LEEDS BECKETT UNIVERSITY

Assessing the Impact of Nitrogen Dioxide in Pool-in-Wharfedale Air Quality Management Area within Leeds Metropolitan District.

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ABSTRACT

Air Pollution is a global concern and a leading cause of mortality among all risk factors. WHO statistics show that over 7 million premature deaths are associated with air pollution annually. The detrimental health impact of air pollution has been observed even at the lowest concentration level. Health impact associated with lower pollution levels provides an opportunity for review of existing air quality regulations and policies. This dissertation investigates the ambient Nitrogen Dioxide concentration level within Pool in Wharfedale Air Quality Management Area, with a focus on historical trends and geographical variation away from the road traffic. The study aims to assess the impact of adopting WHO 2021 NO_2 guideline on the Air Quality Management Area in Pool-in-Wharfedale.

The Analysis of the historical data from 2017 to 2023 shows a general decline in NO_2 concentration levels across the six different monitoring locations (D114, D203, D208, D209, D210, and D211) within Pool in Wharfedale AQMA. There were notable fluctuations and occasional spikes in NO_2 concentration for some years. These spikes suggest that environmental variables (temperature, wind pattern, humidity) and road traffic volume continue to influence air quality in the local area.

The six-week continuous NO_2 monitoring conducted outside the AQMA boundary and 50 meters away from the road traffic reveals significant spatial variation in ambient NO_2 concentration levels. NO_2 concentration levels were observed to decline away from the main road traffic (A658). The results highlight the impact of road traffic on local air quality and its consistency with similar studies that have established the decline in NO_2 concentration levels away from major road traffic. Few monitoring locations at a distance further away from the main road recorded elevated NO_2 concentration levels which could be linked to atmospheric dilution and reactivity.

The research outlined the impact of adopting the stricter WHO 2021 annual NO_2 guideline of 10µg/m^3 over the current UK annual NO_2 objective of 40µg/m^3. The six-week monitoring results showed exceedance of the WHO guideline for majority of the monitoring locations. The Forecast data suggest that, while NO_2 concentration reduced for the next five years, it remains well above the WHO recommended guideline value. The differing situation highlights the need for the UK to adopt strict air quality guidelines.

The paper concludes that despite measures established in the UK to reduce NO_2 levels both nationally and at the local level, more efforts are required to improve air quality and protect public health. Achieving the WHO's annual NO_2 objective will require an integrated approach of policy review, technological innovation, and community engagement. Further research is recommended for extended monitoring duration to capture the complete annual variation in NO_2 concentration level.

DECLARATION

I Sylvester Nicholson declare that this project is my own original work (except where referenced) and does not infringe copy right.

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Terms and Definitions

List of Abbreviation/Chemical Formula	Meaning
AQMA	Air Quality Management Area
NO_2	Nitrogen Dioxide
OHID	The Office for Health Improvement and Disparities
DEFRA	Department for Environment Food & Rural Affairs
WHO	World Health Organization
UK	United Kingdom
TEA	Triethanolamine
LAQMA	Local Air Quality Management Area
AQG	Air Quality Guideline
AQI	Air Quality Index
ISEE	International Society of Environmental Epidemiology
ERS	European Respiratory Society
EEA	European Environmental Agency

1.0 INTRODUCTION

1.1 Background

Air Quality is a critical component of the environment. Globally, poor air quality continues to increase at an alarming rate which impacts public health, the quality of life, and the economy (WHO, 2022). Poor air quality is known to be a local, regional, and international concern primarily caused by pollutant emissions or atmospheric chemical reactions (DEFRA, 2024a). In 2019, the majority of the world population resided in areas that did not comply with the WHO 2021 strictest air quality guideline (WHO, 2022). The new WHO air quality guidelines are robust and reflect the enormous impact of air pollution on global health (Hoffmann et al., 2021).

Studies have shown that air pollution in the United Kingdom extends back to the 13th century. However, these conditions were associated with the rapid increase in population, growing urbanization, and the shift in fuel usage (Parliamentary Office of Science and Technology, 2002). The seriousness of air pollution after some years made the British Government pass the Clean Air Act of 1956. This Act established smoke-free areas and restricted the burning of coal for both industrial and domestic purposes to improve air quality and public health (Martinez, 2024). While the Clean Air Act prioritized addressing pollution from emission sources, the present air quality strategy in the UK has adopted the implementation of standards or target values for the various pollutants emitted into the ambient environment (Parliamentary Office of Science and Technology, 2002).

The Government of UK has developed statutory Air Quality Strategies (AQS) and a system of local air quality management which set targets for various air pollutants like benzene, carbon monoxide, nitrogen dioxide, particulate matter, and others. Some of the AQS implemented include local air quality management, vehicle emission regulations, industrial air pollution control, and fuel regulations (DEFRA, 2023a). The UK is divided into 43 zones for air quality assessment and 28 out of these zones are agglomeration zones (DEFRA, 2023b). The monitoring data recorded from the monitoring zones are augmented by modeling and other method of economical monitoring which is compared with the national air quality objectives (DEFRA, 2024b). It is important to monitor and quantify the ambient air pollutant concentrations of a particular geographical area. In the United Kingdom, the National Atmospheric Emission Inventory (NAEI) documents and provides concentrations of different pollutants (Gaseous and Particulate matter) emitted annually from anthropogenic factors (DEFRA, 2024c).

Globally the UK is ranked 21st on the worlds most polluted countries (IQAir, 2022). The Historical context and importance of atmospheric air quality management in the United Kingdom highlights the development of regulations and policies intended to effectively reduce air pollution. Adopting the current WHO 2021 air quality guidelines which are more stringent and reflective of the current health research will help improve the local air quality management practices and result in enormous health benefits. This research focuses on the impact of adopting the WHO 2021 NO_2 annual guideline on the Air Quality Management Area.

1.2 Local Authority Air Quality Management

Part IV of the Environmental Act 1995 as amended by the Environment Act 2021 set out the legal requirement for Local Air Quality Management (LAQM). LAQM is an obligation placed on all first-tier local authorities in the UK (borough, district, and unitary authorities) to conduct regular reviews and assessments of their local air quality and take immediate action to improve areas that do not meet the AQS target or objective (DEFRA, 2023a). Areas that do not meet these targets are declared as an Air Quality Management Area (AQMA). A proposed action plan is developed by the Local Authority following the declaration within 18 months to effectively reduce air pollution. Despite the steady improvement in the national trends in air quality, 71.7% of Local Authorities within the UK have one or more AQMAs with the majority in the urban areas (DEFRA, 2023c). Table 1.1 and 1.2 below show Air Quality Management Areas within the UK and AQMA by sources respectively.

Table 1. 1: Air Quality Management Areas within the UK

Region	Total LAs	LAs with AQMAs	AQMAs for NO_2	AQMAs for PM_{10}	AQMAs for SO_2
England (outside London)	263	184	509	26	5
London	33	33	34	28	0
Scotland	32	14	25	26	1
Wales	22	11	43	1	0
Northern Ireland	11	9	17	2	0
TOTAL	**350**	**251**	**628**	**83**	**6**

Source: (DEFRA, 2023c)

Table 1. 2: Air Quality Management Area by Source

Source	England	Wales	Scotland	Northern Ireland	London
County or Unitary Authority Road	186	21	4	0	1
Domestic Heating	1	0	0	1	0
Strategic Road Network	43	2	0	0	0
Industrial Source	8	1	1	0	0
Mixture of Road Types	79	5	2	1	2
Not Defined	1	0	1	2	0
Railways	1	0	0	0	0
Road Transport (unspecified)	187	15	27	15	27
Transport and Industrial Source	11	0	2	0	4
Transport, Industrial and Domestic Sources	5	0	2	0	1

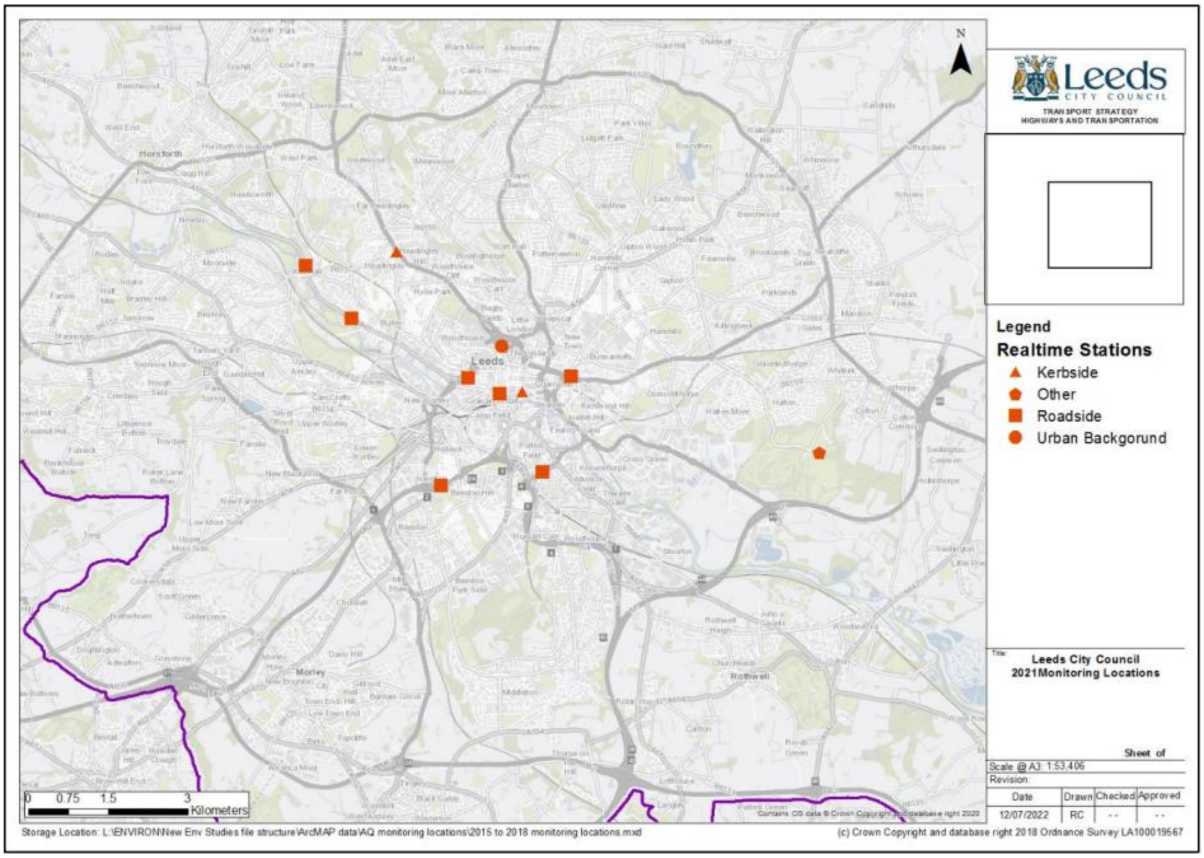
Source: (DEFRA, 2023c)

1.3 Air Quality in Leeds

Leeds urban area is a historic county of Yorkshire, northern England which is located along the river Aire approximately 30 miles northeast of Manchester. Leeds is known to be the industrial capital of Yorkshire because of its resources (coal and iron ore), water supply system, and excellent transportation links (Britannica, 2024a). Leeds City Council established in 1974 is the local government authority responsible for the city of Leeds. It is among one of five metropolitan district councils in the county of West Yorkshire region (Mackett, 1984) with a population size of 812,000 in 2021 (ONS, 2022). The council is responsible for providing local services and facilities to the residents of the city which include social care, education, waste management, pollution control, sustainable development practice, and others.

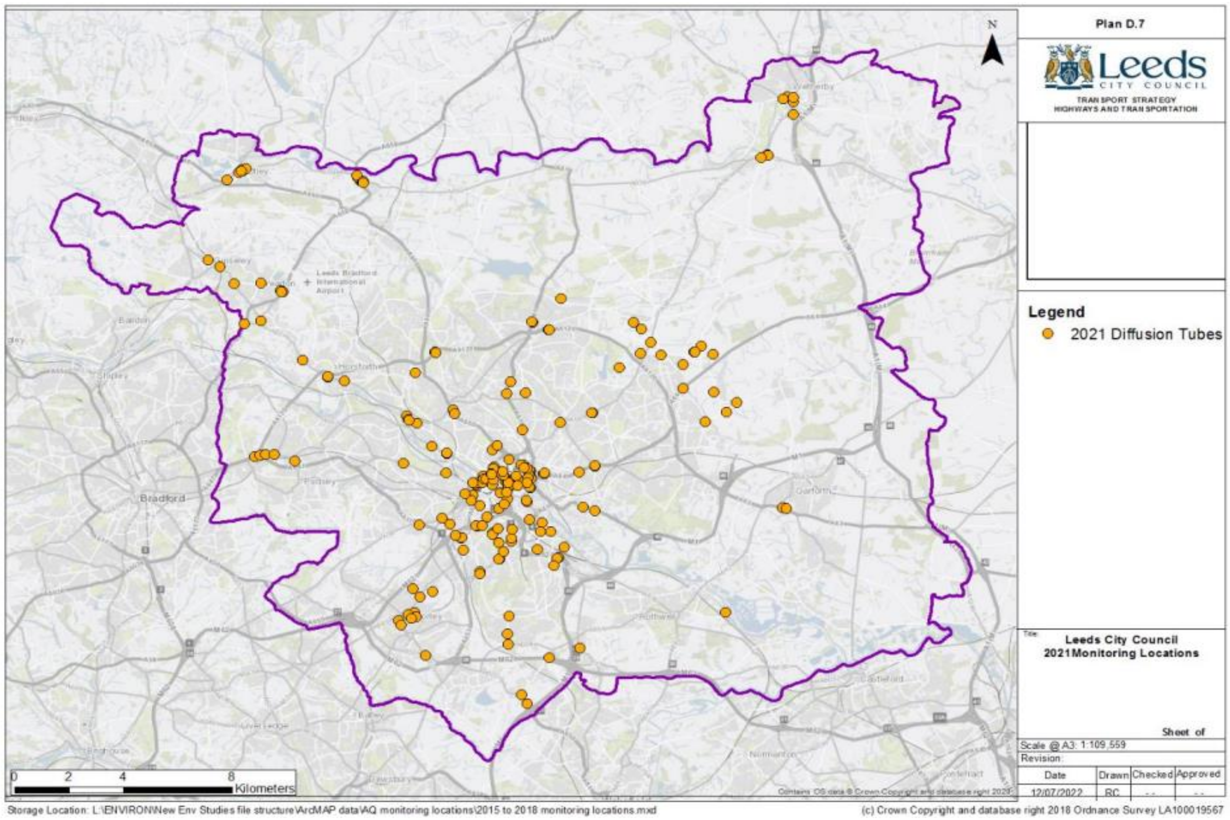
Leeds Metropolitan District air quality has improved significantly over the period and this was mainly due to the COVID-19 pandemic in 2020 where the Metropolitan District experienced a high reduction in vehicular emissions leading to reduced levels of nitrogen dioxide pollutants (Leeds City Council, 2023a). Despite the reduction in ambient pollutant emissions, some areas within the Metropolitan District remain above the UK annual air quality objective (Leeds City Council, 2023b). The two main pollutants of concern in the Metropolitan District include nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$). Leeds City Council in fulfillment of Part IV of the Environmental Act 1995 Local Air Quality Management, as amended by the Environmental Act 2021 continues to conduct air quality monitoring at various locations where air pollution is expected to be higher above the UK national objective.

The ambient air quality monitoring network within the metropolitan district for nitrogen dioxide (NO_2) includes nine (9) automatic nitrogen dioxide monitors and 176 manual diffusion tubes that record monthly and yearly NO_2 concentrations (Leeds City Council, 2023b). Figure 1.1 and figure 1.2 below show monitoring locations for automated nitrogen dioxide monitors and manual nitrogen dioxide (NO_2) diffusion tubes across Leeds Metropolitan District respectively.



Source: Leeds City Council (2023b)

Figure 1. 1: Map Showing Automated NO_2 Monitoring Stations in Leeds



Source: Leeds City Council (2023b)

Figure 1. 2: Map Showing Manual NO_2 diffusion tube Locations in Leeds

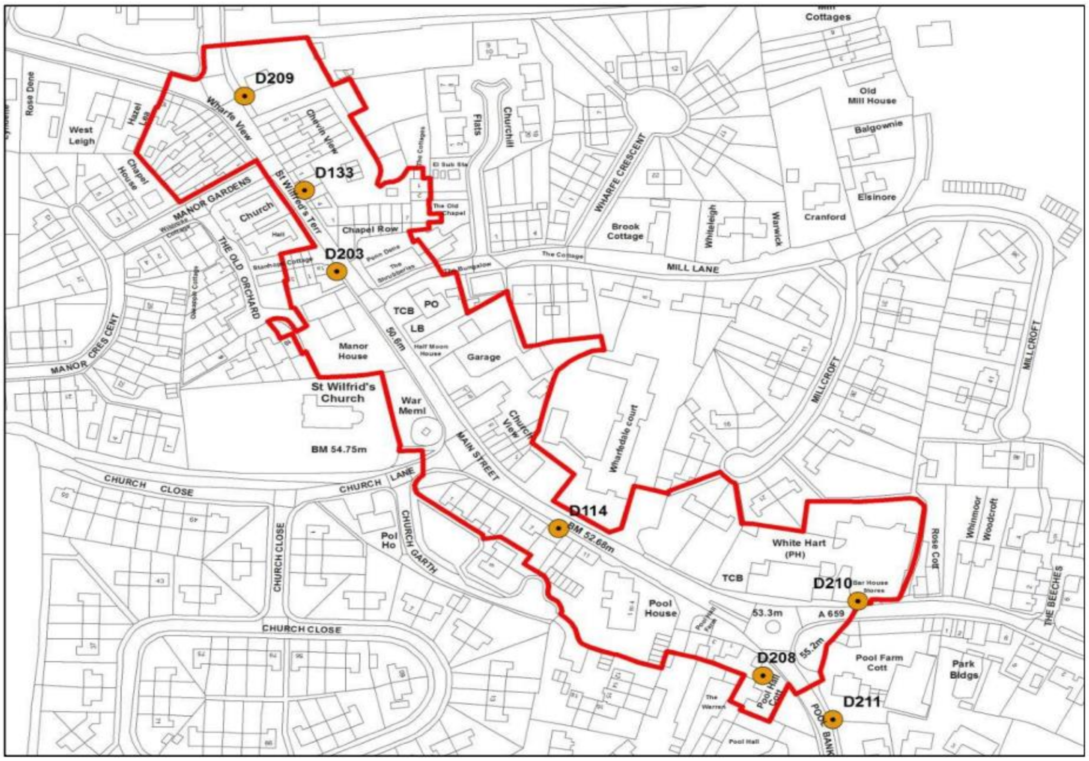
1.3.1 Air Quality Management Area (AQMA) in Leeds

Local Authorities in the UK have been reviewing and assessing their local air quality since 1997, however, local areas that do not meet the national air quality objective must be declared as an Air Quality Management Area (AQMA) and this could cover few streets or a bigger area (Leeds City Council, 2023b). Leeds City Council declared Six (6) areas within the district as AQMAs. These areas (Ebor Gardens, Caspar Apartments, The Normans, The Tilburys, Chapel Hill, and Pool in Wharfedale) were observed to record an annual NO_2 concentration above the national air quality objective (40µg/m^3). Continuous ambient NO_2 monitoring at the AQMAs for several years showed that the majority of these areas comply with the annual air quality standard for NO_2 except for Pool in Wharfedale which did not meet the annual standard. Therefore the council has developed plans to revoke five (5) of these areas off their AQMA status since monitoring records show long-term compliance. Ambient NO_2 monitoring continues in Pool in Wharfedale AQMA to evaluate the long-term trends (Leeds City Council, 2023b).

1.3.1.1 Pool-in-Wharfedale AQMA

Pool-in-Wharfedale is a village in Wharfe Valley, situated on the southern side of an important crossing point of river Wharfe. The Civil Parish of Pool-in-Wharfedale is located in the Adel and Wharfedale ward of the city of Leeds Metropolitan Borough in the county of West Yorkshire. Leeds is approximately 10 miles to the south of Pool-in Wharfedale village. Majority of the area and its woodland is designated as conservational area with some listed building. The area is known for its poor public transport links resulting in a high dependency on private vehicles and continues traffic build up because of it narrow Main Street especially in the morning and evening periods. Residential buildings within area were observed to be in close proximity to the main road (Pool in Wharfedale Parish Council, 2019).

The main street in Pool in Wharfedale was declared as an Air Quality Management Area in 2017 since the area did not achieve the annual air quality objective for NO_2 following the air quality assessment conducted by Leeds City Council in 2016. A total of six (6) active manual diffusion tubes have been positioned at the roadside with diffusion tube identification D114, D203, D208, D209, D210, and D211 (Leeds City Council, 2023b). Figure 1.3 below shows the locations of the manual diffusion tubes and the AQMA boundary in Pool in Wharfedale



Source: Leeds City Council (2023b)

Figure 1. 3: Map showing location of diffusion tubes and AQMA boundary in Pool in Wharfedale

2.0 LITERATURE REVIEW

The literature review for this study outlines a detailed description of ambient air pollution while focusing on the pollutant of concern (NO_2) generated by vehicular emission. The literature examined the health impact, applicable regulations, and policies as well as the measurement of NO_2. To gather comprehensive information for this research, a systematic literature search was conducted using several academic databases and journals mainly PubMed, Google Scholar, Science Direct, Environmental Science & Technology journal, and Leeds Beckett Library. Key search terms used were "air pollution," " NO_2 concentration," "health impact of NO_2," "air quality regulations and policy," "traffic emissions," and " NO_2 monitoring techniques". These materials offered a robust foundation for understanding the historical and present trends, health impact, and NO_2 regulatory frameworks.

2.1 Air Pollution

Air Pollution is the modification and contamination of the indoor and ambient air quality by harmful factors such as physical, chemical, and biological agents which adversely impact the various environmental aspects (Kanwar, 2024; National Geographic Society, 2024). According to (JNCC, 2023) air pollution is a primary environmental stress that impacts a range of scales including local, regional, and global. Air pollution is adversely impacted by factors such as the weather and transboundary dispersion of air pollutants (Kelishadi and Poursafa, 2010). The issue of ambient air pollution has emerged as a serious environmental concern with a wide range of health consequences (Marais et al., 2023; Sullivan, J. and Sorensen, 2023).

According to a recent WHO publication, air pollution is among the leading causes of mortality among all risk factors such as hypertension, smoking, and increased levels of glucose. About seven (7) million premature deaths globally from heart diseases, stroke, lung cancer, and among others are associated with air pollution (WHO, 2023). The global public health economy was impacted enormously in 2019, with an increase in the gross domestic product by 6.1% equivalent to US$8 trillion (WHO, 2023). Air pollution has been considered the largest environmental risk in the UK and adversely impacts the health of most people, especially vulnerable groups. Annual deaths from anthropogenic air pollution in the UK are between 28,000 and 36,000 (OHID, 2022).

In the Leeds Metropolitan District, air quality continues to improve due to citywide actions such as clean transport emissions, promoting active travel (public bike share), reduction of emissions from homes, and raising awareness. Moreover, despite the current improvement in air quality, 54 in every 1000 deaths is linked to air pollution (Leeds City Council, 2023b).

2.1.1 Types of Atmospheric Air Pollutants

Despite the different characteristics of the various air pollutants such as chemical composition, atmospheric reaction, and longevity in the environment, pollutants share some similarities and are classified into various groups such as persistent organic pollutants, heavy metals, gaseous pollutants, and coarse and fine particulate matter (Fino, 2019). Common air pollutants collectively referred to as "criteria pollutants" include particulate matter, ground-level ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead (US EPA, 2024a). Sources of these pollutants can be natural or anthropogenic emissions from industrial processes which are mostly affected by wind patterns, temperature, and humidity (Wei et al., 2023).

Persistent organic pollutants (organochlorine pesticides, industrial chemicals, and by-products or contaminants) are toxic and semi-volatile pollutants that can be transported for long distances through the atmosphere and tend to bio-accumulate (World Bank Group, 2023). Toxic heavy metals like mercury, lead, and cadmium have been natural components of the earth's crust since the earth's formation. Heavy metals are emitted into the environment through industrial processes like combustion and wastewater discharge (Gautam et al., 2016).

Gaseous pollutants such as sulfur dioxide, nitrogen dioxide, carbon monoxide, and volatile organic compounds contribute largely to the atmospheric variation (Morabet, El, 2019). Direct emissions of gaseous pollutants include automobiles, stationary combustion, and burning of natural gas or gasoline Nathanson (2024). Particulate matter is a mixture of solid fragments and liquid droplets present in the air which causes serious health risks when inhaled (US EPA, 2024b). Particle pollution size generated from construction sites, unpaved roads, and smokestacks include PM_{10}, $PM_{2.5}$, and Total suspended particles (EPA, 2024b).

2.1.1.1 Nitrogen Dioxide (NO_2)

Nitrogen dioxides are highly reactive inorganic compounds released into the ambient environment through natural and anthropogenic processes (Britannica, 2024b). NO_2 is an atmospheric air pollutant consisting of nitrogen and oxygen gases that occur during high temperatures (American Lung Association, 2023). Similar studies defined nitrogen dioxide as a precursor of ozone which is generated in the presence of heat and direct sunlight (Subramanian and Khatri, 2019). According to research conducted by (Pryor et al., 2015), NO_2 constitutes a group of nitrogen-containing gases known as oxides of nitrogen (NOx) and is used as an indicator for larger groups of nitrogen oxides.

Nitrogen dioxide is released naturally into the ambient environment from forest fires, volcanoes, and lightning events or strikes which can reach a temperature of 30,000 kelvins (aeroqual, 2024). Anthropogenic sources of nitrogen dioxide are predominantly emitted from the combustion of fossil fuels (coal, natural gas, and oil), automobile exhaust emissions, explosives, and welding activities (Pandey and Singh, 2021).

2.1.1.2 Nitrogen dioxide (NO_2) in Transportation

Globally, road transport is a principal outdoor source of nitrogen dioxide (Jarvis et al., 2010). Traffic congestion elevates vehicular emissions and significantly reduces air quality (Zhang, K. and Batterman, 2013). Large quantities of nitrogen dioxides are emitted from road traffic in urban and suburban areas which serve as a main pathway for NO_2 exposure at the roadside or urban background level (Molle et al., 2013). Heavy-duty vehicles, commercial vehicles, or buses contribute to 76% of the total NOx emission into the ambient environment whereas light vehicles and private automobiles contribute 70% (ICCT, 2017).

The majority of the countries within western and northern Europe reported NO_2 from road traffic as the only source of exceedance of air quality objectives (EEA, 2022). Research conducted by (US EPA, 2024c) identified transportation as the largest contributor to greenhouse gas contributing about 28% of the overall emissions in the United States. In Great Britain, road traffic has increased by 29% from 255 billion miles travelled in 1990 to 328 billion miles travelled in 2018 (ONS, 2019). However, the increase in road traffic makes the transportation sector in the UK the largest contributor of greenhouse gas emissions generating about 26% in 2021 (Department for Transport, 2023).

2.1.1.3 Nitrogen Dioxide Work Exposure Limit

There have been several reviews on the toxicity of NO_2 concentration that might occur in the workplace (Toxicants, 1998). The main route of exposure to NO_2 is through inhalation. NO_2 exposure has been reported to be associated with several occupations such as electroplating, welding, space exploration, military activities, and agriculture (Stieb et al., 2009). NO_2 can trigger a range of clinical reactions based on the concentration and exposure duration. Extreme exposure can result in death (Kamangar, 2024). The WELs and COSHH Regulation 2002 (as amended) set the long (8-hr) and short-term (15-minute) requirements to protect the health of workers from pollutants. Nitrogen dioxide exposure limits for both long and short-term are 0.5 ppm and 1 ppm respectively (Health and Safety Executive, 2018).

2.1.1.4 Health and Environmental Impact of NO_2

Ambient air pollutant generated from road traffic is related to acute and chronic cardiovascular and respiratory health consequences (Tonne et al., 2014). There have been many studies conducted on NO_2 as an independent contributor to poor health conditions. Research studies conducted by (Eum et al., 2019; Roswall et al., 2017) reported a close association between NO_2 and mortality rate due to respiratory and cardiovascular diseases. Similar research conducted by (Brauer et al., 2007) showed a high prevalence of asthma and allergic cases among vulnerable groups, especially children. The close association between pollutants and health risk is dependent on several factors such as the location, time, sample size, and the study population (Liu, F. et al., 2019).

In Europe, exposure to NO_2 above the WHO 2021 guideline objective resulted in 49,000 premature deaths. Exposure to air pollutants causes personal suffering and maximization of healthcare costs. Current statistics show that exposure to NO_2 caused 175,070 years lived with disability (YLDs) due to type 2 diabetes in the majority of European countries including the UK (EEA, 2022b). Despite the health impact of NO_2 on human health, NO_2 emissions cause adverse impacts on the environmental component. The continuous interaction of NO_2 with water, oxygen, and other chemicals present in the ambient environment causes acid rain which destroys structures and cultural sites. Also, it causes nutrient pollution in coastal water. In addition, the haze formed from NO_2 decreases visibility (US EPA, 2023c).

2.1.1.4 How Nitrogen Dioxide (NO_2) is Measured

Ambient NO_2 concentration in an area can be monitored by a variety of monitoring techniques which include the chemiluminescence analyzer, diffusion samplers, electrochemical sensors, thick film sensors, and differential optical absorption spectroscopy (DEFRA, 2004). The common monitoring techniques adopted in the UK is the diffusion samplers and chemiluminescence analyzers (DEFRA, 2004). The chemiluminescence analyzer uses the luminescence phenomenon that generates ultraviolet or infrared radiation due to chemical reactions (Kaveti, 2023). During monitoring the chemiluminescence analyzer is positioned within the monitoring location to collect air samples to detect and quantify trace gases of interest (NO_2) with high resolution over a continuous period.

Diffusion tube application involves the use of small passive air samplers that measure the atmospheric NO_2. The passive samplers contain a metal grid of stainless coated with tri-ethanol amine (TEA) which is a good absorber of atmospheric NO_2. During the diffusion tube application, the spectrophotometer is used to determine the optical density of the azo dye following the application of the Saltzman Technique (AEA Energy and Environment 2008; DEFRA, 2022).

2.2 Regulation, Policies and Air Quality Strategies

The WHO as part of its commitment to combat the biggest environmental threat (air pollution) has developed a new Global Air Quality Guidelines (AQGs) to reduce the risk level of key air pollutants and improve climate change. In relation to nitrogen dioxide, a new air quality guideline of 10μg/m^3 and 25μg/m^3 annually and short-term (24-hour) was established respectively (WHO, 2021a). In the UK actions to manage and improve air quality have been driven by International agreements, European Union Regulations, and National and Domestic Legislation (Smith and Bolton, 2024). The air quality standards that set ceilings and limits in the UK have been sharped into different strands which include standards for ambient air quality, transboundary air pollutants, and key sources of pollutants (Smith and Bolton, 2024).

The stipulated Air Quality Standard Regulation 2010 for NO_2 should not exceed an annual mean concentration of 40µg/m^3 while the hourly NO_2 concentration of 200µg/m^3 should not be more than 18 times in a single year (AQS, 2010). At the local level, Leeds Metropolitan District has adopted various strategies to reduce pollutant emissions. The plan focuses on reducing air pollution from transport, home, industry, and agriculture. Currently, the council is reducing vehicular emissions by replacing council vehicles with electric including bin lorries, improving infrastructure for plug-in vehicles both in public and private car parks, installing cycle lanes, active air quality monitoring and among others (Leeds City Council, 2021).

2.3 Rationale of the Research

The UK annual air quality objective for NO_2 remains at 40µg/m^3 and this spans across all the declared Air Quality Management Areas. The boundary of the NO_2 AQMA may encompass just one or two streets from the emission source mostly the road traffic (Leeds City Council, 2023b). The size of the AQMA reflects the impact of the pollutant gas from the emission source. Pool in Wharfedale AQMA covers just one or two streets from the road traffic therefore, residences outside the AQMA boundary are considered to be within safe exposure limits. Recent research studies and extensive research programs globally continue to establish that the adverse impact of ambient air pollution is not solely associated with high pollutant exposure rather, the detrimental health effect among the population can be observed at very low pollutant concentration levels, with no air quality objective below exposure limit can be considered safe (Brauer et al., 2021; Dominici et al., 2022).

Recognizing exposure to lower pollutant concentration could cause adverse impacts on human health offers an opportunity to review existing air quality policies or legislations and promote cleaner air (Hoffmann et al., 2021). The majority of countries with established air quality objectives rely on the set limit without further pollution control action once compliance is achieved (Kutlar Joss et al., 2017). The recently updated WHO air quality guideline provides a significant reduction in the key atmospheric pollutants of concern which benefit nearby populations or environs with low pollutant concentration (WHO, 2021b). Adopting the 2021 WHO updated global air quality annual standard for NO_2(10µg/m^3) over the AQMA in Pool–in-

Wharfedale will promote a review of existing legislation, ensure enormous health benefits, and improve air quality over time while understanding the extent of exposure away from the emission source. The research study highlights the impact of adopting WHO Guideline on Air Quality Management Area however, further research can be conducted to determine the impact of NO_2 concentration level over an extended period in the AQMA.

2.4 Aim

The aim of this study is to assess the Impact of adopting WHO NO_2 guideline on the Air Quality Management Area in Pool-in-Wharfedale.

2.4.1 Research Objectives

- Evaluate the historic annual NO_2 variations at predetermined locations within the Pool-in-Wharfedale AQMA.
- Measure and document NO_2 exposure levels outside the Pool-in-Wharfedale AQMA to estimate changes in exposure with geographical locations.
- Compare NO_2 exposure levels in different geographical locations with WHO regulatory standards.
- Evaluate the potential impact of adopting the WHO NO_2 annual threshold in place of the UK Air Quality Objectives.

3.0 METHODOLOGY

3.1 Introduction

The research used a quantitative methodological approach to determine the impact of adopting the WHO NO_2 annual guideline on the AQMA in Pool-in-Wharfedale. Unlike qualitative design, quantitative methodological approach deals with numerical data and explains the phenomena by gathering, evaluating, and comprehensively interpreting research findings using a mathematically based method (Aliaga and Gunderson, 2002; Williams, 2007). The selected design for this study provides a deductive approach, relying on experiment and measurement based on general principles to achieve the aim of the study (Johnson and Onwuegbuzie, 2004). Similar designs were adopted by many researchers (Mills et al., 2016; Olstrup et al., 2019; Rowell et al., 2021) to establish the significant impact associated with atmospheric air pollutants and mortality rate.

This chapter describes the ambient NO_2 monitoring and the data collection process (primary and secondary). It further describes how the ambient air quality measuring instrument was prepared and installed. It details the laboratory technique adopted to obtain the NO_2 concentration level and annualization factor applied to the monitored data. This chapter details the advantages and disadvantages of the method used while addressing validity, reliability, and resources required in accordance with the AEA Energy & Environment diffusion tube for ambient NO_2 monitoring and Local Air Quality Guidance Management Technical Guidance (TG22).

3.1.1 Study Area

Pool-in-Wharfedale is a village in Wharfe Valley, situated on the southern side of an important crossing point of river Wharfe. Administratively, the Civil Parish of Pool-in-Wharfedale is in the Adel and Wharfedale Ward of the City of Leeds Metropolitan Borough, in the county of West Yorkshire (Pool in Wharfedale Parish Council, 2019). The total population in Pool in Wharfedale built-up area is 1,992 with a population density and area capacity of 3,104/km2 and 0.6417km2 respectively (ONS, 2021). The area is characterized by its heavy traffic, particularly in the morning and evening times (Pool in Wharfedale Parish Council, 2019). Figure 3.1 below shows the area Map of the research location highlighted in red.

Source: Google Map

Figure 3. 1: Pool-in-Wharfedale Area Boundary

3.2 Historic Annual NO_2 Level in Pool-in-Wharfedale AQMA

Since the declaration of Pool-in-Wharfedale AQMA, extensive NO_2 monitoring has been conducted by Leeds City Council within the AQMA boundary spanning from 2017 to Date. Historic NO_2 data reflect the concentration trends, compliance with air quality objectives, and the extent of exposure within the area (DEFRA, 2023c). According to (Clarity, 2022) historical data provides a large data set of baseline levels associated with the pollutant of concern.

The NO_2 data obtained from Leeds City Council were available upon request. The data comprised of annual NO_2 concentrations levels recorded at six (6) predetermined monitoring points within Pool in Wharfedale AQMA boundary (D114, D203, D208, D209, D210, and D211). The monitoring locations within the AQMA boundary were identified as roadside which was between 1 to 5 meters from the kerb edge to directly monitor NO_2 emissions from the road traffic (Leeds City Council, 2023b). Refer to appendix 4 for confirmatory email from the Leeds City Council.

Several criticisms are associated with secondary data which include the collection of data with different objectives and the researcher's unawareness of conceptual and practical problems (Ortega, 2013; Cheng and Phillips, 2014). However, according to Leeds Air Quality Annual Status Report, monitored data were subject to robust quality control and assurance and reflect the ambient air quality of the area. In addition, the independent analytical proficiency testing conducted on all analytical laboratories for Local Air Quality Monitoring was satisfactory and complied with standard procedures (Leeds City Council, 2023b). The grid reference and site details of the monitoring points are presented in Table 3.1 below.

Table 3. 1 Grid Reference and Site details of AQMA Monitoring Locations

Diffusion Tube ID	Site name	Site Type	OS Grid Reference		Tube Height (m)
			X (Easting)	Y (Northing)	
D114	8 Main Street, Pool	Roadside	424507	445151	2.4
D203	Telegraph post, Main St, Pool		424418	445268	2.4
D208	Pool Hall Cottage		424589	445084	1.8
D209	Old School House, Pool		424381	445348	2.4
D210	White Hart PH, Pool		424627	445118	2.4
D211	Pool Bank New Road		424617	445064	2.4

Trend and time series analysis was conducted using a simple logarithmic model to identify any significant changes in NO_2 concentration over the monitoring period (2017-2023) while predicting NO_2 future concentration at each monitoring location for the next five years. Forecasting and time series models are widely accepted and used in several research fields such as economics, medicine, climate and air pollution (Abhilash et al., 2018; Kumar, K. and Jain, 1999; Siami-Namini and Namin, 2018). Based on the present environmental challenges, scholars have established forecasting to be of paramount importance and provide effective pollution control measures (Bai, L. et al., 2018).

The logarithmic model allows better results when analyzing data that exhibit non-linear correlation Taylor (2022). The transformation of data into corresponding logs enables more effective modeling and response to skewness in larger values unlike linear regression (Robbins, 2012). The R^2 value comparatively with other modules like exponential, linear, and polynomial showed a moderate to strong relationship capturing most variation in the historic NO_2 data in Pool in Wharfedale. The terms of the logarithmic equation are presented below.

$$y = m\ln(x) + c \qquad \textbf{Equation (1)}$$

Where

y = the variable been predicted (NO_2 concentration in 2028)

m = coefficient of ln (x) or the slope

ln(x) = natural logarithm of **x**.

x = the period variable which influences the **y**.

c = the y-intercept of the model and represent the baseline level of **y** when **x** is at a reference value

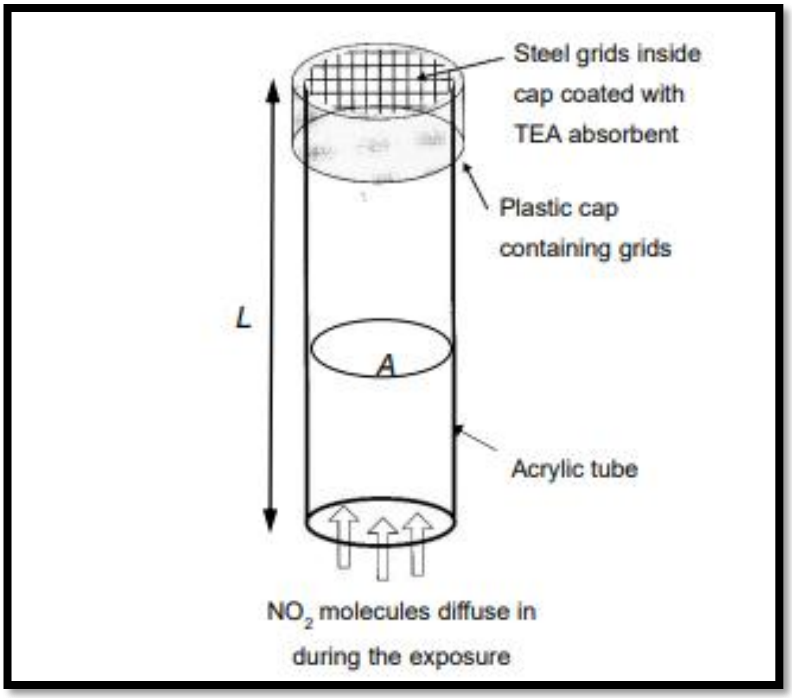
3.3 Ambient NO_2 Monitoring in Pool-in-Wharfedale

The indicative measurement of ambient nitrogen dioxide (NO_2) concentration was conducted in the project location following the AEA Energy & Environment diffusion tube for ambient NO_2 monitoring and Local Air Quality Management Technical Guidance (TG22). The practical guidance incorporates the monitoring tube preparation, usage, and analysis while harmonizing the UK diffusion tube methodology based on the present knowledge of the best practice (DEFRA, 2022).

3.3.1 Passive Diffusion Tube

The passive diffusion tubes introduced by (Palmes et al., 1976) were used to measure the ambient NO_2 concentration in Pool-in-Wharfedale. The passive diffusion tube operates on the principle of molecular diffusion of the ambient NO_2 which passes through a defined path driven by a concentration gradient from the open end of the sampler to a zero concentration steel grid coated with chemical absorbent on the closed end of the tube (Cape, 2009). The requirement of passive diffusion tubes such as lack of power supply, infrastructure, and simplicity promote the use in large quantities at the same period (Heal et al., 2019).

Comparatively with the reference method of chemiluminescence, the passive diffusion tube such as the Palmes-type diffusion tubes is very affordable and provides extensive spatial monitoring (Nash and Leith, 2010). It is recognized that the passive samplers have a greater uncertainty of ±25% compared with the chemiluminescence technique of ±15% (AEA Energy and Environment, 2008). The high expense of the reference method of chemiluminescence limits the geographic reach (Pannullo et al., 2015) and wouldn't be suitable for this study. The use of passive diffusion tubes can be subject to internal bias (Cape, 2009; Hafkenscheid et al., 2009; AEA Energy and Environment, 2008). However, high-standard laboratory QA/QC would ensure the quantification of the trapped NO_2 is free from any significant bias (Heal et al., 2019). Figure 3.2 below shows the diagram illustrating the construction of a Palmes-type passive diffusion tube.



Source (Heal et al., 2019)

Figure 3. 2: Schematic of the construction of a Palmes-type passive diffusion tube

3.3.2 Laboratory Preparation of Diffusion Tubes

All laboratory preparation was conducted following the AEA Energy and Environment practical guidance, 2008. Due to the limited availability of resources, a total of 25 Palmes-type passive diffusion tubes were prepared for each field monitoring every fortnightly. The triethanolamine (TEA) solution was prepared freshly on the day to be used to ensure the stability of triethanolamine (Hamilton and Heal, 2004). Triethanolamine is an organic amine compound that is effective in the absorption of ambient NO_2 (Liu, B. et al., 2021).

Research proves that the pipetting method gives worse performance, worse precision, and significantly low results (Hamilton and Heal, 2004; Hasannezhad Estiri, E. et al., 2023; Kirby et al., 2000). Therefore the dipping method was used during the preparation of the steel metal grid. Steel metal grids were dipped completely into the 50% TEA/acetone solution for one minute. The metal steel grids were dried on an absorbent surface in a well-ventilated area for a few minutes. Figure 3.3 shows the drying of the metal steel grids at the laboratory.

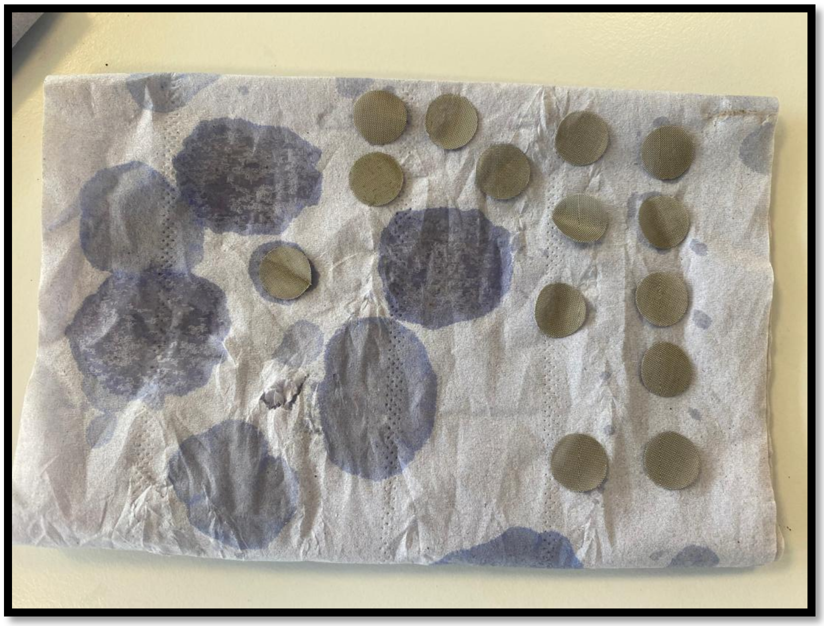


Figure 3. 3: Dried Metal Steel Grids on Absorbent Surface at the Laboratory

Diffusion tubes were assembled immediately after drying to avoid contamination. To ensure maximum absorption of ambient NO_2, two pregnant metal steel grids were placed in the plastic end-cap (red) and applied to one end of the tube and another plastic end-cap (white) was applied at the other end of the tube. The prepared batch was labeled and stored appropriately. Two diffusion tubes out of the 25 for each batch were identified as laboratory blanks and travel blanks. In addition, 3 tubes from each batch were used for co-location study to augment the validity of the monitoring technique. Unexposed blank samples were stored at room temperature to identify any possible contamination while the tubes were in transit or during preparation. The application of blank samples is vital in quantitative analysis since it provides correction for uncertainty in measurement (Raynie, 2018). Figure 3.4 below shows prepared diffusion tubes in a sealed sample bag.

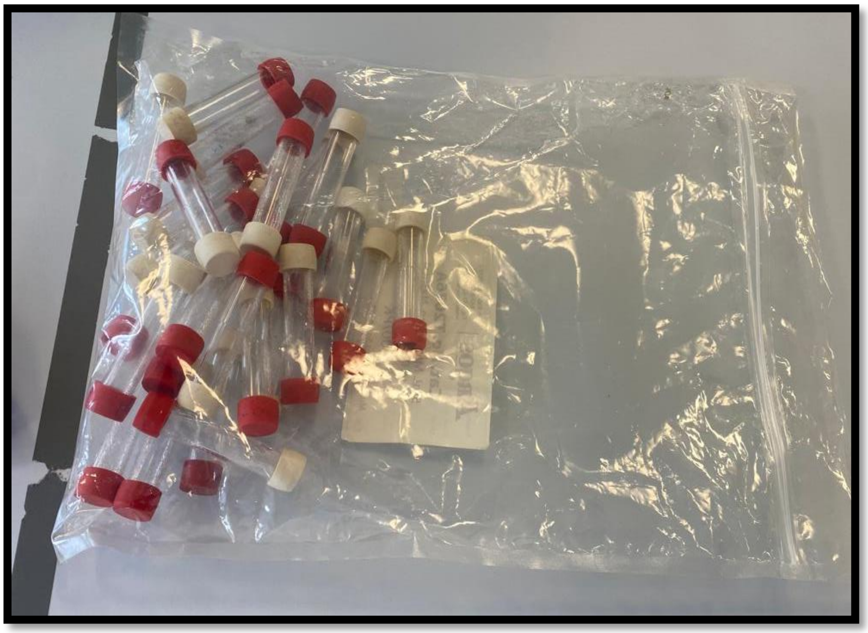
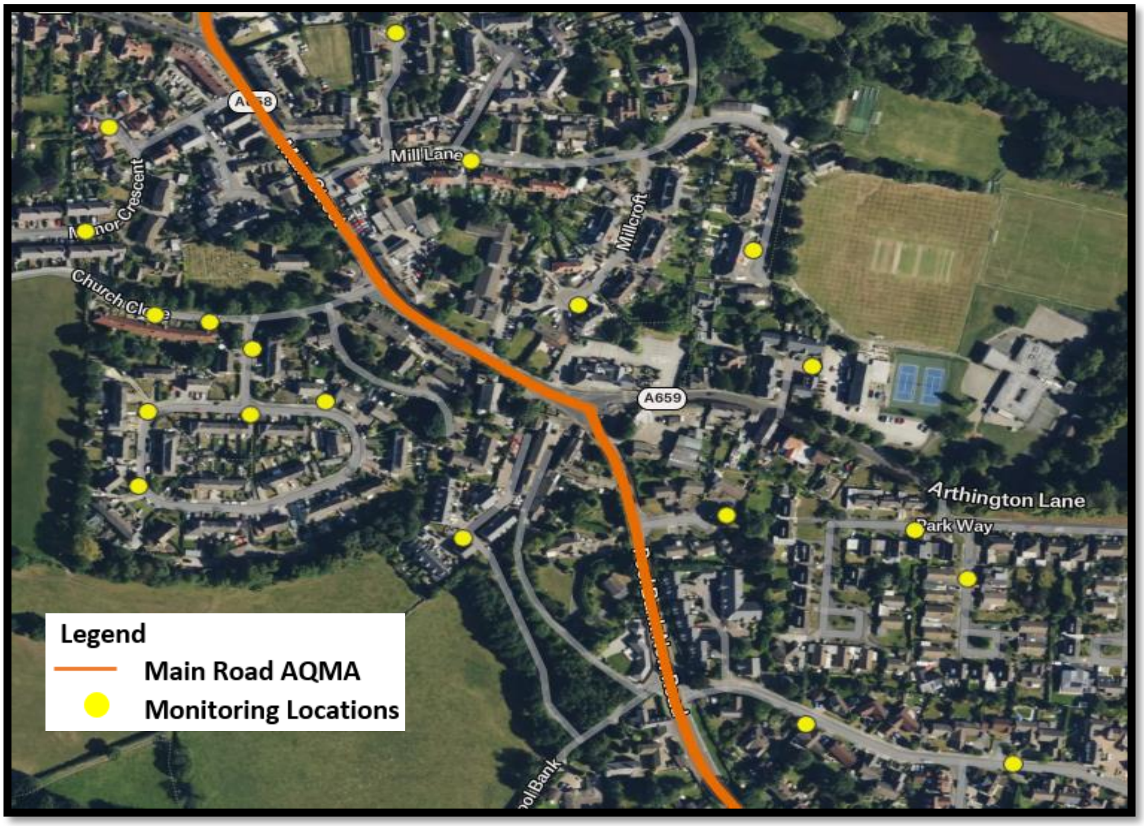


Figure 3. 4: Prepared Diffusion Tubes Sealed in a Sample Bag

3.3.3 NO_2 Field Monitoring in Pool-in-Wharfedale

Six weeks of continuous NO_2 monitoring was conducted in Pool in Wharfedale from Thursday 20th June 2024 to Thursday 1st August 2024. The ambient NO_2 monitoring was undertaken at a suburban site within the project location. All the suburban sites identified were more than 50 meters from the main street AQMA where there was relevant public exposure. It is anticipated that the ambient NO_2 concentrations will have diluted to the local suburban concentration at a distance more than 50 meters away from a busy road (AEA Energy & Environment, 2008). Therefore, NO_2 monitoring conducted within these distances represents the larger area, and monitoring data obtained can be compared with similar suburban areas (AEA Energy & Environment, 2008). A total of 20 diffusion tubes were deployed to the project location. Figure 3.5 below shows the distribution of diffusion tubes to different locations away from the road traffic in Pool-in-Wharfedale.



Source: Felt Map

Figure 3. 5: Ambient NO_2 Mentoring Points within Pool-in-Wharfedale

The passive diffusion tubes were mounted on lamp posts at a height of 2.5 meters above ground at all the monitoring locations to reduce the theft of tubes. The bottom end cap (white) without the metal steel grid was removed and positioned vertically downwards to allow the passage of the surrounding air. The passive diffusion tubes were replaced every fortnightly within the six-week sampling period to analyze the trend in the exposure of atmospheric NO_2 away from the main AQMA street. It has been established by (Cape, 2009; DEFRA, 2008) that exposed diffusion tubes into replicates promotes robust NO_2 monitoring results. Figure 3.6 below shows mounted passive diffusion tubes for some locations.

Figure 3. 6: Mounted Passive Diffusion Tubes at Monitoring Locations

3.3.4 Laboratory Analysis of NO_2 Passive Diffusion Tubes

Deployed passive diffusion tubes (batch samples) were retrieved from all the monitoring locations every fortnightly and sent to the laboratory for analysis. The absorbed nitrate from the triethanolamine coated metal grid was extracted by pipetting 2.0ml of pre-mixed Nitrogen Dioxide reagent solution into each of the diffusion tubes. The pre-mixed reagent was precisely dispensed using a calibrated pipette to an accuracy of 1.00%. The passive diffusion tube was effectively sealed with the plastic cap, shaken, and allowed color change for 20 minutes (AEA Energy & Environment, 2008).

A sample volume of 0.4ml from each passive diffusion tube was analyzed using the spectrophotometer to investigate the optical density of the Azo Dye generated following the application of the Saltzman Technique, a test method used to determine whether a material has been exposed to oxides of nitrogen due to common cause of discoloration (Ohkawa et al., 2001). The absorbance of the resulting solution (25 samples including blanks and co-location) was measured at a wavelength of 540nm following the protocol defined by (AEA Energy & Environment, 2008). The average blank absorbance (laboratory and travel) was used as corrective absorbance and subtracted from each batch sample to eliminate errors in sample preparation. A spreadsheet based on the AEA Energy & Environment guidance was used to determine the NO_2 concentration level.

To validate diffusion tube NO_2 data, a 6-week co-location study was conducted with Northern Terrace automated air quality monitoring station (53.80384° N, 1.54647° W). Direct deployment of 3 passive diffusion tubes 1m adjacent to the automated air quality monitoring machine in accordance with AEA Energy & Environment, 2008 guidance was not achieved due to lack of resources. Three passive diffusion tubes were mounted on a lamp post in close proximity to an automated ambient air quality monitoring station approximately 4 meters away to compare the difference in concentration level. The resultant concentrations were scaled to establish the difference between the standardized diffusion tube measurements with in-situ monitors. Figure 3.7 below shows passive diffusion tubes and automated air quality monitoring station used for the co-location studies.

Figure 3. 7 Co-Location Studies with Automated Air Quality Monitoring Station, Leeds Center

3.4 Comparism between NO_2 Exposure Levels with WHO Guideline

The ambient NO_2 concentration levels recorded for the six weeks monitoring duration in Pool-in-Wharfedale and the 5 years forecast were compared with the updated annual WHO guideline for NO_2 (10µg/m^3). The updated WHO 2021 air quality guideline serves as a global target for national, regional, and local authorities to put in measures to achieve and effectively improve the health of the population through reduction in air pollution (WHO, 2021b). The guideline incorporates robust scientific evidence on the health impact associated with air pollution, recommendations based on literature reviews as well as extensive consultation with experts and end-users globally (WHO, 2021a).

To compare the six (6) week monitoring period with the annual WHO standard for NO_2, the mean averages for the three batches of NO_2 concentration were calculated. The average NO_2 mean for each monitoring point during the six weeks monitoring was annualized in order to compare with the WHO annual NO_2 guideline. Annualization is the process of estimating annual means from the extrapolation of short-term ambient air quality results (DEFRA, 2022). Any monitoring site that does not achieve a minimum of nine (9) months or 75% monitoring data is required to complete the annualization of the monitoring data to compare with the air quality annual objectives (DEFRA, 2022).

The methodology of annualization requires the use of nearby concentration data from continuous monitoring sites (at least 85%) to estimate the annual mean of the short-term monitoring data. Since there wasn't any suburban site within pool-in-Wharfedale, the measured concentration (M) was annualized with 2022 period mean (Pm) and annual mean (Am) of similar sub-urban sites identified within Leeds Metropolitan District to derive the annualization factor (Ra) to estimate the annualized mean at each monitoring point following the Local Air Quality Guidance Management Technical Guidance, TG22 (DEFRA, 2022).

The estimated annual mean for all the monitoring locations were compared with the WHO annual NO_2 guideline to establish if the ambient NO_2 concentration at the suburban locations was compliant with the WHO NO_2 annual threshold of (10µg/m^3). Table 3.2 below presents sub urban sites used for annualization.

Table 3. 2 Annualization Sub Urban Monitoring Sites

Diffusion Id	Site Name	Site Type	OS Grid Ref		Valid Data Captured 2022
			X (Easting)	Y (Northing)	
D204	11 Farnham Close	Suburban	435562	438338	100
D411	Arium	Suburban	437483	438380	92.3
D417	LP 10M58 Manor House Lane	Suburban	431903	440554	92.3
D436	LP39 V107 Victoria Rd	Suburban	426701	428886	84.6

3.4.1 Determining Annualization Factor

The annualization factor (Ra) was determined by the equation

Ra = Am/Pm **Equation (2)**

Where

Am = Annual mean of the calendar year (2022)

Pm = Period mean of the period of interest (June – August 2022)

3.4.2 Determining the Annual Mean

To Determine the annualize mean for the six weeks NO_2 monitoring, the following equation was used.

Annualized Mean = M x Ra **Equation (3)**

Where

M = Measured mean concentration for the six week monitoring

Ra = Annualization Factor

3.5 Potential Impact of Adopting the WHO Annual NO_2 threshold in Place of the UK Air Quality Objective.

The new WHO air quality guidelines are ambitious and reflect the global health impact of pollution (Hoffmann et al., 2021). Programs implemented to effectively reduce pollutant emissions improves the ambient air quality over a specific period. The reduction in the threshold limit for the key pollutant of concern following the updated WHO air quality guidelines promotes public health and environmental sustainability. Many academic research have established clean air promotes public health (Chen, J. and Hoek, 2020; Huangfu and Atkinson, R., 2020; Orellano et al., 2020).

The potential impact of adopting the WHO annual guideline for NO_2 was established following the historical data and the ambient NO_2 monitoring undertaken within Pool in Wharfedale. Epidemiological studies and data were assessed from WHO and relevant public health publications to evaluate the potential impact of adopting the WHO guideline in the UK with robust comparison with similar implementation in different countries. The updated WHO guideline provides a critical tool for various users which include policymakers, technical experts, nongovernmental organizations, academic institutions, and environmental impact assessment practitioners (WHO 2021a). The WHO guideline presents the UK with an opportunity to improve public health, ambient air quality, regulatory reviews, and economic benefits.

3.6 Ethical Issues

Ethical norms are essential for research principles to protect participants, researcher safety, and avoid wasting resources and time. The research involves both primary and secondary data collection and will not recruit participants. Therefore, this academic research only requires the completion of the research ethics stage 1 application. The risk assessment for the researcher during the project duration has been completed. Refer to appendices 1 and 2 for a copy of the submitted ethics form and risk assessment.

4.0 RESULTS

4.1 Introduction

This chapter presents the trend and five-year forecast analysis of the historic NO_2 data. The section further analyzes the ambient NO_2 concentration levels monitored continuously over six weeks in Pool in Wharfedale while providing a comparative assessment with the WHO 2021 annual NO_2 guideline. The outcome of the meteorological data and co-location study have been presented in the sub sections below.

4.2 Historic NO_2 Data

The historic NO_2 data obtained from Leeds City Council comprised of six (6) monitoring locations within Pool in Wharfedale AQMA. The annual NO_2 trend of the six different locations from 2017 to 2023 is shown in Figure 4.1 below.

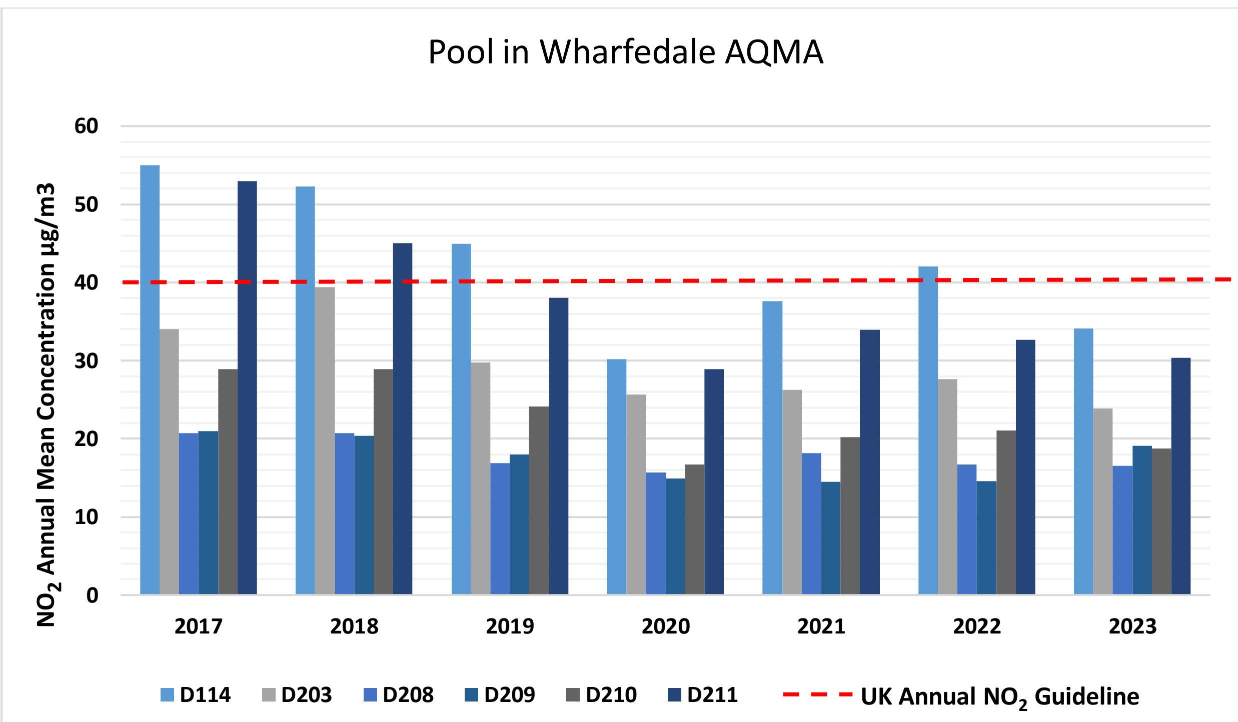


Figure 4. 1: Historic NO_2 trend at Pool in Wharfedale AQMA

4.2 Forecast of NO_2 Concentration Level

A simple logarithmic model was used to predict NO_2 Concentration level in 5 years (2028). The forecast for all six (6) monitoring locations is shown in Figures 4.2 to 4.7 below using the equation **$y = m\ln(x) + c$ ……….. Equation (1).**

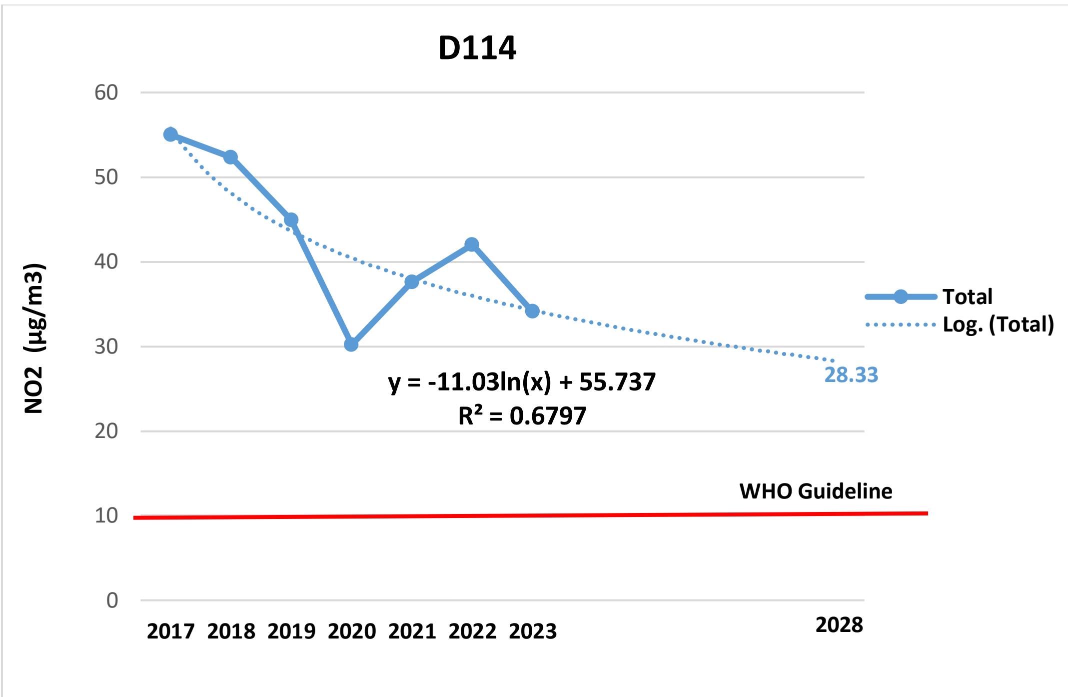


Figure 4. 2: NO_2 2028 Forecast at D114 Monitoring Location

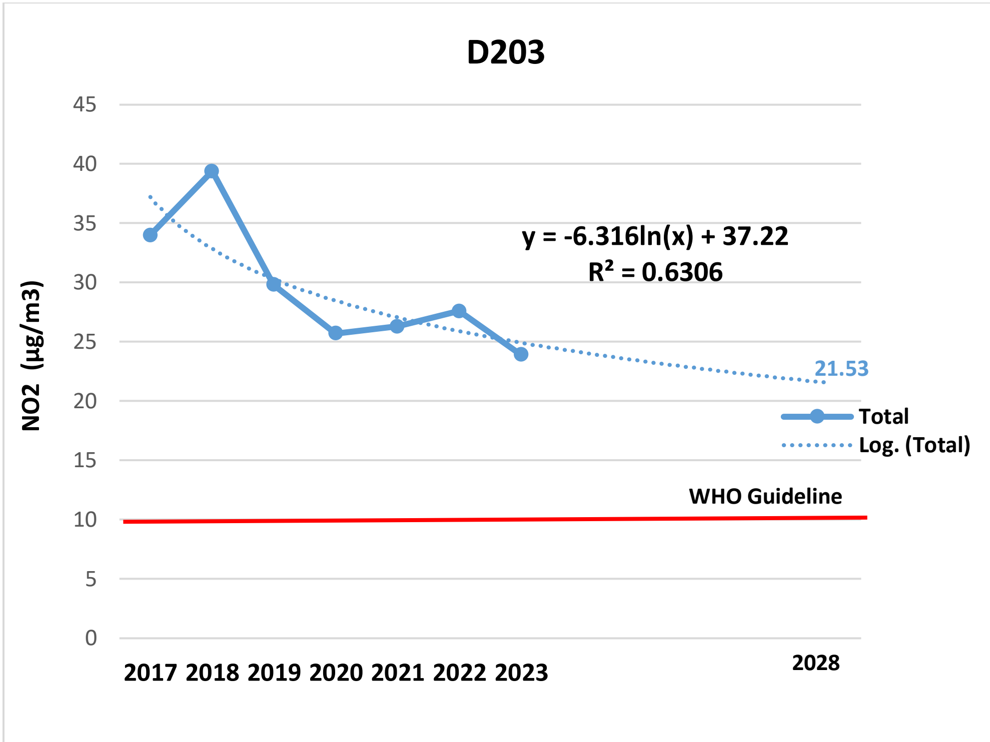


Figure 4. 3: NO_2 2028 Forecast at D203 Monitoring Location

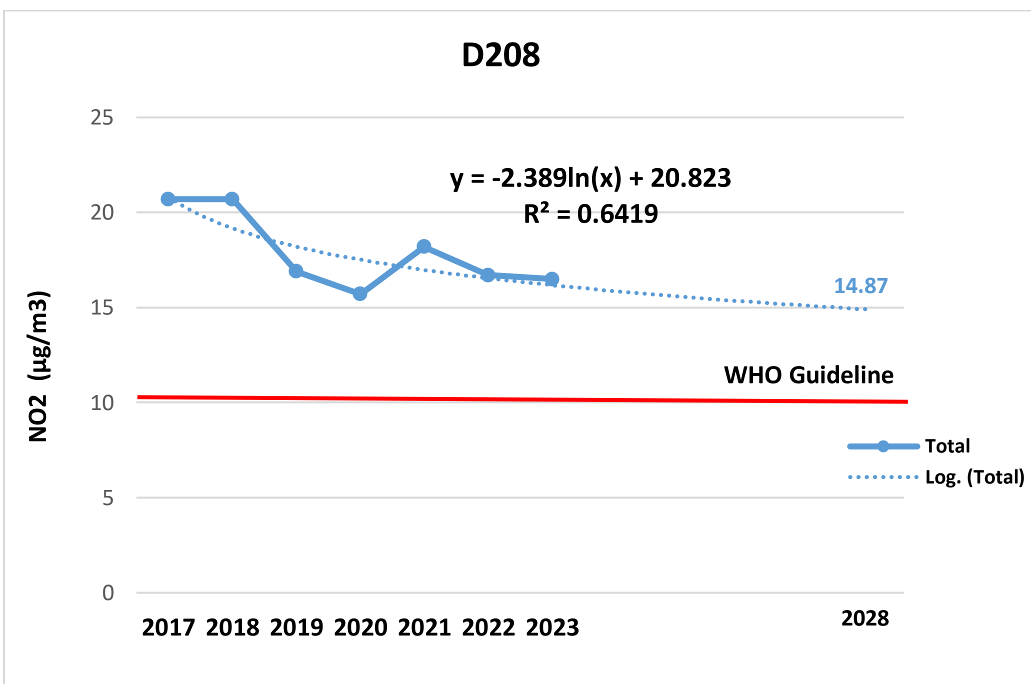


Figure 4. 4: NO_2 2028 Forecast at D208 Monitoring Location

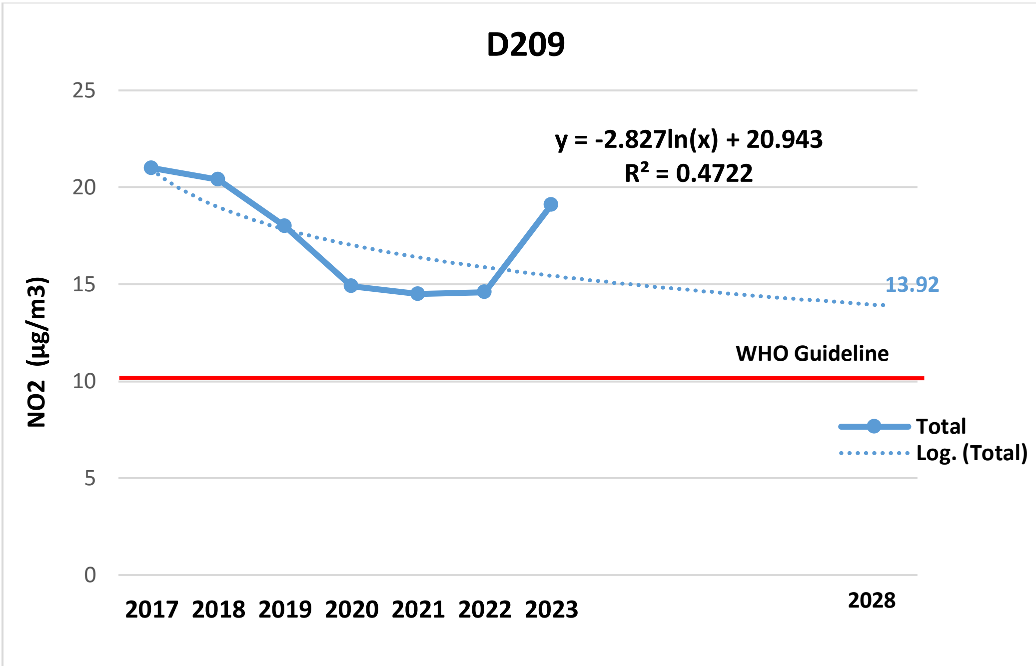


Figure 4. 5: NO_2 2028 forecast at D209 monitoring location

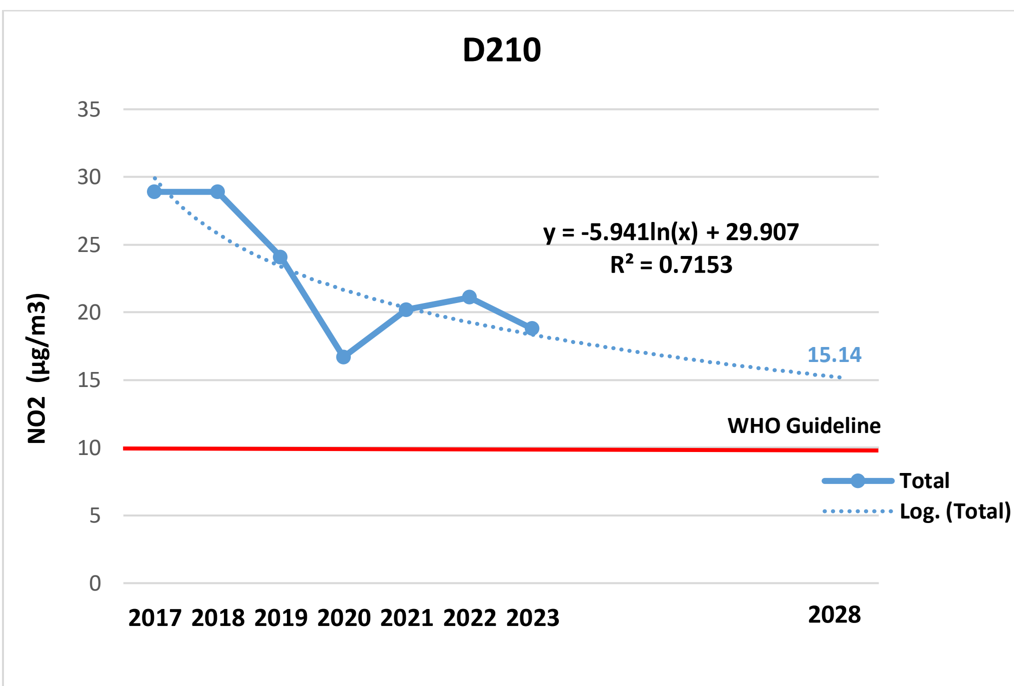


Figure 4. 6: NO_2 2028 Forecast at D210 Monitoring Location

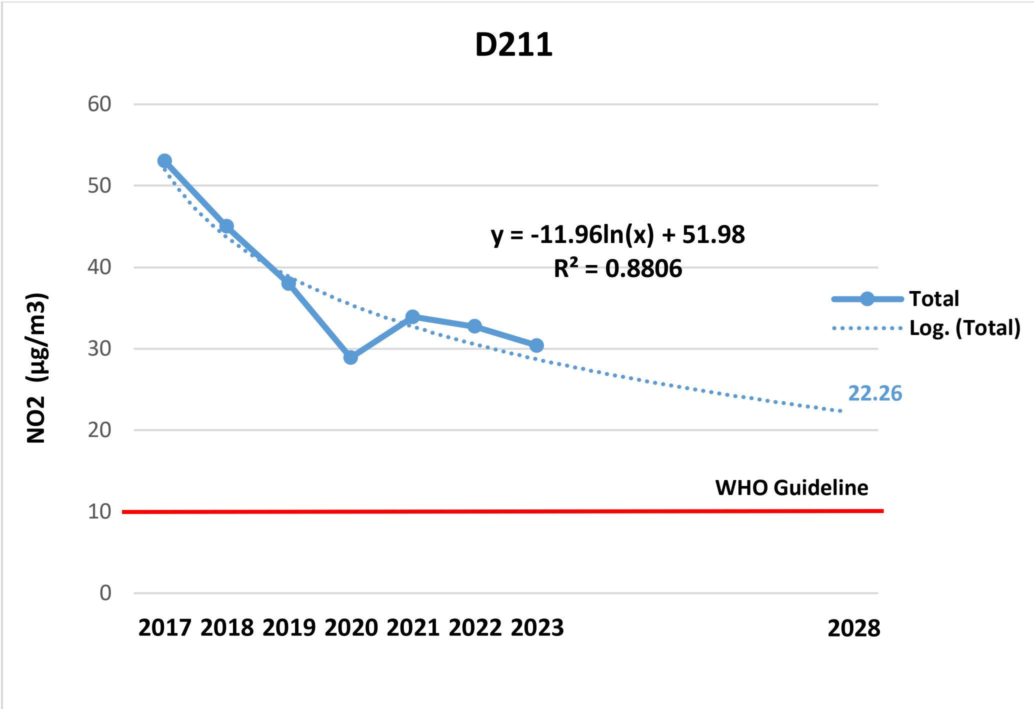


Figure 4. 7: NO_2 2028 Forecast at D211 Monitoring Location

4.3 Ambient NO_2 Monitoring Results in Pool in Wharfedale

The ambient NO_2 Concentration obtained from the six-week monitoring duration has been presented in Table 4.1 below. The NO_2 concentration values show the annualized mean for the six weeks of monitoring for all the twenty (20) locations outside Pool in Wharfedale AQMA boundary.

Table 4. 1: Annualized NO_2 Concentration Level away from the Road Traffic

Diffusion Tube ID	GPS Coordinate		Distance from Road Traffic (m)	Annualized mean 20th June 2024 to 1st August 2024 NO_2 (µg/m³)
D001	53.89969° N	1.62528° W	60	14.7
D002	53.90191° N	1.62794° W	108	9.5
D003	53.90208° N	1.63054° W	96	10.5
D004	53.90262° N	1.63163° W	122	13.3
D005	53.90156° N	1.63108° W	150	8.4
D006	53.9008° N	1.62831° W	100	16.5
D007	53.90324° N	1.63143° W	70	12.3
D008	53.90099° N	1.62611° W	60	16.1
D009	53.90380° N	1.62890° W	86	11.9
D010	53.90071° N	1.62379° W	180	11.6
D011	53.90218° N	1.62728° W	53	12.3
D012	53.90304° N	1.62824° W	82	11.2
D013	53.90251° N	1.62574° W	104	11.9
D014	53.90111° N	1.63117° W	191	9.8
D015	53.90212° N	1.63102° W	117	10.2
D016	53.9016° N	1.62963° W	78	9.5
D017	53.90083° N	1.62394° W	177	15.1
D018	53.90192° N	1.63016° W	80	9.8
D019	53.90182° N	1.62523° W	93	12.3
D020	53.89946° N	1.62346° W	139	13.3
WHO 2021 Annual NO_2 Guideline				**10µg/m³**

Figure 4.8 below shows diffusion tube deployment sites that exceed and comply with the WHO 2021 NO_2 annual guideline limit of 10µg/m^3 displayed with color coding (red and green) at different geographical locations away from the main road traffic in Pool in Wharfedale.

Source: Felt Map

Figure 4. 8: Spatial Distribution Map Showing Compliance with WHO Guideline

4.4 Co-Location Studies

Figure 4.9 below shows the results of the 6 weeks co-location study conducted to validate the diffusion tube NO_2 data with the automated air quality station/ chemiluminescence analyzer at Northern Terrace, Leeds Center.

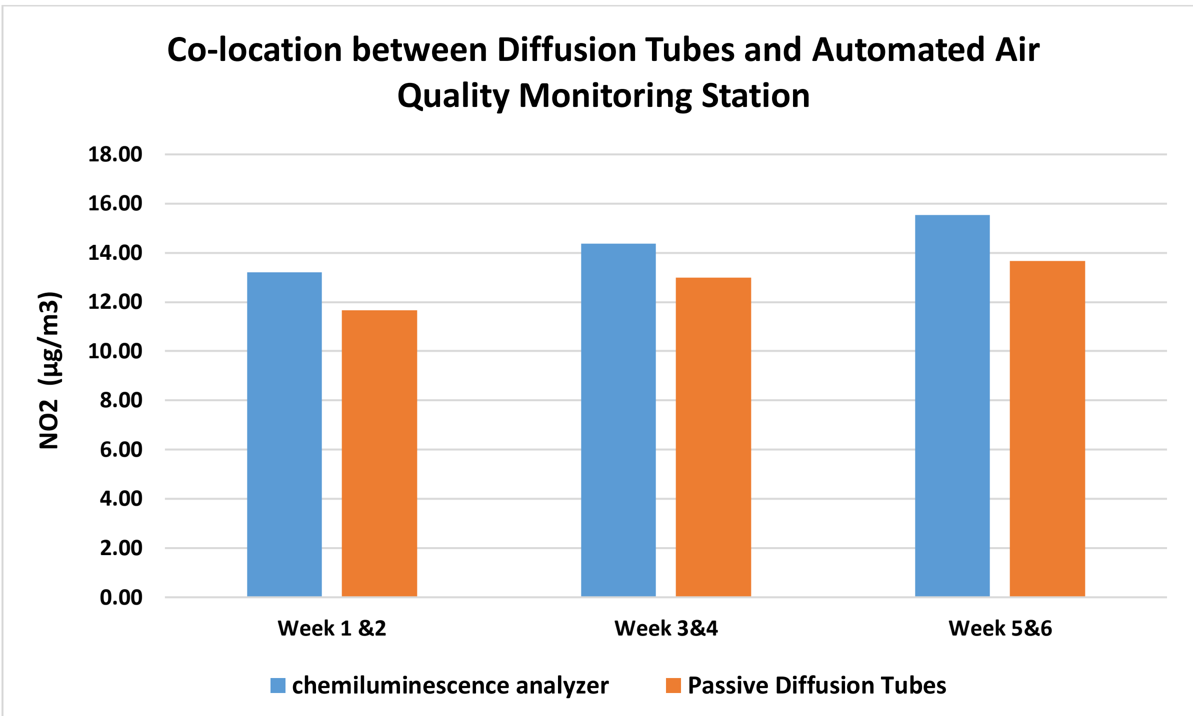


Figure 4. 9: Co-Location between Passive Diffusion Tube and Automated Air Quality Monitoring Station

4.5 Meteorological Data

Table 4.2 below presents the meteorological data (temperature, precipitation, wind speed and humidity) obtained during the NO_2 monitoring period in Pool in Wharfedale.

Table 4. 2 Meteorological data recorded during the monitoring duration

Week	Parameter			
	Average Temperature (°C)	Average Humidity (%)	Average Wind Speed (mph)	Total Rain (mm)
Week 1&2	24	63	10	15
Week 3&4	19	65	13	0.0
Week 5&6	18	59	9	0.0

Source: Weather Outlook, West Yorkshire

5.0 DISCUSSION

5.1 Evaluation of Historical NO_2 Data

5.1.1 Significant Findings

The historic dataset for Pool in Wharfedale AQMA focuses on NO_2 concentration levels across six different roadside locations (D114, D203, D208, D209, D210, and D211) from 2017 – 2023. The yearly NO_2 values as shown in Figure 4.1 range from 14.5 - 55 μg/m^3.

D114 recorded the highest NO_2 annual concentration level of 55 μg/m^3 in 2017. The annual concentration trend ranges from 30.2 - 55 μg/m^3. The NO_2 values for D114 showed a significant decline from 2017 to 2023. Despite the significant reduction in ambient NO_2 concentration from 2017, annual values recorded for 2018, 2019, and 2022 exceeded the UK annual NO_2 objective of 40 μg/m^3.

Annual NO2 data obtained from D203 vary from 23.9 – 39.4 μg/m^3. The NO_2 concentration level from 2017 recorded a higher peak of 39.4 μg/m^3 in 2018 which consistently declined to 23.9 μg/m^3 by 2023. The steepest decline occurred in 2018 from 39.4 μg/m^3 to 29.8 μg/m^3 in 2019. The overall trend indicates a steady decrease in NO_2 concentration over the years. The annual NO_2 values recorded and as shown in Figure 4.1 were in compliance with the UK NO_2 annual objectives.

The annual NO_2 values recorded for D208 range from 15.7 – 20.7 μg/m^3. The annual NO_2 concentration data remains relatively stable between 2017 and 2018 which recorded an annual NO_2 concentration of 20.7 μg/m^3. The NO_2 concentration at D208 showed a continuous decline from 2018 to 2023 up to 16.5 μg/m^3 except for 2021 which showed a slight increase in NO_2 annual concentration up to 18.2 μg/m^3. All the annual values obtained were well below the UK NO_2 annual objectives.

D209 recorded the lowest annual NO_2 concentration of 14.5 μg/m^3 in 2021. The NO_2 annual values at D209 ranged from 14.5 - 21 μg/m^3. Starting from 2017, annual values recorded at D209 showed a reduction in NO_2 concentration level from 21 μg/m^3 to 14.5 μg/m^3 in 2021. There was a notable rise in the concentration thereafter by 2023 (19.1 μg/m^3). This monitoring location was identified to show a different pattern with an initial decline of NO_2 annual concentration followed by a slight increase. All annual values recorded were well below the UK air quality guideline.

D210 annual NO_2 concentration varied from 16.7 – 28.9 µg/m^3. The annual NO_2 concentration remained steady from 2017 to 2018 with an annual NO_2 concentration of 28.9 µg/m^3. The data showed a significant reduction in 2019 and 2020. The values recorded for the subsequent years 2021 and 2023 (20.2 µg/m^3 and 21.1 µg/m^3 respectively) slightly increased but remained lower than the initial concentration level obtained in 2017. The annual values remained compliant with the UK annual NO_2 standard.

At D211, the annual NO_2 values ranged from 28.9 - 53 µg/m^3. The annual NO2 concentration declined steadily from 2017 to 2020 up to a concentration of 28.9 µg/m^3. The trend reversed with NO_2 concentration slightly increasing from 2021 up to 33.9 µg/m^3 while showing stable annual NO_2 concentration results to date. The annual NO_2 concentration obtained for the monitoring period was compliant with the UK annual NO_2 air quality guideline except for 2017 which recorded an annual value higher than the air quality objective of 40 µg/m^3.

The Time series analysis conducted for all six different monitoring locations using a simple logarithmic model as shown in Figures 4.2 to 4.7 provided a forecast for the annual NO_2 concentration level for the next five years given the historical data from 2017 to 2023. The range of the predicted NO_2 levels in 2028 varies from 13.92 -28.33 µg/m^3. However, the forecast for all the monitoring locations exceeded the WHO 2021 annual NO_2 guideline of 10 µg/m^3.

5.1.2 Critical Evaluation of the Historic Data

The evaluation of the ambient NO_2 concentration level over the past seven years at the various monitoring locations within Pool in Wharfedale AQMA indicates a general trend in the reduction of NO_2 concentration level. These findings reflect the broader national and local air quality improvement despite the estimated deaths between 28,000 and 36,000 annually (OHID, 2022). The UK legislative measures established for Local Air Quality Management, advancement in technology, and modeling methodology to reduce vehicular emission and other atmospheric pollutants have contributed to improving both the national and local air quality (DEFRA, 2023a). Interventions undertaken at the local level by Leeds City Council to ensure a citywide switch to cleaner vehicles and increasing infrastructure for plug-in vehicles have significantly improved air quality within the municipal district (Leeds City Council, 2021).

The Ambient NO_2 concentration levels recorded for the AQMA revealed periodic spikes in NO_2 levels which could be attributed to factors such as traffic congestion and meteorological conditions. Many studies have shown extended queuing time in congested roadways causing vehicular idling and increased road traffic emission (Ahn et al., 2002; Colberg et al., 2005). Further studies suggest road traffic accounts for 50% of NO_2 emissions mainly from automobile exhaust pipes (Basarić *et al.,* 2014; Frey et al., 2013; Shon et al., 2011)**.** This was evident as the main street in Pool in Wharfedale is narrow and causes traffic congestion during the day and evening times.

Meteorological factors are generally known to impact atmospheric air pollutants in diverse ways (Chen, Z. et al., 2020; Li, R. et al., 2019; Sun et al., 2019). Several academic research have linked high NO_2 concentration with reduced wind speed, low ambient temperature, and high relative humidity (Yang, J. et al., 2020; Zhang, H. et al., 2015). Seasonal variation shows increase in NO_2 concentration levels in Pool in Wharfedale AQMA during winter period comparatively with summer. These seasonal patterns align with similar research conducted by (Anand and Monks, 2017; Dragomir et al., 2015) where an increase in the use of fossil fuels and a low rate of NO_2 dispersion increases NO_2 concentration during winter while the increase in photochemical reaction during summer results in low NO_2 concentration.

The forecast study predicted future NO_2 concentration based on the historical data available within the AQMA and provides valuable insight into potential future trends. Many countries have adopted forecasting programs to predict future trends of pollutants of special health concern such as nitrogen dioxide, ozone, and particulate matter (Baklanov et al., 2007; Lee, P. et al., 2017; Zhang, Y. et al., 2016). The forecast conducted indicates a continuous decline in NO_2 concentration. While these concentration levels were below the UK national NO_2 annual objective of 40µg/m^3, they were observed to be well above the WHO 2021 NO_2 strictest guideline of 10 µg/m^3. Despite the continuous reduction of NO_2 concentration at the lowest annual concentration of 13.92 µg/m^3 during the forecast, they will have an adverse impact on public health according to WHO.

There is significant evidence that shows that health effects occur even at the lowest exposure level (Brauer et al., 2019; Dominici et al., 2019). The WHO AQGs 2021 provides the opportunity to protect the public health. With several endorsements from more than a hundred medical, public health experts, and patient representative societies such as the European Respiratory Society (ERS) and the International Society of Environmental Epidemiology (ISEE), the WHO AQGs for NO_2 provide science-based target values to improve national air quality (Andersen et al., 2021; Hoffmann et al., 2021). Immediate policy review is required within Pool in Wharfedale AQMA to adopt the strictest WHO guidelines and directly translate into improvement of ambient air quality.

5.2 Evaluation of NO_2 Exposure Levels outside Pool-in-Wharfedale AQMA

The NO_2 concentration levels recorded during the six weeks of continuous monitoring (20th June 2024 to 1st August 2024) outside the AQMA boundary provides an in-depth understanding into the air quality and the diverse NO_2 exposure levels at different geographical locations. The annualized NO_2 concentration levels as shown in Table 4.1 ranged from 8.4 – 16.5 µg/m^3 varying between 53 meters to 191 meters from the main street (A658). As established by (AEA Energy & Environment, 2008), the NO_2 ambient concentration is expected to have diluted into the local suburban concentration at a distance of more than 50 meters.

D006 with an annualized concentration of 16.5 µg/m^3 recorded the highest NO_2 concentration within the suburban location and relatively close to the main street at a distance of 100 meters. Similar elevated NO_2 concentration levels were obtained at varying distances of 60m and 177m for D008 (16.1 µg/m^3) and D017 (15.1 µg/m^3). The majority of the monitoring locations (D003, D004, D007, D009, D010, D011, D012, D013, D015, D019, and D020) were within the mid-range recording moderate annualized NO_2 concentration level between 10 µg/m^3 – 13 µg/m^3 reflecting a balance between distances from the main road in Pool in Wharfedale. The Lowest annualized NO_2 concentration throughout the monitoring duration was observed at D005 with a concentration value of 8.4 µg/m^3 and a distance of 150m from the main road. However, other lower NO_2 concentration values recorded ranged from 9.5µg/m^3 - 9.8µg/m^3 at D002, D014, D016 and D018.

The annualized NO_2 concentration levels of the various monitoring locations showed a significant association between NO_2 levels and proximity to the main road for most of the monitoring locations. Nitrogen Oxides (NO) from vehicular emissions convert to NO_2 over a short time scale causing the NO2 gradient to change dynamically close to the road zone (Richmond-Bryant et al., 2017a). Research conducted by (Baldauf et al., 2013; Karner et al., 2010) identified high concentrations of atmospheric pollutants such as NO_2, CO, and VOC near to road microenvironment forming a complex, multicomponent mixture (Saha et al., 2018). The elevated NO_2 concentration recorded close to the main streets could be associated with the continuous buildup of NO_2 from road transport. According to (DEFRA, 2024b) street canyons or low wind conditions prevent dispersion of pollutants however, the listed buildings near the main streets at Pool in Wharfedale AQMA may result in the elevated NO_2 concentration close to the main street. Similar research undertaken by (Harrison et al., 2014) confirms that heavy-trafficked streets located between a continuous roll of buildings restrict atmospheric dispersion and increase pollutant concentration.

The NO_2 ambient concentration was observed to decrease with distance for some of the monitoring points which include D005, D014, D015, and D010. Nitrogen dioxide has been documented to decrease away from road sources (Roosbroeck, Van et al., 2006). Further studies conducted by (HSY, 2022) highlight the rapid dilution of NO_2 concentration away from road sources. The monitoring points further away from the road traffic were mostly open areas where NO_2 is likely to mix with cleaner air resulting in a significant reduction in ambient NO_2 concentration. According to research conducted by (Richmond-Bryant et al., 2017b), the mixing of NO_2 with cleaner air over a wide area is influenced by wind speed and direction, atmospheric stability, and turbulence. Studies conducted by (Inglezakis and Poulopoulos, 2006) identified the occurrence of chemical reactions where NO_2 reacts with other atmospheric components such as ozone to reduce their concentration as you move away from the pollutant source.

Monitoring data obtained from the continuous six-week duration showed an elevated level of NO_2 concentration at D017 despite the increased distance from the road traffic. This monitoring point was characterized by a closed landscape nearby which could affect wind conditions resulting in higher NO_2 concentration due to poor pollutant dispersion. Academic research conducted by (Łowicki, 2019) identified landscape patterns as a major contributor to modifying atmospheric pollutants. Temperature and humidity play a vital role in pollutant dispersion. During high temperatures especially in summer, atmospheric NO_2 disperse and dilute more efficiently due to stronger thermal convection (Ravina et al., 2022). The meteorological data presented in Table 4.2 likely influence NO_2 levels. Higher wind speeds in week 3&4 could result in more pollutant dispersion. Lower temperature, humidity and no precipitation in week 5&6 may reduce pollutant dispersion leading to higher NO_2 levels. The overall NO_2 concentration results obtained reflect the dilution in NO_2 concentration level away from the road traffic.

5.3 Comparison of NO_2 Exposure Levels with WHO Annual NO_2 Guideline

The NO_2 concentration level obtained for all the monitoring locations (D001 to D020) outside the AQMA boundary represents the NO_2 concentration at different geographical locations away from the AQMA boundary for the entire six-week duration. The updated WHO 2021 guideline set more protective standards based on current scientific findings. The ambient WHO annual NO_2 concentration guideline was significantly reduced from 40 µg/m³ to 10 µg/m³ due to increasing evidence on human health even at lower concentration levels (WHO, 2021b). Epidemiological studies show exposure to nitrogen dioxide even at low concentration levels can lead to inflammation of the airway, reduced lung function, and a higher risk of respiratory infection (Fino, 2019; Jarvis et al., 2010; Kwon et al., 2018). Similar research conducted by (Kurt et al., 2016) identified vulnerable groups (elderly and children) susceptibility to the negative effect of NO_2.

Majority of the annualized NO_2 values exceeded the strictest WHO NO_2 annual guideline of 10 µg/m³. As shown in Figure 4.8 a total of 15 monitoring locations recorded an annualized value higher than the WHO NO_2 annual guideline. Monitoring locations that were in compliant and recorded an annualized NO_2 concentration lower than the WHO guideline include D002, D005, D014, D016, and D018. Several studies have shown that annual and hourly NO_2 exceedance is associated with traffic emission (Degraeuwe et al., 2016; Querol et al., 2014; Wild et al., 2017). Higher levels of atmospheric pollutants primarily NO_2 occur in areas with high road traffic (Barnes et al., 2019). In the UK 65% of NOx concentration level is generated by road transport (DEFRA, 2024b). Industrial emissions (Agudelo-Castañeda et al., 2020) and household heating (Liu et al., 2024) have proved as non-negligible sources of NO_2 emission. During summer, residential heating contributes less to ambient NO_2 emissions (Roberts-Semple et al., 2012). Therefore, it is evident from the data obtained that the dominant contributor to NO_2 concentration exceeding the WHO annual NO_2 guideline was vehicular emission within Pool in Wharfedale.

NO_2 concentration is anticipated to have diluted to the local suburban concentration more than 50 meters away from busy roads (AEA Energy & Environment, 2008). The dilution effect at different geographical locations within Pool in Wharfedale plays a major role in the reduction of ambient NO_2 concentration level from road transport however, the persistent exceedance of the

WHO 2021 updated NO_2 guideline among most of the monitoring locations suggests that while atmospheric dilution occurs, it may not be adequate for ambient NO_2 concentration levels below the recommended WHO target especially in areas with continuous traffic flow.

5.4 Evaluate the Potential Impact of Adopting the WHO NO_2 threshold in place of the UK Air Quality Objectives.

The 2021 WHO air quality threshold reflects growing evidence of the adverse health effects of atmospheric air pollutants (Hoffmann et al., 2021). The reduction in WHO NO_2 guidelines is based on robust epidemiological research. The majority of this research demonstrates a linear exposure-response association between NO_2 and adverse health consequences (Huangfu and Atkinson, 2020a; Huang et al., 2023; Qian et al., 2021). Ambient NO_2 even at low concentration levels and independent of other pollutant exposure can inflict on human health (WHO, 2021b)

According to research conducted by (EPHA, 2023), improvement in air quality below current standards promotes significant health benefits. Adoption of the updated WHO 2021 NO_2 air quality guideline can be seen as a shift towards more rigorous environmental regulation focused on addressing global health impact. (Hoffmann et al., 2021) argue that the WHO 2021 guideline provides an essential tool for policymakers and public health practitioners to adequately mitigate air pollution-related health hazards. Despite the health benefits, the WHO guideline seeks to encourage countries to develop ambitious environmental goals focused on long-term air quality improvement and environmental sustainability (WHO, 2021a).

The ambient NO_2 monitoring data obtained at different geographical locations in Pool in Wharfedale presents a convincing argument for the potential impact of adopting the WHO 2021 NO_2 annual guideline. Out of the twenty (20) monitoring locations where the Palmes-Type Diffusion Tubes were deployed to monitor the ambient NO_2 concentration level, 15 monitoring locations recorded annualized NO_2 concentration exceeding the WHO annual guideline (10 $\mu g/m^3$), with only 5 locations recording an annual concentration value below the WHO NO_2 limit. These results illustrate a significant challenge where many areas that currently comply with the UK annual air quality objective of $40 \mu g/m^3$ fail to achieve the WHO stricter criteria. The forecast conducted using the historic NO_2 data showed reduced NO_2 concentration in the next five (5) years however, these levels failed to comply with the new WHO annual objective for NO_2.

The pollutant concentration level within the suburban areas at Pool in Wharfedale where road transport is a primary source of atmospheric NO_2 emission remains harmful in accordance with the updated WHO 2021 annual NO_2 guideline. The Implications of this are vast, as it implies that substantial regions in the UK, particularly areas previously declared as low risk, would require extensive action to significantly reduce NO_2 concentration level.

Comparative analysis of the UK air quality status with other countries that have implemented stricter air quality objectives provides more insight into the potential impact of adopting the WHO 2021 updated air quality objective. In a recent air quality research conducted, seven (7) out of 135 countries surveyed complied with the WHO 2021 updated guideline for atmospheric emissions from vehicles and industrial processes (IQAir, 2024). Air quality in these countries (Australia, Estonia, Finland, Grenada, Iceland, Mauritius, and New Zealand) remains demonstrably clean due to advanced and sustainable environmental policies. Some of these include the transition to renewable energy, clean mobility, and prevention of forest fires. These countries have also seen significant reductions in respiratory and cardiovascular diseases, correlating with decreased NO_2 concentration levels (IQAir, 2024). Despite the national and local interventions developed to improve air quality in the UK, the annual deaths related to poor air quality still remain between 28,000 and 36,000 (OHID, 2022).

The implementation of the WHO guideline would require a detailed review and assessment of existing UK air quality policies. The present UK annual NO_2 guideline of 40 $\mu g/m^3$ is effective in many aspects and would require extensive amendment to comply with the WHO recommendations. The review could involve changing the national air quality plans for NO_2, modification of existing NO_2 monitoring and reporting procedures, and implementation of strict enforcement measures. This initiative will promote the prioritization of green infrastructure, improve public transportation, and encourage active alternatives like cycling and walking as evident in some parts of Leeds Metropolitan district. The impact of adopting the WHO NO_2 annual guideline in Pool in Wharfedale will require comprehensive air quality monitoring and extension of the AQMA boundary to cover a larger area away from the road traffic instead of one or two streets away from the road traffic as defined by (DEFRA, 2024). The AQMA boundary could cover approximately 200 meters or more since the NO_2 concentration level obtained at a distance of 191 was slightly below the WHO guideline.

The stricter WHO NO_2 guideline would have an essential impact on public health, especially for vulnerable groups such as the elderly, children, and people with underlying health conditions (Manisalidis et al., 2020; EPA 2024d). Evidence suggests both long-term and short-term exposure to NO_2 is detrimental to people's health and causes cardiopulmonary effects, chronic lung diseases, respiratory infection, increased hospital admission, and premature deaths (Huangfu and Atkinson, 2020b; Nuvolone et al., 2018; Urman et al., 2014). Adopting the WHO updated guideline for NO_2 concentration is expected to reduce these health outcomes in the UK, leading to improved quality of life and lower health care costs. Public health benefits associated with improved air quality extend beyond direct health outcomes. Research has shown that cleaner air corresponds with high productivity and improved mental health contributing to a healthier and resilient population (Bhui et al., 2023; Hoffmann et al., 2021).

The adoption of the WHO NO_2 annual guideline in the UK would present substantial regulatory and economic challenges. In urban and suburban areas where ambient NO_2 concentration is predominantly influenced by road traffic emissions, compliance would require significant changes in transportation infrastructure and implementation of more stringent vehicular emission standards. Since road transport is a major contributor and accounts for 65% of the total NOx in the UK (DEFRA, 2024), the economic implication of significantly reducing NO_2 concentration should be carefully considered. This may involve the provision of the local authorities and industries with the necessary resources and support to comply with the stringent WHO standard because transitioning to greener technologies is capital-intensive and will require substantial investment (Jelti et al., 2023). While the immediate cost of implementing the WHO guideline may be high, the long-term benefits with respect to public health and significant economic savings may outweigh the initial cost.

5.5 Limitation and Strength of this Research

5.5.1 Limitation

5.5.1.1 Passive Diffusion Tube

In accordance with the AEA guidance, a spacer block of at least 5 cm must be positioned between the surface and the tube. This was not achieved due to a lack of resources, however, the tube was attached to the lamp post directly with an adhesive tape and this could affect the air circulation around and intake rate of the tube.

5.5.1.2 Monitoring Period

In accordance with the practical guidance (AEA Energy & Environment 2008 and LAQM.TG22), annual NO_2 monitoring should be conducted for a minimum of 9 months. The ambient NO_2 monitoring in Pool in Wharfedale was conducted for a six-week monitoring period. The relatively short monitoring duration did not capture seasonal variation in NO2 concentration. Therefore the NO_2 concentration values obtained may not accurately reflect the yearly air quality in the project area.

5.5.1.3 Monitoring Points

The research was limited to 20 monitoring sites within Pool in Wharfedale due to resource constraints. While these monitoring locations seek to capture the NO_2 concentration level for the area, they may not completely capture the full range of NO_2 concentration gradient across the area. The spatial distribution of the various monitoring sites could influence the overall air quality of the area under consideration.

Three (3) diffusion tubes were stolen by outsiders during week 5&6 at different locations. The average NO_2 mean was calculated using 2 batches instead of 3 batches for these affected locations. This could affect the accuracy of the annualized NO_2 value.

5.5.1.4 Annualization Factor and Historic Data

The annualization factor applied on all the NO_2 concentration level obtained during comparison with the WHO 2021 NO_2 guideline relied on the period and annual mean data from similar suburban site within Leeds metropolitan district and may not reflect the true condition in Pool in Wharfedale. The difference in geographical location might affect the accuracy of the project's annual mean NO_2 concentration.

5.5.2 Strength

This research demonstrated several notable strength that enhances its validity and significance. The study implemented high-standard laboratory QAQC processes for the passive diffusion tube preparation, deployment, and analysis. The rigorous procedure which included the preparation of both travel and laboratory blanks helped minimize potential errors and biases while ensuring the reliability of the data collected.

The co-location study conducted successfully for the six (6) week duration with an automated air quality monitoring machine proved the validity of the passive diffusion tubes deployed as it showed a close relationship between the data obtained for both NO_2 measurement techniques. The historic secondary data obtained from Leeds City Council showed valid data captured for over 9 months for the majority of the monitoring locations. Therefore the forecast predicted shows a comprehensive analysis of the future NO_2 exposure level in the area.

6.0 CONCLUSION

This academic research examined Nitrogen dioxide (NO_2) concentration within Pool in Wharfedale Air Quality Management Area (AQMA), focusing on historical trends, spatial variation at different geographical locations, and the impact of adopting the WHO stricter air quality guideline for NO_2 instead of the UK objectives. The dissertation also focuses on the effectiveness of current air quality management practices in meeting the WHO guidelines.

The analysis of NO_2 historic data obtained from Leeds City Council indicates a positive trend in the decline of NO_2 concentration levels across the six monitoring locations within Pool in Wharfedale AQMA from 2017 to 2023. D114 monitoring location which recorded the highest NO_2 concentration value of 55 µg/m³ in 2017 showed a substantial reduction by 2023. Similar trends were observed at D114, D203, and D208 achieving compliance with the UK NO_2 annual objective. There were notable fluctuation trends and period spikes in NO_2 level at a few monitoring locations implying temperature, prevailing winds, humidity and traffic volumes continue to have an impact on local air quality (Richmond-Bryant et al., 2017). In addition, the five-year forecast conducted showed a downward trend for all the monitoring locations within the AQMA boundary.

The six weeks of continuous monitoring conducted outside the AQMA boundary varied significantly with proximity to the main road (A658). Monitoring points close to the road traffic recorded elevated NO_2 levels compared with monitoring locations situated further away. The spatial trend demonstrates the impact of road traffic on local air quality and confirms studies that have established the decrease in ambient NO_2 level with an increase in distance away from major roads (Roosbroeck, Van et al., 2006b; HSY, 2022b). Despite the general decline in NO_2 concentration away from the road traffic few monitoring points were observed to record elevated NO_2 levels away from the main road which could be associated with less atmospheric dilution. In situ measurements of NO_2 concentration are affected by dilution and atmospheric reactivity (Dieudonné et al., 2013).

The ambient NO_2 monitoring results recorded during the six weeks duration presents a significant challenge in Pool In Wharfedale. The results showed elevated NO_2 levels above the WHO 2021 annual NO_2 guideline for the majority of the monitoring locations. It was evident from the forecasted data that while NO_2 concentration levels declined, they remained well above the WHO guideline. These results highlight the substantial difference between the UK’s present air quality regulation and recommendations from the World Health Organization. The WHO 2021 annual NO_2 guideline of 10 µg/m³ is more stringent and effective than the UK's current annual NO_2 objective of 40 µg/m³. Without changes in air quality policy and practices, achieving compliance with the WHO NO_2 annual guideline will be challenging, particularly in areas known for high road traffic emissions.

While significant progress has been made to reduce NO_2 concentration nationally and locally in the UK, the findings from the NO_2 concentration within Pool in Wharfedale indicate that more needs to be done to improve the local air quality and protect public health. Achieving the WHO annual NO_2 guideline would require an integrated approach such as technological, policy change, and community engagement. By aligning with the WHO guidelines and adopting proactive measures for pollution control, the UK can make considerable progress with cleaner air and a healthy environment for future generations.

6.1 Recommendations

- **Enhance monitoring duration and research**

  Future academic research should extend the monitoring duration beyond six weeks. Year-round monitoring would offer more extensive data on NO_2 variation with meteorological conditions and other local sources.

- **Implement and enforce strict emission standard**

  It is essential for the UK to align the present air quality regulations with the WHO 2021 guideline. The current health impact of poor air quality is between 28,000 and 36,000 deaths annually (OHID, 2022). Therefore aligning with the WHO's current guideline would ensure the provision of enforcement action to achieve a lower NO_2 level.

- **Investment in Air Quality Technologies**

  Support should be provided for the development and deployment of advanced air quality monitoring technologies and modeling tools. Innovations within these fields will provide more accurate data and help in predicting future variations in atmospheric pollutants. This recommendation would encourage green urban initiatives and infrastructure.

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Appendix 1: Ethical Consideration

APPLICANT DETAILS	
Your name (if a group project, include all names)	Sylvester Nicholson
School	Leeds Beckett University
STATUS	
• Undergraduate student	☐
• Taught Postgraduate student	☒
• Research Postgraduate student	☐
• Staff member	☐
• Other (give details)	
IF THIS IS A STUDENT PROJECT	
• Student ID	77368158
• Course title (eg, BA (Hons) History)	MSc (Hons) Environmental Health
• Student email	S.Nicholson6237@student.leedsbeckett.ac.uk
• Research Supervisor's name Or Director of Studies' name	Previous - Stephen Mole Current – Jayne Enright
THE PROJECT/STUDY	
Project /study title	Assessing the Impact of Nitrogen Dioxide in Pool-in-Wharfedale Air Quality Management Area within Leeds Metropolitan District.
Start date of project	29/05/2024
Expected completion date of project	30/08/2024
Project summary – please give a brief summary of your study (maximum 100 words)	
Assessing the Impact of Nitrogen Dioxide (NO_2) in Pool-in-Wharfedale Air Quality Management Area within Leeds Metropolitan District. This study will assess the Impact of adopting WHO NO_2 Guideline on the Air Quality Management Area in Pool-in-Wharfedale.	
CONFIRMATION STATEMENTS	

The results of research should benefit society directly or by generally improving knowledge and understanding. <u>Please tick this box</u> to confirm that your research study has a potential benefit. *If you cannot identify a benefit you must discuss your project with your Research Supervisor to help identify one or adapt your proposal so the study will have an identifiable benefit.*	☒
<u>Please tick this box</u> to confirm you have read the Research Ethics Policy and the relevant sections of the Research Ethics Procedures and will adhere to these in the conduct of this project.	☒

RISK CHECKLIST - Please answer ALL the questions in each of the sections below – tick YES or NO **WILL YOUR RESEARCH STUDY……..?**		**<u>YES</u>**	**<u>NO</u>**
1	Involve direct and/or indirect contact with human participants?	☐	☒
2	Involve analysis of pre-existing data which contains personal or sensitive information not in the public domain?	☐	☒
3	Require permission or consent to conduct?	☐	☒
4	Require permission or consent to publish?	☐	☒
5	Have a risk of compromising confidentiality?	☐	☒
6	Have a risk of compromising anonymity?	☐	☒
7	Collect / contain sensitive personal data?	☐	☒
8	Contain elements which you OR your supervisor are NOT trained to conduct?	☐	☒
9	Use any information OTHER than that which is freely available in the public domain?	☐	☒
10	Involve respondents to the internet or other visual/vocal methods where participants may be identified?	☐	☒
11	Include a financial incentive to participate in the research?	☐	☒
12	Involve your own students, colleagues or employees?	☐	☒
13	Take place outside of the country where you are enrolled as a student, or for staff, outside of the UK?	☐	☒
14	Involve participants who are particularly vulnerable or at risk?	☐	☒
15	Involve any participants who are unable to give informed consent?	☐	☒
16	Involve data collection taking place BEFORE informed consent is given?	☐	☒
17	Involve any deliberate deception or covert data collection?	☐	☒
18	Involve a risk to the researcher or participants beyond that experienced in everyday life?	☐	☒
19	Cause (or could cause) physical or psychological harm or negative consequences?	☐	☒
20	Use intrusive or invasive procedures?	☐	☒
21	Involve a clinical trial?	☐	☒
22	Involve the possibility of incidental findings related to health status?	☐	☒
23	Fit into any of the following security-sensitive categories: concerns terrorist or extreme groups; commissioned by the military; commissioned under an EU security call; involves the acquisition of security clearances? If yes, see the guidance.	☐	☒

CLASSIFICATION **The following guidance will help classify the risk level of your study**	**Tick the box which applies to your project**
If you answered **NO** to all the above questions, your study is provisionally classified as **Risk Category 1** (literature reviews will be Risk Category 1).	☒
If you answered **YES** to any question from 1-13 and **NO** to all questions 14-22, your study is provisionally classified as **Risk Category 2**.	☐
If you answered **YES** to any question from 14-22, your study is provisionally classified as **Risk Category 3**.	☐
If question 23 has been answered **YES**, your application will be reviewed by the Chair of the University Research Ethics Sub-committee	☐

DECLARATION AND SIGNATURE/S			
I confirm that I will undertake this project as detailed above. I understand that I must abide by the terms of the approval and that I may not make any substantial amendments to the project without further approval.			
Signed	Sylvester Nicholson	*Date*	05/03/2024

FOR RISK CATEGORY 1 STUDENT PROJECTS					
Approval from the Research Supervisor or Director of Studies for a student project: *I have discussed the ethical issues arising from the project with the student. I approve this project.*					
Name	Stephen Mole	*Signed*		*Date*	29/05/24

Appendix 2: Risk Assessment Form

Activity Detail/Title: *(Please give a brief outline of the activity below): This is a research based activity which involves the assessment of short term NO2 exposure level and the impact to respiratory health. The main activity from this project will involve field monitoring, laboratory analysis and literature review.*							
Location/Campus: City Campus		**Building: Calverley**					
Completed By: Sylvester Nicholson		**Signed:**		**Role: Student**			
Date Completed:		**Review date:**					
What are the hazards? (use the table above to help)	**Who might be harmed and how**	**What are you doing already**	**Risk Level H/M/L**	**Do you need to do anything else to manage the risk?**	**Action by whom**	**Action by when (Priority)?**	**Completed Yes/No**
Display screen Equipment	Researcher	Use of display protection glasses during literature review and other project related documentation	L	NO	Researcher	Commencement of project	Yes
Long hours of sitting	Researcher	Take intermittent break to reduce the potential risk of waist and back pain	L	NO	Researcher	Commencement of project	Yes
Road incident due to traveling to monitoring location	Researcher	Will commute to the monitoring location with a secured transport system	M	NO	Researcher	Commencement of project	Yes
Outdoor/Extreme weather	Researcher	Wear protective clothing against unfavourable condition. In cases of extreme weather condition field activity will be postponed	L	NO	Researcher	Commencement of project	Yes
Monitoring activity by the roadside	Researcher	Wear reflective vest during field monitoring for easy identification by oncoming vehicles.	L	NO	Researcher	Commencement of project	Yes
Use of reagent for laboratory analysis	Researcher	Wear protective cloth clothing in the lab and adhere strictly to laboratory safe operating procedure	L	NO	Researcher	Commencement of project	Yes
Fall from height above 2meters	Researcher	Ladder will be properly secured at each monitoring point to avoid falling from height	L	NO	Researcher	Commencement of project	Yes
Broken glass from test tube	Researcher	The use of PPE'S and follow strict laboratory rules	L	NO	Researcher	Commencement of project	Yes
Stress	Researcher	Early planning of project framework and establishment of realistic goals. Seek professional advice from project supervisor	L	NO	Researcher	Commencement of project	Yes

Appendix 3: Meeting Log

Log for meetings - Final Year Research Project

Name of student: _______Sylvester Nicholson______________________

Title of Dissertation Project: Assessing the Impact of Nitrogen Dioxide in Pool-in-Wharfedale Air Quality Management Area within Leeds Metropolitan District.

				Agreed (signature)	
Meeting date	Topic	Action points	Length of meeting	Supervisor (or other module staff)	Student
03/05/24	Discussion of Research Proposal feedback	Amend my research topic together with the aims and objectives.	30 minutes	Online Stephen Mole	Online Sylvester Nicholson
02/07/24	Discussion on progress of work	Follow the technical guidance as far as practicable and identify all uncertainties in measurements.	30minute	Online Stephen Mole	Online Sylvester Nicholson
11/07/24	Change of Project Supervisor	Briefing on dissertation and progress of work	30 minutes	Online Jayne Enright	Online Sylvester Nicholson

Appendix 4: Email Confirming Data Received from Leeds City Council

TC Terro, Christina<Christina.Terro@leeds.gov.uk>

To: Nicholson, Sylvester (Student)

Fri 5/10/2024 5:42 PM

Leeds ASR 2023 .pdf
3 MB

Caution External Mail: Do not click any links or open any attachments unless you trust the sender and know that the content is safe.

Hi Sylvester

I've attached ASR 2023 which contains the information for the Pool in Wharfedale AQMA.

The Pool in Wharfedale diffusion tubes are:

D114 D203 D208 D209 D210 D211

There's a map towards the end of the ASR which shows the AQMA boundary and monitoring locations. D133 on the map is an historical site that's not currently being monitored. Data for 2024 is being processed now and will be available in around 10 days' time.

Kind regards

Christina Terro
Senior Technical Officer
Environmental Protection
Leeds City Council
Seacroft Ring Road
Leeds

TC Terro, Christina<Christina.Terro@leeds.gov.uk>

To: Nicholson, Sylvester (Student)

Thu 6/20/2024 3:52 PM

Diffusion tubes 2023.xlsx
29 KB

Caution External Mail: Do not click any links or open any attachments unless you trust the sender and know that the content is safe.

Hi Sylvester

Please find attached 2023 data.

Kind regards

Christina Terro
Senior Technical Officer
Environmental Protection
Leeds City Council
Seacroft Ring Road
Leeds
LS14 1NZ