8.0. Research Question

What impact has Local Air Quality Management had on air quality?

8.1. Aim

The aim of this study is to determine the impact LAQM has had upon air quality in a mainstream locality – Plymouth, Devon in the United Kingdom (UK).

8.2. Objectives

- Appraise Plymouth City Council's annual air quality reports from 2004 - 2014
- Review monitoring undertaken in Plymouth
- Evaluate LAQM initiatives cited in the AQAP
- Assess and highlight the impact of LAQM

8.3. Philosophical Perspective

The case study followed the philosophical perspective referred to as realism. Realism adopts the position that the social and physical worlds exist independently of our perceptions. This is required in relation to the presence of air pollution because it is often invisible and therefore at times requires apparatus to identify the pollutions presence. However, the effects on environmental and public health further validate the existence of air pollutions, through tendencies to produce detrimental effects (Benton and Craib, 2010: p125).

Benton and Craib (2010: p36) refer to the realist perspective as an '*immense complex array of common-sense*'. This perception builds upon by Emerson's statement noted in O'Connell's (2014: p41) work '*common sense is genius dressed up in working clothes*'. Realism is therefore the acknowledgement that matter exists outside of the human mind. In relation to Russel's well-known theory cited in Williams and May (2005: p5) on the presence of matter depicted by the existence of a cat, in the absence any visual or sensory-data by a human. Realism draws the conclusion the animal does exist outside of the human mind as with air pollution in this context.

Realism in research uses exploratory approaches linking causes and effect (Potter, 1999). The basis for the study is the premise of a causal link between air pollutant produced by transportation and air quality, and seeks to investigate the potential impact of LAQM on air quality. The purpose of which was to theorise potential influential factors relating to LAQM. Empirical data was utilised to determine the impact LAQM has had on Plymouth's air quality and rationales provided from a combination of quantitative and narrative findings, drawn from the natural and social worlds based on their mutual exclusivity relative knowledge and independence (*ibid*).

8.4. Methodology

This case study focused on Plymouth, a City in the South West of the UK and employed a documentary analysis of Plymouth City Council's LAQM related documentation. In order to meet the objectives of this study a mixed-methods approach was used,

combining two specific forms of secondary evaluation: analysis of text within relevant documents and quantitative data analysis of recorded air pollutant concentrations. These techniques combined provide the researcher with the ability to develop theoretical propositions on a contemporary, real world scenario that permits no control to the investigator over the evaluation results. Although, the research looks at historical data, a historical study was ruled out because observation is still possible as LAQM is still in operation throughout the UK. Additionally, the data is not limited to a specific range of evidence but rather influenced and amended by evolving new scientific information and legislative guidance relating to air pollution (Thorpe & Holt, 2008). Quasi experiments were also considered due to their ability to estimate the impact of an intervention such as those cited in AQAPs on air pollution. However, quasi experiments compare variables between groups and Plymouth City Council has not implemented any intervention that enables comparison within the area or the confines of this study, hence this approach was deemed unsuitable for the research question (Shadish *et al*, 2001).

Experimental design is not applicable to the aim of this study as regulations requiring LAQM prohibit the use of a randomised controlled trial in this context. Additionally, in relation to the survey research it was noted in *Chapter 2*, systematic literature review that the perspectives of those in local authority have been utilised in preceding studies by other researchers, with deviations noted in perceptions and practise. Therefore, this study seeks to establish realities based on factual data rather than opinions from secondary sources. Whereas, archival analysis seeks to establish meaning from

primary data and was therefore disregarded (L'Eplattenier, 2018).The aim and objectives of this proposed research appraises the implementation and impact of LAQM rather than data sets and the method of collection alone. A documentary analysis permits the evaluation of impact through the review of relevant documentation. This is a form of investigation is popular in public health research, such as is applicable to LAQM. Furthermore, the appraisal enabled interpretation of the subtext, to present unconscious preconceptions that may have potentially influenced LAQM (Corbin & Strauss, 2008).

8.5. Data Source

The documents for this study comprised of: annual appraisals, detailed assessments and the most recent local transport plan, and was sourced via Plymouth City Council's online web page. A formal request was put forward through email to Plymouth City Council to provide access to documentation relating to LAQM in Plymouth. However, following recent legislation changes a three-figure charge would now be incurred for a single report. This resulted in limitations in relation to the number of reports that could be sourced due to the financial restraints (non-funded) of the proposed research. A decade of LAQM assessments were obtained running from 2004 – 2014.

8.6. Data type

The documentation sourced for the proposed documentary analysis was based on reports published by Plymouth City Council relating to LAQM. The documents provided comprehensive quantitative data and permit narrative interpretation of the text, providing

an insight into the previous, current and potential future of air pollution in the area. This permitted an appraisal of monitoring, initiatives and LAQM in general. Additional data was sourced which included weather patterns from Plymouth University researcher Helen Nance and traffic volume in Plymouth from the Department for Transport. This information was used to determine if such variables have influenced or will potentially influence present and future air quality in the city of Plymouth.

8.7. Documentary Analysis

A documentary analysis was undertaken using the Plymouth City Council reports as the data source. Furthermore, the content of the reports was reviewed against themes highlighted in the previous systematic literature review and other areas identified on evaluation that link to the aim and objectives of this case study. The purpose of which was to understand how Plymouth City Council makes sense of and interprets environmental data, and the extent to which values and judgments are influential factors in interpreting and acting on LAQM. (McKee, 2003: Bauer *et al*, 2014).

The documentary analysis included a review of the following themes highlighted in the *Chapter 2* literature review and corresponds with subjects noted in Plymouth City Council LAQM documentation: Management, Consultation and Air Quality Action Plans (AQAPs). In additional to key areas identified in the appraisal of the Plymouth City Council annual air quality reports from 2004 – 2014.

8.8. Quantitative data

The quantitative data was based on the monitored monthly and annual air pollution concentration levels. The air pollutants monitored were those perceivably applicable to Plymouth and therefore, does not include all known air toxins incorporated in the AQO found in *Chapter 2, Table 1*. This in turn was linked to the documentary analysis as it potentially reflected the perceptions of air quality in Plymouth City Council. The quantitative monitoring data was utilised to indicate if there has been any significant impact upon air quality in the area since the introduction of LAQM. The error margin in relation to predictions about future air quality was also assessed. In addition, to data sources for weather and traffic which were drawn from governmental agencies and accredited record repositories. The purpose of which was to enable analysis of quantifiable influential factors on air pollution, during specific time periods and strengthen predictions theorised about the future of air quality in Plymouth.

8.9. Statistical Analysis

The quantitative data was analysed from three perspectives:

(i) Firstly, air pollution annual average concentrations derived from monthly deployments were extracted from Plymouth City Council reports and consolidated with breaches in AQOs highlighted. The purpose of which was to identify any noteworthy changes in the yearly mean since the introduction of LAQM in general or localised variations following the declaration of AQMAs and the corresponding AQAPs. This was performed through a statistical difference analysis, aiding observation of relationship indicators. NO_2 mean levels for areas outside of designated AQMAs in Plymouth were also included, to

provide a control reading. This indicated if possible regional or national influential factors are at play rather than AQAPs. However, due to the evolution and expansion of air quality monitoring, in any given area of Plymouth since the initiation of the LAQM key areas were identified to provide an accurate representation of the impact (Field *et al*, 2012).

The significant difference analysis was performed by Analysis of Variance (ANOVA), which was be carried out using Microsoft Excel 2010. This type of examination allowed for multiple data set comparisons enabling a review of monitored sites in Plymouth across several years to identify statistically significant differences in areas, trends and variations. The analysis provided a *t* test, which is a scientifically recognised systematic approach through the review of independent means to gauge the physical impact or variability of LAQM and the subsidiary AQMAs and AQAPs. This generates a *p* value which was compared against a standard measurement of statistical significance ($p < 0.05$). The *p* value indicated if the sites monitored in Plymouth have seen significant changes in air pollution levels in general since the introduction of LAQM or if AQMAs specifically have experienced any statistically significant changes in air pollution annual mean recordings (Rowntree, 1981 and Field *et al*, 2012).

(ii) Further statistical evaluation was undertaken through a correlation analysis. A correlation analysis was used to compare different independent variables, potentially determining key factors at play that may have influenced air pollution concentrations

independently from any LAQM interventions. As mentioned previously, data sets for weather and traffic flow in Plymouth was sought to be obtained for corresponding with the LAQM annual assessment reports. This enabled a review of, for example, the 'mean' average monthly air pollution levels in any given area and time against potential influential weather patterns or traffic flow, that may relate to identified disparities and variables in the air quality report data (Field *et al*, 2012).

A correlation analysis generates two values: A correlation coefficient *r* value demonstrating the strength and relationship between two variables; and a *p* value, which is used to validate if the relationship between the two variables is statistically significant ($p < 0.05$). These results may aid in determining if the weather or traffic volume has significantly influenced air pollution levels in Plymouth since the introduction of LAQM. The data is presented in scatterplots to illustrate results; calculations are provided in the appendices (Spiegel *et al*, 2013; Rowntree, 1981).

(iii) Lastly, an assessment of the error margins in predicted air pollution concentrations is also presented using Microsoft Excel. The purpose of which is to evaluate the accuracy with which projected air pollution concentrations are estimated. This was determined by calculating the percentage between the predicted and actual air pollutant concentration levels at a selected number of sites. The sites evaluated are those sourced in the Plymouth City Council annual LAQM assessment report with presented predicted and actual recordings.

8.10. Description of location for the case study

Plymouth, lies between two prominent rivers with a national park to the North and a Southern shoreline merging into the English Channel (Plymouth City Council, 2009). The terrain of the land is typical of the English country side with rolling hills, which have been encompassed into the cities formation covering just under 80km^2 (Devon County Council, 2017; Parliament, 2011). This topography could present a valley like effect in some areas, with proximity to the sea further influencing air pollution levels by prevailing winds importing relatively unpolluted air but sea salt contributing to the overall PM burden.

The city centre has been under continual redevelopment and currently houses properties 4-5 storeys high, in addition to a large multi-storey shopping centre (Plymouth City Council, 2008). Motorised vehicles are permitted throughout the city centre with the main bus stops located centrally, potentially significantly contributing to air pollution in this area. Additionally, there are multiple commercial suburban streets in the city housing 3-4 storey properties with two-way traffic running through the centre; creating a tunnel/valley like topography (Plymouth City Council, 2014).

Plymouth hosts a historically famous port, a large naval base, and numerous commercial docks (Plymouth City Council, 2017; Plymouth City Council, 2009). Furthermore, Plymouth accommodates multiple international nautical competitions and

national aerobatic and pyrotechnics displays (Visit Plymouth, 2017). This potentially establishes a long-standing source of transportation air pollution and possible causation of spikes in pollution level readings of NO_2 due to the potential increase in vehicle volume as participants and spectators travel into Plymouth to attend the event.

Historically the large Naval port made the city one of the main targets during the second world war. The scale of recent regeneration in the area is second only to the post war reconstruction period, progressing into the present day and future '*visions*' into 2020 (Plymouth City Council, 2017a). The redevelopment could have potentially impacted traffic flow in and out of the city over the years causing '*hotspots*'; for example, Royal Parade, Exeter Street and Tavistock Road, which are concentrated areas with air pollution issues from emissions.

The city houses an estimated 260,000 persons with an additional transient population relating to tourism, education and workers residing in surrounding conurbations (Office for National Statistics, 2011; Plymouth University, 2017; Plymouth City Council, 2009). This possibly impacts on seasonal traffic flow in and out of the city.

The surrounding local authorities have smaller populations with much larger geographical areas. Plymouth City Council is stated to regularly interact with the neighbouring authorities to address transboundary issues such as air pollution showing a commitment to continual development (*ibid*).

The city is in a region rated by uSwitch (2015) as one of the least favourable places to live in the United Kingdom due to low incomes and the high cost of living, which may influence AQAPs; with initiatives sought that do not further financially burden the city's population. Furthermore, there is a perceived noteworthy increasing ageing population cited in 2016 by Plymouth City Council at a ratio of 52.9, meaning roughly half of the population is of working age and supporting the other half with the dependency ratio projected to only increase until 2034; potentially influencing future infrastructure requirements (Plymouth Herald, 2015; Plymouth City Council, 2017: p19). These attributes could potentially influence the review and feasibility of environmental and public health initiatives in Plymouth.

8.11. Legal Requirements

The Air Quality (England) Regulations 2000, as amended by the *Air Quality (England) (Amendment) Regulations 2002*, provide the statutory basis for the AQOs under LAQM in England. Local Authorities in England are expected to report on NO_2, PM_{10} and SO_2 as standard within their jurisdictions. Local authorities are to not expected to report annually on Benzene, 1,3-butadiene, Carbon Monoxide and Lead as objectives for these pollutants have been met. In addition to the AQOs set in Regulations, Local Authorities are to work towards reducing $PM_{2.5}$ (Department for Environment, Food and Rural Affairs, 2016d).

Part IV (Sections 80 to 91) and Schedule 11 of the *Environment Act 1995* sets out the legal obligations on local authorities and section 82 stipulates every local authority shall review the air quality within its area, both at the present time and the likely future air quality. Section 83 requires local authorities to designate an Air Quality Management Area (AQMA) where air quality objectives are not being achieved, or are not likely to be achieved, as set out in the Air Quality (England) Regulations 2000. Once the area has been designated, Section 84 requires the local authority to develop an Action Plan detailing remedial measures to tackle the problem within the AQMA (Department for Environment, Food and Rural Affairs, 2016d).

The Department for Environment, Food and Rural Affairs has provided LAQM Technical Guidance following the implementation of LAQM which now includes a template report complete with aims and objectives. Local authorities are expected to populate the report and submit in line with their duties. Following completion and submission of the report the Department for Environment, Food and Rural Affairs is to provide comments, to which the local authorities are expected to have regard. The report should also be made available to key stakeholders (*ibid;* Department for Environment, Food and Rural Affairs, 2016e).

9.0. Documentation

Thirteen documents were accessible for data collection and analysis; these were based on LAQM related to annual assessment reports from 2004 - 2014. The reports cover the years from 2003 – 2013. There were no documented assessments earlier than 2003. The annual reports from 2004 - 2014 were accessed directly from Plymouth through the local authority's and the Department for Environment and Food and Rural Affairs' webpages, prior to public access being restricted.

On review of the documentation, monitoring of benzene (C_6H_6) had ceased following the revocation of the associated AQMA. This presents the opportunity to determine if the LAQM intervention made a statistically significant impact in the reduction of C_6H_6 and conjecture over subsequent appraisal through documentary analysis. Monitoring data for PM was limited and therefore not assessed. O_3 as a secondary pollutant, is not monitored by local authorities. Although O_3 'mean' average levels are recorded in Plymouth by the Department for Food and Rural Affairs, they were not consistently reported upon in the annual air quality reports and therefore they have been excluded from this documentary analysis. There were extensive records for NO_2 'mean' average level recordings in Plymouth for the years 2003 – 2013. Therefore, the NO_2 data was utilised for the statistical analysis to appraise LAQM. Furthermore, the actions relating to this air pollutant provide context to the present NO_2 issues in Plymouth.

Following thematic tabulated analysis of the Plymouth City Council reports additional themes were identified, the results of which can be found in *Table 5*, *Appendix 3*. These themes were added to the documentary analysis framework and include:

- Monitoring
- Benzene (C_6H_6)
- Particulate Matter (PM)
- Planning and Development

Findings: Documentary Analysis of Plymouth City Council Reports

Monitoring

Plymouth City Council state they have carried out air quality monitoring in some form since the 1960s. On review of the 2004 air quality council report for Plymouth, the opening statement '*it is necessary to assess which pollutant, if any, will exceed prescribed objectives*' potentially suggests a perception within the local authority that air pollution was initially not perceived to be an issue in the area. However, the aforementioned 2004 report results, in accordance with the Local Air Quality Management Technical Guidance (LAQM.TG) (2003), concluded potential air pollution issues relating to NO_2, PM and C_6H_6 in the city, recommending further review. This culminated in 2014 into a city wide AQMA, still in place at the time of writing this paper and a far cry from the initial perceived perception; past and present AQMAs shown below in *Figure 3, 4 and 5* (Plymouth City Council, 2014). Therefore, LAQM has held Plymouth City Council accountable and required the council to acknowledge and

remediate long standing air quality issues in the city, which had previously failed to be addressed by central government initiatives (Plymouth City Council, 2006; section 1.2).

Figure 3. Historic AQAM in Mutley Plain, Plymouth

(Plymouth City Council, 2007)

Figure 4. Historic AQMA in Exeter Street, Plymouth

(Plymouth City Council, 2007)

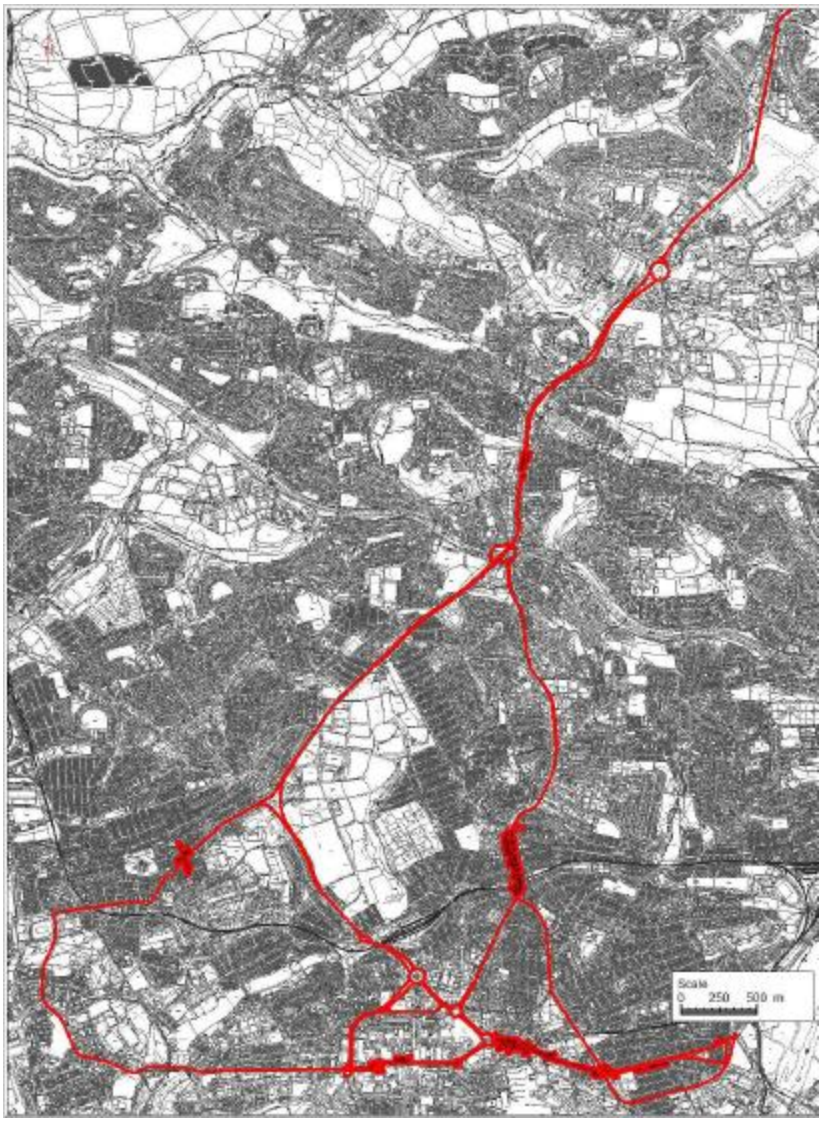

Figure 5. Present city wide AQAM in Plymouth encompassing historic AQMAs

(Department for Food and Rural Affairs, 2018)

From 2003 - 2013 the Plymouth City Council's monitoring network had grown from a handful of monitoring locations to over 70 diffusion tube sites and multiple automatic monitoring units (Plymouth City Council, 2004 and 2014). The monitoring data presented by Plymouth City Council alternates throughout the reports running from 2004 – 2014 between, non-bias adjusted, locally bias adjusted and national bias

adjusted figures for diffusion tube data; discussed further under, *Quantitative Analysis of Annual Benzene (C_6H_6)*. A bias adjustment calculation is performed because this low cost monitoring technique can be influenced by a number of variables. Therefore, a bias adjustment figure is formulated to counteract any potential interference, influencing recordings. However, councils have the option of adopting either the local or national bias adjustment factors potentially over or underestimating levels (Department for Environment Food and Rural Affairs, 2017). Plymouth City Council state in their 2014 air quality report (p64) that they opt for the bias adjustment factor that provides a more conservative result, highlighting the disparities mentioned in *Chapter 2*, under section, *Management*.

The 2010 Air Quality Progress Report (2011, p4) states there to be no exceedances outside of AQMAs. Although, neither the previous 3 AQMAs or the present 1 city wide AQMA proposed at the time to encompass Union Street and Cobourg Street. The NO_2 recordings for Cobourg Street are shown in *Table 8* and show a clear breach in the AQS for NO_2 in 2010 and 2011. Also, under *Appendix F* of the 2011 Plymouth report (p46), background validation results predict these two streets breach the AQS and will continue to into 2018. However, the breaches in the AQS are not discussed. Although, the data states to present NO_2 and PM prediction, only one figure is provided. These errors reoccur in reference to a pre-existing AQMA in Royal Parade prior to 2014. There are further apparent errors in relation for example, to a statement about there being no busy roads or junctions in '*Scotland*'; in section 8.5 of the 2006 Update and Screening Assessment; raising questions around the report appraisal process and adding weight

to Walton's *et al* (2010) recommendation for independent external analysis in *Chapter 2,* under section *Air Quality Action Plans* (Plymouth City Council, 2013).

The background Automatic Urban and Rural Network (AURN) network sited in Armada Way, Plymouth; as previously stated is located in a large open area, over a 100m from transportation emissions. This site has been utilised as by Plymouth City Council to depict overall background levels of air pollution for the city, as permitted by the LAQM framework (Plymouth City Council, 2009; p27-28). Potentially providing an overly-optimistic representation of air quality in Plymouth for example, in the same report 3 AQMAs are recommended for declaration. References points are further queried in relation to perhaps the fallacious representation Cardiff provides on Lead levels in Plymouth, as seen in the 2006 & 2009 Air Quality Updating and Screening Assessment for Plymouth. The result of which concluded no potential exceedances. This standardisation of locations is contrary to the purpose of LAQM, which is to address localised problems; it also clearly presents an incorrect representation of Plymouth's air quality; for instance, '*Unsafe lead levels at Plymouth school site and field'* (BBC, 2010).

The assessment, monitoring and review of alternative forms of air pollution by Plymouth City Council seems somewhat inconsistent; for example, while it is selective to report on radiation, Plymouth City Council 2004 - 2014 Air Quality Progress Reports, fail to acknowledge the high concentrations of radon in the region documented and publicised in the media (Independent, 2010). Additionally, the absence of a review process is seen in the Plymouth City Council 2009 (p3) report which cites guidance given to Train Drivers to reduce air pollution, although there appears to be no monitoring on compliance reported upon from 2009 - 2014. Furthermore, evaluation of domestic fuel

burning is based on a historical review of a 500m^2 area in the city and professional judgement, concluding there to be no issue. The methodology behind this review is questionable when domestic fuel burning has been publicised for its increased popularity in the area, over the last decade (The Guardian, 2009; Country Life, 2017). This highlights the point raised in *Chapter 2*, under *Management*, in regard to perception being presented as a certainty.

Monitoring anomalies are data readings outside of the perceived normal levels recorded in any given area. These perceived inconsistences or significant fluctuations are stated to be removed from data sets by Plymouth City Council in the 2004 report, with little to no further reference in the subsequent reports. Although known errors in data collection are subsequently mentioned, the method and justification for filtering unidentified irregularities is not provided. Therefore, spikes in readings potentially relating to surges in transportation emissions linked to, for example, events such as nautical and aerobatic competitions are likely to be screened out of the data sets. A fixed, clear, rational and repeatable method for handling air pollution readings would inhibit assertions, promote transparency and may aid more accurate long-term predictions on future concentrations, rather than individual perceptions being utilised to support a perceived sound scientific knowledge base.

9.1. Bus Services Monitoring

From 2004 – 2006 Royal Parade, a main street in the city centre of Plymouth, lined with bus stops, connecting the east and west regions of the city, was not considered to be a

cause for concern. No independent evaluation had been conducted; this perception was concluded by the Plymouth City Council's Public Protection Service team's own judgement, '*based on local knowledge*'. Bus movements in the area were *estimated* to be below 1,000 per day following confirmation from the main bus service provider '*Plymouth City Council*'. A reversal in perception occurred in the Plymouth City Council's 2007 report with monitoring initiated and the area highlighted as '*busy*', occupied by a high proportion of buses, owned and operated by Plymouth City Council. *Table 8* shows Plymouth's monitoring data for nitrogen dioxide (NO_2) in the area and readings have breached the AQS from 2007 – 2013, with present levels unknown. The main initiative to rectify this issue is retrofitting engines*;* discussed further under section*, Air Quality Action Plans (AQAPs)*.

9.2. Shipping Monitoring

Plymouth has three main shipping areas along the southern bank. Under section 4.5 and 7.7.G of the 2005 and 2006 reports respectively, a consideration to shipping was said to have occurred. However, the only information provided on the review of shipping is that no areas were identified as being a potential problem. In the 2007 report, it was again reported as not being a cause for concern.

The 2009 Plymouth City Council air quality report states naval shipping to exceed 5000 movements per annum. However, no exact figure was provided for each of the three ports. The 2009 report also states shipping emissions to have been factored into previous reports with no exceedances of SO_2 predicted. No previous reference or further details elaborated as to the methodology behind the integration of the undefined

shipping data into the Plymouth City Council reports from 2004 – 2009. The following 2010 and 2011 reports stated ports for shipping had been considered with no further details. Under section 4.3 of the 2012 report, actual numerical vessel movements are presented for the area of Plymouth, with an estimated 60338 shipping movements, sourced by Plymouth City Council from the Queen's Harbour Master. The following report published in 2013 states 65430 vessel movements around Plymouth with no further detail, assessment or consideration cited.

9.3. Consultation - Communication

Consultation is stated to have occurred between the city's governmental departments and undefined consultants, referred to in the text as '*strategic partners*' relating to air quality evident in the 2009, 2010, 2011 and 2012 council reports. However, reference of consultants utilised only refers to internal departments of Plymouth City Council or adjacent councils. Furthermore, Plymouth City Council's 2008 report contains the corresponding air quality action plan which details a consultation on taxi emissions to have occurred. However, it does not state when, where, or how this was undertaken or who was consulted.

The council reports from 2004 - 2014 indicated consultation has been quite minimal in Plymouth. There is reference to the Plymouth City Council's Public Protection Service pursuing an external engagement with peripheral government bodies in relation to air quality, with reference of a consultation exercise between public officials, at the air quality focus group meeting. The meeting was part of the Devon Chief Officers

Environmental Protection Sub Group and is stated to have occurred in the 2004 and 2006 reports. However, the date of the event/s, attendees and outcome of the meeting/s was not provided. Furthermore, there is no public consultation relating to LAQM explicitly stated in Plymouth City Council reports from 2004 - 2014. However, in the 2014 AQMA declaration meeting report under consultation 5.7. Plymouth City Council state public consultation is '*good practice*' and paradoxically '*previous AQMA declarations have shown us that public interest is likely to be limited*'. This could potentially be a result of the spectatorship role given to '*idler public*' and hinder the success of LAQM as mentioned in *Chapter 2,* under *Public Communication* and *Management*.

In 2009 the Local Air Quality Management Policy Guidance document recommended councils '*should*' consult the public under section 5.5, although, not mandatory. In 2016 the revised Policy Guidance stated Local Authorities are '*encouraged*' to consult with the public but were permitted their own judgment as to whether public consultation is required, under section 6.4. This is contradictory to a number of the values detailed in the 2016 Consultation Principles, issued by the Cabinet Office. Most prominently the value of consulting a range of persons affected and to review consultation practises to promote stakeholder engagement. In the 2004 – 2014 council reports, there is no reference to Plymouth City Council's Public Protection Service consulting the key stakeholder, named in the title of the department '*Public*', on matters of air quality. This indicates central government's adoption of Leksmono *et al* (2010) and Longhurst e*t al*

(2010) '*shared ownership'* highlighted in *Chapter 2*, under *Management* but a discourse in local government's implementation.

9.4. Benzene (C_6H_6)

In 2004 there was a noted issue with high levels of C_6H_6 breaching the annual AQS of 5µg.m^{-3} at a 24-hour petrol station due to the close proximity to a primary school. The petrol station is positioned between student accommodation and a retail outlet with accommodation overhead. Although not considered a potentially significant source of C_6H_6 by the LAQM.TG 09 (*ibid*) extensive monitoring was undertaken around the school, with a diffusion tube located on the student accommodation building. There was no reference to monitoring being undertaken around the retail outlet. On review of remediation of the C_6H_6 issue in the area, the 2004 report states there to be no legal requirement to fit a stage II vapour recovery system to reduce the air pollutant to meet air quality objectives at the site. Illogically, the only predictions for estimated future 2010 C_6H_6 levels at the petrol station in the 2004 report were based on a stage II vapour recovering system being in place.

In the 2005 Plymouth City Council air quality report an AQMA for C_6H_6 was declared at the petrol station (see *Figure 6*, for reference of the AQMA boundary and monitoring sites). By 2007 a stage II vapour recovery unit had been installed. However, no elaboration is provided as to how Plymouth City Council interacted with the privately-owned petrol station vendor, to install the vapour recovery unit in the absence of

statutory powers legally compelling the installation. In 2008 the reductions in C_6H_6 levels around the site and future predicted reductions were attributed to the stage II vapour recovery installation and a proposal was put forward to revoke the AQMA. However, this does not explain the reduction between 2005 and 2006, as seen in *Table 6*. In the Plymouth City Council 2009a report the C_6H_6 monitoring pump was stated to have been removed from the site and in 2010 despite an unevaluated elevation in concentration levels as seen in *Table 7*, the AQMA was revoked and monitoring ceased (Plymouth City Council, 2011). Subsequently, the petrol station has been taken over by another company with the present state of the stage II vapour recovery unit and C_6H_6 levels around the area unknown.

Figure 6. Benzene (C_6H_6) AQMA (shaded area) and monitoring sites (circles/square)

(Plymouth City Council, 2005)

Table 6. Benzene (C_6H_6) Annual Monitoring Mean Results

Results of Benzene Annual Monitoring Mean (µg/m3)								
Monitoring Site	2003	2004	2005	2006	2007	2008	*t-Stat*	*p-value*
School Wall	5.074	4.46	3.06	3.01	1.36	1.47*	-4.924	0.016
School Door	N/A	2.59	2	2.35	1.12	1.15*	-1.825	0.209
Exeter Street Flats	N/A	1.98*	1.41	2.18	1.01	1.288*	-0.619	0.598
Exeter Student Accommodation 'St Theresa's House'	N/A	5.47*	4.35	3.84	2.92	2.09*	-12.474	0.006

Table 7. Benzene (C_6H_6) Annual Mean Bias Adjusted Results

Results for Benzene Annual Monitoring Bias Ajusted µg/m3									
Monitoing Site	2004	2005	2006	2007	2008	2009	2010	*t*-stat	*p*-value
Exeter Student Accomidation 'St Theresa's House'	6	4	4	2	2	2	3.7	-0.829	0.453

The results from Table 6 and 7 are discussed in detail under the *Quantitative Analysis of Annual Benzene (C_6H_6)* section.

9.5. Particulate Matter (PM) Background Levels & Hotspots

In section 4.2 of the 2004 Plymouth City Council report the background AURN monitoring site located in the centre of Plymouth, in an open area away from industrial activity and a substantial distance from the nearest roadside. The AURN monitoring site is used to depict background levels of PM and has been utilised by Plymouth City Council to depict overall levels across the conurbation showing PM concentrations well within the air quality objectives.

The 2004 air quality report conversely noted an issue with PM in a 'hotspot' around an unnamed '*port*' in Plymouth, due to a number of nuisance complaints in previous years from residents in relation to commercial activities in the port. In 2003 air quality monitoring was initiated in the area with results indicating a large number of exceedances. An abatement noticed was served in 2003. However, in 2004 and 2005 complaints continued and large streams of air quality data were lost which Plymouth City Council stated to be a result of a fault with the equipment. In the 2006 report under section 8.1.1. Plymouth City Council noted a number of prosecutions relating to breaches at the port; in relation to the abatement notice, no further details are provided. However, according to the 2007 Plymouth City Council report monitoring had ceased at the site due to a resident requesting the prompt removal of the monitoring unit from their property in 2006.

On review of the site in the 2007 report, section 2.5.1. (p15) states that the activities at the port were now deemed to be within the legal annual mean concentration of air quality standards. This is justified through the data captured, with acknowledgement of

the significant data loss and a change in environmental activities at the port following prosecution.

In the 2008 report further nuisance complaints are stated to have arisen in relation to the port's activities. However, section 4.1. (p24) states the site is deemed not to be a statutory nuisance. In the 2009 report under section 1.4.2. Plymouth City Council stated

> "*there was no evidence to suggest the annual mean would not be met at the site but there was some indication that the number of exceedances of the 24-hour objective would be breached. However, monitoring continued over the next twelve months to assess the number of exceedances of the 24-hour objective and the situation was reviewed after 12 months*."

Furthermore, section 1.4.5. states:

> "*The PM10 monitoring that was being carried out at" the port "ceased in 2006 as the annual mean objective of 40µg/m3 had been met during each year of monitoring.*"

In the 2010, 2011, 2012, 2013 and 2014 reports there are no further updates in relation to this unnamed port.

In the 2007 council air quality report an additional unnamed port referred to here as '*port 2*' was identified through complaints as a potential new issue relating to PM due to changes in loading practices and products. The site's explicit location is not provided and monitoring was due to start in 2007. In the 2008 report (p24) *port 2* is stated as '*not to have been confirmed as a statutory nuisance to date*', with further investigation

underway. No data is provided on port 2 and no further reference in the 2009, 2010, 2011, 2012, 2013 or 2014 reports.

9.6. Particulate Matter (PM) Monitoring

In the Plymouth City Council 2008 report under section 4.1.4. Plymouth is noted to be undergoing significant redevelopment which had contributed to a number of dust complaints relating to construction activities. The report states the council had published a Code of Practise for Construction and Demolition, available to developers and attached to the planning permission for schemes with the potential to cause a nuisance. Furthermore, monitoring of PM_{10} is now undertaken as of 2007 in Exeter Street alongside NO_2. No historical precedence or reasoning is provided for the installation of the PM_{10} monitoring unit in this location, 8.03 meters from roadside; the site is shown below for reference in *Figure 7*. However, the 2010 report states that exceedances of the annual mean in the area are related to transportation, associated to redevelopment work. By the 2013 report the annual mean had significantly dropped with 24-hour objective breaches accredited to road closures causing congestion in the area.

In the 2009 Plymouth City Council air quality assessment report under section 2.1.1. the city centre AURN monitoring site is stated to have undergone refurbishment and to be awaiting the reinstallation of a PM_{10} monitoring unit alongside the addition of a $PM_{2.5}$ monitoring unit. The 2010 report confirms the installation of a $PM_{2.5}$ monitoring unit. The 2011, 2012 and 2013 reports state $PM_{2.5}$ not to be included in the LAQM regulations but were optionally reported upon in line with section 4.28 of the LAQM.TG (09). However,

there is an overall national objective to contribute to a 15% reduction in $PM_{2.5}$. The monitoring results show readings within the air quality objectives. The readings remain consistent and therefore do not contribute to the overall national 15% reduction objective. Conversely, data capture of $PM_{2.5}$ is stated to have '*degraded*' since installation within 2012. Degraded means a failure in the equipment to attain readings. Therefore, the conclusion drawn in the 2014 Plymouth City Council report that levels have remained consistent is speculative.

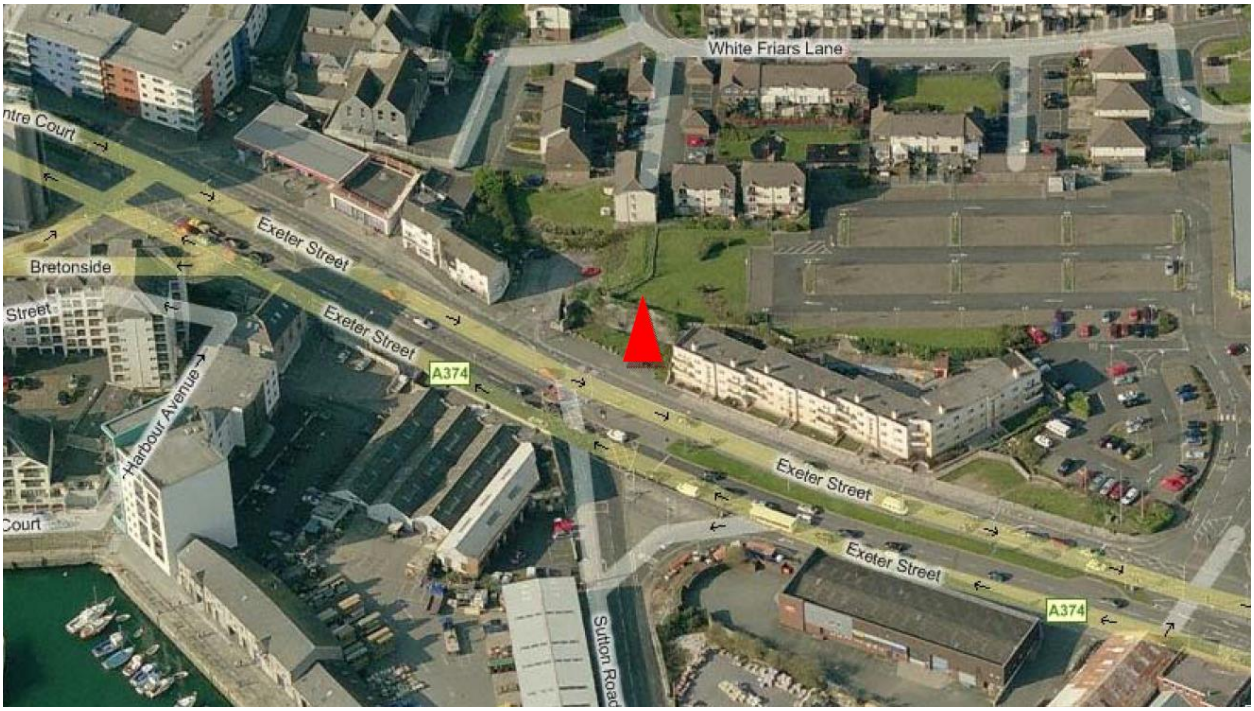

Figure 7. Exeter Street Particulate Matter (PM) Monitoring Unit

(Plymouth City Council, 2009)

9.7. Planning Developments

Mackay's Vision for Plymouth is a renovation project to rejuvenate and create a healthy functional city from 2003 – 2020s. This vision, reviewed by Plymouth City Council, makes no mention of means to mitigate pollution in general, and makes no reference to air quality. More congestion in the city centre is attributed to subsequent developments (MBM Arquitectes and AZ Urban Studio, 2003: Plymouth City Council, 2005; section 4.3.1., 2007: p18). Succeeding developments included a 1500 residential development incorporating commercial units, schools and health and leisure facilities within Plymouth City Council's domain (Plymouth City Council, 2005: section 5). By 2008 an additional 1200 residential developments were underway within the district alongside minor multiple residential brown field in-fill plots. In 2009 planning permission had been requested to use the city's airfield for residential development. The approximate number of developments was not initially stated but the 2012 - 2013 reports estimated between 375 - 400. Additionally, the 2010 report cites there to be further considerable residential and mixed developments in the northern area of the district over the next 15 years with no mention of the perceived air quality impact or mitigation measures.

In 2005 construction of a new retail outlet '*Drake Circus*' had begun which was cited to have the potential to impact upon pre-existing LAQM issues with the significant increase in the number of vehicle movements. However, the Plymouth City Council 2007 air quality report stated:

“planning permission was approved for this site a number of years ago, there is nothing that can be included to alter the effects on air quality.”

Plymouth City Council state that, due to permission being granted years prior to the ‘*Drake Circus*’ development, remediation measures to reduce air pollution during construction are not possible. There is no cited discussion with the ‘Drake Circus’ development team or review of alternative mitigation measures to reduce the effect as the noted purpose of LAQM, *Chapter 2,* section *Management* (Plymouth City Council, 2005; section 5.2, 2007:p20).

In the 2010 air quality report Plymouth City Council cite a proposed ‘energy from waste’ power plant to be developed in the Northern area of the conurbation to be operational by 2014 (pictogram provided in the report). By the 2012 Updating and Screening Assessment, there is reference to an approved mitigation plan to reduce PM during the construction of the waste plant, a proactive measure to address air quality issues in the city. However, it is the only such reference to a plan for proposed developments in the area.

In Plymouth City Council’s 2013 Detailed Assessment of NO_2 and PM (p13) a third-party air quality assessment was submitted with a planning application for the proposed development of an Art school in Plymouth. A summary of the third-party audit findings are provided in the 2013 assessment. However, the validity of the assessment does not

appear to have been verified; echoing the absent auditing function mentioned previously.

Plymouth City Council conclude in the 2014 Progress Report (p49) that a large scale proposed development at Home Park Football Ground (not the sports and wellbeing centre) would present an imperceptible to small increase in NO_2. How this conclusion was drawn is not elaborated upon. Conversely, in relation to the smaller scale retail outlet '*Drake Circus,*' constructed in the city years prior, Plymouth City Council considered large/heavy goods vehicle movements in and out of the area and their inevitable continuation after the build was complete to have a potential significant impact on air quality.

Developments in the neighbouring council have also potentially influenced Plymouth's air quality; for example, the Sherford development, a new town currently being constructed on the edge on South Hams, virtually within Plymouth as depicted in *Figure 8* This potentially indicates a '*Not in My Backyard/Neighbourhood*' (NIMBY) mentality because the site selection is in the outermost regions of the council's jurisdiction reducing the impact on their main residential areas. The 2005 Air Quality Progress report under section 5.1.2. states the Sherford development to present '*significant transportation implications'*. However, Plymouth City Council later changes its opinion in the 2007 Air Quality Progress Report (p22) suggesting there is no cause for concern relating to the Sherford 4500 new homes development due to the lack of public

exposure. However, this '*perception*' appears not to consider transboundary air pollution or the overall increase in vehicles in the area from the development.

Figure 8. South Hams Sherford Town Development Proximity to Plymouth

(Planning For Sustainable Travel, 2018)

The same neighbouring authority also granted permission for a gas fired power station and an advanced anaerobic digestion plant on the edge of Plymouth City Council's conurbation and equally outside of Plymouth City Council's statutory jurisdiction (Plymouth City Council, 2006: section 3.1. and Plymouth City Council, 2012). The 2006 report reviewed the power station output and concluded NO_2 production would '*never*'

generate in isolation an exceedance of air quality standards. However, there are two key factors to consider with this statement: the location of the '*Centrica Langage*' plant, on the edge of South Hams juristriction away from their main residential areas and the closer proximity to the residents of Plymouth, highlighting again the potential NIMBY attitude in occurrence and the known NO_2 issue in Plymouth at this time. Therefore, while it may not in isolation breach the AQS for NO_2 it will potentially contribute to the overall NO_2 levels in the city which already breached the AQS, at this time. Plymouth City Council also stated they had confirmation from their South Hams Council colleagues that the advanced anaerobic digestion plant would not affect Plymouth's air quality. No report is mentioned or further detail provided; the basis of this statement appears founded on the '*perception*' of South Hams Council.

Other planning developments include new roads and road layouts. The 2005 Plymouth City Council Report under section 4.5.3. speculate a '*modest increase*' of 11 - 14% in traffic relating to a proposed development along Tavistock Road in the north of the city. Details on the development/s in the area are not clear with undefined options used as references. The '*modest increase'* may relate to the breach in the AQS at site 15 in 2007 (see *Table 8*) but not likely the sustained breach to 2013.

In 2005, traffic management and road alterations were underway throughout the city to improve transportation as part of the ongoing redevelopment scheme. However, by 2008 there was reported to be no new major road developments. In 2010 Plymouth City Council cite the new local transport plans for 2011 - 2026 to be closely aligned to the

development framework which aims to deliver sustainable development. The 2011 report states no additional traffic management development outside of the transport scheme. In Plymouth City Council's 2012 report under section 2.2.1.1. the council states that reductions in diffusion tube readings at a number of sites should be treated with caution as the results may relate to temporary road closures and diversions in place as a result of the traffic management scheme.

In absence of a regional or local air quality strategy Plymouth City Council cite the CS22 Pollution Policy in their 2010 Air Quality Report (2011), which states '*no unacceptable developments permitted impacting on water and air quality'* (Plymouth City Council, 2008). However, the threshold or parameters of unacceptable are not defined. Furthermore, the 2013 council report makes an initial reference to a completed sports and wellbeing development and acknowledges retrospective air quality monitoring taking place around the site. This is a noticeable contradiction to Plymouth City Council's own unambiguous statement in their 2008 report, under section 1.2 and 4.4, that the local authority should list planning applications that have the potential to affect air quality, so that Environmental Health Officers have visibility. There are also hyperlinks provided to planning applications of perceivably smaller developments, the criteria for which are not provided and the links are no longer functional, inhibiting the review process to assess if Plymouth City Council's CS22 Pollution Policy has been adhered.

9.8. Air Quality Action Plans (AQAPs)

Issues are noted in Plymouth in the 2004 council air quality report and 3 AQMAs are declared in 2005: 1 for C_6H_6 covering a petrol station off of Exeter Street and 2 for NO_2encompassing Exeter Street and Mutley Plain. The Plymouth City Council 2005 Air Quality Progress Report under secton 2.3. states the Council has 12-18 months to prepare an AQAP. An AQAP is not seen until 2008 (Plymouth City Council, 2004, 2005 & 2008). The forecasted impact of each initiative is present but the justification for the perceived impact is not provided. Furthermore, the 2008 Air Quality Progress Report looks to manage '*hotspots*', through monitoring equipment. This can be criticised as a weakness of the AQAP because management is the function of dealing with or controlling items such as air pollution rather than observing them. This is an issue noted in general with AQAPs across the UK in *Chapter 2*, under section *Air Quality Action Plans*. Although, Plymouth City Council's AQAPs do additionally contain management measures which serve to reduce air pollutants rather than just monitoring.

Under section 4.7 of the Plymouth's Options of the Plymouth City Council AQMA declaration meeting report (2014), Plymouth City Council promoted a single large AQMA to reduce the administration burden on the council; '*allowing resources to be directed to other priority work*'. This statement potentially shows Plymouth City Council seeking avenues to make the LAQM process more efficient. However, the phrase '*other priority work*' is not defined and could equally potentially be misconstrued to mean air quality is not deemed as '*priority work*' by Plymouth City Council.

The following are the initiatives planned or undertaken by Plymouth City Council to reduce air pollution in the city:

9.8.1. Road Space Reallocation

The 2012 AQAP Progress and Update in the Plymouth City Council 2014 report, cites a reallocation of road space to potentially have a reduction value in NO_2 of between 2 – 11µg/m3 along Embankment Road (Plymouth City Council, 2014, p83-84). Multiple schemes are cited in relation to this initiatives at differing staging of completion in the 2012 AQAP. On review of *Table 8* site 12 Embankment (PK) from 2008 – 2013 there is a drop in NO_2 from 31.11 to 25.65µg/m3. Although, not deemed statistically significant, there is an evident reduction. The data from the 2004 – 2014 Plymouth City Council reports on NO_2 has been collated and is depicted in *Table 8* and shows a decrease in NO_2 at the majority of sites. Although, not statistically significant, Plymouth City Council do not attribute the reduction to any initiative but rather, throughout the annual air quality reviews, accredit previous elevated levels to construction work in any given area of Plymouth.

9.8.2. Tree Planting

Plymouth City Council Tree planting alongside roads initiative is estimated to potentially reduce NO_2 levels by $<0.1µg/m^3$ in the city (Plymouth City Council, 2014, pp95-96). However, the simplicity of this initiative is flawed because planting tall trees in built up areas has been shown to create a tunnel/valley like effect exacerbating air quality issues (Abhijith *et al*, 2017). Furthermore, tree planting along roadsides could be seen

as a trade off with road safety. This is because when trees sit unguarded close to the road side they present an impact barrier that provides no deflective function as seen in the 2014 review of Roadside Tree Safety in Poland (Budzynski & Jamroz, 2014). Furthermore, no specifics are provided in relation to the type of tree utilised, as there are certain genus more adapted to the job; for example, the Plane Tree's bark absorbs pollution and the species is exploited as such in parks and squares throughout London (BBC, 2014).

9.8.2. Travel Plans

Travel Plans look at alternative and environmentally friendly ways for individuals to get from A to B. Plymouth City Council aimed to utilise personalised travel plans within AQMAs in the city in a bid to reduce NO_2 by <0.1µg/m^3 (Plymouth City Council, pp94-95). The AQAP Progress and Update 2012 shows the initiative as being complete with an aim to extend the resource to the North of the city in 2015 and 2016. The small scale of the initiative perhaps indicates it to have been an initial trial and the extension plan may indicate that the initial scheme was perceived as a success by Plymouth City Council.

9.8.3. Advice/Incentives

Advice/incentives for cleaning up larger vehicles by retrofitting engines is an initiative relating predominantly to bus operations in Plymouth (Plymouth City Council, 2014). Ironically, the main bus service in Plymouth was previously owned and operated by Plymouth City Council until being sold off to a private company in 2009 (Go-Ahead,

2017). Now the council requires support from the bus operators in the city to enable them to address the air pollution produced by the vehicles which has been highlighted as an issue since the 2007 council report. The support had still not been obtained by the time of the 2014 Plymouth City Council report and there was no published update on this action at the time of writing this paper. The second element of this initiative relates to freight emissions. However, the vehicles in question are not defined. Furthermore, both initiatives do not state Transportation and Highways Department involvement (*ibid*).

9.8.4. Land use/planning

There is an ongoing venture by Plymouth City Council to assess new planning applications with air quality implications (Plymouth City Council, 2008). This statement was contradicted by the later 2013 Plymouth City Council report, with no previous reference to a then completed sports and wellbeing centre, with nonchalant mention of subsequent air quality monitoring taking place in the area after construction.

9.8.5. Informational Awareness

The *Pollution and Exercise* initiative to raise awareness of air pollution by informing the public of the effects of driving on health was a credit to Plymouth City Council as a marketing angle to promote environmentally friendly modes of transportation in the city. The success of which in 2013 was hailed as best practise by British Cycling (Plymouth City Council, 2014). Although, a press release providing information and awareness on

air quality is stated to have been released by Plymouth City Council in 2008 (Appendix 5). The publication platform and the contents of the release was not defined, and the item has not been sourced.

9.8.6. Scrappage Scheme

There is a central government initiative to incentivise the scrapping of older vehicles as they are deemed more polluting, although the emissions scandal mentioned in *Chapter 2* may refute this perception. The AQAP provides little to no detail on this initiative and it is presumed to be drawn from the Central Government car scrappage scheme once funded and since ironically scrapped. A continuation of a similar scheme in Plymouth without funding by Central Government seems unlikely. However, this is assumed due to the limited detail provided. (Plymouth City Council, 2014).

9.8.7. Traffic Management

Traffic in pollution '*hotspots*' can be managed via the implementation of an advanced traffic control system, moving traffic away from AQMAs during peak times. This initiative has the potential to reduce NO_2 by 0.5 - 20µg/m^3 (Plymouth City Council, 2014, pp88-90). However, by Plymouth City Council's own admission, this initiative works by diverting traffic from AQMAs and therefore potentially only moves the air quality problem elsewhere in the city (Plymouth City Council, 2014).

9.8.8. Taxi Licencing Standards

An initiative to reduce taxi emissions was brought about by a central government legislative change, empowering local authorities to require vehicles to be Euro IV compliant as a minimum standard to obtain licencing. The predicted reduction in NO_2 by the initiative is 0.5µg/m^3 (Plymouth City Council, 2014, pp90-91).

9.8.9. Cycling Facilities – Vehicle Restrictions

The cycling facilities in AQMAs initiative in Plymouth ran from 2011 – 2013. Multiple schemes in relation to this initiative were proposed in Plymouth with mixed results on funding bids. Overall the initiative has led to an estimated NO_2 reduction of 0.1µg/m^3 in Plymouth (Plymouth City Council, 2014). Whereas, the parking and delivery restrictions in AQMAs initiative cited in the 2008 AQAP, does not appear and is not referenced in the 2012 update (Plymouth City Council, 2008, 2014)

9.8.9. Roadside Emission Testing

Roadside emissions testing was conducted once in Plymouth in 2008 with the aim of a repeat at some point in 2016. No publication was sourced relating to a reoccurrence of this initiative in 2016. Along with action against idling vehicles, without local authority statutory powers these initiatives are difficult to enforce and labour intensive with each only providing an estimated <0.1µg/m^3 reduction in NO_2 emissions (Plymouth City Council, 2014, p92).

9.8.10. Greener Council Fleet

There was a central government initiative to turn council fleets green. The initiative potentially relates more to the public image of the council or a precedent for other businesses than having a significant impact on NO_2 in isolation. *Table 8* indicates there to have been no notable reduction in NO_2 levels in Plymouth from 2003 – 2013. The initiative did win funding for 19 electric vehicle charge points in the city promoting a potentially[3] alternative fuel source to fossil fuels combustion throughout the city (Plymouth City Council, 2014).

9.8.11. Local Transport Plan (LTP)

Air quality is cited as being a key theme in the LTP 2 (Plymouth City Council, 2007; p23) On review of the 2011 - 2016 LTP, the '*Managing Air Quality and Transport Noise*' section, although predominantly dedicated to noise, does mention continued review of air quality through LAQM and the adoption of pollution response traffic management; which means steadying the flow of traffic and priority for public and environmentally-friendly modes of transport. The 2010 Air Quality Report (2011, p47) states the local transport plan is on target to meet the objectives relating to traffic management but not air quality. The LTP 3 for 2011 - 2026, overlaps the Air Quality Report's publication in 2011. As mentioned under '*Air Quality Action Plans (AQAPs)'* with management and noise subtracted, this infers the transport department was failing to support the public protection service in the continual review of air quality.

[3] Electric cars are only as environmentally friendly as their construction and fuel source, see the *Discussion* for further detail.

10.0. Quantitative Analysis Findings

10.1. Quantitative Analysis of Annual NO_2 Levels

Table 8 presents a consolidated version of annual mean NO_2 levels collected and calculated by Plymouth City Council for the city of Plymouth from 2003 - 2013. Sites shown in *Table 8* do not present all monitored sites but those which were still being monitored in 2013 and those with sufficient amount of data to support statistical appraisal, deemed by the researcher to be a minimum of five sets of chronological figures. Five years of data sets was also considered to be sufficient in depicting the outcome of AQAP initiatives.

The information was obtained from Plymouth City Council air quality reports running from 2004 – 2014, including 2009b and excluding 2009a. The extracted information provides monitoring data over several years to strengthen the validity of the *t* test and *p* value results. However, due to formatting rules, data in any given location, prior to a year where the reading states N/A, could not be included in calculations. In occurrences where 2013 NO_2 levels are stated as N/A, data utilised ran from the earliest to the latest uninterrupted recorded readings. Annual means highlighted red indicate breaches in the AQS. Results in the highlighted columns, *t* stat and *p* value are explained below.

Table 8. Plymouth Monitoring Data for Nitrogen Dioxide (NO_2)

Plymouth Monitoring Site Data for Nitrogen Dioxide															
Site ID	Location	Within AQMA?	Annual mean concentrations (µg/m3) Bias Adjustment Factor (BA)											t-stat	p-value
			2003 (BA 0.91)	2004 (BA 0.96)	2005 (BA 0.86)	2006 (BA 0.98)	2007 (BA 0.94)	2008 (BA 0.92)	2009 (BA 0.9)	2010 (BA 1.9)	2011 (BA 1.03)	2012 (BA 0.99)	2013 (BA 0.95)		
			2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013		
2	St. Catherine's Hse.	N	N/A	N/A	N/A	29.6	34.48	31.19	33.61	43.92	36.74	33.73	29.47	-0.2534	0.8100
3	81a Vauxhall St	N	N/A	N/A	N/A	25.7	34.32	33.61	29.68	36.07	31.10	28.42	26.87	-2.3156	0.0684
4	Mariners Court	Y	37.27	34.57	31.31	26.7	33.41	28.2	27.66	35.49	28.28	26.62	N/A	-1.0848	0.3140
5	Charles Cross	Y	43	42	36.31	37.4	45.13	39.57	37.02	45.99	42.30	35.36	35.71	-0.5734	0.5821
6	Exeter Street Flats	Y	47.35	40.95	41.48	37.2	40.34	35.66	35.87	44.03	35.92	35.98	35.55	-1.5718	0.1547
7	4 St Judes Road	Y	N/A	34	30.51	30.1	30.58	32.54	32.52	38.67	35.69	29.58	29.72	0.4590	0.6602
8	11 Tothill Road	Y	N/A	33	28.53	27.8	31.87	30.37	29.48	35	34.57	29.64	28.21	0.6670	0.5262
9	212a Exeter Street	Y	45	44	35.29	34.1	40.63	39.98	36.09	41.87	40.79	32.95	32.35	-1.2177	0.2580
10	48 Embankment Rd	Y	N/A	38	42.13	43.96	46.2	41.68	37.70	49.71	44.88	34.54	32.11	-1.5502	0.1650
11	211 Embankment Rd	Y	32	36	35.96	32.7	39.96	39.19	35.58	50.08	37.89	26.19	28.25	-0.7262	0.4884
12	Embankment Road(PK)	N	34	30	26.01	28.3	33.15	31.11	29.52	39.33	34.55	27.88	25.65	0.3066	0.7670
13	2 Woodford Avenue	N	N/A	31	25.56	26.2	30.26	27.95	27.62	30.62	31.66	22.74	N/A	0.1999	0.8482
14	422 Tavistock Road	N	N/A	N/A	36.83	27.6	36.63	35.94	35.79	48.33	39.3	36.92	N/A	1.5771	0.1756
15	45 Tavistock Road	Y	N/A	N/A	37.86	36.5	45.31	45.08	37.85	49.05	40.2	44.22	45.97	1.0179	0.3480
16	203 Crownhill Road	Y	N/A	N/A	N/A	8.4	20.84	25.15	20.56	24.53	24.65	19.89	19.09	-0.8374	0.4406
17	Outland Road	Y	N/A	35	28.02	28.6	35.33	33.0	32.02	40.3	37.01	30.88	30.73	0.8986	0.3987
18	161 Molesworth Road	Y	N/A	N/A	N/A	N/A	44.22	43.69	40.12	50.09	46.25	42.33	37.98	-0.6688	0.5402
19	Pennycomequick Flats	N	N/A	36	31.27	N/A	34.42	31.43	29.69	39.65	36.51	31.15	29.31	-0.4136	0.6963
20	Caprera Place	N	N/A	37	31.82	N/A	35.57	30.65	33.93	38.14	35.38	29.10	29.45	-1.1067	0.3188
21	2 Hyde Park Road	Y	N/A	N/A	34.35	N/A	35.60	33.47	32.08	41.45	37.11	32.50	32.1	-0.3745	0.7234
22	Connells Mutley	Y	N/A	N/A	38.41	N/A	37.72	35.27	36.06	41.29	38.95	36.71	34.98	-0.1890	0.8575
23	6 Alexandra Place	Y	N/A	N/A	N/A	N/A	38.80	33.97	35.03	39.64	37.53	32.51	33.68	-0.4543	0.6732
24	140 North Hill	Y	N/A	33.39	35.94	N/A	32.22	29.88	30.55	38.39	36.59	29.38	28.18	-0.3189	0.7627
25	14a Mutley Plain	Y	N/A	49.3	47.41	N/A	48.92	42.81	42.05	51.19	52.02	41.05	41.91	-0.5393	0.6128
26	22 Mutley Plain	Y	N/A	N/A	N/A	N/A	49.54	46.24	43.49	56.70	54.69	47.27	41.19	-0.2785	0.7945
27	Mutley Plain (shop)	Y	52.71	50.35	51.17	N/A	52.94	46.41	49.27	54.43	52.17	43.69	43.21	-1.4335	0.2112
28	28 Oxford Place	N	N/A	N/A	N/A	N/A	38.15	35.03	30.22	40.78	37.06	28.08	30.56	-0.7704	0.4840
29	Cobourg Street	N	N/A	N/A	N/A	N/A	33.71	31.89	35.15	43.17	40.30	34.07	34.59	0.1854	0.8619
30	Royal Parade (2)	Y	N/A	N/A	N/A	N/A	59.38	52.92	46.81	58.24	49.9	46.33	44.88	-0.8822	0.4275
31	AURN 1	N	N/A	26	N/A	N/A	26.69	24.76	21.41	32.19	28.56	23.44	22.86	-0.3257	0.7578
32	AURN 2	N	N/A	26	N/A	N/A	27.62	24.10	23.62	32.86	27.50	22.24	21.84	-0.8046	0.4576
33	AURN 3	N	N/A	25	N/A	N/A	26.33	24.80	20.14	33.11	29.90	22.92	22.6	-0.1993	0.8498
34	Milehouse Road	Y	N/A	N/A	N/A	N/A	46.00	39.97	40.90	55.63	50.49	41.98	41.47	0.0932	0.9302
35	12 Devonport Road	Y	N/A	N/A	N/A	N/A	45.47	34.33	32.39	43.77	40.86	33.74	42.16	0.9700	0.3870
36	Morshead Road	Y	N/A	N/A	N/A	N/A	40.47	39.93	38.38	48.92	44.0	40.75	32.96	-0.6874	0.5296
37	Great Berry Road	Y	N/A	N/A	N/A	N/A	51.10	46.80	44.02	54.32	48.7	45.12	N/A	0.0893	0.9345
38	Royal Parade	Y	N/A	N/A	N/A	N/A	56.29	48.39	43.83	53.13	42.1	45.74	43.26	-1.2561	0.2774
39	Derry's Cross	Y	N/A	N/A	N/A	N/A	57.33	53.56	51.10	57.74	43.4	50.98	50.57	-0.7194	0.5117
40	15 Devonport Road	Y	N/A	N/A	N/A	N/A	N/A	37.72	36.84	50.18	49.39	40.32	38.46	-0.2924	0.7890
41	Nomony Children's Ctr	Y	N/A	N/A	N/A	N/A	N/A	53.90	42.17	46.35	42.6	47.74	N/A	1.0809	0.3927
42	East End Resource Ctr	N	N/A	N/A	N/A	N/A	N/A	37.70	28.07	35.38	32.41	29.11	28.83	-0.4367	0.6919
43	68 Mainstone Avenue	N	N/A	N/A	N/A	N/A	N/A	38.52	28.31	32.25	42.8	35.07	36.99	1.2648	0.2953
44	7a River View	N	N/A	N/A	N/A	N/A	N/A	42.03	36.36	39	35.96	26.89	21.33	-3.4137	0.0420
45	8a River View	N	N/A	N/A	N/A	N/A	N/A	37.50	27.49	28.17	31.49	29.89	23.5	-0.6032	0.5889

10.2. Quantitative Analysis of Annual NO_2 Levels Results

Table 8 presents the results of a *t* test for each year monitored for 45 sites in Plymouth in column *t* stat. The *t* stat provided from the *t* test provides an indication of the difference between the annual mean NO_2 levels. The *p* value establishes if the changes in NO_2 levels at each location in Plymouth from the earliest to the most recent streams of viable data were statistically significantly different. The results displayed in *Table 8*, column *p* value, highlighted in red, presents a *p* value greater than 0.05. A *p* value greater than 0.05 means there has been no statistically significant change in NO_2 levels in Plymouth over this period. The single green highlighted result for site 44 *'7a River View',* out of 45 sites monitored for NO_2 shows a statistically significant difference in the reduction of NO_2 levels from 2008 – 2013. However, this positive reading has arisen from a site outside of an AQMA, meaning there has been no localised initiative to reduce NO_2 levels in the area. The possibility of general LAQM initiatives undertaken by Plymouth City Council having contributed to this reduction is unlikely, due to the localisation of the decrease. The *p* value used (0.05) means that there is only a 5% chance (i.e. a 1 in 20 possibility) that a recorded significant difference is coincidental. Therefore, the 1 positive result shown in *Table 8* out of 40 may indeed be coincidental.

On review of the monitored site 44 '*7a River View'*, the only site with a significant reduction in NO_2, a visual inspection was conducted by the researcher on November 25th 2017. Upon visiting the locality, it was evident the area had been redeveloped in recent years, although corresponding data was not sourced in the Plymouth City

Council air quality reports from 2004 – 2014. The elevated NO_2 level may have occurred during redevelopment. Subsequently reducing when construction was complete and the associated traffic movements ceased, supporting Plymouth City Council's general theory on elevated NO_2 levels in the city. However, dates would need to be validated against historical development records, with inactive hyperlinks.

The general lack of significant differences in air quality readings may be attributed to failures in LAQM or a continuation of the AQAP imprecise calibration to address air quality, mentioned in *Chapter 2*, under *Air Quality Action Plans* (Longhurst *et al*, 2010). The concept of natural variability in weather patterns and their subsequent influence on NO_2 concentration, is assessed in *Table 9,* and subsequent sections. Furthermore, common theory would accredit an increase in the number of vehicles counteracting any positive effect which is reviewed in *Table 10*, and the following sections. Although, outside the parameters of this study there is the potential theory of additional sources of NO_2 from new developments, might be counteracting the AQAP effects and presenting a maintained level of NO_2 rather than a clear significant reduction.

10.3. Quantitative Analysis of Annual Benzene (C_6H_6)

The purpose of the following tables are to review the impact of the stage II vapour recovery unit fitted by Plymouth City Council in 2007 for the C_6H_6 AQMA, on pollution levels. A detailed assessment had been under taken in the area due to the close proximity of a petrol station to a busy main road and school. Following the implementation of this air pollution remediation method, the C_6H_6 AQMA was formally revoked in 2010, indicating the recovery system sufficiently reduced C_6H_6 in the area to within the AQS. Therefore, the following tables show the statistical significance the intervention had upon this pollutant. Bias and non-bias adjustment figures are presented and appraised for comparison of the data. The Plymouth City Council annual review reports from 2004 – 2014 tend to state the pollutant recordings for the previous year. The monitoring data presented in the 2005, 2009 and 2009a reports for 2004 C_6H_6 levels at monitoring site 'Exeter street flats and St Theresa's House' differed. As the initial report in 2005 stated the number of recorded C_6H_6 levels captured, it was therefore deemed more accurate and these results have been utilised in the following data. The 2009 report under section 3.3.2 states to present bias adjusted data for C_6H_6 for years 2004-2008. Although, the bias adjustment factor is not apparent in the appendix as stated. Therefore, this data could not be verified and has not been used. Monitoring ceased in the area for C_6H_6 following the revocation of the AQMA.

Table 6 provides the consolidated mean average non-basis adjusted annual C_6H_6 recordings in Plymouth from 2003 – 2008. The reductions in C_6H_6 levels were statistically significant, (highlighted green) at '*School Wall*' and '*St Theresa's House*'

evident by the *p* values presented <0.05 but not for 'School Door' or 'Exeter Street Flats'. However, the 'Exeter Street Flats', although monitored, were not encompassed within the AQMA. The reason for the variation in statistical significance shown below is unclear, it may relate to the positioning stage II vapour recovery unit, not specified in the Plymouth City Council air quality reports or may be a result of variables such as additional emissions from Exeter street traffic and/or potentially wind direction.

Table 6. Benzene (C_6H_6) Annual Monitoring Mean Results[4]

Results of Benzene Annual Monitoring Mean in µg/m3								
Monitoring Site	2003	2004	2005	2006	2007	2008	*t-Stat*	*p-value*
School Wall	5.074	4.46	3.06	3.01	1.36	1.47*	-4.924	0.016
School Door	N/A	2.59	2	2.35	1.12	1.15*	-1.825	0.209
Exeter Street Flats	N/A	1.98*	1.41	2.18	1.01	1.288*	-0.619	0.598
Exeter Student Accommodation 'St Theresa's House'	N/A	5.47*	4.35	3.84	2.92	2.09*	-12.474	0.006

Table 7 presents the bias adjusted figures for only one site 'St Theresa's House' monitored, within the C_6H_6 AQMA. The data was taken from the 2010 report and includes a 2010 reading as the report was produced in the second quarter of 2011. The data presents a greater number of air quality readings for the monitoring site incorporating 2009 and 2010. However, as C_6H_6 levels increased in the area in 2010 presenting a *p* value = 0.453 and bias adjusted figures are to account for variables, the

[4] The recordings with asterisks next to them indicate less than 12 results were obtained for the monitoring site in that year. Data was extracted from Plymouth City Council Air Quality Reports for years 2004, 2005, 2006, 2007, 2008, 2009, 2009a, 2010 and 2011.

stage two vapour recovery unit is no longer deemed to have had a statistically significant impact on pollution levels at this monitoring site by the researcher.

Table 7. Benzene (C_6H_6) Annual Mean Bias Adjusted Results

Results for Benzene Annual Monitoring Bias Ajusted µg/m3									
Monitoing Site	2004	2005	2006	2007	2008	2009	2010	*t* -stat	*p* -value
Exeter Student Accomidation 'St Theresa's House'	6	4	4	2	2	2	3.7	-0.829	0.453

10.4. Average Weather Vs Average NO_2 Levels

Plymouth weather recordings (temperature, wind and rainfall) were reviewed as they were considered significant factors potentially influencing NO_2 concentrations month to month outside of AQAP initiatives. Source data for weather averages was extracted from data sets provided by Researcher Helen Nance from Plymouth University, available in *Appendix 4*. *Table 9* depicts the mean average weather recordings for each month in the year 2013. The temperature was calculated by formulating the average of the highest and lowest temperature for each month. The weather data is presented alongside the background 'mean' average recorded NO_2 levels from the AURN monitoring sites. The AURN figure was obtained by calculating the average of the 3 AURN sites' readings for 2013. The purpose of reviewing the following data is to assess if weather patterns have influenced NO_2 concentrations confounding air quality issues and subsequently hindered the impacts of LAQM and interventions in the AQMA in Plymouth.

Table 9. 2013 Average Weather Vs Average NO_2 Levels[5]

Months of the Year	Average Weather Vs Average Background Nitrogen Dioxide µg/m3 2013			
	Average Temperature - Dry Bulb (°C)	Average Wind - Mean Speed (knots)	Average Rain - Amount (mm)	Average AURN
1	6	11	6*	28
2	5	9	3*	30
3	5	11	5*	24
4	8	11	11*	22
5	11	10	1*	19
6	15	10	2*	19
7	18	8	1*	22
8	17	8	2*	21
9	15	8	2*	18
10	14	12	6*	25
11	8	9	3*	21
12	11	14	6	34

[5] Note Average rainfall figures are lower than the actual rainfall over 2013. This is because data was missing from the daily readings and as a result reduced the average monthly reading. Those months with missing data have been marked with an asterix.

10.4.1. Figures 9.1- 9.3 Weather Vs NO_2

The following three scatter diagrams referred to as *figures 6.1 – 6.3* respectively depict the monthly NO_2 level and average AURN sites' readings for 2013 (Plymouth City Council, 2014). The figures show the trend between temperature, wind and rainfall and NO_2 levels for 2013 in Plymouth.

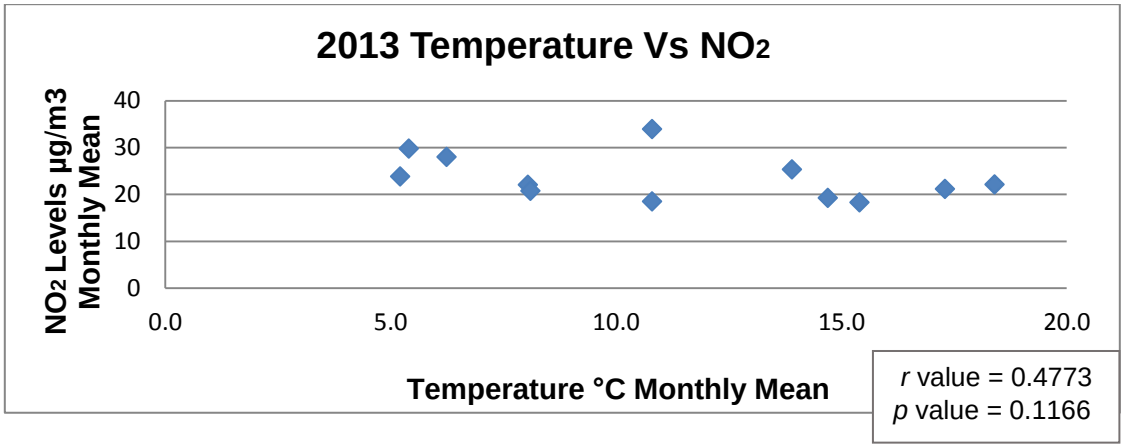

Figure 9.1. Temperature plotted against NO_2 concentrations

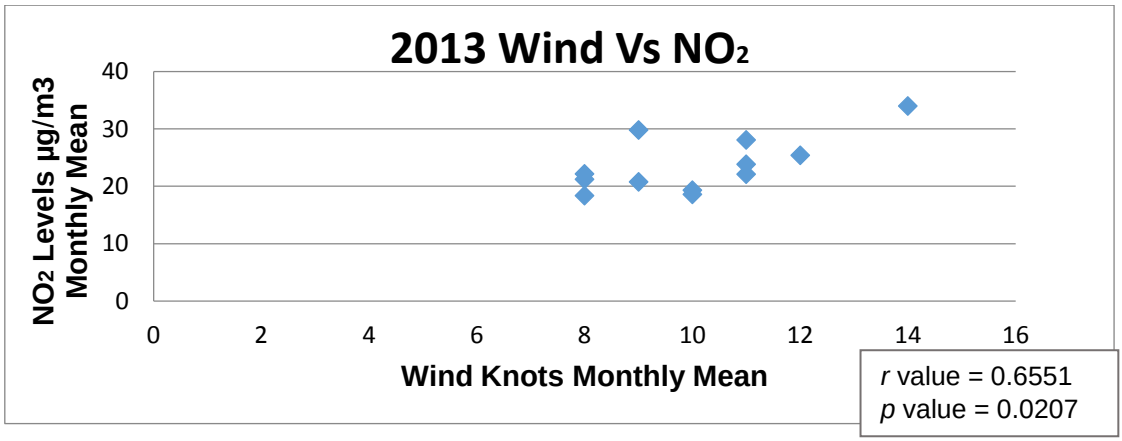

Figure 9.2. Wind plotted against NO_2 concentrations

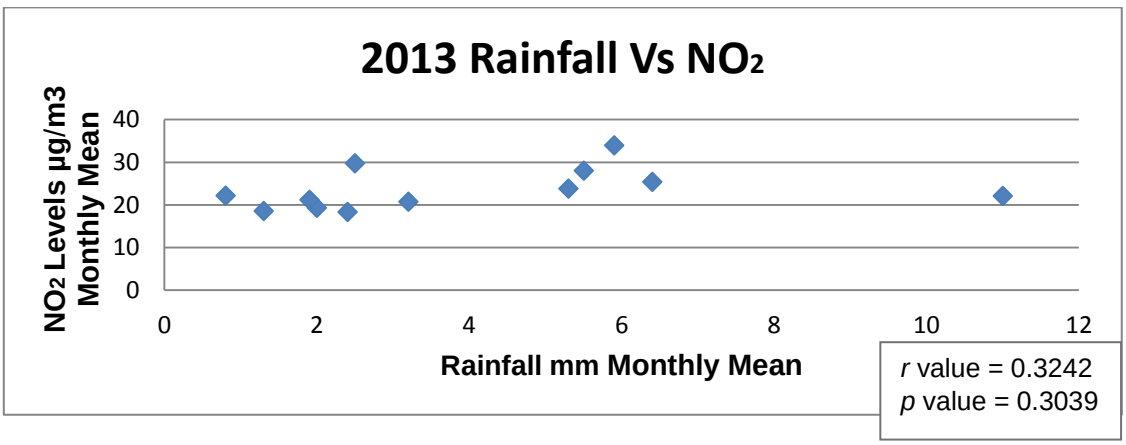

Figure 9.3. Rainfall plotted against NO_2 concentrations

10.4.2. Figure 9.1 Temperature Vs NO_2

Figure 9.1 shows no distinct trend between the average monthly temperature in 2013 and background NO_2 levels in Plymouth. The *r* and *p* value validate this remark with no statistically significant observation found. Although not significant, there is a slight decrease in NO_2 levels as temperature increases; this is potentially related to reactive processes that occur between NO_2 and sunlight forming O_3 in warmer temperatures. Conversely, this inverse relationship between temperature and NO_2 levels occurs in the winter with the cold air trapping air pollution at or near ground level explaining the elevated levels at low temperatures (National Aeronautics and Space, 2017; European Environment Agency, 2016).

10.4.3. Figure 9.2 Wind Vs NO_2

Figure 9.2 presents a *p* value of 0.0207, <0.05, a statistically significant result as the average monthly wind strength in 2013 increased, so did background NO_2 levels in Plymouth. Theoretically wind would aid in the dispersal of NO_2. However, the trend may be explained by, for example, elevated emissions of NO_2 such as those released or produced in higher atmospheric levels perhaps being returned more readily to ground level during greater wind speeds. Another potential cause is transboundary emissions were being blown into Plymouth, as seen in Tiwari *et al*'s (2015) paper on the relationship between wind and NO_2 (National Atmospheric Emissions Inventory, 2017).

10.4.4. Figure 9.3 Rainfall Vs NO_2

Figure 9.3 displays no statistically significant trend between the average rainfall and background NO_2 levels in Plymouth in 2013. This may be because of the washout effects of precipitation, removing NO_2 from the atmosphere reducing background levels as seen in Kim ***et al's*** (2014) study on the Effect of '*Precipitation on Air*

Pollution'. However, as the readings are not significant the washout effect may be limited.

10.5. Traffic Vs NO_2 Levels

Table 10 presents a consolidation of annual mean NO_2 levels and the corresponding consolidated annual traffic volume in specified areas within Plymouth. The traffic monitoring data sourced from the Department for Transport did not cover the whole of Plymouth, nor did the date provide well-defined detail on the areas monitored and required interpretation. *Appendix 5*, elaborates on the process undertaken to extract corresponding traffic data to areas monitored for NO_2 in Plymouth. The purpose of reviewing this information is to assess if traffic density has influenced NO_2 level in Plymouth over the past ten years and subsequently impacted upon air quality independently of any LAQM measures. Figures in bold indicate breaches in the AQS

***Table 10*. Traffic Volume Vs NO_2 µg/m^3 Concentrations**

Traffic Volume Vs NO_2 µg/m3 Concentrations												
Location	**Exeter Street NO_2**	**Traffic Volume Exter Street**	**Embankment Road NO_2**	**Traffic Volume Embankment Road**	**Outland Road NO_2**	**Traffic Volume Outland Road**	**Tavistock Road NO_2**	**Traffic Volume Tavistock Road**	**Cobourg Street NO_2**	**Traffic Volume Cobourg**	**Tothil Road NO_2**	**Traffic Volume Tothil Road**
2003	**46**	41494	33	15288	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	**43**	43209	35	16011	35	44206	N/A	N/A	N/A	N/A	33	41488
2005	38	44194	35	16766	38	45651	37	50738	N/A	N/A	29	43279
2006	36	46959	35	12855	29	47697	32	53635	N/A	N/A	28	44076
2007	40	36652	40	12512	35	46255	**41**	47988	34	32849	32	42925
2008	38	37272	37	12750	33	43985	**41**	48865	32	33568	30	42925
2009	36	38235	34	12959	32	40546	37	49660	35	32849	29	43521
2010	**43**	38106	**46**	6274	40	40703	**49**	48494	**43**	23621	35	45745
2011	38	28862	39	12282	37	44697	40	50081	40	24297	35	47314
2012	34	29093	30	9985	31	44795	**41**	56559	34	24415	30	38958
2013	34	34345	29	28054	31	44503	**46**	56088	35	23350	28	38749

10.5.1. Figures 10.1 - 10.6 depict annual average traffic volumes for 6 sites in AQMAs in Plymouth against NO_2 levels for each of the years from 2003 – 2013. The quantitative analysis of traffic data for these sites is depicted in *Appendix 6*. The NO_2 levels were taken from the Plymouth City Council monitoring site data and correspond with those in *Table 10*.

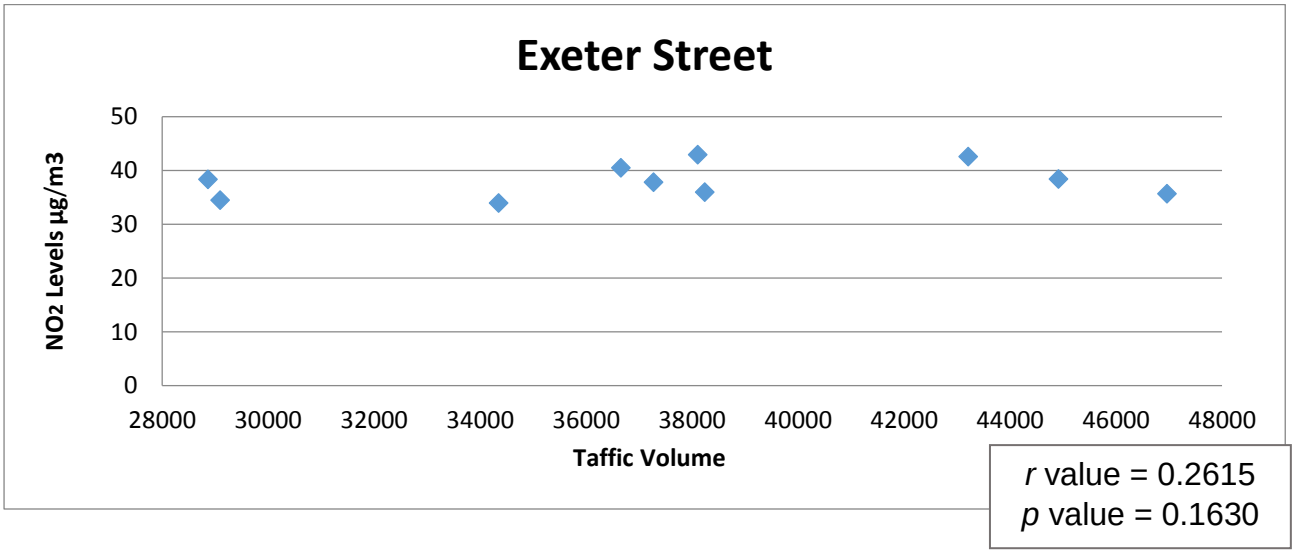

Figure 10.1. Traffic volume plotted against NO_2 concentrations (Exeter St)

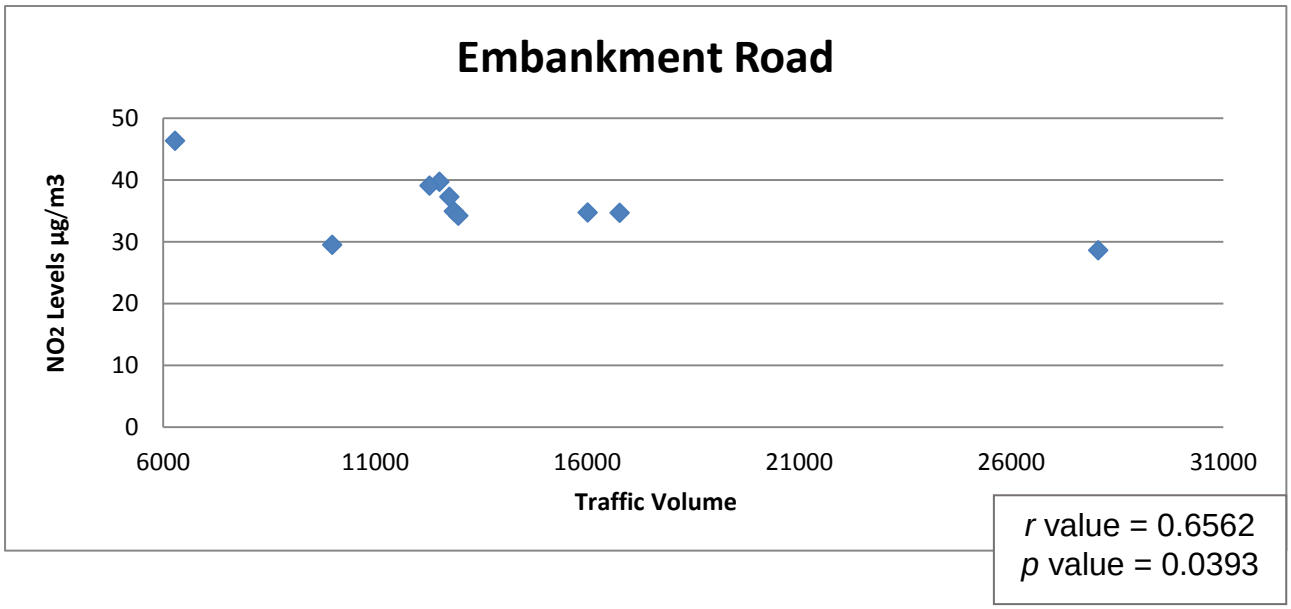

Figure 10.2. Traffic volume plotted against NO_2 concentrations (Embankment Rd)

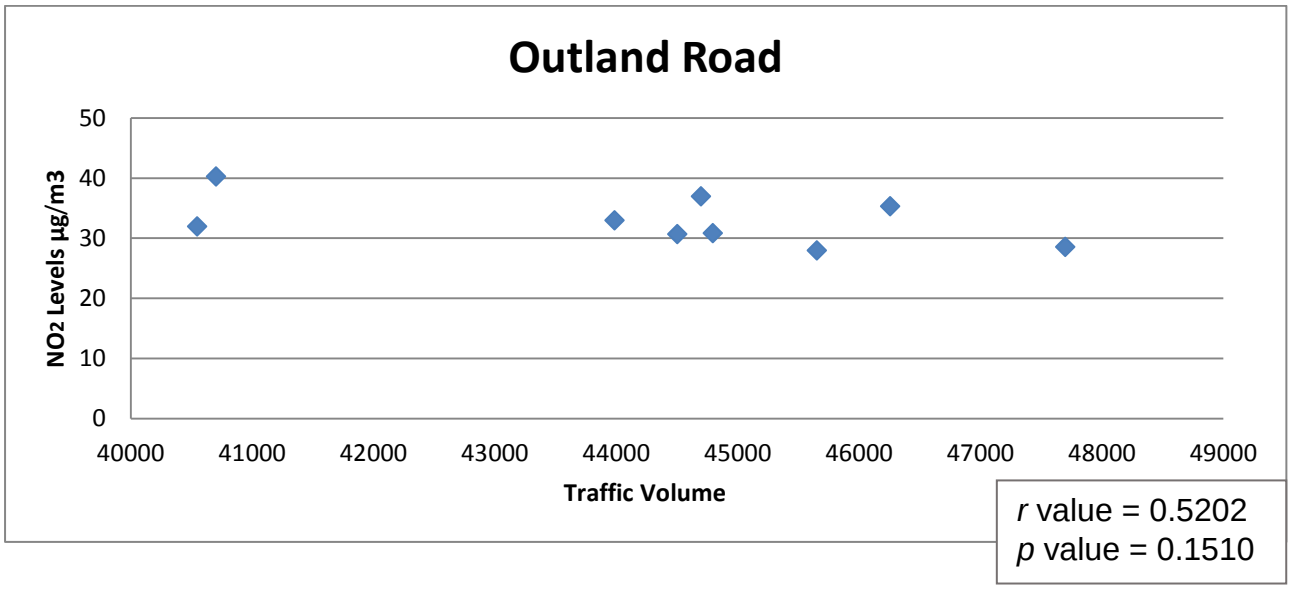

Figure 10.3. Traffic volume plotted against NO_2 concentrations (Outland Rd)

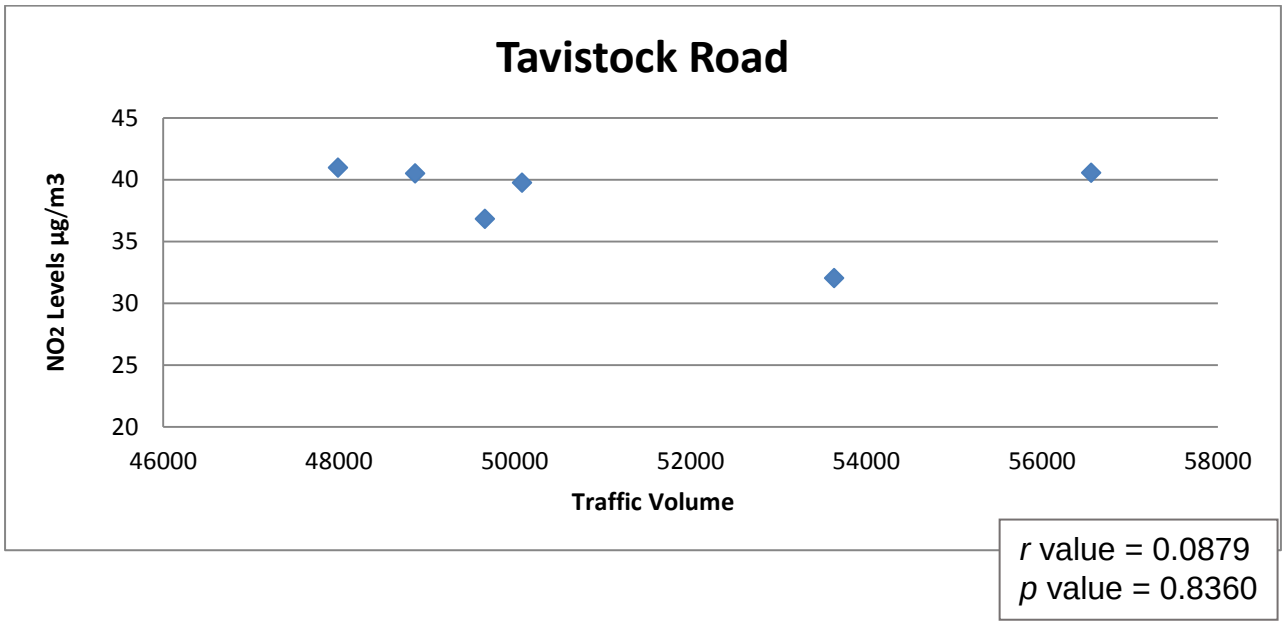

Figure 10.4. Traffic volume plotted against NO_2 concentrations (Tavistock Rd)

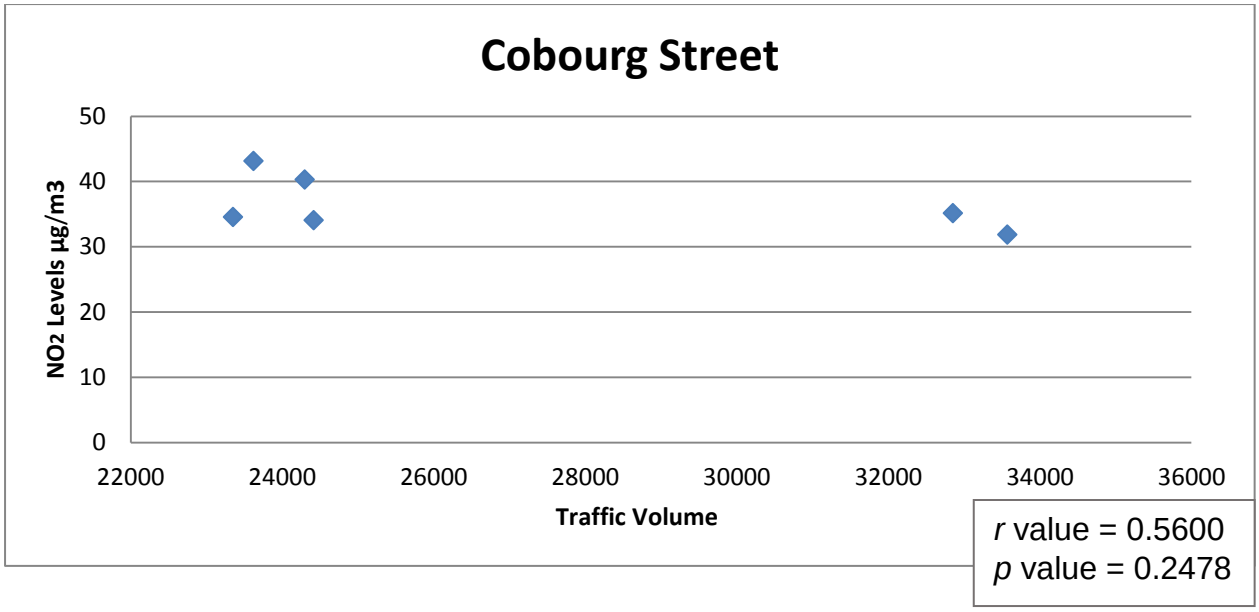

Figure 10.5. Traffic volume plotted against NO_2 concentrations (Cobourg St)

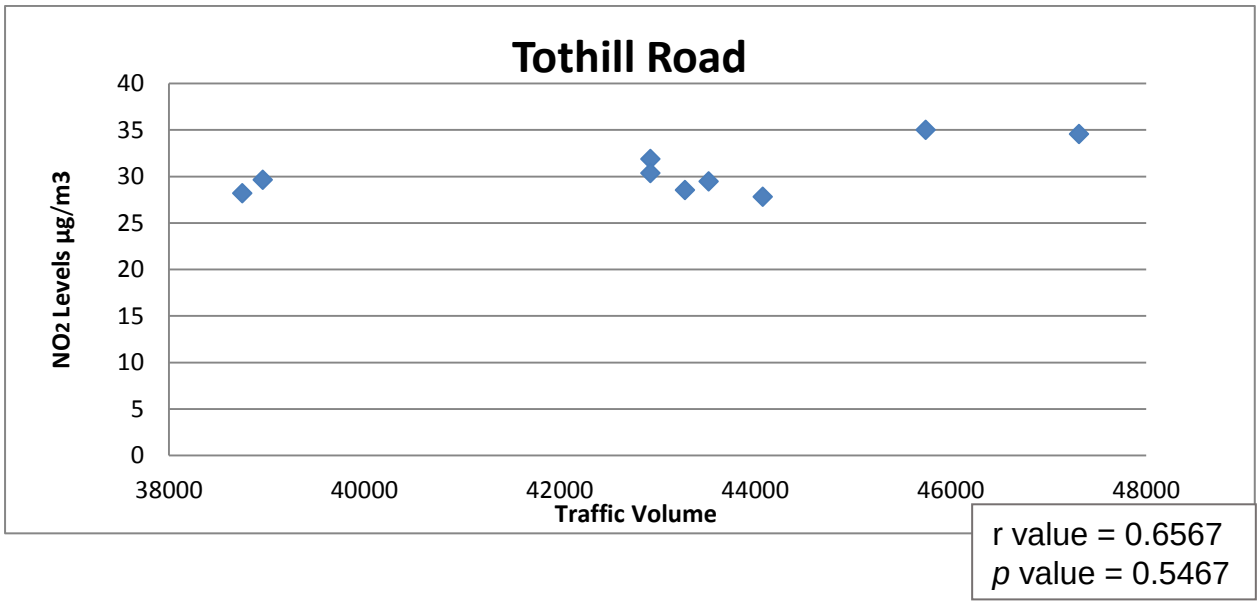

Figure 10.6. Traffic volume plotted against NO_2 concentrations (Tothill Rd)

10.5.2. Traffic Vs NO_2 Levels Summary

When taken together, *Figure 10.1 – 10.*6 show no clear trend between traffic volume and NO_2 levels. *Figure 10.6* '*Tothil Road'* contains 9 observations and illustrates increased traffic volume corresponding with elevated NO_2 levels. However, statistical analysis shows this not to be statistically significant. *Figure 10.2* '*Embankment Road*' presents the largest disparity in traffic volume between 2003 - 2013 with the highest count 3.5 times higher than the lowest, which may indicate significant development/change in relation to Embankment Road, although not cited in the Plymouth City Council reports from 2004 – 2014. '*Embankment Road'* contains 10 observations presenting a *p* value of 0.0393 indicating a significant inverse correlation between high density traffic and NO_2 levels. This contradicts the general association between traffic density and NO_2, indicating other influential factors as noted by Richmond-Bryant *et al* (2018). Therefore, other variables are likely to be in occurrence influencing this data. Confounding factors may include for example, the relatively small number of observations, weather patterns year on year, development work in the area and potentially general NO_2 AQAP mitigation initiatives, as there is no are specific scheme related to Embankment Road.

10.6. NO_2 level Predictions

As mentioned above on review of the Plymouth City Council annual air quality reports, NO_2 predicted levels appeared to change year on year. An analysis was undertaken of the Plymouth City Council 2004 predictions for 2005 and 2010 NO_2 levels. 2005 and 2010, represent AQO achievement dates, as seen in *Chapter 2, Table 1*.

Table 11. NO_2 level Predictions

Site Predictions NO_2 (µg/m3), Actual Readings and Percentage Error							
Site	**Location**	**2004 Prediction for 2005**	**2005 Data**	**Percentage Error**	**2004 Prediction for 2010**	**2010 Data**	**Percentage Error**
4	**Mariners Court**	33.87	31.31	**8.17%**	29.02	35.49	**-18.23%**
5	**Charles Cross**	**41.62**	36.31	**14.62%**	35.65	**45.99**	**-22.48%**
6	**Exeter Street Flats**	**40.11**	**41.48**	**-3.30%**	34.37	**44.03**	**-21.93%**
7	**St Judes Road**	33.64	30.51	**10.25%**	28.83	38.67	**-25.44%**
8	**Tothill Road**	32.66	28.53	**14.47%**	27.98	35	**-20.05%**
9	**212a Exeter Street**	**43.25**	35.29	**22.55%**	37.06	**41.87**	**-11.48%**
10	**48 Embankment Road**	37.4	**42.13**	**-11.22%**	32.04	**49.71**	**-35.56%**
12	**Embankment Road (Portokabin)**	29.15	26.01	**12.07%**	24.98	39.33	**-36.48%**
17	**Outland Road**	33.97	28.02	**21.23%**	29.11	**40.3**	**-27.76%**
19	**Pennycomequick (flats)**	34.87	37.6	**-7.26%**	29.88	39.65	**-24.64%**
20	**Caprera place**	35.89	37	**-3.00%**	30.75	38.14	**-19.37%**
21	**Hyde Park**	29.64	34.35	**-13.71%**	N/A	**41.45**	N/A
22	**Connells Mutley**	36.35	38.41	**-5.36%**	31.14	**41.29**	**-24.58%**
24	**140 North Hill**	32.71	35.94	**-8.98%**	28.02	38.39	**-27.01%**
25	**14a Mutley Plain**	**48.29**	**47.41**	**1.85%**	**41.38**	**51.19**	**-19.16%**
31	**AURN 1**	25.54	N/A	N/A	21.89	32.19	**-31.99%**
32	**AURN 2**	25.67	N/A	N/A	21.99	32.86	**-33.07%**
33	**AURN 3**	24.47	N/A	N/A	20.97	32.11	**-34.69%**
		Average		**3.49%**	**Average**		**-25.52%**

Table 11. NO_2 level Predictions Summary

Table 11, presents as a percentage the accuracy of Plymouth City Council predictions of future NO_2 levels in the City. Figures highlighted in red indicate readings which breached the NO_2 AQS. *Table 11*, shows in 2004 Plymouth City Council had an average error margin, over estimating NO_2 levels for 2005 by 3.49%, presenting a high level of confidence in the prediction. However, the 2010 predictions indicate a much larger negative error margin with an average under estimation in NO_2 levels of -25.52%. This may be a result of the prediction being made over a more prolonged length of time and therefore a greater number of variables in occurrence. This may also explain the continual change in predicted NO_2 levels in Plymouth City Council annual air quality reports, indicating that as the variables incurred by time decrease, accuracy increases.

11.0 Discussion

Appraisal of the Plymouth City Council air quality reports concluded the 2003 ‘Vision for Plymouth’ did not consider air quality despite LAQM implementation in 1997. This may have been a result of the perception by Plymouth City Council that air quality was not a cause for concern, evident in the initial statement of the 2004 air quality report. This perception has been contradicted by LAQM numerical data, necessitating the need for a city wide AQMA. However, now two decades on from the implementation of LAQM, the air quality issues in Plymouth have been acknowledged, but have yet to be remediated in their entirety.

Only touched upon in this report is the seemingly open manipulation of air quality data through the removal of anomalies and the alternation of adjustment factors year on year providing the results best suiting the local authority. Anomalies are scarcely addressed throughout the Plymouth City Council reports. However, they do contain all 3 types of data sets from 2004 – 2014: non-bias, local bias adjusted, and national bias adjusted. The results of which formulate two counter arguments in relation to the statistical significance of the Stage II vapour recovery unit fitted to reduce C_6H_6 levels at the petrol station. However, less apparent was the absent acknowledgement of a perceived and potential future issue at Union and Cobourg Street in Plymouth. This in conjunction with the AQMA and location discrepancies warrants speculation over the appraisal of the LAQM reports by local and central government.

On review of monitoring in Plymouth it is noted a critical theme in any data set is the reference point. Queries were raised over the positioning of the AURN and Exeter Street PM monitoring units located further from the road side than residential dwellings. The AURN site, when considered in isolation, provides a historically inaccurate representation of air pollution levels in the city. Perhaps triangulation, utilising other sites more representative of persons living and working environmental proximity to air pollution produced by transportation emission would provide a more accurate depiction of PM and NO_2 exposure. This would require remediation of the LAQM framework.

The evaluation process in general for air quality in the absence of documented procedures seems heavily based on perception and, to some extent, the word of private sector companies which as stated in *Chapter 2*, in relation to the emissions scandal, is not the most reliable source of information. The absence of sound statistical data from internal and external bodies resulted in a misinterpretation of air quality in the city, delaying or inhibiting action in relation to emissions produced by buses and shipping.

The evaluation of air pollution sources, as part of the LAQM system noted the selective acknowledgment of known air pollutants such as, Radon, O_3 and $PM_{2.5}$. Alongside this, undefined evaluation processes used to determine fuel burning in the city and a lack of review/auditing of train operator's adherence to guidance raises concerns again over internal governmental review of LAQM reports.

In relation to communication there has been evident effective communication by Plymouth City Council to address air quality issues such as: The installation of C_6H_6 stage II vapour recovery unit at a privately-owned petrol station without legal obligation. A cited discussion with the manager of Cattedown Wharves which resulted in product stored in a warehouse adjacent to housing being changed, alleviating dust nuisance complaints (Plymouth City Council, 2004). In addition to a marketing campaign acknowledging the links between air quality and exercise that created an acknowledged best practice initiative relating to cycling. However, there have been equally evident pitfalls; for example, consultation from the 2004 – 2014 Plymouth City Council reports appears to be predominantly in-house with subsequent restriction on information hindering the information and awareness initiative in the AQAP. The absent functions of Plymouth City Council to address the '*idler public'* from 2004 – 2014 and restrictions on public access to documentation relating to air quality is neither transparent nor representative of a public body. This failure may be contributing to headlines such as that in the Plymouth Herald '*Plymouth's polluted air too dangerous to breathe*' (Von Radowitz and Moor, 2017).

Furthermore, the information provided in the LAQM reports from 2004 – 2014 has been insufficient at times in relation to cryptic references to ports, creating a seeming reluctance to detail locations in the city with air quality issues. Data had been presented as complete and as showing no cause for concern when large streams of data have previously been stated to be missing and the 24hour AQS potentially breached without follow up. In addition to failing to evaluate areas such as *Port 2* by the 2014 report, with the present status unknown.

Construction throughout the city in line with the ‘Vision for Plymouth’ has subsequently been supplemented with a guidance document supplied to developers when planning applications are submitted. However, there is no cited auditing of compliance. Significant infrastructure developments have also either been cited as authorised prior to LAQM with retrospective measures not assessed or not mentioned within the LAQM reports until the construction is completed. Neither aligning to Plymouth City Council’s CS22 Pollution Policy and statement of procedures. Additionally, an energy from waste plant is cited to have been constructed in the city but prior to approval the facility was cited in the LQMA report with a pictogram; this was mentioned because no other development in the reports accompanied such imagery, perhaps indicating the council support for the development.

Further construction on the outskirts of Plymouth sees a possibly NIMBY approach taken by surrounding conurbations to problematic infrastructure. The contradictory LAQM reports also raise further concerns over the evaluation process with the word of colleagues at the neighbouring local authority accepted as evidence rather than scientifically validated data.

Plymouth City Council has accredited elevated levels of air quality in the city to construction work. The one statistically significant reduction in NO_2 occurs at a site outside of an AQMA. The assessment of AQAP initiatives established that no initiative cited in the AQAP 2008 and 2012 update has contributed to reducing air pollution in the city. The AQAP looks at a number of indirect resolutions to mitigate

air pollution issues in the city. Central government initiatives appear to be intertwined but not defined, such as the scrappage scheme and taxi licensing restrictions. Other initiatives appear short sighted; for example:

- The management of air quality through monitoring and emission testing, which is not management but rather observation.
- Tree planting, without reference to layout, species or location.
- Travel plans for only people located in AQMA despite the transient population through the AQAM potentially heavily influencing air quality.
- Traffic management, moving the issues elsewhere.
- Delivery restrictions, subsequently removed from the updated AQAP.

Notably, the Green Council Fleet initiative, replacing diesel and petrol with electric vehicles, which will reduce roadside emission to some extent but at the expense of increased emission during manufacturing and their perceived ‘Green’ image is dependent upon their fuel source. If the electric is generated by unsustainable fossil fuels or energy from waste plants the emissions are moved from the consumer, to the producer. This is relevant to Plymouth because a producer the energy from waste power plant and a fossil-fuel power station (at Langage), lies on the edge of the city boundary. Furthermore, PM remains an issue for electric vehicles in relation to brake pads and tyre wear.

LAQM has effectively required local authorities to monitor and acknowledge key air pollutants. However, there are shortfalls in the Plymouth City Council parameters of recognition. The extent of NO_2 issues throughout the UK and Plymouth are well documented and evident in *Chapters 1 and 2*, highlighting that the problem is not

localised and requires central government initiatives. LAQM had statistically significantly reduced C_6H_6 at a petrol station in Plymouth, dependent upon the data set utilised. Plymouth City Council PM monitoring seems limited considering many sources of NO_2 are the same for PM. Additionally, monitoring has predominantly been initiated in response to complaints, highlighting a reactive culture rather than proactive. Furthermore, the Exeter Street monitoring site's location is more comparable with the city centre background AURN position than other roadside sites. The AQAP has had no acknowledgeable impact on air pollution in the city. The effects of the AQAP were not hidden by influential factors such as traffic volume and weather. As the 2013 review showed, neither significantly impacted NO_2 level to the detriment of air quality in Plymouth. The failures noted in the performance of LAQM do not appear to have been addressed, or the strategy revised to ensure remediation and continual improvement.

12.0. Recommendations

- Prescriptive guidance where possible in LAQM to prevent inconsistences

- A review of central government's appraisal of LAQM reports to ensure criteria are being met, actions elaborated upon and that there is continual development

- A central government initiative to address the national issue of NO_2 levels

- A switch when possible from variable perceptions as a form of evaluation within a local authority to verifiable numerical data

- Consistent and justified adjustment calculations when recording air quality levels to providing reliable and more accurate data sets and long-term predictions

- AQAPs that not only serve the purpose of actively reducing air pollution but also present sufficient detail to explain how the initiative will improve air quality

- Consideration of air quality in all aspects of local authority duties to ensure a holistic approach to the management and remediation of air pollution

- Auditing of private sector functions that have the potential to impact air quality to ensure remedial measures are adhered and unforeseen influential factors have not arisen

Chapter 4

Conclusion of Literature Review and Case Study

13.0. Conclusion

The previous chapters have described the rationale for this research with the literature generated by other researchers on LAQM consolidated in *Chapter 2*. *Chapter 3* builds upon the outcome of *Chapter 2* with a selection of local governmental reports explored and presented to address the research question, '*What impact has Local Air Quality Management had on air quality?*'. The research methodology has been explained and the findings presented accordingly.

In this concluding summary findings from *Chapters 2* and *3* will be discussed, alongside an account of the contribution that this work brings to the Environmental, Health and Safety profession. Furthermore, the limitations of the literature review and documentary analysis will be discussed, with recommendations for future research.

The use of a realist perspective as indicated by Benton and Craib (2011: p36) provided a 'common sense' approach to the complex subject matter of air pollution and management. The systematic literature review highlighted areas of policy and implementation perceived to be pertinent by those in local authority. This thesis adds a 'realist' approach to what is actually happening in practice. Through the case study analysis, it has been possible to gain a deeper understanding of the way the local air quality management framework is implemented, including the potential constraints and challenges local authorities encounter. This methodical approach has wider applications to other areas of environmental health.

13.1. Chapter two and three Synopsis

Thirteen key themes identified in *Chapters 2* and *3* were: Management; Politics: Conflicts and Competing Interests; Air Quality Objectives/Standards; Consultation Process; Intergovernmental Communication; Public Communication; O_3/Climate Change; Air Quality Action Plans; European Union; Monitoring; Benzene (C_6H_6); Particulate Matter (PM) and Planning and Development. These highlight influential factors impacting the success of LAQM.

There have been noted advancement in reducing the administration burden of LAQM as noted in *Chapter 2* and *3*. However, the numerous noted issues with the *management* and inconsistence relating to non-prescriptive guidance raised in *Chapter 2* and *3* are likely to have contributed to the breach in AQOs in 2005 and 2010. These same shortfalls were subsequently highlighted in the data found in the case study, their continuation suggests their likely reoccurrence with the impending 2020 AQOs.

Chapter 2 noted the established theory that weather influences air pollution concentration. However, the results in *Chapter 3* relating to NO_2 levels in comparison to temperature, wind and rainfall defy this common perception. This is most likely not the result of a flawed scientific theory but the skewed results provided by background sites such as the AURN on NO_2 concentrations. In turn, validating the need to step away from utilising these monitoring sites in isolation and adopting a method of triangulation providing a less fictitious representation of air pollution.

The political influences mentioned in *Chapter 2* are apparent in *Chapter 3* with an elusive shipping evaluation, retrospective monitoring following a previous undisclosed development and a social-economic trade for Mackay's vision at the expense of public and environmental health. Furthermore, the sound scientific basis of LAQM is scrutinised as political manipulation of data stated in *Chapter 2* appears validated with inconsistences in bias adjustment factors utilised and extraction of perceived anomalies without justification in *Chapter 3*.

The relaxed AQOs put in place by the dissolved EPAQS and subsequently supported by the Air Quality Expert group's safety data sheets, have failed to be achieved in their entirety; evident with the empirical data provided in *Chapter 3*, *Table 8*. Absent legal obligations on local authorities to achieve AQOs was theorised to contribute to their non-attainment. However, the pending UK withdrawal from the EU will remove central government's imposed duties in relation to air quality and highly likely exacerbate this issue.

The consultation process is a legal requirement with central government guidance specifying that key stakeholders in public health issues such as air pollution should be consulted. Furthermore, public engagement is potentially a highly influential component to the success of LAQM enabling shared ownership. *Chapter 2* concluded that public consultation was widely undertaken in the UK. However, *Chapter 3* indicates that Plymouth City Council is not part of this majority, with the spectatorship role reduce further by restrictions place of access to information.

The case study on Plymouth City Council indicated discrepancies between central and local government initiatives and implementation, with key intergovernmental departments either disregarding air quality or only supporting monitoring of air pollutants rather than mitigation. AQAPs were suggested to fall short of their required purpose in *Chapter 2. Chapter 3* provided an example of best practise in relation to Plymouth City Council '*Pollution and Exercise*' initiative but subsequently validated the claim made in *Chapter 2* with little to no detail provided on other local initiative and an evident failure in statistically significantly reducing air pollution in over a decade. Furthermore, controversially *Chapter 3* provided an evident side step by a local authority seen in the actions of South Hams in positioning potentially problematic developments to the edge of their jurisdiction placing the air pollution burden on the neighbouring authority, Plymouth.

The LAQM framework seems theoretically a logical way to reduce air pollution at a local level. However, the findings from the case study fail to conclusively support this notion. The shortfall appears to be in the practical implementation and supporting management structure rather than the initiative or the actions of a single local authority.

13.2. Relevance to the Environmental, Health and Safety Profession

This research consolidates decades of studies on the subject of LAQM and provides the empirical data scarcely utilised in the sector to evaluate the impact this management system has had upon air quality. The research is timely in relation to

media coverage and political changes ahead and could be utilised as evidence to inform the review and revalidation of LAQM in the UK outside of the European Union.

13.4. Limitations

The external validity and thus credibility of this study is dependent on the governmental and University data sources utilised. While, interpretation was required in relation to matching traffic volume to corresponding monitoring sites, the same data sets were consistently used each year in the presented data and therefore the traffic increases are credible.

The literature review presented in *Chapter 2* represents a snap-shot in time of the body and age of work on the subject found in databases searches over the specified time-frame. Furthermore, the studies closely aligned to the issues identified from Plymouth City Council air quality reports in *Chapter 3*.

The *Chapter 3* case study reports run from 2004 – 2014. The 2015 report was unobtainable when research was initiated and the evolution of time prohibited continued sourcing of documentation and amendments from subsequent years. The case study is also specific to one region in England and is deemed by the researcher to represent a mainstream locality rural county with no significantly different terrain or industry in operation. There is different therefore the conventional implementation of LAQM. Transferability of the study is feasible due to the rigour employed in the

choice and application of the documentary analysis, the quantitative methods utilised and the research design; which demonstrates credibility.

Time was a constraint for this full time research project as the researcher moved mid investigation to the capital, away from the University of study and worked full time alongside the writing this paper. Additionally, the council that was the subject of the case study was not forthcoming with information, and a significant amount of time was consumed sourcing annual reports online through a less than user friendly council and governmental websites.

Retrospectively it was noted there were additional journals that published papers on LAQM. However, these journals were not accessible through the databases available to the researcher. Furthermore, only journals were used in the systematic review to present an up-to-date account of the LAQM framework that had been peer reviewed. Books where not used as a point of reference in the systematic review due to their tendency to present a singular viewpoint, the perceived age of information and the consolidation of material on LAQM under the spectrum of air pollution.

The weather data sourced from Plymouth University researcher Helen Nance and appraised under section 10.4. was recorded above 7m from ground level, therefore presenting a limitation in meteorological parameters of the dataset used to assess the impacts on the variability in NO_2. Furthermore, weather and traffic volume were reviewed within the case study to demonstrate there are variables impacting air pollution within Plymouth. The researcher chose to exclude the review of

transboundary air mass impacts and trajectories from the case study because of the limited scope of the project and the aim of the research being to assess the impact of LAQM rather than focusing significantly on the numerous influential factors.

On reflection these limitations were perhaps additional hindrances the researcher had to overcome during the development of this research project. In the researcher's opinion this thesis provides an insightful evaluation, and tangible empirical data to an Environmental, Health and Safety Management System currently in the spot light. This takes government requirements and examines the extent to which the required procedures related to air quality are assessed and reported in the research literature. More significantly, through the use of a case study methodology, the thesis demonstrates the reality of implementing LAQMs and the extent to which this has been effective.

14.0. Recommendations

Department for Environment, Food and Rural Affairs

- Implement an appraisal process which ensures feedback is adequate and acted upon by the local authority: Ensuring criteria is met, sound rationales are provided for action taken or not taken and to prevent the continuation of rectifiable air quality issues

Plymouth City Council

- Seek public feedback on LAQM

- Publicise the air quality issues in Plymouth rather than hide them

- Engage Plymouth University to look at initiatives to tackle air pollution in Plymouth – raising the profile of air quality

- Publicise the private sectors impact on air quality to shame them into action, along with neighbouring authorities

- Require every department within Plymouth City Council to consider and implement improvements to air quality into their actions or justify to the public why they did not

Future Researcher

- Establish the information which can be obtained from the data sources available withholding any opinion on the outcome. From this information establish the structure of the work. This will inhibit evolving tangents as research topics need to be on point and within a certain word count

14.1. Future Research

The insight this research project has provided into the impact of LAQM has highlighted further investigation is required in the following areas:

- A review of the impact leaving the EU has upon the UKs air quality

- An assessment of air quality funding allocation to determine if subsidies are granted on need or the quality of application

- An analysis of the benefits and challenges supportive legislative powers could bring to LAQM

- An appraisal of the feasibility and benefits of incorporating O_3 into LAQM

- A review of LAQM management reports submissions in lieu of the restricted public access and the pending UK withdrawal from the EU

- An evaluation into the practicality of local authorities incorporating O_3 into LAQM

- An assessment of the extent to which local authorities are placing controversial developments at the edge of their boundaries and reducing their air pollution burden at the expense of their neighbours

Appendix 1.

Causes of Air Pollution

What are the causes of air Pollution

Pollutant	Description and main UK sources	Potential effects on health/environment
Particulate Matter (PM-PM_{10} and $PM_{2.5}$)	Particulate Matter is generally categorised on the basis of the size of the particles (for example $PM_{2.5}$ is particles with a diameter of less than 2.5µm). PM is made up of a wide range of materials and arise from a variety of sources. Concentrations of PM comprise primary particles emitted directly into the atmosphere from combustion sources and secondary particles formed by chemical reactions in the air. PM derives from both human-made and natural sources (such as sea spray and Saharan dust). In the UK the biggest human-made sources are stationary fuel combustion and transport. Road transport gives rise to primary particles from engine emissions, tyre and brake wear and other non-exhaust emissions. Other primary sources include quarrying, construction and non-road mobile sources. Secondary PM is formed from emissions of ammonia, sulphur dioxide and oxides of nitrogen as well as from	Both short-term and long-term exposure to ambient levels of PM are consistently associated with respiratory and cardiovascular illness and mortality as well as other ill-health effects. The associations are believed to be causal. It is not currently possible to discern a threshold concentration below which there are no effects on the whole population's health. PM10 roughly equates to the mass of particles less than 10 micrometres in diameter that are likely to be inhaled into the thoracic region of the respiratory tract. Recent reviews by WHO and Committee on the Medical Effects of Air Pollutants (COMEAP) have suggested exposure to a finer fraction of particles ($PM_{2.5}$, which typically make up around two thirds of PM_{10} emissions and concentrations) give a stronger association with the observed ill-health effects, but also warn that there is evidence that the

	emissions of organic compounds from both combustion sources and vegetation.	coarse fraction between (PM_{10} – $PM_{2.5}$) also has some effects on health.
Oxides of nitrogen (NO_x)	All combustion processes in air produce oxides of nitrogen (NO_x). Nitrogen dioxide (NO_2) and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NO_x. Road transport is the main source, followed by the electricity supply industry and other industrial and commercial sectors.	NO_2 is associated with adverse effects on human health. At high levels NO_2 causes inflammation of the airways. Long term exposure may affect lung function and respiratory symptoms. NO_2 also enhances the response to allergens in sensitive individuals. High levels of NO_x can have an adverse effect on vegetation, including leaf or needle damage and reduced growth. Deposition of pollutants derived from NO_x emissions contribute to acidification and/or eutrophication of sensitive habitats leading to loss of biodiversity, often at locations far removed from the original emissions. NO_x also contributes to the formation of secondary particles and ground level ozone, both of which are associated with ill-health effects. Ozone also damages vegetation.
Ozone (O_3)	Ozone is not emitted directly from any human-made source. It arises from chemical reactions between various air pollutants, primarily NO_x and Volatile Organic Compounds (VOCs), initiated by strong sunlight. Formation can take place over several hours or days and may have arisen from	Exposure to high concentrations may cause irritation to eyes and nose. Very high levels can damage airways leading to inflammatory reactions. Ozone reduces lung function and increases incidence of respiratory symptoms, respiratory hospital admissions and mortality. Ground level ozone can also cause

	emissions many hundreds, or even thousands of kilometres away.	damage to many plant species leading to loss of yield and quality of crops, damage to forests and impacts on biodiversity.
Sulphur dioxide (SO_2)	UK emissions are dominated by combustion of fuels containing sulphur, such as coal and heavy oils by power stations and refineries. In some parts of the UK, notably Northern Ireland, coal for domestic use is a significant source.	Causes constriction of the airways of the lung. This effect is particularly likely to occur in people suffering from asthma and chronic lung disease. Precursor to secondary PM and therefore contributes to the ill-health effects caused by PM_{10} and $PM_{2.5}$. Potential damage to ecosystems at high levels, including degradation of chlorophyll, reduced photosynthesis, raised respiration rates and changes in protein metabolism. Deposition of pollution derived from SO_2 emissions contribute to acidification of soils and waters and subsequent loss of biodiversity, often at locations far removed from the original emissions.
Polycyclic aromatic hydrocarbons (PAHs)	There are many different PAHs emanating from a variety of sources. This strategy uses benzo[a]pyrene (B[a]P) as a marker for the most hazardous PAHs. The main sources of B[a]P in the UK are domestic coal and wood burning, fires (eg accidental fires, bonfires, forest fires, etc), and industrial processes such as coke production. Road transport is the largest source for total PAHs, but this source is dominated by species thought to be	Studies of occupational exposure to PAHs have shown an increased incidence of tumours of the lung, skin and possibly bladder and other sites. Lung cancer is most obviously linked to exposure to PAHs through inhaled air. Individual PAHs vary in their ability to induce tumours in animals or humans. The carcinogenic potency of some PAHs is unknown or uncertain. Individual PAHs have been classified by the International Agency

	less hazardous than B[a]P.	for Research on Cancer, with three classified as "probably carcinogenic to humans", including B[a]P, and three classified as "possibly carcinogenic to humans".
Benzene	Has a variety of sources, but primarily arises from domestic and industrial combustion and road transport.	Benzene is a recognised human carcinogen which attacks the genetic material and, as such, no absolutely safe level can be specified in ambient air. Studies in workers exposed to high levels have shown an excessive risk of leukaemia.
1,3-butadiene	Mainly from combustion of petrol. Motor vehicles and other machinery are the dominant sources, but it is also emitted from some processes, such as production of synthetic rubber for tyres.	1,3-butadiene is also a recognised genotoxic human carcinogen, as such, no absolutely safe level can be specified in ambient air. The health effect of most concern is the induction of cancer of the lymphoid system and blood–forming tissues, lymphoma and leukaemia.
Carbon monoxide (CO)	Formed from incomplete combustion of carbon containing fuels. The largest source is road transport, with residential and industrial combustion making significant contributions.	Substantially reduces capacity of the blood to carry oxygen to the body's tissues and blocks important biochemical reactions in cells. People with existing diseases which affect delivery of oxygen to the heart or brain, such as angina, are at particular risk.
Lead (Pb)	Emitted from the combustion of coal and also the iron and steel combustion and nonferrous metals.	Exposure to high levels in air may result in toxic biochemical effects which have adverse effects on the kidneys, gastrointestinal tract, the joints and reproductive

		systems, and acute or chronic damage to the nervous system. Affects intellectual development in young children.
Ammonia	Mainly derived from agriculture, primarily livestock manure/slurry management and fertilisers. Small proportion derived from variety of sources including transport and waste disposal.	Ammonia can lead to damage of terrestrial and aquatic ecosystems through deposition of eutrophying pollutants and through acidifying pollutants. Precursor to secondary PM and therefore contributes to the ill-health effects caused by PM_{10} and $PM_{2.5}$.

(Department for Environment, Food and Rural Affairs, 2011)

Appendix 2

Table 4. Excluded studies

Author	Study Title	Study type	Reason
Beverland *et al,* 2000	Effect of long-range transport on local PM [sub 10] concentrations in the UK	- Descriptive, cause and effect of secondary data analysis.	- The paper examines the distribution of particulate matter and distribution from 1992-96. Data that is excluded from this review.

Fisher *et al*, 2001	The designation of fuzzy air quality management areas	- Analytical review through secondary data analysis.	- The document looks at boundaries of AQMAs and software interpretation when designating a zone. Review of the paper shows know reference to how boundary marks influence air pollution levels.
Gegisian *et al,* 2006	Environmental justice consequences of the UK's Local Air Quality Management (LAQM) system	- Analytical, cause and effect secondary analysis.	- The paper looks at the relation between deprivation and environmental quality rather than the effectiveness of air quality management to tackle air pollution in the UK.

Gegisian *et al*, 2005	preliminary investigation of local air quality management and environmental justice in England and Wales	- Analytical review through secondary analysis.	- The paper reviews social equality and links to exposure of air pollution. This does not meet the objective set out for this systematic review.
Leksmono *et al*, 2004	An assessment of the contribution of industrial emission sources to the declaration of an Air Quality Management Area in England and Wales	- Analytical review through secondary analysis.	- This project looks at AQMAs in relation to industrial emission rather than transportation.

McKean-Cowdin *et al*, 2009	Ambient air pollution and brain cancer mortality	- Analytical review through secondary analysis.	- The paper specifically investigates the implications of air pollution on public health (brain cancer). Although, the public health implications of air pollution are relevant to AQMAs the narrow field of the document does not address the objective of this review.
Winiwarter *et al*, 2009	Quality considerations of European PM emission inventories	- Analytical review through secondary analysis.	- The paper reviews particulate matter in detail of measurement, source, type and overall mass. While particulate matter is a reviewed pollutant relating to AQMAs, this analysis of detail fails to address the objective of this paper.

Kelly and Kelly, 2009	London air quality: a real-world experiment in progress.		- Article only.
Chatterton, 2015	European Union Air Quality Policies Framework Contract.		- No peer-reviewed publications from research.
Chatterton, 2005	INTEGAIRE - Integrated Urban Governance and Air Quality Management in Europe		- 2005, journal paper not sourced. Contacted research connection, no response (emailed 12/11/2016).

Chatterton, 2012	Appraisal of Greater London Authority Planning Applications for Air Quality Considerations		- 2012, journal paper not sourced. Contacted research connection, no response (emailed 12/11/2016).

Appendix 3.

Table 5. Thematic Tabulated Analysis

Document	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	Summery	Two areas requiring assessment?	+/- 25% accuracy on diffusion tube readings.
	1.0.	Site content described but not site location.	Indication of exceedance of AQO C_6H_6. Reviewed for another 12 months.
	1.1.		2005 AQMA for NO_2 at 2 sites.
	1.2.	'*if any*'	PM_{10} requiring review at two sites which involve the loading and unloading of dusty cargo.
	2.1.	Consultation, discussion, meeting minutes and attendees not provided.	'*It is necessary to assess which pollutants, if any, will exceed the prescribed objectives*'
		'*not considered significant*'	Checklist for pollutant conducted.

			Consultation at air quality focus group. Terminals not considered a significant source of C_6H_6 LAQM.TG but assessment advanced due to the close proximity to a school and busy road.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	2..3.	Months impacted upon not specified. Background readings to not account for hotspots. Date not stated as bias adjusted.	C_6H_6 data from AURN site missing due to water ingress. Site shows C_6H_6 levels below 2003 and 2010 AQOs. – No stated as bias adjusted.
	2.4.	Exeter Street considered busy but not Royal Parade with the same setup.	Error in co-location exercise. Depiction of Exeter Street busy, two bus lanes, four lanes of traffic.
	2.4.1.	Planning application for student accommodation not considered/mentioned.	C_6H_6 noted as a concern due to school
	2.5.	Prediction of future C_6H_6 levels based on abatement technology not fitted or expected to be as there is no legal requirement.	LAQM.TG 03 states no legal requirement to fit stage II vapour recovery at petrol station.

			Predictions for 2010 C_6H_6 levels based on vapour recovery unit being fitted.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	3.2.		C_6H_6 considered to be lower in winter months due to wind and high in summer as less dispersion.
			Bias adjusted data provided for NO_2.
	3.3.		2005 and 2010 prediction given.
	3.4.	Is any review of plaining application impacting on people's health in the area considered?	2003 co-location exercise errors for NO_2.
			Highest readings in winter months contradicting consultants advise.
	3.4.1.	What is considered an anomaly?	Error on graph
		Assumption not justified.	Mutley plain noted as an issue.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	3.4.1.	Future Declaration.	Finical constraints cited as impact upon monitoring equipment.
			Anomalies in data removed.
	3.5.1.		Worst case scenario used to reflect the assumed slightly order average age of cars in Devon.
	3.5.2.		
	3.7.3.		Financial constraints on monitoring.
			Modelling data underestimating prediction results.
			Predicted results for Embankment road indicate no need to declare an AQMA.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	3.9.		Two locations considered to breach NO_2 AQOs Exeter Street and Mutley Plain.
	4.2.		PM_{10} considered to be well within the AQOs due to AURN site readings. Subsequently site hotspots and docks in Plymouth.
	4.4.	Effective communication.	Plymouth City Council discussed with the manager of Cattedown Wharves who agreed to change the product stored in the warehouse directly adjust to the public house to alleviate dust nuisance. Persistent issue with dust noted at Victoria Wharves.
	4.5.		July 2003 Abatement noticed served at Victoria Wharves.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	4.5.1.		Victoria Wharves deemed to exceed the 24-hour objective for PM_{10} in 2004 by April when the report was produced.
	4.6.		Equipment installed in resident's garden to monitor issue at Victoria Wharves.

Documentation	Page/Section	Wording	Notes
Detailed Assessment of Air Quality in Plymouth – April 2004	5.0. Appendix 1.		No indication of annual mean breach at Victoria Wharves but some indication of 240hour objective. Monitoring tubes for NO_2 located above head height. And reviewed every four weeks.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth - April 2005	2.2.		Predictions for 2005 and 2010 NO_2
	2.3	Transport only related to NO_2?	C_6H_6 AQMA not considered related to transportation
		'Council has 12-18months'. Limit not a target.	Council has12-18 months to prepare action plan
	2.3.1.		Missing data from automatic monitoring site in Mutley plain
	2.4.	No reference is made to the surge in NO_2 levels at the site in 20/01/2004	Anomaly in data for AURN site in Sept 2004
	2.4.2		Monitoring data for automatic monitoring pump near the petrol station for C_6H_6 only working for a number of months

			Few results obtained for student accommodation and flats in 2004 Number of faults/breakdowns with automatic monitoring equipment at Victoria Wharves site – resulting in a significant loss of data.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth - April 2005	2.5.1.	'*Significant loss of data'*	
	3.0.	'*Statutory nuisance action underway*'	A number of complains continue to be received about – Victoria Wharves and statutory nuisance action is currently underway
	3.1.	Relevant exposure – people working in the area?	Landfill sites or quarries considered with relevant exposure and where planning permission has been granted
		'*has been granted'* retrospective action rather than proactive prior imputing in on planning permission	
	3.4.	Predominant wind direction – what happens when it changes?	Gas fire power station to be built in South Hams – wind direction, terrain and unlikely need of fuel oil, it is deemed to contribute to a small percentage of Plymouths long term NO_2 objectives

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth - April 2005	4.3.1.	Which prior document?	Referred to in a later updating and assessment and screening assessment – landfill extension to potentially increase PM_{10} emissions
	4.4.	Why is critical information not stated?	A386 Forecasted traffic growth – refer to draft alternative report and purpose of the alternative report
	4.5.1	33 sites current reported on	No new area of exposure identified
	4.5.3.	Train delays, trains held at platforms. What are the procedures?	Locomotives not stationary for 15minsutes
		'Modest increase… 11-14%'	Development proposals for Tavistock road result in a modest peak traffic range between 11-14%. Full impact of scheme not known until the end of 2006
	4.1.	How was this assessed?	Shipping – there has not been a significant increase in the number of

			shipping movements within Plymouth. Further details well be obtained at the next stage of review and assessment

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth - April 2005	4.3.1.	Vision for Plymouth resulting in traffic congestion	Vision result there is more traffic congestion in the city centre – transfer of traffic to minor routes – new diffusion tube sites identified – Royal Parade and Notte Street
	5.0.		Development 10,000 new homes in Plymouth
	5.1.		1500 new homes in Plymstock Quarry
	5.1.2.	‘*Significant transport implication’*	Sherford New Town on the edge on Plymouth 4500 new homes – significant transport implications for Plymouth
	5.2.	***‘Cause for concern’ action?***	Drake Circus to likely to significantly increase number of vehicles and HGV’s
			Number of developments on the Eastern side of the City a cause for concern

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth - April 2005	6.1.	Positive but details of interaction?	Significant interaction between transport and environmental health teams
	6.2.	Corrective action?	AQMAs to be formally declared in May 2005
	7.1.1.		Additional areas of concern for NO_2 outside proposed AQMAs – AQMAs predicted to breach 2010 AQOs
	7.1.3.	'*Significant loss of data*'	Intermittent problems with equipment… resulted in a significant loss of data PM_{10} – Victoria Wharves
	7.2.2.		Number of transport proposal likely to have an impact with the current AQMA for Exeter Street
	7.3.	No recommendations	Development over the next 12years to impact significantly on NO_2 levels

Documentation	Page/Section	Wording	Notes
Updating and Screening Assessment of Air Quality in Plymouth – May 2006	1.2.	Large Navel port - shipping not seen as an issue to-date Issues only coming to light now?	Description of Plymouth – population about 250,000, largest city in the South West, prime tourist location and a large Navel port Plymouth City Council has carried out air quality monitoring in some form since the 1960s Monitors for sulphur dioxide, oxides of nitrogen and O_3 were installed 1992 and in 1997 the site become part of the Automatic Urban Network – AURN. Defra added carbon monoxide analyser and a TEOM particulate monitor. In 2002 a benzene C_6H_6 diffusion tube monitor was added to the site – background monitoring

Documentation	Page/Section	Wording	Notes
Updating and Screening Assessment of Air Quality in Plymouth – May 2006	2.2.	Details of consultation, when, what was said, attendees and outcome?	Consultation exercise was carried out at the air quality focus group meeting part of Deon Chief Officers
		Reference details not provided – How was this established?	
		Yet 2 NO_2 AQMAs and further areas on concern	No roads in Plymouth classified as 'Very busy'
	3.2.	NO_2 and C_6H_6 examples – sources of 1, 3-butadiene not provided	C_6H_6 AQMA difference in AURN levels
	3.7.	Lead is Cardiff used as an example of Plymouth	Reduction in fuel storage at depots threshold not specified
	4.1.	No exceedances of AQO by 2010	1, 3-butadiene background taken as overall levels –
	5.1.	Presumption	Lead concentration in Cardiff taken as an example of concentration in Plymouth

Documentation	Page/Section	Wording	Notes
Updating and Screening Assessment of Air Quality in Plymouth – May 2006	6.1.		2010 prediction for NO_2 within AQOs
			No exceedance of the NO_2 1 hour mean in Exeter street based on the context there hasn't been one anywhere else monitored
	6.5.		No busy street in Plymouth were people spend more than 1 hour close to traffic
			Royal Parade bus stops, dwelling above shops and open shop fronts, Mutley Plain, bars, coffee shops and restaurants line the street?
	6.6.		No high flow of HGV and buses based on local knowledge
	7.5.	'*Based on local knowledge"*? – Royal parade	Bus movements below 1000 movements no relevant exposure within 10m

Documentation	Page/Section	Wording	Notes
Updating and Screening Assessment of Air Quality in Plymouth – May 2006	7.7	Based on previous assessment?	Screening assessment in 2003 reviewed a 500m^2 area concluding coal burning at less than a 100-houses – no changes
		Shop workers and dwelling lining Royal Parade	
	8.1.	500m^2 review representative?	3 shipping areas within Plymouth were considered – no potential problems
		Alternative measures?	
	8.3.	How do you know conditions have not changed without further review?	Significant losses of data at Victoria Wharves – 2003-2005 25, 72 & 100 days
	8.5.	How was this considered?	No busy road and Junction in Scotland
			No Road with 20% HGV's or buses in Plymouth – based on recent traffic data & local knowledge
	8.8.	Scotland?	

		Interpretation or data basis of evaluation? Royal Parade lined with bus stops. Majority is not all busy route intertwined to this street. Hot spots not considered?	PM_{10} levels based on background readings

RDocument	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	Summery		Significant regeneration at present impacting on traffic.
	p2, Section 1.1.		No further monitoring outside of AQMA required.
	p3, 2.1.		Back ground NO_2 decreased from 2003 -2006.
	p4, 2.2.		33 sites currently monitored. 15 within AQMAs.
	p5, 2.2.	No corrective action cited	Predictions made for 2010 NO_2
	p6, 2.2.	Contradiction to previous reports	'*Royal Parade is a busy slow-moving road with a high proportion of buses'.*
	p6, 2.3.1		Royal Parade Monitoring tubes stolen.

			Mutley Plain Shop refurbishment caused continuous analyser to be removed. New site found awaiting installation.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p9, 2.3.2.		2010 predictions confirm requirement for an AQMA for NO_2 in Mutley Plain.
	p10 2.4.1.		Embankment Predicted 2010 breach of AQOs, no AQMA mentioned for area.
	p11, 2.4.1.		Monitoring now commenced for C_6H_6 on student accommodation now occupied next to petrol station.
	p13, 2.4.1.		April 2004 Plymouth City Council AQMA statement in Exeter Street for C_6H_6.
	p14, 2.4.3		2005 and 2006 annual C_6H_6 levels for Exeter Street.
	p14, 2.5.	No detail given on how Plymouth City Council arranged the installation of the vapour recovery system.	C_6H_6 stage II vapour recovery system fitted at AQMA site.

	.	Presumption	‘it is apparent the concentrations of PM_{10} in Plymouth are well within the air quality objectives’ This is based on the low levels recorded at the AURN site… low levels also recorded for NO_2 at AURN site.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p15, 2.5.1.	Detail?	'A number of statutory nuisance actions has been taken with a number of successful prosecutions for breaching the abatement notice' – Victoria Wharves.
	p16, 2.5.1.		Large quantities of lost data due to a number of equipment failures. Owner of property subsequently requested the removal of monitoring equipment for their property – Victoria Wharves. Company significantly improved their environmental impact and have been prosecuted for dust nuisance. – Victoria Wharves. Different location indicated as source of PM_{10} but disregarded due to a change in product. New complaints caused

		Ambiguous – why is the location not given?	monitoring to commence at the location.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p16, 3.1.		Permission granted for gas fired power station in devouring district – South Hams. Planning conditions being reviewed by the Environmental Agency for A1 Permit
			Due to wind direction, nature of terrain and highly unlikely situation of using fuel oil for in excess of 250 hours per annum – Plant deemed to contribute to a small percentage of long term NO_2 objectives.
			7 dry cleaning and 2 for metal surface cleaning applications granted – deemed to '*not have any impact on emissions*''
	p17, 3.3.		Mackey's Vision for Plymouth considered through local development framework process in 2005.
	p18, 4.1.	Was Air Quality considered in this vision?	

		How many and what sites?	'*Consequence*' some new diffusion tube monitoring locations have been identified.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p19, 4.3.1.		A386 Tavistock Road new road layout: preferred option to increase peak period traffic by 11-14% compared to 2010 base forecasts
			Tavistock Road monitoring subsequently started '*not showing any cause for concern'*.
	p20, 4.3.2.		Drake Circus/North Hill '*Planning permission was approved for this site a number of years ago, there is nothing that can be included to alter the effects on air quality*'
			Drake Circus sits just west of the current Exeter Street AQMA any likely impact will be assessed against existing monitoring
	p21, 4.5.3.	'*Any likely impact'*	Shipping – there has not been any significant increase in the number of

		How was this assessed?	shipping movements within Plymouth – Further details will be obtained at the next stage of review and assessment.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p21, 5.1.1.		Planning development for 1500 new homes in Plymstock Quarry.
	p22, 5.1.2.	Presumption	Large scale development planned on edge on Plymouth – Sherford 4500 new homes. Air currently has air quality concern due to lack of public exposure.
	p22, 5.2.		Drake circus to significantly increase the number of vehicles and HGVs from deliveries
	p23, 6.1. & 6.2.		Air Quality is a key theme of the Local Transport Plan (2).
		Anticipated not confirmed!	Action plan for two AQMAs anticipated to be included in the annual performance review of the Local Transport Plans.

			Draft Action plan for the three 2005 AQMAs submitted as a chapter of the Local Transport Plan (2).

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p24, 7.1.1.		Continuous analysers to be installed at both NO_2 AQMA.
	p24, 7.1.2.		C_6H_6-Stage II vapour recovery installation '*expected that levels will drop significantly'*.
	p25, 7.1.3.	Contradiction	PM_{10} – Victoria Wharves monitoring ceased in august 2006 annual mean met – significant loss of data, issued resolved – calculation '*not an expectable method*'
		Why is site not named?	Monitoring now to commence at another port where dusty cargoes are handled due to commence in June 2007.
	p25, 7.2.1.	What industrial processes? Why are they not listed?	A number of industrial processes were identified that have been authorised since the last review and assessment – found not to be considered significant in

			terms of their air quality impact – LAQM.TG03.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth 2007	p25, 7.2.2.		Developments likely to impact on Exeter Street AQMA. The A386 transport scheme is likely to impact on general NO_2 levels. Impact of Drake Circus to be examined in the fourth coming year
	p26, 7.3.	No recommendations made!	Recommendations - Progress report has identified a number of potential developments impacting on traffic and related emission in the next 12 months.

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008	Front Cover		Image of Royal Parade with numerous buses lining the street
	Summery	No detail given or direction of plans	Additional work is ongoing in relation to the action plan
	p4,1.		Guidance notes - Planning applications require close co-operation between planners and Environmental Health Officers
	p5, 2.1.		Monitoring for Carbon Monoxide and Sulphur Dioxide sated to have ceased at the AURN site in 2007
			35 sites monitored for NO_2 23 outside of AQMAs
	p6, 2.2.		High reading reported at Royal Parade, Tavistock Road and Moleworth Road

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008	P7, 2.2.	Royal Parade*, Tavistock road predicted but Moleworth Road first mentioned	Predicted breaches of the 2010 NO_2 AQO
	P8, 2.2.		Sites 34-39 chosen to represent relevant exposure
	p9, 2.3.1.	Contradiction to previous paper	Tube 38-39 are in a busy city centre location used predominantly by buses
	p12, 2.3.3.	Contradiction to previous paper	Loss of monitoring data due to stolen tubes in Mutley Plain – predicted breaches of 2010 AQO
	p16, 2.4.1.		Predicted breaches of 2010 AQO in Exeter Street
	p18, 2.4.2.		Stage two vapour recovery fitted in January 2007

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008	p19, 2.4.2.	Without legal backing, how was this made possible? No detail given	Result of reduction at St Theresa's House in C_6H_6 from 2005-2007 accredited vapour recovery system
	p20, 2.5.	Small reduction in 2005-2006 without system in place?	2010 prediction for C_6H_6 with vapour recovery in place
	p21, 3		PM_{10} now monitored on Exeter Street – exceeding 24hr mean
		What promoted monitoring previous papers indicated no issues?	Developments - Gas fired power station edge of Plymouth, permits granted for 7 dry cleaners and 2 metal surface cleaning processes, New residential developments considered minor, redevelopment of Millbay 1200 dwellings food and retail outlets
	p22, 4.1.1.		O_3 monitored since 1997 at AURN site – below AQO

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008			Radiation monitoring and odour monitoring first mentioned
	p23, 4.1.2.	Contradiction to previous paper	Complaint in 2007 relating to port activities deemed not to be a nuisance
	p24, 4.1.4.	Source LTP2!	Draft action plan summited as a chapter to LTP2?
	p24, 4.2.	Focus group details?	No regional or local air quality strategies – focus group meet regularly
	p24, 4.3.	Proactive but a fulltime job?	New planning developments are passed to EHOs to identify and comment on potential concerns
	p24, 4.4.	Reviewed by EHOs? Mitigation methods not given	

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008	p25-26, 4.5.		Strategic aim to include 10,000 new homes in area of Plymouth
	p26-27, 5.0.	On only one side of the city?	Implication for traffic in relation to Plymstock Quarry potential development and Sherford – significant implications. Millbay additionally to increase traffic impacting on Exeter Street
			NO_2 3 new area of concern
			Interim AQAP provided – detailed to be submitted in 2009
			AQAP – Increased priority for buses, cyclist and pedestrians along eastern corridor
			Tree planting in AQMAs

Documentation	Page/Section	Wording	Notes
Air Quality Progress Report for Plymouth – April 2008 submitted November 2008	p34-43, Appendix 5	Specifics, certain plants more suitable than others	Travel plans – encouragement
			Land use planning AAP reinforcing relationship between land-use planning and EHOs
		Review press releases – not presented as a cause for concern!!!	Information and awareness – press release
			Parking and delivery restrictions being considered
		Monitoring equipment is not management!	Management of hotspots – variable message sign to reduce congestion and monitoring equipment, modelling use to inform improvements in traffic management
			Taxi licensing policy proposed to adopt Euro III, IV AND V standards

			Review of cycling infrastructure
		Which press and what data?	Emissions testing publicised
		Applicable to a small number of vehicles	Greener council fleet

Documentation	Page/Section	Wording	Notes
2009 Air Quality Updating and Screening Assessment for Plymouth City Council – April 2009	Summery		Now referring to LAQM.TG 09
	p1, 1.1.		Description of Plymouth – massive regeneration project
	p3, 1.4.1.	Refers to earlier point raised	Guidance given to Plymouth Railway Station driver to turn off engines after 10mins stationary
	p6, 1.4.7.		AQMAs Predicted to exceed in 2005
	p8, 2.1.1.		AURN site has under gone refurbishment with new NO_2 and O_3 analysers installed and awaiting PM_{10} and $PM_{2.5}$ sampler
	p11, 2.1.2.	Automatic monitors for Exeter Street to be place in an odd location.	3 new automatic monitors to be installed within Plymouth

Documentation	Page/Section	Wording	Notes
2009 Air Quality Updating and Screening Assessment for Plymouth City Council – April 2009			55 sites now monitored for NO_2 in Plymouth
	p12, 2.1.3.	Review previous paper to see if monitored sites are shown	Confusion over reference to monitored site Exeter Street flats
			Royal Parade, Stoke village and Tavistock Road breaching AQOs
	p21, 3.1.3		C_6H_6 chart shows breaches but details not provided
			AURN used as a base line for other pollutant monitoring and Cardiff for Lead
	p26, 3.3.2.	Reliable source?	Bus company used as reference to number of bus movements

Documentation	Page/Section	Wording	Notes
2009 Air Quality Updating and Screening Assessment for Plymouth City Council – April 2009	p27-28, 3.4.4.-3.4.2.	If a threshold of 5000 movements is stated why is it not considered a potential issue – factored into previous reports?	Details provided on 3 shipping ports in the area – commercial, ferries and navel.
	p31, 4.7.	How was it determined there had been no significant changes?	While over 5000 movements per annum in the navel port alone – not deemed any potential issue – shipping emissions from the ports have been factored into previous reports – no significant change in shipping movements
	p33, 5.3.	Still possibility. How will be it reviewed?	Multi-fuelled stack power station in South Hams – models ran show some circumstances where it may lead to a breach of the EA guidance note H1. However, this is unlikely
			Biomass combustion application rejected
	p35, 61.1.	Individual perception presented as a form of evaluation	Domestic fuel burning review based on professional judgement

Documentation	Page/Section	Wording	Notes
2009 Air Quality Updating and Screening Assessment for Plymouth City Council – April 2009	p39, 7.1. p39, 7.3.		75% monitoring data is required for the AURN site Permits listed for industrial processes

Documentation	Page/Section	Wording	Notes
2009 Detailed Assessment of Nitrogen Dioxide for Plymouth City Council – April 2009	Summery		Issues at Royal Parade, Tavistock Road and Stoke Village
	p4, 2.2.		DA last done in 2004
	p7-8, 2.7.		Current AQMAs
	p8-9, 3.0.		Description of Plymouth
	p9-10, 4.0.		National sources of NO_2
	p12, 5.2.		55 NO_2 diffusion tube monitoring sites in Plymouth
	p14-27, 7.1.		Monitoring location of 3 key areas
	p27, 8.1.		Background levels of NO_2 in 3 key areas

Documentation	Page/Section	Wording	Notes
2009 Detailed Assessment of Nitrogen Dioxide for Plymouth City Council – April 2009	p28-31, 8.3.-8.5.		NO_2 raw data for 3 sites
	p32, 9.0.		Low data capture on diffusion tube
	p35-38, 12.1.-12.3.		Modelling details provided
	p39, 14.1.		Modelling perceived to be underestimating results in Royal Parade
	p14, 15.0.		Conclusion – consider AQAM in 3 key sites
	p41, 16.		Recommendation declare AQMA in 3 key sites

Documentation	Page/Section	Wording	Notes
2009 Detailed Assessment of Benzene for Plymouth City Council – April 2009	p2, 2.1.		Previous DA in 2004
	p3, 3.0.		Population growth to an estimated 255,000
	p5-6, 6.1.		C_6H_6 source described
			UK C_6H_6 levels shown
	p6-7, 6.2.		Local levels attributed to road traffic – other sources reviewed
	p8, 6.4.	AQMA site throughput of 5 million translates to 5000m3	Petrol Station deemed to have a significant throughput of over 1000m3 to legal oblige vapour recovery installation

Documentation	Page/Section	Wording	Notes
2009 Detailed Assessment of Benzene for Plymouth City Council – April 2009	p15, 7.3.		Raw data of C_6H_6 levels since 2003 – 2008 provided
			Projected decrease in level for 2009 and 2010
	p22, 8.0.	How was the installation of this unit agreed with the owner?	2007 drop in levels attributed to fitting of stage 2 vapour recovery
	p22, 9.0.		Recommendation- revoke C_6H_6 AQMA

Documentation	Page/Section	Wording	Notes
2010 Air Quality Progress Report – April 2011	Summary		NO_2 levels higher in 2010 than the last two years as a result of increased traffic levels anticipated to return to normal in November 2011
			33 sites monitored within AQMAs
			Now proposed AQMA and seven sites of concern outside of these
			C_6H_6AQMA revoked November 2010
	p1, 1.1.		Population growth
	p4, 1.1.	?	No exceedances outside of AQMAs
	p5, 1.1.		5 automatic monitoring sites and 72 diffusion tubes

Documentation	Page/Section	Wording	Notes
	p7, 2.2.4.		Alma Road site of automatic monitoring
	p10-11, 2.4.1.		2 proposed options for future AQMAs
	p15, 2.5.1.		AURN Shows increase in background NO_2
	p19-23, 2.5.3.		Diffusion tube data since 2005

Documentation	Page/Section	Wording	Notes
2010 Air Quality Progress Report – April 2011	p23, 2.5.3.		EET and gas main replacement possible cause for raise in NO_2 levels
	p26, 2.6.1.		From August 2010 NO_2 levels begin to raise breaching AQO
	p28-30, 2.7.		PM_{10} at Exeter Street automatic monitoring site breaching AQOs although 24-mean breached 35 times in 2009 and only 14 times in 2010
			PM2.5 below AQO at AURN site
	p31, 2.8.		Sept-Dec 2010 sees a breach in AQOs for C_6H_6 at St Theresa's House – overall levels below AQO
	p32, 2.9.	Why was this not shown before?	O_3 data provided – 2006-2008 breaches in AQO

Documentation	Page/Section	Wording	Notes
2010 Air Quality Progress Report – April 2011	p34, 2.1.0.	Assessment?	Energy from waste proposal for Plymouth – assessment shows no negative impact
	p28, 3.3.		No city-wide air quality strategy
	p41, 4.0.		Energy from waste plant illustration
	p42, 5.1.	Who judges acceptability?	Policy CS22 Pollution – no unacceptable developments permitted impacting on water and air quality
	p42-43, 6.0.		Vision for Plymouth by 2020 – 'Healthy'
	p43, 6.0**.**		Air Quality issue fully integrated into LTP
	p44, 7.1.		Transport improvement along Eastern and Northern corridor

Documentation	Page/Section	Wording	Notes
2010 Air Quality Progress Report – April 2011	p46, 7.4.-7.5. p47, 7.2. p48, 7.7. p50-64, 9.0.	Remediation methods? How?	LTP air quality not on target – traffic management effort on target 20 %reduction in O_3 by 2013 and continued reductions Action plan objective – Sees a <0.1-0.5 action measures with the 0.5 attributed to treatment of cause rather than mitigation methods

Documentation	Page/Section	Wording	Notes
2011 Air Quality Progress Report for Public Protection Service – April 2011	Report		Appear the same as the 2010 report bar one NO_2 reading Additional appendix documents

Documentation	Page/Section	Wording	Notes
2012 Updating and Screening Assessment – April 2012	Summery		NO_2 and PM_{10} exceedances traffic related
	p8, 1.1.		Growth in population
	p12, 1.5.		Proposed AQMA options still being reviewed
	p12, 1.6.		P.C.C making good progress with AQAP
	p14, 2.1.1.		AURN site noted as not being the worst-case exposure site
	p20, 2.2.1.		Data for 2007-2011 NO_2 shown
	p21, 2.2.1.		88% data capture considered acceptable

Documentation	Page/Section	Wording	Notes
2012 Updating and Screening Assessment – April 2012	p23, 2.2.1.		23 sites breaching AQO for NO_2 17 of which are within the proposed AQMAs
	p,24-32, 2.2.1.		Diffusion tube data for NO_2 2007-2011
	p33-34 ,2.2.1.1.		Tubes 41 and 43 deemed not to be a true representation due to EET
			Not all sites included in each proposed AQMA
	P34, 2.2.1.2.		2005 NO_2 AQMAs still exceeding AQO
	p36, 2.2.2.		PM_{10} breaches in Exeter street not a result of traffic volume but potentially vehicle journey times – comparisons made between 2009 and 2011

Documentation	Page/Section	Wording	Notes
2012 Updating and Screening Assessment – April 2012	p37, 2.2.2.		PM_{10} 24 hours mean data high – verification sought
	p38, 2.2.3.		C_6H_6 data 2007-2011
	p39, 2.2.5.1		$PM_{2.5}$ P.C.C. to contribute to a national 15% reduction
	p40, 2.2.5.2.		O_3 – 0 breaches in 2011
	p44, 3.5.2.	First mention!	Plymouth Life Centre opened – southern access – Outland Road and Alma Road monitoring use to access impact
	p44, 3.5.3.		400 new home to be built along airport link road – not considered to impact on Tavistock Road

Documentation	Page/Section	Wording	Notes
2012 Updating and Screening Assessment – April 2012	p45, 3.6.1.		EET affecting Gdynia Way
	p48, 5.1.1.	Proactive	Planning permission granted for waste plant – mitigation plan approved to reduce PM_{10} during construction
	p49, 5.1.1.2.	Evidence of assessment not sought?	South Hams Neighbouring council granted permission for ADD plant 6 mile from Plymouth boundary – consultation with South Hams colleagues established air quality in Plymouth not to be impacted
			Biomass boiler in Plymouth Life Centre
	p52, 6.2.		Monitoring sites locations and data – current and proposed AQAMs mapped – AQAP updates
	p53-92, Appendix		Traffic management of hotspots potential impact of 0.5-20 on NO_2

			Increased priority for buses, cyclist and pedestrians impact potential of 2-11 of NO_2

Documentation	Page/Section	Wording	Notes
2013 Detailed Assessment for Nitrogen Dioxide and Particulates (PM_{10}) – May 2014	Summary	Existing AQMA in Royal Parade? Proposed!	A single exceedance of NO_2 AQO in Cobourg Street outside of the existing AQMA in Royal Parade as a result of human error in relation to deployment PM_{10} exceedance on the limit in 2013 with 35 breaches of the 24hour mean as a result of the EET No predicted future exceedances for 2014 and 2018 in Cobourg, Union or Exeter Street. DA concludes a AQMA not required in Cobourg, Union or Exeter Street. But P.C.C. intend to declare a city-wide AQMA encompassing these areas Description of sites reviewed for DA

Documentation	Page/Section	Wording	Notes
2013 Detailed Assessment for Nitrogen Dioxide and Particulates (PM_{10}) – May 2014	p9-12, 2.1.-8.4.		Negligible impact on air quality from the construction on free Art School
	p13, 3.1.	Third part assessment? Mitigation of PM_{10} during construction?	Tube data for future exceedances for Cobourg, Union or Exeter Street. Union Street high reading presumably a result of over exposure
	p15-20, 4.1.-4.3.		Peaks in PM_{10} in 2012 and 2013 may be related to road works in Exeter Street
	p20, 4.1.		Prediction data presented for 3 streets
	p21, 5.1.		Receptor location for Cobourg Street few and located on only one side of the street
	p22, 5.2.2.		Modelling against background data – does not account for hot spots

Documentation	Page/Section	Wording	Notes
2013 Detailed Assessment for Nitrogen Dioxide and Particulates (PM_{10}) – May 2014	p22-29, 5.2.1-5.2.3.		Conclusion no predicted existences but all 3 streets will be included in AQMA
	p31-33, 6.1.-7.		Action plans to reduce traffic emissions
	p46, Appendix F	Why is this data not discussed?	Local background validation results show Union Street and Cobourg Street breaching AQO in 2014 and 2018.

Documentation	Page/Section	Wording	Notes
2014 Air Quality Progress Report – May 2014	p8, 1.1.		Description of local authority area
	p9, 1.4.1.		Progress report stated the need to declare a AQMA in Royal Parade, Stoke Village and Tavistock Road
	p14, 1.4.2.		Formal declaration of City-wide AQMA expected shortly - Defra to-date shows option 1 and 2 rather than formally declared AQMA - https://uk-air.defra.gov.uk/aqma/details?aqma_id=1059
			AURN site no longer monitors for O_3as of 2013
	p16, 2.1.1.	How do P.C.C account toward the national 15% reduction?	72 diffusion tube sites throughout site
	p19, 2.1.2.		Plymouth no longer monitors for C_6H_6

Documentation	Page/Section	Wording	Notes
2014 Air Quality Progress Report – May 2014	p26-35, 2.2.1.2.	Attributed too?	Monitoring data from 2008-2013
			Data shows a decrease in NO_2 at the majority of sites
			Multey Plain, Stoke Village and Royal; Parade continues to breach AQOs
	p41, 2.2.2.		PM_{10} data same as DA 2013 written at same time
	p45, 2.2.5.2**.**		O_3 breaches increase in 2012 and 2013. P.C.C. note and issue but as they are note required to ac, they have not taken any action
			Noted failure to comply with NO_2 and O_3
	p46, 2.2.6.		High breach of NO_2 in Royal Parade

Documentation	Page/Section	Wording	Notes
2014 Air Quality Progress Report – May 2014	p47, 2.2.6.	Based on what? Construction site not presented as exposure location but what about traffic to and from?	Home Park Football Ground large scale redevelopment application – deemed to present imperceptible to small increase in NO_2
	p49, 3.2.2.1.		Installation of new boiler at Derriford hospital – air quality assessment link invalid
			Air quality matters fully integrated into LTP dedicated chapter
	p50, 3.2.2.2.		Negotiating with operator of Energy from Waste Plant that the air quality monitoring program, required as part of planning permission is suitable
	p51, 2.		Policy CS22
	p53, 3.1.1.		Council creating new Strategy EHOs ensuring air quality is considered

Documentation	Page/Section	Wording	Notes
2014 Air Quality Progress Report – May 2014	p54, 4.	How?	Climate change strategies – reduce Plymouth carbon footprint by 30% by 2020
			Energy from waste plant becoming operational in 2014 will need review
	p56, 6.		Updates to AQAP – cycle training for council staff.
	p59, 8.2.		
	p83-92, E.2.		

Documentation	Page/Section	Wording	Notes
Local Transport Plan 2011-2026	p12	Implementation of remediation measure rather than identification	Measure and assess air quality to identify measure for improvement
		Management of effects rather than cause	Identify and use new technology to deliver air quality benefits through traffic flow, management and priority for other form of transport
		Not air quality impact and mitigation?	Noise action plan and review significant developments in relation to noise

Documentation	Page/Section	Wording	Notes
Plymouth City Council AQMA declaration meeting report – August 2014	Purpose		Declaration of AQMA were higher levels of NO_2 exist as a result of traffic emissions
			City-wide AQMA to permit one AQAP and report, prevent improvement scheme having a knock-on effect in other areas
	Pioneering Plymouth		AQAP currently focuses on reducing the reliance on cars and encouraging sustainable transport – in-turn reducing carbon dioxide emissions
			DA NO_2 and USA available online
	Publish work/ information	Not anymore!	69 air quality monitoring sites

Documentation	Page/Section	Wording	Notes
Plymouth City Council AQMA declaration meeting report – August 2014	Monitoring within Plymouth, 2.2.	Contradiction to 2014 progress report	Defra stated AQAMs 'needs to be a priority for council'
	Monitoring within Plymouth, 2.5.		City-wide AQMA more manageable and less burdensome
	Plymouth Options 4.1.		Reduce amount of report, allowing resources to be directed to priority work
	Plymouth Options 4.7.	Air Quality priority?	
	Plymouth Options 4.8.		City-wide AQAP would enable a broader range of initiatives
	Plymouth Options 4.10.		Traffic in Plymouth main source of air pollution

Documentation	Page/Section	Wording	Notes
Plymouth City Council AQMA declaration meeting report – August 2014	Consultation 5.1.		Planning and transport Dept support city-wide AQMA
	Consultation 5.5.		Transport Dept and Protection service will look at funding opportunities
	Consultation 5.6.		Public protection service is not required to carry out any formal consultation and the designation of AQMAs
	Consultation 5.7.	Not operating good practice - Publication of AQMAs is not consultation - No mention of consultation with public in any documents reviewed	Public consultation is considered good practice. Preferred approach would be to publish AQMAs in the press and on P.C.C. website – previous consultation shown public interest is limited

Appendix 4.

Weather calculations.

Jan-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/01/2013	8.5	4.7		9	tr
02/01/2013	10.9	4.7		7	0.4
03/01/2013	10.8	6.2		8	0.2
04/01/2013	11.1	9.4		7	1.2
05/01/2013	11.2	9.6		7	tr
06/01/2013	10.1	9.3		9	2.0
07/01/2013	10.8	8.8		12	0.0
08/01/2013	11.1	9.9		10	5.2
09/01/2013	9.5	4.7		5	0.6
10/01/2013	8.7	5.4		6	6.4
11/01/2013	9.3	2.2		6	10.6
12/01/2013	8.2	3.2		12	3.6
13/01/2013	5.0	1.5		6	0.8
14/01/2013	8.3	1.7		7	5.2
15/01/2013	7.8	2.3		8	0.2
16/01/2013	6.9	3.4		7	tr
17/01/2013	6.1	3.9		12	24.6
18/01/2013	4.4	0.9		12	2.4
19/01/2013	1.8	1.0		10	0.0
20/01/2013	0.1	-0.7		5	0.0
21/01/2013	6.0	-2.8		5	9.0
22/01/2013	4.1	-0.4		8	8.8
23/01/2013	3.9	1.3		6	tr
24/01/2013	6.0	1.9		7	0.0
25/01/2013	9.9	0.3		14	16.4
26/01/2013	10.9	4.2		17	11.8
27/01/2013	9.3	4.7		22	0.6
28/01/2013	11.3	4.6		22	16.4
29/01/2013	11.4	8.7		25	9.4
30/01/2013	11.1	8.9		18	0.6
31/01/2013	10.7	8.1		20	10.8
Average	8.2	4.2	6.2	11	5.5

Feb-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/02/2013	8.1	5.4		10	0.6
02/02/2013	7.7	3.2		10	0.4
03/02/2013	10.5	0.7		11	0.4
04/02/2013	9.5	7.6		16	4.0
05/02/2013	7.8	2.2		18	3.2
06/02/2013	7.7	2.8		17	tr
07/02/2013	6.9	1.0		8	4.8
08/02/2013	7.9	2.0		8	0.6
09/02/2013	9.3	4.6		5	13.6
10/02/2013	9.0	6.2		9	4.0
11/02/2013	10.7	-0.1		4	0.8
12/02/2013	6.7	1.0		4	1.6
13/02/2013	9.8	2.7		9	13.4
14/02/2013	10.9	6.0		12	0.2
15/02/2013	11.5	3.8		4	tr
16/02/2013	11.8	2.6		7	tr
17/02/2013	9.7	4.6		10	tr
18/02/2013	10.0	4.1		10	0.2
19/02/2013	10.0	2.7		7	0.2
20/02/2013	8.7	3.0		11	0.0
21/02/2013	4.9	3.6		14	0.0
22/02/2013	2.1	0.6		11	0.0
23/02/2013	3.7	0.4		8	tr
24/02/2013	4.9	-0.2		8	0.0
25/02/2013	5.9	-0.1		8	tr
26/02/2013	5.3	2.9		10	tr
27/02/2013	6.6	3.5		7	tr
28/02/2013	7.3	1.7		9	tr
Average	8.0	2.8	5.4	9	2.5

Student Number: 10120981

Mar-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/03/2013	6.9	2.6		9	tr
02/03/2013	4.7	2.9		6	0.0
03/03/2013	5.7	1.5		10	0.0
04/03/2013	8.7	3.9		10	0.0
05/03/2013	12.7	4.1		9	tr
06/03/2013	13.3	7.4		10	0.2
07/03/2013	10.6	8.5		10	10.4
08/03/2013	13.3	9.4		10	0.6
09/03/2013	13.4	8.9		10	3.4
10/03/2013	4.8	3.3		18	0.4
11/03/2013	2.5	-0.1		20	tr
12/03/2013	4.4	-2.2		15	0.0
13/03/2013	6.5	-1.8		7	0.4
14/03/2013	9.3	-1.9		6	1.0
15/03/2013	10.0	2.0		20	18.8
16/03/2013	10.6	4.7		14	4.0
17/03/2013	10.5	2.7		7	0.2
18/03/2013	11.0	0.1		5	0.4
19/03/2013	10.8	0.4		5	tr
20/03/2013	11.9	2.6		5	5.4
21/03/2013	8.8	4.7		14	57.8
22/03/2013	8.0	5.1		14	20.0
23/03/2013	6.4	5.1		13	0.0
24/03/2013	2.9	2.0		12	0.0
25/03/2013	2.9	0.2		11	0.0
26/03/2013	3.2	-1.0		9	tr
27/03/2013	4.1	0.1		9	tr
28/03/2013	7.8	-0.3		7	0.0
29/03/2013	4.5	1.1		13	0.0
30/03/2013	7.1	0.6		9	tr
31/03/2013	6.9	2.1		10	tr
Average	7.9	2.5	5.2	11	5.3

Apr-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/04/2013	5.9	2.6		13	13
02/04/2013	8.5	-0.1		9	9
03/04/2013	8.5	-1.2		9	9
04/04/2013	6.3	0.7		15	15
05/04/2013	9.2	0.8		12	12
06/04/2013	10.1	0.3		6	6
07/04/2013	7.3	0.7		11	11
08/04/2013	7.7	4.8		11	11
09/04/2013	8.3	5.1		7	7
10/04/2013	9.3	2.9		9	9
11/04/2013	12.6	6.0		12	12
12/04/2013	13.1	7.1		12	12
13/04/2013	11.9	6.2		17	17
14/04/2013	11.8	8.8		21	21
15/04/2013	12.4	8.8		19	19
16/04/2013	12.7	8.9		13	13
17/04/2013	12.7	9.2		21	21
18/04/2013	13.3	8.2		n/a	n/a
19/04/2013	13.7	7.0		10	10
20/04/2013	13.2	2.5		5	5
21/04/2013	12.4	0.8		7	7
22/04/2013	12.3	6.0		9	9
23/04/2013	15.0	7.4		7	7
24/04/2013	11.6	9.1		5	5
25/04/2013	13.9	7.6		6	6
26/04/2013	11.3	7.2		12	12
27/04/2013	12.6	3.9		10	10
28/04/2013	11.7	3.7		9	9
29/04/2013	13.1	5.4		9	9
30/04/2013	15.2	4.8		7	7
Average	11.3	4.8	8.0	11	11

Student Number: 10120981

May-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/05/2013	16.9	3.3		6	0.0
02/05/2013	15.2	5.8		6	0.0
03/05/2013	14.0	5.3		8	0.0
04/05/2013	15.2	9.0		12	0.0
05/05/2013	14.7	8.6		6	0.0
06/05/2013	17.3	7.0		6	0.0
07/05/2013	18.6	9.6		10	0.2
08/05/2013	14.1	10.3		14	5.0
09/05/2013	12.0	7.1		24	0.2
10/05/2013	13.4	8.8		14	6.4
11/05/2013	12.6	7.3		17	3.4
12/05/2013	11.1	6.9		12	1.6
13/05/2013	13.7	9.5		15	11.8
14/05/2013	9.5	7.6		15	tr
15/05/2013	12.5	4.1		11	1.8
16/05/2013	13.0	2.3		5	0.6
17/05/2013	15.0	2.7		5	tr
18/05/2013	16.5	6.0		7	1.0
19/05/2013	16.4	6.5		6	0.0
20/05/2013	15.4	8.5		10	0.2
21/05/2013	14.7	11.0		10	0.8
22/05/2013	16.2	8.0		10	1.2
23/05/2013	12.0	5.9		13	0.2
24/05/2013	12.5	5.7		14	0.4
25/05/2013	13.6	4.0		7	0.4
26/05/2013	14.1	2.7		7	tr
27/05/2013	13.4	6.8		14	tr
28/05/2013	14.7	6.6		7	0.6
29/05/2013	17.2	8.0		8	0.0
30/05/2013	18.7	10.4		12	0.0
31/05/2013	20.3	9.0		9	0.0
Average	14.7	6.9	10.8	10	1.3

Jun-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/06/2013	16.5	9.5		11	0.0
02/06/2013	18.6	7.5		7	0.0
03/06/2013	18.7	6.9		5	0.2
04/06/2013	19.5	6.2		6	0.0
05/06/2013	18.4	8.5		7	0.0
06/06/2013	21.9	11.3		10	0.0
07/06/2013	21.6	15.5		12	0.4
08/06/2013	23.3	14.9		11	0.0
09/06/2013	19.4	8.9		7	0.0
10/06/2013	15.9	7.8		8	6.8
11/06/2013	16.6	10.8		14	5.2
12/06/2013	13.7	12.2		17	6.4
13/06/2013	17.2	12.2		19	1.0
14/06/2013	16.7	11.3		16	4.6
15/06/2013	16.7	10.2		17	2.4
16/06/2013	14.4	11.2		10	1.8
17/06/2013	20.8	11.3		12	3.2
18/06/2013	18.2	13.8		7	0.0
19/06/2013	24.5	11.1		8	3.2
20/06/2013	17.6	13.4		5	3.0
21/06/2013	19.1	12.3		10	11.0
22/06/2013	14.6	11.6		19	2.6
23/06/2013	15.4	12.1		15	tr
24/06/2013	17.4	10.3		8	0.0
25/06/2013	17.1	6.6		5	0.0
26/06/2013	19.9	8.6		5	0.0
27/06/2013	20.2	10.1		7	tr
28/06/2013	20.2	13.0		10	tr
29/06/2013	20.8	14.1		8	tr
30/06/2013	19.9	11.4		8	0.2
Average	18.5	10.8	14.7	10	2.0

Student Number: 10120981

Jul-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/07/2013	19.5	11.4		8	tr
02/07/2013	15.3	10.7		12	4.2
03/07/2013	18.2	12.6		10	0.6
04/07/2013	19.6	13.4		9	tr
05/07/2013	18.8	11.3		6	0.2
06/07/2013	21.0	8.8		6	0.0
07/07/2013	25.7	11.9		5	0.0
08/07/2013	28.1	14.9		6	0.0
09/07/2013	27.0	15.3		6	0.0
10/07/2013	26.6	13.5		6	0.0
11/07/2013	21.5	13.7		7	0.0
12/07/2013	24.0	9.3		5	0.2
13/07/2013	25.9	11.8		5	0.0
14/07/2013	27.5	14.2		6	0.0
15/07/2013	24.3	14.5		6	0.2
16/07/2013	24.5	12.8		6	0.0
17/07/2013	24.5	13.5		5	0.0
18/07/2013	29.6	13.9		4	0.0
19/07/2013	27.0	15.3		7	0.0
20/07/2013	25.9	16.6		12	0.0
21/07/2013	24.6	15.9		12	0.0
22/07/2013	19.9	16.6		5	tr
23/07/2013	22.6	15.7		7	0.2
24/07/2013	22.7	16.3		8	n/a
25/07/2013	21.7	16.2		9	0.0
26/07/2013	22.1	13.7		5	0.0
27/07/2013	22.5	12.8		5	0.8
28/07/2013	20.1	13.5		13	2.8
29/07/2013	20.8	16.2		15	10.8
30/07/2013	21.3	14.3		8	1.2
31/07/2013	19.6	16.4		13	tr
Average	23.0	13.8	18.4	8	0.8

Aug-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/08/2013	22.6	15.5		7	0.4
02/08/2013	21.9	16.9		14	3.0
03/08/2013	21.1	14.2		13	0.4
04/08/2013	18.1	16.3		19	14.4
05/08/2013	19.8	16.1		12	4.4
06/08/2013	20.8	10.2		5	0.0
07/08/2013	23.4	10.8		5	0.0
08/08/2013	21.7	11.6		8	1.0
09/08/2013	20.9	14.7		10	0.0
10/08/2013	20.5	11.5		5	1.2
11/08/2013	22.9	15.0		7	tr
12/08/2013	20.2	14.0		8	0.0
13/08/2013	20.4	10.2		4	4.8
14/08/2013	19.4	12.1		8	5.0
15/08/2013	19.9	15.5		10	3.0
16/08/2013	22.7	16.4		9	tr
17/08/2013	17.6	12.8		13	7.8
18/08/2013	21.3	14.5		9	0.6
19/08/2013	21.3	10.8		5	0.2
20/08/2013	20.9	10.1		4	0.0
21/08/2013	21.7	11.2		5	0.2
22/08/2013	25.1	13.6		6	0.0
23/08/2013	21.5	12.9		4	1.6
24/08/2013	19.1	14.1		10	1.4
25/08/2013	21.6	12.8		7	0.2
26/08/2013	22.6	14.9		5	0.2
27/08/2013	24.4	13.0		5	tr
28/08/2013	21.5	12.1		5	0.2
29/08/2013	22.3	11.3		5	0.6
30/08/2013	22.3	14.7		7	tr
31/08/2013	19.0	13.4		9	0.2
Average	21.2	13.3	17.3	8	1.9

Student Number: 10120981

Sep-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/09/2013	20.2	7.7		5	0.0
02/09/2013	22.1	10.8		7	0.0
03/09/2013	21.3	11.7		4	0.2
04/09/2013	24.3	11.7		5	0.2
05/09/2013	23.9	10.8		7	0.0
06/09/2013	20.5	11.5		6	4.8
07/09/2013	18.0	8.1		7	1.8
08/09/2013	17.2	8.9		9	6.8
09/09/2013	19.1	12.1		11	0.0
10/09/2013	18.7	9.9		10	0.0
11/09/2013	17.5	12.0		7	0.4
12/09/2013	21.1	14.6		7	1.4
13/09/2013	17.8	15.9		12	8.4
14/09/2013	17.9	9.0		6	0.0
15/09/2013	16.0	6.8		12	6.8
16/09/2013	14.2	9.8		12	2.0
17/09/2013	16.8	10.3		15	2.0
18/09/2013	16.6	12.7		11	0.8
19/09/2013	18.4	9.7		11	3.2
20/09/2013	18.4	9.6		6	0.8
21/09/2013	18.0	12.3		5	0.2
22/09/2013	21.5	15.5		4	tr
23/09/2013	19.0	14.9		9	0.2
24/09/2013	21.2	14.6		6	0.2
25/09/2013	18.7	12.0		4	4.2
26/09/2013	19.4	15.3		8	tr
27/09/2013	18.8	15.4		14	tr
28/09/2013	17.1	14.9		13	15.6
29/09/2013	16.6	14.0		8	tr
30/09/2013	19.3	14.4		8	2.2
Average	19.0	11.9	15.4	8	2.4

Oct-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/10/2013	17.0	15.5		9	14.0
02/10/2013	18.2	15.3		12	14.8
03/10/2013	18.9	16.2		11	19.0
04/10/2013	18.6	15.5		13	0.2
05/10/2013	19.9	11.6		5	0.2
06/10/2013	19.0	10.1		4	0.2
07/10/2013	17.5	14.3		7	tr
08/10/2013	19.7	13.0		6	1.2
09/10/2013	15.5	11.6		8	0.2
10/10/2013	13.4	7.1		9	tr
11/10/2013	16.4	5.6		11	0.0
12/10/2013	14.8	10.4		8	2.4
13/10/2013	15.5	8.5		5	6.2
14/10/2013	15.1	10.3		7	1.4
15/10/2013	16.3	6.3		5	22.8
16/10/2013	17.9	9.6		15	1.4
17/10/2013	18.0	13.7		11	0.2
18/10/2013	16.1	14.1		12	7.2
19/10/2013	17.0	13.5		18	6.4
20/10/2013	15.5	12.6		21	11.6
21/10/2013	16.3	12.4		25	4.0
22/10/2013	17.6	14.8		20	9.4
23/10/2013	16.9	12.9		11	1.0
24/10/2013	15.8	9.1		10	12.0
25/10/2013	17.1	13.6		21	0.2
26/10/2013	16.0	13.6		20	8.8
27/10/2013	15.3	9.4		23	27.0
28/10/2013	13.6	10.7		22	4.4
29/10/2013	12.9	7.6		9	0.6
30/10/2013	14.8	4.7		14	4.0
31/10/2013	13.8	9.6		12	4.8
Average	16.5	11.4	13.9	12	6.4

Student Number: 10120981

Nov-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/11/2013	13.6	11.5		11	2.6
02/11/2013	14.0	9.6		19	3.0
03/11/2013	13.4	7.4		18	18.8
04/11/2013	12.5	6.3		9	6.2
05/11/2013	13.7	7.4		15	2.6
06/11/2013	14.1	10.3		20	2.6
07/11/2013	12.0	8.5		8	5.6
08/11/2013	10.7	8.0		9	2.0
09/11/2013	11.2	7.1		12	11.6
10/11/2013	13.2	6.1		7	19.4
11/11/2013	14.1	7.3		10	1.8
12/11/2013	13.0	9.8		7	0.2
13/11/2013	11.3	2.0		9	1.4
14/11/2013	10.7	3.2		12	0.4
15/11/2013	10.6	6.0		6	0.0
16/11/2013	11.2	2.4		2	0.0
17/11/2013	9.8	3.5		4	0.0
18/11/2013	10.3	7.2		5	1.2
19/11/2013	8.6	3.1		9	2.6
20/11/2013	9.5	2.2		14	6.8
21/11/2013	9.4	4.9		15	0.0
22/11/2013	8.8	1.7		6	0.2
23/11/2013	8.8	1.7		5	0.0
24/11/2013	9.0	0.4		5	0.2
25/11/2013	7.7	1.5		6	0.0
26/11/2013	7.7	-1.7		2	0.2
27/11/2013	9.7	-0.8		3	tr
28/11/2013	10.6	7.7		3	tr
29/11/2013	11.2	7.9		9	0.2
30/11/2013	10.2	5.3		6	0.2
Average	11.0	5.3	8.1	9	3.2

Dec-13					
Date	Daily Maximum Temperature (0900-0900) (°C)	Daily Minimum Temperature (0900-0900) (°C)	Average Tempature	Daily Mean Windspeed (0100-2400) (kn)	Daily Total Rainfall (0900-0900)(mm)
01/12/2013	7.3	7.3		3	0.0
02/12/2013	9.5	9.5		n/a	0.0
03/12/2013	8.8	8.8		3	tr
04/12/2013	10.4	10.4		6	0.2
05/12/2013	11.0	11.0		12	0.2
06/12/2013	10.9	10.9		6	0.2
07/12/2013	10.4	10.4		6	1.0
08/12/2013	12.2	12.2		10	0.4
09/12/2013	11.6	11.6		8	0.0
10/12/2013	11.9	11.9		11	0.2
11/12/2013	11.7	11.7		8	0.2
12/12/2013	12.7	12.7		11	7.2
13/12/2013	12.4	12.4		16	1.4
14/12/2013	12.1	12.1		23	5.4
15/12/2013	12.4	12.4		19	12.6
16/12/2013	12.1	12.1		13	3.8
17/12/2013	11.0	11.0		5	5.4
18/12/2013	11.6	11.6		27	13.4
19/12/2013	9.1	9.1		13	4.0
20/12/2013	11.7	11.7		22	18.8
21/12/2013	11.6	11.6		23	9.0
22/12/2013	11.1	11.1		20	3.0
23/12/2013	12.0	12.0		33	25.0
24/12/2013	8.4	8.4		22	5.8
25/12/2013	7.6	7.6		9	14.4
26/12/2013	11.7	11.7		13	7.6
27/12/2013	11.1	11.1		25	0.6
28/12/2013	8.1	8.1		9	1.4
29/12/2013	10.9	10.9		14	14.8
30/12/2013	11.0	11.0		23	4.6
31/12/2013	10.6	10.6		21	16.8
Average	10.8	10.8	10.8	14	5.9

Appendix 5.

Street and associated traffic volume metrix.

The following notes elaborate on the interpreted road traffic levels and reasoning for data selected. The data sourced did not provide exact routes monitored and numerous roads seem to be incorporated several times. The duplication of roads monitored could be to validate traffic reading and/or the direction of travel. The definition of the term '*Spur*' cited in the data in unknown and the site stated as '*Local Authority boundary*' could not be identified due the undefined direction of travel. Single level readings were utilised that were deemed the most applicable as the flow of traffic is undefined throughout the data and the variability of traffic volume over the years verses pollution level is required rather than particulars. Data utilised in the report is highlight bold.

1. Cobourg St Roundabout – Exeter street Roundabout area covers Charles street and Exeter street.
2. A379 Laira Bridge - Embankment Road, relatively small distance not incorporating relevant sites.
3. Cobourg Street Roundabout – A3064 encompasses Alma road which is not included in air quality data.
4. **Beauchamp Road – A38 applicable to Outland Road data.**
5. A386 – B3413 applicable possibly to Outland Road and a small section of Tavistock Road. Although exact monitored area of A386 unknown.
6. A38 – B3413 covers a small section of Tavistock Road.
7. B3214 – A38 incorporates Old Laira Road not relevant to data.

8. **Weston Approach – Charles Street Roundabout encompasses Cobourg Street and Charles Street but exact area or amount of Western Approach unknown. Cobourg Street applicable to data.**
9. Wolsey Road – A38 covers Wolsey Road and Victoria Road neither relevant to data.
10. Tothill Road Roundabout – A379 includes a small section of Embankment Road. Embankment Road is relevant to data.
11. Union Street – Cobourg Street Roundabout incorporates Western Approach not related to data.
12. A374 Embankment – Hele's Terrace perceivably covers the whole of Embankment road applicable to the data.
13. **Charles Street Roundabout – Tothill Road Roundabout incorporates the entire length of Exeter Street applicable to the data.**
14. B3413 – B3432 includes Forder Valley Road and Novorossiysk Road neither pertinent to the data.
15. Weston Mill Drive – A386 perceivably encompasses Wosley Road and Alma Road neither relevant to the data.
16. Gdynia Way – B3214 Mid Junction covers Tothill road applicable to the data.
17. A374 Spur – Stentaway Road Roundabout includes Billacomb Road unrelated to the data
18. A3064 – Beauchamp Road appears to cover the first half of Outland Road.
19. Local Authority boundary – A3064, direction of travel North, East, West of South of the Local Authority boundary undefined.

20. Ferry – Weston Approach Roundabout. Perceivably, Ferry refers to Torpoint Ferry. This would include Park Avenue, Cumberland Road and Union Street none applicable to the data.
21. B3413 – A374, direction of travel presumed across the A386 covering Outland and Alma Road Outland Road only applicable to data.
22. **A3064 – A386 interpreted to encompasses to encompass the whole of Outland and Tavistock road.**
23. Stentaway Road Roundabout – Springfield Road Roundabout includes a section of Elburton Road not relevant to the data.
24. B3432 – Local Authority Boundary direction of travel North, East, West of South of the Local Authority boundary undefined.
25. A374 – Local Authority Boundary direction of travel North, East, West of South of the Local Authority boundary undefined.
26. Spur A379 – Exeter Street Roundabout includes Embankment Road applicable to the data.
27. Hele's Terrace – Gdynia Way is perceived to incorporate Gdynia Way which is not included in the data.
28. Helen's Terrace – A374 Spur appears to cover Embankment Road, Exeter Street, Charles Street and Cobourg Street. All applicable to the data.
29. Gdynia Way main – A379 Laira Bridge Road – the length of road across Gdynia Way mani and Laira Bridge Road is undefined and neither are incorporated in data.
30. **Spur from A370 – Embankment Road perceivably defines level across Embankment Road applicable to the data.**

31. Springfield Road - Local Authority Boundary direction of travel North, East, West of South of the Local Authority boundary undefined.
32. A379 – Hele's Terrace perceivably defines level across Embankment Road applicable to the data.

Appendix 6.

Nitrogen Dioxide and traffic data calculations.

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels			
	Nitrogen Dioxide Levels			Traffic Levels
	6	9		13
Location	Exeter Street Flats	212a Exeter Street	Average of two sites	Charles St roundabout to Tothill Rd roundabout
2003	47.35	45	46	41494
2004	40.95	44	43	43209
2005	41.48	35.29	38.39	44914
2006	37.2	34.1	35.7	46959
2007	40.34	40.63	40.485	36652
2008	35.66	39.98	37.82	37272
2009	35.87	36.09	35.98	38235
2010	44.03	41.87	42.95	38106
2011	35.92	40.79	38.355	28862
2012	35.98	32.95	34.465	29093
2013	35.55	32.35	33.95	34345

SUMMARY OUTPUT								
Exeter Street Taffic-Pollution								
Regression Statistics								
Multiple R	0.261578388							
R Square	0.068423253							
Adjusted R Square	-0.04802384							
Standard Error	3.240889911							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	6.171683183	6.171683183	0.587590907	0.46536809			
Residual	8	84.02693932	10.50336741					
Total	9	90.1986225						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	32.92027096	6.782287546	4.853859518	0.001265633	17.28028783	48.56025409	17.28028783	48.56025409
41494	0.000136086	0.000177531	0.766544785	0.46536809	-0.000273302	0.000545473	-0.000273302	0.000545473

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels				
	Nitrogen Dioxide Levels				Traffic Levels
	10	11	12		30
Location	48 Embankment Road	211 Embankment Road	Embankment Road(PK)	Average of three sites	Spur from A370 – Embankment Road
2003	N/A	32	34	33	15288
2004	38	36	30	35	16011
2005	42.13	35.96	26.01	34.70	16766
2006	43.96	32.7	28.3	34.98666667	12855
2007	46.2	39.96	33.15	39.77	12512
2008	41.68	39.19	31.11	37.32666667	12750
2009	37.70	35.58	29.52	34.27	12959
2010	49.71	50.08	39.33	46.37333333	6274
2011	44.88	37.89	34.55	39.11	12282
2012	34.54	26.19	27.88	29.54	9985
2013	32.11	28.25	25.65	28.67	28054

SUMMARY OUTPUT

Embankment Road Taffic- Pollution

Regression Statistics	
Multiple R	0.656228497
R Square	0.430635841
Adjusted R Square	0.359465321
Standard Error	4.097359654
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	101.5823387	101.5823387	6.050761488	0.039329211
Residual	8	134.3068491	16.78835613		
Total	9	235.8891878			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	44.20690577	3.596953307	12.2900972	1.7867E-06	35.91231657	52.50149497	35.91231657	52.50149497
15288	-0.000587684	0.000238913	-2.459829565	0.039329211	-0.001138617	-3.67508E-05	-0.001138617	-3.67508E-05

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels	
	Nitrogen Dioxide Levels	Traffic Levels
	17	4
Location	Outland Road	Beauchamp Road – A38
2003	N/A	N/A
2004	35	44206
2005	28.02	45651
2006	28.6	47697
2007	35.33	46255
2008	33.0	43985
2009	32.02	40546
2010	40.3	40703
2011	37.01	44697
2012	30.88	44795
2013	30.73	44503

SUMMARY OUTPUT								
Outland Road Taffic-Pollution								
Regression Statistics								
Multiple R	0.520290811							
R Square	0.270702528							
Adjusted R Square	0.166517175							
Standard Error	3.672156191							
Observations	9							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	35.03708234	35.03708234	2.598278164	0.151014947			
Residual	7	94.39311766	13.48473109					
Total	8	129.4302						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	72.08440493	24.35444231	2.959805197	0.021110895	14.49530001	129.6735098	14.49530001	129.6735098
44206	-0.000884758	0.000548885	-1.611917542	0.151014947	-0.002182665	0.00041315	-0.002182665	0.00041315

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels			
	Nitrogen Dioxide Levels			Traffic Levels
	14	15		22
Location	422 Tavistock Road	45 Tavistock Road	Average of two sites	A3064 – A386
2003	N/A	N/A	N/A	N/A
2004	N/A	N/A	N/A	N/A
2005	36.83	37.86	37.35	50738
2006	27.6	36.5	32.1	53635
2007	36.63	45.31	40.97	47988
2008	35.94	45.08	40.51	48865
2009	35.79	37.85	36.82	49660
2010	48.33	49.05	48.69	48494
2011	39.3	40.2	39.8	50081
2012	36.92	44.22	40.57	56559
2013	N/A	45.97	45.97	56088

SUMMARY OUTPUT								
Tavistock Road Traffic - Pollution								
Regression Statistics								
Multiple R	0.087954554							
R Square	0.007736004							
Adjusted R Square	-0.157641329							
Standard Error	5.493895033							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1.411891726	1.411891726	0.046777895	0.835933758			
Residual	6	181.0972958	30.18288263					
Total	7	182.5091875						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	47.29880019	30.72767044	1.539290142	0.174658089	-27.88910076	122.4867011	-27.88910076	122.4867011
50738	-0.000128985	0.000596372	-0.216281981	0.835933758	-0.001588255	0.001330286	-0.001588255	0.001330286

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels	
	Nitrogen Dioxide Levels	Traffic Levels
	29	8
Location	Cobourg Street	Weston Approach – Charles Street
2003	N/A	N/A
2004	N/A	N/A
2005	N/A	N/A
2006	N/A	N/A
2007	33.71	32849
2008	31.89	33568
2009	35.15	32849
2010	43.17	23621
2011	40.30	24297
2012	34.07	24415
2013	34.59	23350

SUMMARY OUTPUT								
Cobourg Street Traffic - Pollution								
Regression Statistics								
Multiple R	0.560047302							
R Square	0.313652981							
Adjusted R Square	0.142066226							
Standard Error	3.963465181							
Observations	6							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	28.71545838	28.71545838	1.827955668	0.247759299			
Residual	4	62.83622495	15.70905624					
Total	5	91.55168333						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	49.9658124	10.06967653	4.962007692	0.007695105	22.00790828	77.92371651	22.00790828	77.92371651
32849	-0.000497377	0.000367877	-1.352019108	0.247759299	-0.001518769	0.000524014	-0.001518769	0.000524014

Site	Comparison of Nitrogen Dioxide Levels Vs Traffic Levels	
	Nitrogen Dioxide Levels	Traffic Levels
	8	16
Location	11 Tothill Road	16. Gdynia Way – B3214 Mid Junction
2003	N/A	N/A
2004	33	41488
2005	28.53	43279
2006	27.8	44076
2007	31.87	42925
2008	30.37	42925
2009	29.48	43521
2010	35	45745
2011	34.57	47314
2012	29.64	38958
2013	28.21	38749

SUMMARY OUTPUT								
Tothill Road Traffic - Pollution								
Regression Statistics								
Multiple R	0.656774424							
R Square	0.431352644							
Adjusted R Square	0.350117307							
Standard Error	2.148045279							
Observations	9							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	24.50046591	24.50046591	5.309913907	0.054641753			
Residual	7	32.29868965	4.614098521					
Total	8	56.79915556						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3.5525487	11.76287696	0.30201359	0.771417361	-24.26223542	31.36733282	-24.26223542	31.36733282
41488	0.000628392	0.000272701	2.304325044	0.054641753	-1.64437E-05	0.001273229	-1.64437E-05	0.001273229

References

Abhijith, K. V., Kumar, P., Gallagher, J., McNabola, A., Baldauf, R., Pilla, F., Broderick, B., Sabatino, S. D. and Pulvirenti, B. (2017) Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments – A review, *Atmospheric Environment*. 162, pp. 71-86.

Ambient Air Quality Assessment and Management 2006 and Council Directive 96/62/EC European Union. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31996L0062 [Accessed: 3rd January 2017]

Barnes, J., Hayes, E.T., Longhurst J.W.S., Chatterton, T.J. (2013) Air quality action planning: why do barriers to remediation in local air quality management remain?, *Journal of Environmental Planning and Management*, 57 (5), pp. 660-681

Bauer, M., W., Bicquelet, A. and Suerdem, A., K. (2014) *Text analysis: an introductory manifesto***.** London: SAGE

BBC (2014) *Plane Trees*, Available at: http://www.bbc.co.uk/england/sevenwonders/london/plane_trees/ [Accessed: November 12th 2017]

BBC (2010) *Unsafe lead levels at Plymouth school site and field*, Available at: http://news.bbc.co.uk/1/hi/england/devon/8598186.stm [Accessed: June 12th 2017]

Beattie, C.I., Elsom, D. M., Gibbs, D. C., Irwin, J. G., Jefferson, J. G., Longhurst, J. W. S., Newton, A. J., Pheby, D. F. H., Pill, M. A. J., Rowe, J., Simmons, A., Tubb, A. L. T. and Whitwell, I. (1998) Regional developments in Air Quality Management (AQM) in the United Kingdom – evidence from a study of South West England, *Transactions on Ecology and the Environment,* 21(1998), pp. 319-332.

Beattie, C.I., Longhurst, J. W. S. and Woodfield, N. K. (2000) Air quality management in urban areas of England: the changing role of transport planning, *Urban Transport*, 6(2000), pp. 339-348.

Beattie, C.I., Longhurst, J. W. S. and Woodfield, N. K. (2001) Urban air quality: a comparison of the air pollution dilemma facing urban and rural local authorities and approaches to managing them, *Transactions on Ecology and the Environment* 47(2001), pp. 183-192.

Beattie, C.I., Longhurst, J. W. S. and Woodfield, N. K. (2002) A comparative Analysis of Air Quality Management Challenges and Capabilities in Urban and Rural English Local Authorities, *Urban Studies,* 23(13), pp. 2469-2483.

Beattie, C. I. and Chatteron, T. J., Hayes, E., Leksmono, N., Longhurst, J. W. S. and Woodfield, N. K. (2006) Air Quality Action Plans in the UK: an overview and evaluation of process and practice, *Transactions on Ecology and the Environment*, 86(2006), pp. 503-512.

Beattie, C. I. C. and Longhurst, J. (2001) Progress with implementation local air quality management in rural areas of England, *Journal of Environmental Planning and Management,* 61 (2), pp. 137-147.

Brunt, H., Barnes, J., Longhurst, J.W.S., Scally, G., Hayes E.T., (2016), Local Air Quality Management policy and practice in the UK: the case for greater Public Health integration and engagement Environmental Science and Policy, *Journal of Environmental Planning and Management,* 58, pp. 52-60

Budzynski, M and Jamroz, K. (2014) *Roadside Trees as a Road Safety Hazard in Poland*, Available at: http://www.rrs.erf.be/images/09-Roadside_Trees_as_a_Road_Safety_Hazard_in_Poland-K.pdf [Accessed: November 11th 2017]

Benton, T. and Craib, I. (2010) *Philosophy of Social Science.* 2nd edn. London: Palgrave

Caparino, L. and Togna, G. I. (1998) Potential health effects of gasoline and its constituents: A review of current literature (1990-1997) on toxicological data, *Environmental Health Perspective*, 106(3), pp. 115-125.

Carrington, D. (2016) *UK government faces second court battle over air pollution plans*. Available at: https://www.theguardian.com/environment/2016/apr/28/uk-government-faces-second-court-battle-over-air-pollution-plans [Accessed: 4th June 2017]

Chatterton, T. J., Hayes, E. T. and Longhurst (2006) Managing air quality – are we doing enough? *Air Pollution*, 86, pp.155-164.

Clean Air Act 1952 repealed 1993, c. 52. Available at: http://www.legislation.gov.uk/ukpga/Eliz2/4-5/52/contents [Accessed: 8th October 2016]

Clean Air Act 1993, c 11. Available at: http://www.legislation.gov.uk/ukpga/1993/11/contents [Accessed: 8th October 2016]

Committee on the Medical Effects of Air Pollution (2010) *The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom* - A report by the Committee on the Medical Effects of Air Pollutants. Available at:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/304641/COMEAP_mortality_effects_of_long_term_exposure.pdf [Accessed: 30th October 2016]

Conlan, D. E., Crumbley, A., Raper, D. W. and Owen, B. (1997) The role of Local Authorities in developing Air Quality Management in the UK, *Transactions on Ecology and the Environment*, 15(1997), pp. 69-78.

Corbin, J. and Strauss, A. (2008). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (3rd edition). California: SAGE

Country Life (2017) *Stoves – The best Log burners and gas stoves*, Available at: http://www.countrylife.co.uk/interiors/log-burners-stoves-149657 [Accessed: November 12th 2017]

Davis, D. L., Bell, M. L. and Fletcher, T. (2001) A Look Back at the London Smog of 1952 and the Half Century Since, *Environmental Health Perspectives*, 110(12), pp. 734-735.

Department for Environment, Food and Rural Affairs (2003) *Part IV of the Environment Act 1995 Local Air Quality Management. Technical Guidance*, Available at:https://www.thenbs.com/PublicationIndex/documents/details?Pub=DEFRA&DocID=262523 [Accessed: June 2018]

Department for Environment, Food and Rural Affairs (2010) *Public bodies announcement*. Available at: https://www.gov.uk/government/news/public-bodies-announcement# [Accessed: 13th November 2016]

Department for Environment, Food and Rural Affairs (2011) *Causes of air pollution*. Available at: https://uk-air.defra.gov.uk/air-pollution/causes [Accessed: 4th December 2016]

Department for Environment, Food and Rural Affairs (2012) *UK and EU Air Quality Limits*. Available at: https://uk-air.defra.gov.uk/air-pollution/uk-eu-limits [Accessed: 8th October 2016]

Department for Environment, Food and Rural Affairs (2013) *Air quality and emissions statistics* Available at: https://www.gov.uk/government/collections/air-quality-and-emissions-statistics [Accessed: 4th June 2017]

Department for Environment, Food and Rural Affairs (2015) *Local air quality management review Summary of responses and government reply*. Available at: https://consult.defra.gov.uk/communications/laqm-review-next-steps/results/summary_of_responses_laqm_review.pdf [Accessed: 13th November 2016]

Department for Environment, Food and Rural Affairs (2016) *Air Quality Expert Group*. Available at: https://uk-air.defra.gov.uk/library/aqeg/ [Accessed: 13th November 2016]

Department for Environment, Food and Rural Affairs (2016a) *Causes of air pollution*. Available at: https://uk-air.defra.gov.uk/air-pollution/causes [Accessed: 12th March 2017]

Department for Environment, Food and Rural Affairs (2016b) *List of Local Authorities with AQMAs*. Available at: https://uk-air.defra.gov.uk/aqma/list [Accessed: 13th November 2016]

Department for Environment, Food and Rural Affairs (2016c) *What are Air Quality Management Areas?*. Available at: https://uk-air.defra.gov.uk/aqma/ [Accessed: 13th November 2016]

Department for Environment, Food and Rural Affairs (2016d) *Local Air Quality Management Policy Guidance (PG16)*, Available at: https://laqm.defra.gov.uk/documents/LAQM-PG16-April-16-v1.pdf [Accessed: 10th June 2018]

Department for Environment, Food and Rural Affairs (2016e) *Part IV of the Environment Act 1995 Local Air Quality Management. Technical Guidance*, Available at: https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf [Accessed June 2018]

Department for Environment Food and Rural Affairs (2017) *Bias Adjustment Factors*, Available at: https://laqm.defra.gov.uk/bias-adjustment-factors/bias-adjustment.html [Accessed: November 11th 2017]

Department for Environment Food and Rural Affairs (2018) *AQMA Details,* Available at: https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1583 [Accessed: June 6th 2018]

Department of Health (2011) *Public health in local government.* Available at: https://www.gov.uk/government/publications/public-health-in-local-government [Accessed: 3rd January 2017]

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*, Volume 1. London: TSO (The Stationary Office)

Devon County Council (2017) *Walking Trails in Devon*. Available at: http://www.devon.gov.uk/dd 9 [Accessed: 13th May 2017]

Doherty, R. M., Heal, M. R., Wilkinson, P., Pattenden, S., Vieno, M., Armstrong, B., Atkinson, R., Chalabi, Z., Kovats, S., Milojevic, A. and Stevenson, D. S. (2009) Current and future climate- and air pollution-mediated impacts on human health, *Environmental Health,* 8(1), pp. S8.

Dorfman, P., Beattie, C., Burnet, F., Gibbs, D., Longhurst, J., Weitkamp, E. and Leksmono, N. (2005) Consultation for local air quality management in the UK: opportunity for and barriers to successful science communication, *Transactions on Ecology and the Environment,* 82(2005), pp. 139-147.

Dorfman, P., Leksmono, F., Burnet, D., Gibbs, Longhurst, J. and Weitkamp, E. (2006) A preliminary review of local air quality management consultation practices in England, *Transactions on Ecology and the Environment*, 86(2006), pp. 145-153.

Elsom, M. D. and Longhurst, J. W. S. (1997) Assessment of first phase of the UK National Air Quality Strategy, *Transactions on Ecology and the Environment*, 15(1997), pp. 15-24.

Elsom, M. D. (1999) Development and implementation of strategic frameworks for Air Quality Management in the UK and European Community, *Journal of Environmental Planning and Management*, 42 (1) pp. 103-119.

Elwood, P. L. and Gallacher. J. E. (1984) Lead in petrol and levels of lead in blood: scientific evidence and social policy. Journnal of Epidemiol Community Health, 38 (4), pp. 315-8.

Environment Act 1995, c 25. Available at: http://www.legislation.gov.uk/ukpga/1995/25/section/4 [Accessed: 13th November 2016]

European Chemical Agency (2015) *Guidance on the completion of safety data sheets*, Annankatu 18, Helsinki, Finland.

European Environment Agency (2016) Temperature inversion traps pollution at ground level, Available at: https://www.eea.europa.eu/media/infographics/temperature-inversion-traps-pollution-at/view [Accessed: January 6th 2018]

Field, A., Miles, J. and Field, Z. (2012) *Discovering Statistics Using R.* London: SAGE

Gegisian, I., Grey, M., Longhurst, J. W. S. and Irwin, J. G. (2008) Potential contribution of local air quality management to environmental justice in England, *Ecology and the Environment,* 118(2008), pp. 597-606.

Go-Ahead (2017) *News*, Available at: https://www.go-ahead.com/en/media/news/2009/go-ahead-completes-plymouth-citybus-acquisition.html [Accessed: November 24th 2017]

Gowers, A. M., Miller, B. G. and Stedman, J. R. (2014) *Estimating Local Mortality Burdens Associated with Particulate Air Pollution*. Public Health England, 2014016. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf [Accessed: 30th October 2016]

Hassen S. M., Ling, K. A. and Longhurst, J. W. S. (2006) Local air quality management process in Great Britain in its second round of review and assessment: efficiency vs. effectiveness. *Air Pollution*, 86, pp.185-194.

Harvey, F. (2016) *What is behind the diesel cars emissions scandal?* Available at: https://www.theguardian.com/environment/2016/apr/21/what-is-behind-the-diesel-cars-emissions-scandal [Accessed: 4th June 2017]

Hayes, E. T., Chatterton, T. J. and Leksmono, N. S. (2006) Intergrating climate change management into local air quality management process at a local and regional governance level in the UK. *Air Pollution*, 86, pp.439-446.

Health and Safety Executive (2016) *Ionising radiation*. Available at: http://www.hse.gov.uk/radiation/ionising/index.htm [Accessed: 13th November 2016]

Health and Safety Executive (2016a) *Medical Exposure*. Available at: http://www.hse.gov.uk/radiation/ionising/exposure.htm [Accessed: 13th November 2016]

Independent (2010) *Radon Gas: The silent killer in the countryside*, Available at: http://www.independent.co.uk/life-style/health-and-families/features/radon-gas-the-silent-killer-in-the-countryside-2047987.html [Accessed on: November 12th 2017]

Johnston, I (2014) *UK faces £300m fine over failure to meet air pollution targets by 2010*. Available at: http://www.independent.co.uk/environment/climate-change/european-commission-to-take-legal-action-against-britain-over-high-levels-of-dangerous-gas-9142478.html [Accessed: 8th March 2017]

Kim, A., Hong, K., Jun, H., Park, Y., Park, M. and Sunwoo, Y. (2014) 'Effect of Precipitation on Air Pollutant Concentration in Seoul, Korea'. *Asian Journal of Atmospheric Environment*. 8(4), pp. 202-211.

L'Eplattenier, E. B. (2018) An Argument for Archival Research Methods: Thinking Beyond Methodology. *College English*. 72(1), pp. 67-79.

Lindley, S. J. and Crabbe, H. (2004) What lies beneath?-issues in representation of air quality management data for public consumption, *Science of the total Environment*, 334(335), pp. 307-325.

Leksmono, N. S., Dorfman, P., Burnet, F., Gibbs, D. C., Longhurst, J. W. S. and Weitkamp, E. (2010) Enhancing consultation practices on Air Quality Management in local authorities, *Environmental Planning and Management*, 53(5), pp. 559-571.

Longhurst, J. W. S., Beattie, C. I., Chatterton, T. J., Hayes, E. T., Leksmono, N. S. and Woodfield, N. K. (2006) Local air quality management process: Assessing, managing and remediating the risk of exceeding an air quality objective in Great Britain, *Environmental International*, 32 (2006). pp, 934-947.

Longhurst, J. W. S., Barnes, J., Chatterton, T. J., Hayes, E. T., Irwin, J. G. and Olowoporoku, A. O. (2010) Recalibrating the United Kingdom's local air quality management regime to deliver desired goals, *Ecology and the Environment*, 136(2010), pp. 73-82.

MBM Arquitectes and AZ Urban Studio (2003) *A Vision for Plymouth*, Available at: https://www.plymouth.gov.uk/sites/default/files/AVisionForPlymouthFinalReport.pdf [Accessed: November 24th 2017]

Mckee, A. (2003) *Textual Analysis: A Beginner's Guide*. London: SAGE

Mediavilla-Sahagún, A. and ApSimon, H. M. (2005) Urban scale integrated assessment of London: Which emission reduction strategies are more effective in attaining prescribed PM_{10} air quality standards by 2005? Environmental Modeling and Software 21(2006), pp. 501-513.

Mindell, J. and Joffe, M. (2004) Evidence Based Public health Policy in Practice – Predicted health impacts of Urban air quality management, *Journal of Epidemiological Community Health*, 2(58), pp. 103-113.

Motor Fuel Composition and Content Regulations 1999, c. 3107. Available at: http://www.legislation.gov.uk/uksi/1999/3107/contents/made [Accessed: 8th October 2016]

Morgan, M. G. (1993) Risk Analysis and Management. *Scientific American,* 269 (1), pp. 32-41.

Nierynck, R. (2016) *Defra outlines revised Air Quality Plan timetable*. Available at: http://www.airqualitynews.com/2016/12/07/9322/ [Accessed: 3rd January 2017]

National Aeronautics and Space Administration (2017) *Chemistry in the Sunlight.* Available at: https://earthobservatory.nasa.gov/Features/ChemistrySunlight/chemistry_sunlight3.php [Accessed: 10th September 2017]

National Atmospheric Emissions Inventory (2017) *About Nitrogen Oxides*. Available at: http://naei.beis.gov.uk/overview/pollutants?pollutant_id=6 [Accessed: 10th September 2017]

O'Connell, F. (2014) *Stuff Id wished I'd Known When I Started Working*. Brighton: Roundhouse Group

Office for National Statistics (2011) *Population Density*. Available at: https://data.gov.uk/dataset/population-density-2011/resource/c61a6f86-db63-46e8-a946-66fdc58210d0 [Accessed: 13th May 2017].Olowoporoku, A. O., Longhurst, J. W. S., Hayes, E. T., & Parkhurst, G. (2012) The rhetoric and realities of integrating air quality into the local transport planning process in English local authorities, *Journal of Environmental Management*, 101, pp. 23-32.

Oxford University Press (2016) *English Oxford Dictionary*. Available at: https://en.oxforddictionaries.com/help [Accessed: 8th October 2016]

Parliament (2011) *Transport Committee*. Available at: https://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/720/720vw28.htm [Accessed: 13th May 2017]

Pencheon, D., Guest, C., Melzer, D. and Muir Gray, J. A. (2001) *Oxford Handbook of Public Health Practice*. Oxford: Oxford University Press

Planning For Sustainable Travel (2018) *Case Study: Sherford Plymouth*, Available at: http://www.plan4sustainabletravel.org/case_studies/sherford_plymouth/ [Accessed: January 5th 2018]

Plymouth City Council (2003) *Eastern gateway Plans*. Available at: https://www.plymouth.gov.uk/sites/default/files/PlymouthEasternGatewayFrameworkStudyAppendix2_0.pdf [Accessed: 10th September 2017]

Plymouth City Council. Air Quality Progress Report for Plymouth. Public Protection Services, Plymouth, 2008.

Plymouth City Council (2004) *Detailed Assessment of Air Quality in Plymouth*. Plymouth: Plymouth City Council

Plymouth City Council (2005) *Air Quality Progress Report for Plymouth*. Plymouth: Council

Plymouth City Council (2006) *Updating and Screening Assessment of Air Quality in Plymouth*. Plymouth: Plymouth City Council

Plymouth City Council (2007) *Air Quality Progress Report for Plymouth*. Plymouth: Plymouth City Council

Plymouth City Council (2008) *Air Quality Progress Report for Plymouth*. Plymouth: Plymouth City Council

Plymouth City Council (2009) *Air Quality Updating and Screening Assessment for Plymouth City Council*. Plymouth: Plymouth City Council

Plymouth City Council (2010) *2010 Air Quality Progress Report*. Plymouth: Plymouth City Council

Plymouth City Council (2011) *2011 Air Quality Progress Report*. Plymouth: Plymouth City Council

Plymouth City Council (2010) *2012 Air Quality Updating and Screening Assessment*. Plymouth: Plymouth City Council

Plymouth City Council (2013) *2013 Air Quality Progress Report*. Plymouth: Plymouth City Council

Plymouth City Council (2014) *2014 Air Quality Progress Report*. Plymouth: Plymouth City Council

Plymouth City Council (2009a) Detailed Assessment of Benzene for Plymouth City Council. Plymouth: Plymouth City Council

Plymouth City Council (2009b) Detailed Assessment of Nitrogen Dioxide for Plymouth City Council. Plymouth: Plymouth City Council

Plymouth City Council (2017) *Mayflower Museum*. Available at: https://www.plymouth.gov.uk/visitorsandtourism/attractions/mayflowermuseum [Accessed: 13th May 2017]

Plymouth City Council (2017a) *A Vision For Plymouth*. Available at: https://www.plymouth.gov.uk/planningandbuildingcontrol/designandhistoricenvironment/visionplymouth [Accessed: 13th May 2017]

Plymouth City Council (2017b) *Plymouth Report – October 2017*. Available at: https://www.plymouth.gov.uk/sites/default/files/PlymouthReport2017.pdf [Accessed: 9th June 2018]

Plymouth Herald (2015) *Plymouth is growing - and getting older, latest census reveals*. Available at: http://www.plymouthherald.co.uk/plymouth-growing-getting-older-latest-census/story-26788145-detail/story.html#hPlDZXX4RUQ8peXD.99 [Accessed: 13th May 201]

Plymouth University (2017) *Facts and Figures*. Available at: https://www.plymouth.ac.uk/your-university/facts-and-figures [Accessed: 13th May 2017]

Potter, G. (1999) *The Philosophy of Social Science: New perspectives*. Harlow: Longman.

Richmon-Bryant, J., Snyder, M. G., Owen, R. and Kimbrough, S. (2018) Factors associated with NO_2 and NO_X concentration gradients near a highway, *Atmospheric Environment*. 174, pp. 214-226.

Rowntree, D. (1981) *Statistics without Tears A Primer for Non-mathematics*. London.

Spiegel, R. M., Schiller, J. and Srinivasan, A. R. (2013) *Probability and Statistics*. London. Fourth Edition.

Shadish, W. R., Cook, T. D. and Campbell, D. T. (2001) *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Wadsworth, USA: Wadsworth Publishing.

The Air Quality Standards Regulations 2010, c. 1001. Available at: http://www.legislation.gov.uk/uksi/2010/1001/contents/made [Accessed: 10th June 2018]

The Guardian (2009) *All fired up*, Available at: https://www.theguardian.com/lifeandstyle/2009/nov/21/wood-burning-stoves [Accessed: November 12th 2017]

Thorpe, R. & Holt, R. (2008) *The SAGE Dictionary of Qualitative Management Research - Historical Analysis*. London: SAGE.

Tiwari, S., Dahiya, A. and Kumar, N. (2015) 'Investigation into relationships among NO, NO_2, NO_x, O_3, and CO at an urban background site in Delhi, India'. *Atmospheric Research*. 157, pp.119-127.

USwitch (2015) *Devon is the 7th worst place to live in the UK*. Available at: https://www.uswitch.com/place-to-live/devon/ [Accessed: 13th May 2017].

Walton, W., Carmichael, K. and Hunter, C. (2010) Local Air Pollution Control in the USA: Potential lessons for the Introduction of Air Quality Management Areas and Action Plans in the UK, *International Planning, Studies* 6(3), pp. 311-333.

Weitkamp, E.L.C & Longhurst, J.W.S., (2012) Mediating Consultation: insights from private sector consultancies involved in air quality consultations, *Journal of Environmental Planning and Management,* 55 (1) 113-125.

Williams, T.and May, M. (1996) *An Introduction To The Philosophy Of Social Research*. London: Routledge

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2001) Emerging political and collaborative decision-making frameworks for designating air quality management areas (AQMAs) in the UK: implications for future air quality action plans (AQAPs), *Transactions on Ecology and the Environment*, 47(2001), pp. 285- 294.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2002) A review of air quality management areas in Great Britain: implications for land-use planning, *Air pollution,* 52(2002), pp. 133-140.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2002a) Designating Air Quality Management Areas (AQMAs) in the UK: Implications for securing UK Air Quality Objectives, Water, Air and Soil Pollution, 2(2002), pp. 677-688.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2003) Critical evaluation of the role of scientific analysis in the UK local authority AQMA decision-making: method development and preliminary results, *The Science of the Total Environment*, 311(2003). pp,1-18.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2003a) The application of scientific uncertainty and error in the designated AQMAs of GB:

implications for further air quality assessments, *Transactions on the built Environment*, 64(2003), pp. 263-272.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2006) Regional collabative urban air quality management: Case studies across Great Britain, *Environmental Modelling and Software*, 21(2006), pp 595-599.

Woodfield, N. K., Longhurst, J. W. S., Beattie, C. I. and Laxen, D. P. H. (2010) Regional Variations in the Implementation of Local Air Quality Management Process within Great Britain, *Journal of Environmental Planning and Management*, 46(1), pp. 49-64.

World Health Organisation (2017) *Air Pollution*. Available at:http://www.who.int/sustainable-development/transport/health-risks/air-pollution/en/ (12th March 2017)

Vidal, J. (2016) *Young Londoners launch independent air pollution billboard campaign.* Available at: https://www.theguardian.com/environment/2016/aug/16/young-londoners-launch-independent-air-pollution-billboard-campaign [Accessed: 15th January 2017]

Visit Plymouth (2017) *Events*. Available at: http://www.visitplymouth.co.uk/whats-on/events [Accessed: 13th May 2017]

Von Radowitz, J. and Moor, E. (2017) *Plymouth's polluted air too dangerous to breathe.* Available at: http://www.plymouthherald.co.uk/news/health/plymouths-polluted-air-dangerous-breathe-704029 [Accessed: 14th December 2017]

Zhang, L., Guan, Y., Leaderer, B. P. and Holford, T. (2013) 'Estimating Daily Nitrogen Dioxide Level: Exploring Traffic Effect'*. US Library of Medicine National Institute of Health*. 7(3), pp. 10-14.