Particulates Monitoring: Guide for Planning and Case Study

NZIP Particulates
For West Suffolk Council

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Issue 2.0 October 2023

Guide to Inclusion of Particulate Monitoring in Planning Conditions

Step	Action
1	Identify concern appropriate for planning or other condition
2	Identify air quality and related parameters to monitor
3	Specify sensor requirements, including calibration. Identify location, power, and access
4	Identify period of monitoring, including pre-, during and post-development
5	Identify other data to collect
6	Identify other organisations collaborating or contributing
7	Analysis requirements
8	Specify reporting requirements, frequency of intermediate and final reporting
9	Monitor implementation, receipt of reporting and values
10	Assess any additional action required

Draft Potential Planning Condition

Prior to <*first occupation*> of the development hereby approved, details of the following shall be submitted to and approved in writing by the Local Planning Authority:
Continuous air quality monitoring equipment to be installed <*at stated location, specified height*>. Equipment should be <*specified model if required, or as agreed in correspondence*>; it should measure <*specified parameters, associated with DEFRA objectives and targets, such as* $PM_{2.5}$, PM_{10} *and* NO_2> at a frequency of <*specified frequency, such as every 15 minutes*>.
A programme of monitoring to take place for a period of 3 years to include the annual submission of a report detailing the findings, *within <stated time> of each twelve-month period. This should include comparison with current national objectives, and for second and subsequent years include preceding years' data. A final report should be submitted to detail all findings, <including any requested comparison with wider data, potentially including traffic data or data from DEFRA or other monitoring>.*
The monitoring equipment shall be installed and retained in accordance with the above agreed details.
Reason: so potential impact of poor air quality on the <*relevant receptors*> can be monitored in line with <relevant local policy> and paragraphs 174 and 186 of the National Planning Policy Framework.

This two-page note and ten-step guide has been produced by University of Suffolk for West Suffolk Council, as part of a project funded by the Local Government Association in their Net Zero Innovation Programme (NZIP). Further details are included in the full report, Particulates Monitoring: Guide for Planning and Case Study, By Steventon, H., and Leggett, L., from University of Suffolk. Contact: h.steventon@uos.ac.uk

Consideration of steps for planning

1. Identify a concern that would require the condition. This could be potential impact on relevant receptors; increased receptors or sources; changes in physical structure. Could the Local Authority be required to declare an air quality management area? Is post-development monitoring data required?

2. Likely required parameters include those represented by national air quality objectives, standards and targets: PM_{10}, $PM_{2.5}$, nitrogen dioxide, ozone, and potentially other pollutants depending on potential sources. Physical parameters including temperature, relative humidity and pressure are important in understanding sensor data.

3. Identify and agree calibration requirements for the sensor, any constraints on model, and location including height above ground (for safety of public and of equipment) and power source.

4. Agree monitoring period, covering more than one year in multiples of twelve-months.

5. Identify other required data to collect during the project, such as traffic, road closures and sensor data from existing sensors (such as local authority and DEFRA monitoring).

6. Involve other organisations providing location, data or other support.

7. Confirm data analysis and reporting required: this may include comparison with national air quality objectives, provision of summary statistics and comparison with baseline data.

8. Specify reporting requirements, including content and frequency. Include annual (or more if required) interim reporting and a final report including all monitoring data. Include provision of data as well as data analysis.

9. Monitor implementation of the installation, review provision and content of interim and final reporting, pursue enforcement if necessary.

10. Assess and enact any required actions following monitoring and potential identification of increasing or exceeding air quality pollutants, which may include further assessment, monitoring, mitigation or other actions.

This two-page note and ten-step guide has been produced by University of Suffolk for West Suffolk Council, as part of a project funded by the Local Government Association in their Net Zero Innovation Programme (NZIP). Further details are included in the full report, Particulates Monitoring: Guide for Planning and Case Study, By Steventon, H., and Leggett, L., from University of Suffolk. Contact: h.steventon@uos.ac.uk

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1 Executive Summary

This document reports on a project undertaken by University of Suffolk for West Suffolk Council within their Local Government Association funded Net Zero Innovation Programme. The project sought to improve the process for including air quality monitoring, specifically particulates, as a planning condition, and was based on a case study of a previous such planning condition. This project has built upon and worked closely with specialist officers from West Suffolk Council and other district councils across Suffolk.

Air pollution is the lead environmental health problem in the UK and EU, impacting human health causing serious illnesses, and also ecosystem damage.

Particulate matter (PM) is the non-gas component in the air, forming physical particles which can be a wide range of chemical materials. It is classified by size, and named by a number representing the largest diameter of the particles (hence $PM_{2.5}$ is particles with a diameter less than 2.5μm). In the UK, approximately 15% of PM is considered to be naturally occurring, around 35% from international migration, and around 50% from UK-based anthropogenic sources. PM can travel long distances in the air over time periods of weeks or more, so sources may not be close to the measurement location and therefore do not correlate with local traffic volume. UK-based anthropogenic emissions of $PM_{2.5}$ are understood by DEFRA to include:

- 12.9% road transport including exhaust and non-exhaust (brake, tyre and road wear)
- 27.3% domestic combustion
- 26.0% industrial combustion
- 13.4% industrial processes (construction work can lead to local increases)
- 20.4% from other sources

Planning and development plans influence air quality and take into account impact and designated areas.

UK policy has developed targets including reduction targets as well as objectives not to exceed.

A ten-step guide is presented for inclusion of air quality monitoring as a planning condition:

Step	Action
1	Identify concern appropriate for planning or other condition
2	Identify air quality and related parameters to monitor
3	Specify sensor requirements, including calibration. Identify location, power, and access
4	Identify period of monitoring, including pre-, during and post-development
5	Identify other data to collect
6	Identify other organisations collaborating or contributing
7	Analysis requirements
8	Specify reporting requirements, frequency of intermediate and final reporting
9	Monitor implementation, receipt of reporting and values
10	Assess any additional action required

This is included as a stand-alone two-page guide, with brief explanations of the steps and potential draft planning condition. It is further expanded with details and reasoning within the main body of this report. Incorporating air quality monitoring as a condition of planning applications can support the protection of public health and the environment, and the guide may support the formulation of such a planning condition to request and implement air quality monitoring measures.

The case study also analysed data provided from a sensor installed during previous monitoring condition, incorporating additional data from NO_2 diffusion tubes, traffic sensor and road closure periods, and regional DEFRA monitoring. This indicated that DEFRA objectives were met over the monitoring period, and that PM varied closely with regional PM, including elevated measurements during a period of international migration (Saharan dust storm). During closure of the adjacent road, NO_2 was observed to decrease but PM did not appear to be similarly affected. Strongest correlations with PM values were observed regionally rather than with traffic volumes, indicating geographical spread from national and international sources. Variation during November considered to be associated with bonfires and fireworks was observed.

It is concluded that incorporation of air quality monitoring as a planning condition where appropriate can be useful and well managed.

2 Introduction

This report sets out a review of the impact of particulate matter, and potential to use planning conditions in monitoring of particulate matter changes related to developments, built on a case study of a specific monitoring condition.

The report comprises an Executive Summary (Section 1), and this Introduction (Section 2). These are followed by a summary review of information and literature (Section 3), and of air quality in policy and planning (Section 4), before a ten-step guide to including particulate and air quality monitoring in planning applications (Section 5). This guide has been developed from the analysis data from and experience of a local case study, which is presented in Section 6 with conclusions drawn from the data analysis. Overall conclusions are discussed in Section 7, and references are included at the end of this report (Section 8).

The European Commission (2023) states *"Air pollution is the number one environmental health problem in the EU. It causes serious illnesses such as asthma, cardiovascular problems and lung cancer, and vulnerable groups are affected the most. Air pollution also damages the environment and ecosystems through excess nitrogen pollution and acid rain. It is also costly for our economy, as it leads to lost working days and high healthcare costs."*

This project and report focuses on particulate matter, and in the UK the Public Health Outcome Framework Indicators indicate that $PM_{2.5}$ is assessed as attributable for around 5 to 7% fraction of mortality (Office for Health Improvements & Disparities, 2023). Whilst decreasing trends appear to be observed from 2018 & 2019, to 2020 & 2021, the UK Health Security Agency (UKHSA) cautioned against *"over-interpreting change"* on an annual basis, because:

- *"Concentrations of $PM_{2.5}$ vary from year to year due to the weather. This variation due to weather is generally greater than the year to year variation from changes in emissions.*
- *The methods and data inputs for the pollution modelling are continually updated and improved.*
- *… this is an annual average metric, which for the last years (2020, 2021) has … included periods of lockdowns."*

This report and guide reviewed and do not replace existing guidance from multiple sources, and users are recommended to build on such existing guidance, whether included here or not. This guide and report are not aimed at vehicle or dust risk associated with construction or demolition phase of the work, for which construction/demolition specific conditions may apply including dust management plans.

2.1 Aims of case study and data analysis

Aims for the data and analysis were agreed with West Suffolk Council (specific contributors acknowledged in Section 2.2) and identified as:

- Analysis of supplied air quality monitoring data from one sensor across a period of two years.
- Identification of aspects of data and analysis that are more or less important.

- Exploration of expected and encountered trends, including relationship to traffic volumes and consideration of other potential sources.
- Summary of data potentially usable for air quality campaigns, including overall levels and relationship to traffic volumes.
- Comparison with national air quality objectives.

These aims, and wider data exploration and analysis have been undertaken and discussed in Section 6.

2.2 Stakeholder engagement and local officer input and acknowledgement

Engagement with local air quality officers across Suffolk in meetings and by email has contributed to this report. Specific acknowledgements for contributions include:

- Matt Axton, Environment Officer, West Suffolk Council
- Elysia Scully, Environmental Management Officer, West Suffolk Council
- Richard Calton, Traffic Data Manager, Suffolk County Council
- Rebecca Brooks, Senior Environmental Protection Officer, East Suffolk Council
- Denise Lavender, Environmental Protection Officer, East Suffolk Council

Discussion for the project was also held by the Suffolk Air Quality Group, including participants from Suffolk County Council, West Suffolk Council, East Suffolk Council, Babergh and Mid Suffolk Council, and Ipswich Borough Council. Input from these discussions is included throughout this report, including in Case Study and comparative discussion of findings in Section 6.2.

Work included in this report also draws on discussions with air quality sensor manufacturers and suppliers.

The draft copy of this report has been shared locally with Suffolk Air Quality Officers, and nationally with air quality officers via the Air Quality Hub; comments have been gratefully received and incorporated. The authors thank representatives from Hammersmith and Fulham Council; Newnham Council; and other members of the Air Quality Hub.

This project work has also been shared for presentation and discussion at the Together for Transformation Conference hosted at University of Suffolk in May 2023.

The authors of this report are grateful for the time and expertise shared by this wide stakeholder group.

3 Literature and Information Review

This project has focused on the presence of particulate matter measured by the sensor as part of a planning condition. To put this into context, a review of academic and specialist literature on the sources of particulate matter has been undertaken and is presented in this Section. Particulate matter is defined as *'everything in the air that is not a gas'* (DEFRA, 2023b) and is therefore physical particles. These can be a wide range of chemical materials and physical structures, and have a range of different health impacts, which can vary in part due to their varying chemical toxicity. Particulate matter (PM) is classified by size, with the number representing the largest diameter of the particles (hence, PM_{10} is particulate matter with diameter less than 10μm, $PM_{2.5}$ less than 2.5μm and so on). Particulate matter has a negative impact on health, with 4.9 million annual deaths globally attributed to fine particulate matter in ambient air pollution (WHO, 2022).

3.1 PM sources and concentrations

Approximately 15% of PM in the UK is considered to be naturally occurring (pollen and sea spray), and around a third resulting from international migration in the atmosphere (particulate matter and precursor chemicals can travel significant distances) (DEFRA, 2023b). This indicates that around half the PM in the UK results from UK-based anthropogenic sources. As PM migrates over significant distances depending on PM size and weather conditions, anthropogenic sources are not necessarily geographically close to the location of measuring. $PM_{2.5}$ can remain in the air for weeks and can therefore migrate for long distances (Wentworth and Blake, 2023), enabling non-UK and non-local origins, a behaviour very different to NO_2 migration. This review discusses sources of PM (focused on $PM_{2.5}$) in the UK, using public sector and academic literature information, to provide the context for the case study presented in this report.

The UK Emissions Inventory indicates current $PM_{2.5}$ emissions of 83.2kt (Figure 1), with approximately 12% attributed to road transport (Ingledew *et al.*, 2023). Other larger sources are *'small stationary combustion'* (*'combustion in the residential / commercial / public sectors'*, which includes domestic burning) contributing 28%, *'stationary combustion in … industries'* contributing 25% and *'industrial processes'* contributing approximately 12%. Similar presentation of the data by DEFRA (DEFRA, 2023b) (Figure 2) indicates 12.9% $PM_{2.5}$ from *road transport*, with *'domestic combustion'* accounting for 27.3%, *'industrial combustion'* accounting for 26.0%, and *'industrial processes'* for 13.4%.

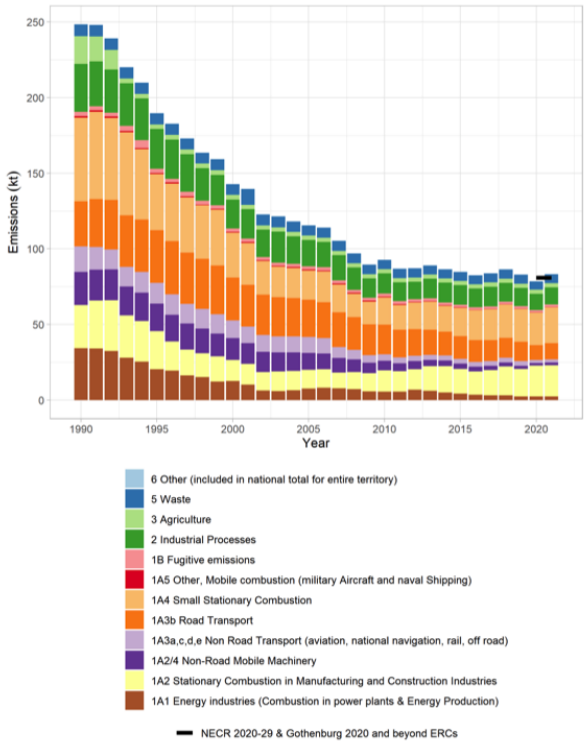

Figure 1: Total UK Emissions by Source Sectors, Particulate Matter < 2.5 um (PM2.5) 1990 – 2021 (Ingledew *et al.*, 2023 from National Atmospheric Emissions Inventory)

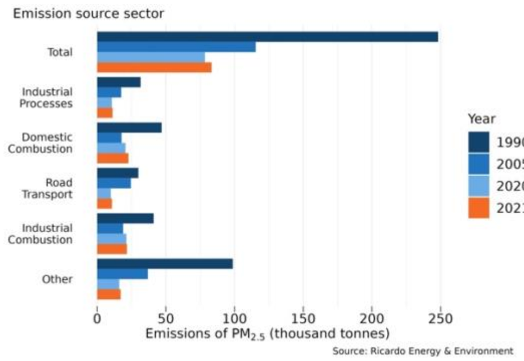

Figure 2: UK annual emissions of PM2.5 by 2019 major emissions sources: 1990, 2005, 2019 and 2020 (DEFRA, 2023b *from Ricardo Energy and Environment*)

Long term decrease of PM since the 1970s is attributed to multiple factors, including reduction in coal burning, and improved standards for transport and industry emissions (DEFRA, 2023b), though emissions from domestic wood and industrial biomass burning have increased, offsetting some other gains.

Road transport is a major source of PM emissions (DEFRA, 2023b) including both exhaust and non-exhaust (brake, tyre and road wear) emissions. Non-exhaust emissions are said to account for approximately 10% of road transport emissions for both PM_{10} and $PM_{2.5}$ (DEFRA, 2023b, 2023c), and a small fraction (0.3%) of total $PM_{2.5}$ (Panko *et al.*, 2019). However, *'airborne $PM_{2.5}$ is not necessarily correlated to local traffic volume, rather, regional sources and meteorological conditions are often stronger influences'* (quoted in Panko *et al.*, 2019). Identifying sources of larger particulate matter (PM_{10} and $PM_{2.5}$) based on chemical profiles has been undertaken (for example, Viana *et al.*, 2008) and have revealed the wide range of sources described in this report. More recent investigations on even smaller particles ($PM_{0.1}$, ultrafine particles) indicate they are considered to be predominantly sourced in traffic emissions in urban areas (Rivas *et al.*, 2020).

Research has shown that both construction activity and post-development increased road traffic lead to increases in air quality parameters, with increases in PM_{10} measured during construction work and increases in all analytes monitored but notably NO_2, NO_x and PM_{10} associated with post-construction increased traffic, and also indicated by modelling (Font *et al.*, 2014; Giunta, 2020). Other construction activity has been shown to lead to increases in $PM_{2.5}$ and PM_{10} during construction (Azarmi *et al.*, 2016) with health impacts on occupants (Jung *et al.*, 2019).

These reviews indicate that temporary contributions to PM due to construction works, and long term contributions due to increases in traffic can be anticipated, and monitoring to identify impact and exceedances is an appropriate approach. However, whilst road traffic contributes around 12%, variations in wider geographical sources and weather conditions means that the impact of traffic volume on measured PM concentrations is unlikely to be easily identified. This has been repeated recently by UK Health Security Agency Public Health England, who warned via circular email that *'concentrations of $PM_{2.5}$ vary from year to year due to the weather. This variation … is generally greater than the year to year variation from changes in emissions.'* They additionally commented on the potential for periods of COVID-19 related lockdowns to impact $PM_{2.5}$ data.

4 Air Quality in Planning Applications

The UK Government provides guidance on how planning can take account of the impact of new development on air quality (Department for Levelling Up Housing and Communities and Ministry of Housing Communities and Local Government, 2019). This guidance discusses considerations, plan-making, concerns, existing information and issues relating to assessment. This links to the 2008 Ambient Air Quality Directive and UK's national emission reduction commitments for five specific air pollutants:

- Fine particulate matter ($PM_{2.5}$)
- Ammonia (NH_3)
- Nitrogen oxides (NO_x)
- Sulphur dioxide (SO_2)
- Non-methane volatile organic compounds (NMVOCs)

Development plans influence air quality through the proposed development and transport provision, and should take into account air quality management areas, clean air zones, and other designated areas. Plans are advised to consider existing trends and potential changes in the context of the new development, point sources and cumulative emissions including vehicle emissions, reduction and mitigation measures (Department for Levelling Up Housing and Communities and Ministry of Housing Communities and Local Government, 2019).

> *"As part of the strategic environmental assessment or sustainability appraisal of a plan, consideration will need to be given to potential trends in air quality in the presence and absence of development, as well as any impacts and mitigation / improvement opportunities arising from the plan's proposals."*

In this context, air quality concerns can be relevant to neighbourhood planning and individual planning decisions. Whether air quality is relevant depends on the development and location, including current air quality conditions at a location, how construction and development could impact air quality, and the potential impact on residents or users of the new development or existing facilities. A key example of a relevant consideration would be if the development could lead to changes in local vehicles and related emissions, if the development could increase presence of people in areas of existing poor air quality, have impact during construction, or have impact on biodiversity. Such concerns would lead to the consideration of relevance for an air quality assessment, and potentially appropriate mitigation. Assessment could include a process for *"assessing impacts and determining the significance of an impact"*. Monitoring and assessing is not a mitigation measure, but an assessment process.

4.1 Existing information and data

Existing sources of air quality information include (from Department for Levelling Up Housing and Communities and Ministry of Housing Communities and Local Government, 2019):

- UK Air Information Resource (DEFRA, 2023g) including the UK Ambient AQ Map (DEFRA, 2023i)
- DEFRA and local government records on air quality management areas (such as West Suffolk Council, 2022)
- Modelled background pollution data (DEFRA, 2023d)
- Air pollution emissions maps (National Atmospheric Emissions Inventory, 2023)
- Air Pollution Information System focused on species and habitats (CEH, 2023)

These can be used to identify concerns during the application stage, and as potential sources of further data collected during the monitoring, analysis and assessment stages (See Section 5.7). Selected sources of existing data were used and analysed in the Case Study (Section 6).

4.2 Air Quality in policy

UK Parliament published a POSTnote on Urban outdoor air quality describing air pollution as *"the greatest UK environmental public health threat"* (Wentworth and Blake, 2023). Air quality legislation includes the Air Quality Standards Regulations 2010 providing annual reporting requirements, and limits and target values for specified parameters. Devolved regulations provide for Scotland (with more stringent PM levels), Wales and Northern Ireland. The National Emission Ceilings Regulations (2018) provide some reduction commitments, and The Environment Act 2021 requires introduction of air quality targets in England. Wentworth and Blake (2023) set out the government's targets to reduce $PM_{2.5}$ to an annual mean concentration of 10 $\mu g/m^3$ and a population exposure reduction target of 35% to be achieved by 2040 (DEFRA, 2023f). WHO's latest recommendation for $PM_{2.5}$ below 5 $\mu g/m^3$ is more stringent (World Health Organisation, 2021b, 2021a) reflecting latest WHO standards and policies (World Health Organisation, 2022).

The UK targets reflect, though are not identical to, international targets such as the National Emissions Ceiling Regulations (NECR) and Convention on Long Range Transboundary Air Pollution amended Gothenburg Protocol, which require UK reduction of $PM_{2.5}$ emissions compared with 2005 concentrations by 30% in 2020, and by 46% in 2030 (DEFRA, 2023b). The UK did not meet these reductions, achieving a 28% reduction in $PM_{2.5}$ emissions by 2021 (DEFRA, 2023b).

Wider relevant published policy documentation and guidance includes:

- Clean Air Strategy (DEFRA, 2019)
- National Air Pollution Control Programme (revised 2023) (DEFRA, 2023a)
- Air Quality Guidance on how planning can take account of the impact of new development on air quality (Department for Levelling Up Housing and Communities and Ministry of Housing Communities and Local Government, 2019)

- National Planning Policy Framework (Ministry of Housing Communities & Local Government, 2021)
- Land-Use Planning and Development Control: Planning For Air Quality Guidance for the consideration of air quality within the land-use planning and development control processes (Environmental Protection UK & Institute of Air Quality Management, 2017)

5 Guide for Air Quality Sensing in Planning Applications

5.1 Introduction

Air quality monitoring plays a crucial role in assessing and mitigating environmental impact of development projects. UK local authority planning authorities can decide when to incorporate air quality monitoring as a condition of planning applications. This guide aims to provide a step-by-step approach to request air quality monitoring effectively, compliant with relevant regulations and safeguarding well- being of local communities. The process will include stages:

- Understand the importance of air quality monitoring including impact on public health, environment, and climate change, and recognize the significance of integrating air quality monitoring into the planning process.
- Familiarise with applicable legislation and policies, including relevant national and local legislation, policies and guidelines related to air quality management and planning, and understand specific requirements from regulatory bodies including DEFRA.
- Identify relevant projects considering types of projects and potential impact, and scale, location and emission sources associated with those projects.
- Incorporate air quality monitoring conditions (see Section 5.2) following assessment of potential impacts (including from Environmental Impact Assessment), collaborate with relevant departments such as environmental health and air quality teams, engage with developers to request any additional information.
- Communicate with stakeholders including developers and where appropriate, local communities and community groups.
- Monitor implementation and compliance (See Section 5.11) collaborating with planning and environmental / air quality teams.
- Continually improve and share knowledge regarding advancements in techniques and best practices, collaborate with other local authority officers and relevant wider networks to share experiences and lessons learned.

Incorporating air quality monitoring as a condition of planning applications can support the protection of public health and the environment. This guide may support with an approach to request and implement air quality monitoring measures. Due to ongoing changes, ensure compliance with current regulations, and build sustainable development within your local authority. Where air quality is an issue, some councils aim to exercise the planning system to fund actions to improve air quality (eg London borough of Richmond Upon Thames, 2020)

5.2 Guide

Based on the case study analysis (Section 6), stakeholder discussions, consideration of existing planning conditions and of policy documentation, a ten-step guide for requesting air quality sensing and reporting in planning applications has been developed. This is summarised below (Table 1) and detailed in the following sub-sections (Sections 5.3 to 5.12). This aims to support local authorities to develop and draft clear and enforceable planning conditions related to air quality monitoring.

Step	Action
1	Identify concern appropriate for planning or other condition
2	Identify air quality and related parameters to monitor
3	Specify sensor requirements, including calibration. Identify location, power, and access
4	Identify period of monitoring, including pre-, during and post-development
5	Identify other data to collect
6	Identify other organisations collaborating or contributing
7	Analysis requirements
8	Specify reporting requirements, frequency of intermediate and final reporting
9	Monitor implementation, receipt of reporting and values
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Table 1: Ten-step guide for including air quality sensing in planning applications.

5.3 Identify concern for condition

The initial step in requesting air quality monitoring as a planning condition is to identify a concern that would require the condition, due to new relevant receptors, increased impact due to additional sources or changes in physical structure impacting air movement. This may affect Local Authority designation of air quality management areas if air quality improvements are necessary (DEFRA, 2022).

The example as presented in the accompanying case study is included in Table 2Table 3Table 4 in Section 6.2, and relates to the existing knowledge of air quality in the location, the additional relevant receptors and existing and potential traffic volumes during and following development, other potential sources (such as industrial burning and construction processes (Section 3.1), the air quality assessment, and the potential for the physical structure of the development to further affect local air quality. Monitoring was requested to *"allow the Local Authority to monitor levels of pollution and whether this development, due to its height and position, has any effect on it. Therefore we have the necessary information to establish if there's a need to designate the area as an air quality improvement zone."* (West Suffolk Council, 2016c)

5.4 Requested Parameters

This study has focused on the analysis of particulate matter data, and the set of parameters requested should be identified. These may include (as for this project):

- Relevant physical parameters:
    - Temperature
    - Relative Humidity
    - Pressure

- Chemical / air quality parameters:
    - Nitric Oxide (NO)
    - Nitrogen Dioxide (NO_2)
    - Ozone (O_3)
    - Particulate Matter sub 1 μm (PM_1)
    - Fine particulate matter sub 2.5 μm ($PM_{2.5}$)
    - Particulate matter less than 10 μm (PM_{10})

Physical parameters and weather conditions can influence measurements of air quality parameters, and may or may not be adjusted for within the device and service data supply. This is considered most impactful for PM_{10}, which is impacted by humidity to a greater extent than for smaller particles (Ricardo, 2022b).

Other parameters to consider are the other three (not already listed above) identified by the UK's national emission reduction commitments should the proposed development provide concern:

- Ammonia (NH_3)
- Sulphur dioxide (SO_2)
- Non-methane volatile organic compounds (NMVOCs)

5.5 Sensor requirements, location

In this step requesting officers will identify sensor requirements in addition to parameters (see Section 5.4), calibration and standards. Air quality sensors do not provide the same level of information as a reference analyser (Ricardo, 2022a), but can provide useful information about variation in analytical parameter concentrations and may be suitable as supplementary monitoring data (Wentworth and Blake, 2023) over the term of the project, and highlight potential requirements for ongoing measurement. Whilst comparative studies of sensors have been undertaken (Ricardo, 2022c) specific product recommendations are outside the scope of this guide, given ongoing development in the field, especially with respect to particulate matter sensors. MCERTS indicative scheme certification to ±50% (CSA Group, 2023) is available to particulate matter sensors, and has currently been obtained by a number of providers (for details, see the link included in the references to this document). Calibration requirements, including co-location with reference analyser if required, should be identified and stated in this step; external quality assurance / quality control (QA/QC) will add significantly to the pricing and may not be required for indicative and comparative data, but provides potential to confirm (or otherwise) the data (Ricardo, 2022b).

Some planning authorities may have comparative data from specific sensor supplier or model which they require to match for consistency.

Together with identifying sensor requirements, this step also includes the identification of location. This will include consideration of sources and of relevant receptors.

Additionally, in identifying a suitable location, consideration of safety (for the sensor and for the public, which may suggest providing security for the sensor or placing it at height) and provision of power are required. Sensors can typically be powered by mains connection to suitable buildings, or to street infrastructure such as street lighting columns. Solar power may be an appropriate power source if confirmed as adequate for year-round use by the sensor manufacturer.

Previous studies (Steventon, 2022) have suggested that enclosing sensors in additional protective casing beyond that designed by the sensor manufacturer may potentially limit flow of representative air to the sensor, or otherwise impair the sensor's function, unless care is taken in sensor and casing design to avoid this.

5.6 Monitoring period

The monitoring period needs to be identified to include any pre-development baseline required for comparison, development period and post-development operational period. The case study presented here (Section 6) covered two years of monitoring data, during and post development, to include impact of residents and users of the development. It is noted that this was during periods of reduced travel due to COVID-19 restrictions and therefore did not provide the stable conditions initially anticipated.

Due to seasonal variations in air quality, complete years (twelve-month periods) of data should be collected, though these need not correspond to calendar years.

Interim reporting during the monitoring period will be required, as well as final reporting at the end of the monitoring period. This is discussed in Section 5.10.

5.7 Other data

In this step the requesting officers will identify other data required for analysis and consideration of the air quality sensing data (Section 3.1). Such data will build the understanding of the context and the impact of the proposed development.

Following development of the Case Study (Section 6) the following list of data to collect has been compiled. Specific data sources used in the Case Study are detailed in Section 6, and are likely to be applicable in most locations. Potential additional data to collect may include the following, and consider others depending on context:

- Traffic data may be available from the single tier or upper tier local authority. Consider whether the location of the existing traffic sensors are appropriate for the location of the project.
- Air quality data from other regional or local locations, such as DEFRA monitoring data, especially for the analytes and parameters requested for sensing (see potential data sources in Section 4.1).
- Existing or new NO_2 diffusion tubes or other current air quality monitoring data collected by the lower or upper tier, or unitary, local authority.
- Dates and period of development construction and occupation phases.
- Dates, times and period of any road closures, including if uni- or bi-directional.
- Dates and period of travel or other restrictions that may impact on representativeness of data collected.

- Any other relevant data, for example, this could include specific working methodologies if impactful on particulate matter, and periods during which these were applied.

The organisation(s) responsible for identifying and collecting this data should be made clear, and may be different for different items of additional data. Collecting data at the time, such as time periods of road closures, may be important as it can be challenging to identify details subsequently.

5.8 Other organisations

In this step, identify and confirm with any other organisations you are working with on this project. This could include upper tier authorities with access to traffic or wider air quality data, adjacent authorities with related interests, or third party organisations who may be supporting with data assessment analysis.

Confirm with those other organisations their interest and involvement, and agree their requirements and roles.

5.9 Analysis requirements

Confirmed with stakeholder discussions (Section 2.2) during this project, the following data analytical and summary details have been identified as important to include:

- Comparison of all analytes collected with national air quality objectives (DEFRA, 2023h, 2023e)
- Provision of Summary Statistics, including mean, and interquartile range, for each year of analysis to observe any trends
- Comparison with any predetermined baseline or other data (Section 5.7)

Other statistical analysis and presentation may be important for specific developments and planning applications, in consideration with purpose of requesting the monitoring (Section 5.3), and therefore application-dependent requirements may be added.

These should be provided for annual intermediate stages, and for final reporting.

5.10 Reporting requirements

This step identifies and specifies requirements in interim and final reporting of data, and the assessment and analysis of the data.

An example of analysis of air quality data is included in the Case Study in this report (Section 6), though this is considered likely to include additional analysis undertaken as part of this project that may be beyond requirements of planning applicants.

Frequency of measurement and speed of reporting should be stated in the condition and confirmed in the reporting.

It is suggested likely that annual interim reporting (due to seasonal variation, Section 5.6), within two months of each year end, and a final report at the end of the agreed period is likely to be appropriate.

As each project is individual, more frequent interim reporting may be requested, potentially associated with phases in the development and occupation.

5.11 Monitor implementation, receipt of reporting and compliance

Frequency, receipt and content of monitoring data and reporting should be checked by the local authority so that requested interim reporting is not missed.

This includes:

- the implementation of the installation to verify that monitoring equipment is installed correctly and meets requested standards;
- review provision of interim and final data and reporting submitted by the developer or applicant, and ascertain the collection of data from the installed sensor and other agreed sources;
- therefore review compliance with the condition and comparisons with objectives and other requests;
- pursue appropriate enforcement or planning and mitigation actions if non-compliance with conditions or significant air quality impacts are identified.

This process is likely to be a collaboration between planning and air quality or environmental health teams within the location authority, to oversee the implementation of the air quality monitoring programme.

5.12 Assess required actions

Interim or final reporting may identify potential increased concentrations of relevant air quality analytes, and therefore lead to further assessment, monitoring or other actions. Consider if monitoring outcomes indicate requirement for an air quality management area or other action.

5.13 Draft potential planning condition

Based on these guidelines and the planning condition presented in the case study, a potential draft planning condition is proposed, to be adapted as required.

> Prior to <*first occupation*> of the development hereby approved, details of the following shall be submitted to and approved in writing by the Local Planning Authority:
> Continuous air quality monitoring equipment to be installed <*at stated location, specified height*>. Equipment should be <*specified model if required, or as agreed in correspondence*>; it should measure <*specified parameters, associated with DEFRA objectives and targets, such as $PM_{2.5}$, PM_{10} and NO_2*> at a frequency of <*specified frequency, such as every 15 minutes*>.
> A programme of monitoring to take place for a period of 3 years to include the annual submission of a report detailing the findings, *within <stated time> of each twelve-month period. This should include comparison with current national objectives, and for second*

and subsequent years include preceding years' data. A final report should be submitted to detail all findings, <including any requested comparison with wider data, potentially including traffic data or data from DEFRA or other monitoring>.
The monitoring equipment shall be installed and retained in accordance with the above agreed details.
Reason: so potential impact of poor air quality on the <*relevant receptors*> can be monitored in line with <relevant local policy> and paragraphs 174 and 186 of the National Planning Policy Framework.

6 Case Study

6.1 Case Study in context of guide

The guide produced in this project has been developed from the case study of an existing planning condition for monitoring air quality impact from a development. The planning condition is described in Section 6.2 and forms the basis for the guide included in Section 5. Data from this planning condition was provided to West Suffolk Council without analysis, and analysis of this data with focus from discussion with West Suffolk Council's Environment Teams is included in this section and further informs Section 5.

6.2 Planning condition, Tayfen Road

The case study forming the basis of this guide and data analysis is based on conditions on a planning application made to West Suffolk Council for construction and conversion of 36 one or two bedroom flats, with potential for increased associated traffic, available on the local authority planning portal (West Suffolk Council, 2018). The Officer Report referenced concerns over air quality and condition relating to monitoring to establish a need for air quality improvement area designation (West Suffolk Council, 2016c). The Officers Report included the condition as presented in Table 4 below.

There are concerns over air quality on the Tayfen Road frontage of the site. An air quality assessment has been produced to calculate air pollution at Tayfen Road and confirms that this proposal should not result in unacceptable living conditions for occupants. However, to ensure this is the case, an information pack will be provided so residents, particularly in ground floor flats, have the option of opening windows or using mechanical ventilation. Additionally, monitoring equipment will be installed on the new building fronting Tayfen Road to allow the Local Authority to monitor levels of pollution and whether this development, due to its height and position has any effect on it. Therefore, we have the necessary information available to establish if there's a need to designate the area as an air quality improvement area.

Table 2: Impact on air quality, from Officer Report (West Suffolk Council, 2016c)

Initial objections were made by the local authority Environment Team due to impact to relevant residential receptors from poor air quality, with request for an air quality assessment (Table 3) (West Suffolk Council, 2016a). The air quality assessment was provided (REC Ltd, 2016) which includes modelling of PM_{10} concentrations indicating no air quality objective exceedances.

The application proposes four storey residential dwellings within approximately 2m of a highway with over 15,000 movements per day (Department for Transport traffic count data 2014). This will introduce relevant receptors into an area at risk from poor air quality, whilst also reducing the capacity for dispersion of pollutants, which will cause an increased level of pollutants at the roadside. *We therefore object to the proposals until an air quality assessment is provided that proves the annual mean air quality objective for Nitrogen Dioxide will not be exceeded at the façade of the proposed residential dwellings. We would request that the scope of any assessment is agreed with this Service prior to being undertaken.* *The application does not contain sufficient information on the risk posed by air quality at the site and therefore does not accord with the National Planning Policy Framework (NPPF), Policy CS2 (Sustainable Development) of the Core Strategy and Policy DM14 of the Joint Development Management Policies Document.*

Table 3: Initial objection on basis of air quality impact to residential receptors from highway (West Suffolk Council, 2016a)

Following the submission of an air quality assessment, a request for monitoring was included as a planning condition in the Decision Notice (West Suffolk Council, 2016b) as condition 9 (Table 4):

Prior to first occupation of the development hereby approved, details of the following shall be submitted to and approved in writing by the Local Planning Authority: *Continuous air quality monitoring equipment to be installed on the Tayfen Road elevation* *A programme of monitoring to take place for a period of 3 years to include the annual submission of a report detailing the findings.* *The monitoring equipment shall be installed and retained in accordance with the above agreed details.* *Reason: so potential impact of poor air quality on the residents of the development can be monitored.*

Table 4: Initial planning condition request (West Suffolk Council, 2016b)

The details were agreed in application letter (Rees Prior Architects LLP, 2019 available at West Suffolk Council, 2019) following consultation with the Environmental Health Team at West Suffolk Council, which specified:

EQUIPMENT *The proposal is to install a Zephyr Air Quality Sensor on the eastern end of the Tayfen Road elevation as indicated on the attached drawings. Also attached are data sheets and quality statement from the sensor manufacturer.* *The unit will be mounted at a height of 2.5 metres above ground level to be consistent with other monitoring equipment within the district.* *Enviro Technology Services have confirmed that readings are taken and recorded every 10 seconds from the Zephyr sensor, and all of this data is sent to the web portal every 15 minutes as default. The unit will operate with the solar panel and on board battery in this configuration as standard, which should be sufficient to satisfy Environmental Health's requirements.* ***COMMITMENT BY HAVEBURY HOUSING PARTNERSHIP*** *To satisfy the condition Havebury agrees to:* • *Install 1 nr Earthsense Systems, Zephyr unit with solar panel (distributed through Enviro Technology Services) – to include standard cartridge, one year's operation fee, warranty, SIM card and data/web hosting, etc.* • *Commits to a further two years of ongoing air quality monitoring (3 years total monitoring as required by the planning condition) – to include supply of calibrated standard cartridge change per year, GSM SIM card, data/web hosting, warranty, etc.*

Table 5: Supporting statement for discharge of Condition (Rees Prior Architects LLP, 2019)

Accompanying specification sheet (Earthsense, 2019) indicates the inclusion of the following analytes:

- NO_2
- NO
- O_3
- PM_1
- $PM_{2.5}$
- PM_{10}
- Temperature
- Relative Humidity

6.3 Introduction to case study data analysis

The case study focussed primarily on analysing data from the Zephyr Air Quality sensor installed as part of the planning condition described above. Data from an additional six sources were also included to add breadth and depth to the analysis (Table 6). Locations of these sensors are shown in Figure 3 and Figure 4.

Data Source	Owner	Location	Distance	Data format
Zephyr air quality monitoring sensor	Enviro Technology Services/Havebury Housing Partnership	Tayfen Road, Bury St Edmunds (52.251748 0.71387)	0	Monthly csv files 15-minute readings
NO2 diffusion tube	West Suffolk District Council	Tayfen Road, Bury St Edmunds (52.251268, 0.712627)	93 m	Single csv file Monthly readings
Traffic volume sensor	Suffolk County Council	Compiegne Way, Bury St Edmunds (52.25310112, 0.717824385)	322 m	Annual excel spreadsheets Hourly readings
DEFRA air quality sensor (Wicken Fen)	DEFRA	Wicken Fen, nr Cambridge (52.298500, 0.290917)	35.4 km	Annual csv files Hourly readings
DEFRA air quality sensor (Lakenfields)	DEFRA	Lakenfields in Norwich (52.614823, 1.302686)	67.6 km	Annual csv files Hourly readings
DEFRA air quality sensor (St Osyth)	DEFRA	St Osyth, near Clacton on Sea, Essex (51.777874, 1.049010)	77.2 km	Annual csv files Hourly readings
Road closures	One.network platform (Paid login required – access provided by Suffolk County Council)	Tayfen Road, Bury St Edmunds	0.006 m (closest point)	Interactive map of closure dates/times

Table 6: Data sources for case study analysis

Figure 3: Bury St Edmunds sensors locations

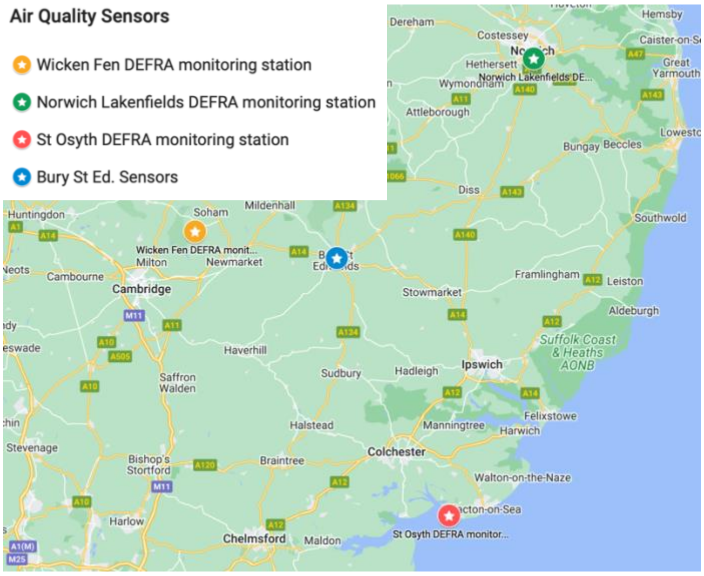


Figure 4: Air Quality sensors locations

The data provided and gathered covered two years, which have been analysed as two twelve-month periods, 1 September 2020 to 31 August 2021, and 1 September 2021 to 31 August 2022.

The analysis focussed primarily on particulates covered by national air quality objectives: namely $PM_{2.5}$, PM_{10} and NO_2 data and their relationship to traffic volumes. Initial analysis was also undertaken on provided PM_1 and humidity data.

The format of the data differed across the data sources, thus requiring manual preparation before analysis could be undertaken. This is described in more detail in Section 6.4. Following data cleansing and preparation, each sensor's prepared csv files were ingested into a Jupyter Notebook, and Python's data analysis modules (Pandas, NumPy and Matplotlib) were used to undertake the analysis. As the sensors record data over different time periods (15 minute, hourly, monthly), Python's resampling function was used throughout the analysis, in order to create aligned time periods with which to compare different data sets.

The flow of data sources and their analysis during this project is shown in Figure 5 below.

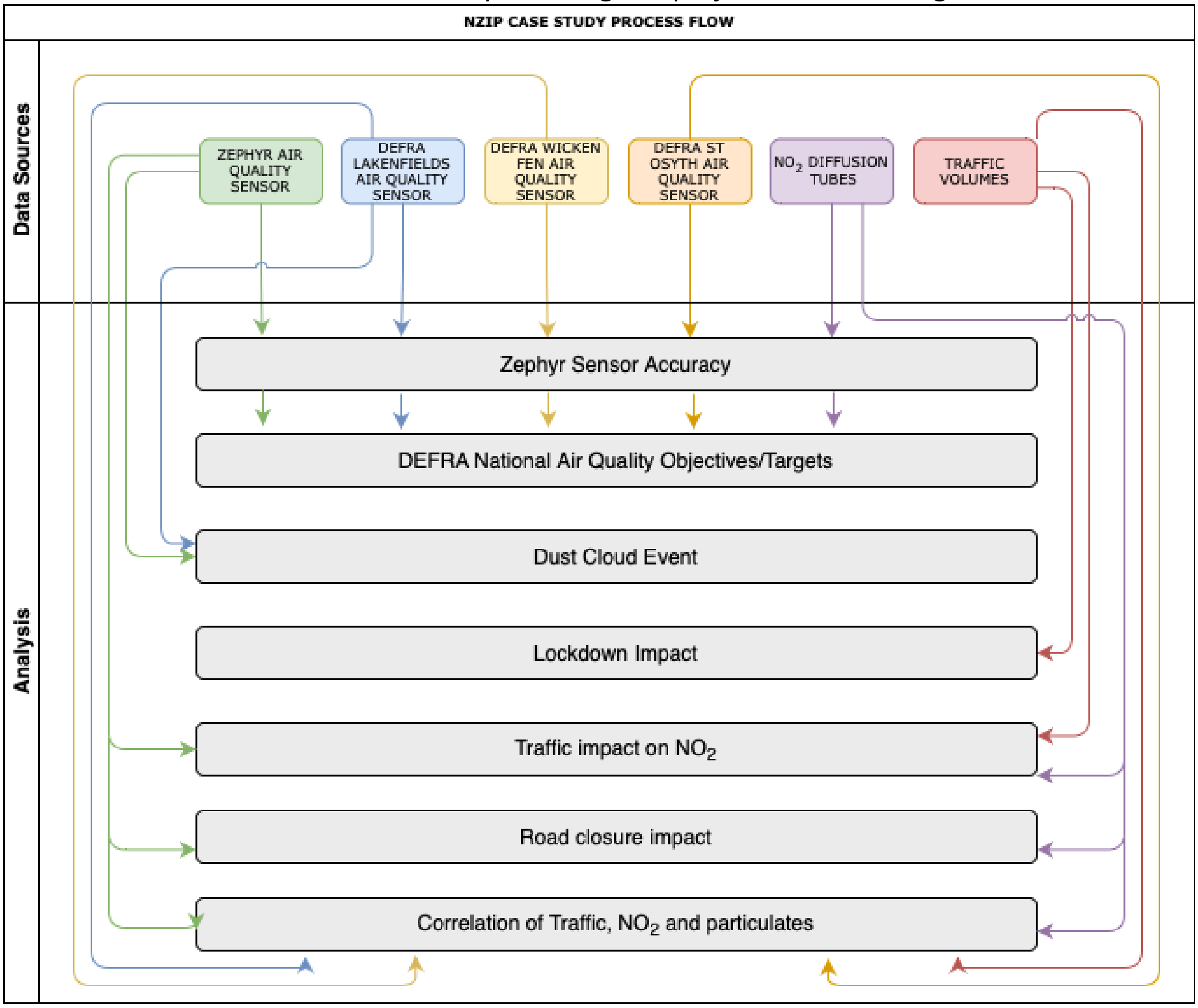


Figure 5: Data sources and analysis flow

6.4 Data Preparation and Cleansing

The case study analysed data from seven sources for the two-year period 1 September 2020 to 31 August 2022 (Table 6):

- Zephyr air quality monitoring sensor located on Tayfen Road, Bury St Edmunds
- NO_2 diffusion tubes located on Tayfen Road, Bury St Edmunds
- Traffic volume sensor located on Compiegne Way, Bury St Edmunds
- Road closure dates for Tayfen Road
- DEFRA air quality monitoring sites at:
    - Wicken Fen near Cambridge,
    - Lakenfields Norwich,
    - St Osyth near Clacton on Sea in Essex

6.4.1 Zephyr sensor

The Zephyr sensor was installed on the Tayfen Road elevation as part of the planning conditions for planning application DC/16/0267/FUL to monitor "potential impact of poor air quality on the residents of the development" prior to first occupation of the new development (West Suffolk Council, 2018).

The sensor recorded the following data; the data elements analysed during the case study are emboldened below:

- Temperature/Ambient temperature
- **Humidity/Ambient humidity (used during analysis)**
- **NO_2 (used during analysis)**
- O_3
- NO
- **PM_1 (used during analysis)**
- **$PM_{2.5}$ (used during analysis)**
- **PM_{10} (used during analysis)**
- Ambient pressure

Data was supplied to West Suffolk Council by the developer, and then to University of Suffolk, as monthly csv files (two files per month) with readings at 15-minute intervals. It is noted that this differs from the 10-second interval implied by the planning correspondence (Table 5, Section 6.2). Some column headings differed slightly between files, and some files included latitude and longitude data; therefore, in order to standardise the data, the latitude and longitude columns were removed, and headings renamed for the 46 csv files covering the analysis period.

6.4.2 NO_2 Diffusion Tube

West Suffolk Council's diffusion tube is located on Tayfen Road, Bury St Edmunds to collect monthly NO_2 data. Monthly raw and bias adjusted data (against a reference monitor) were supplied in one csv file by West Suffolk Council; the bias adjusted data was used during the analysis. This is referenced as 'TayfenDT adjusted'.

6.4.3 Traffic Volume Sensor

Suffolk County Council's closest traffic volume sensor is located on Compiegne Way, Bury St Edmunds (location shown on Figure 3) to collect northbound, southbound and total flow traffic volumes. The data was supplied by Suffolk County Council transport department initially as annual Excel spreadsheets with a tab per month. However, in this format night-time traffic (00:00 – 05:00 hrs) was recorded as a single figure for each day. In order to reflect the monitoring periods of the other sensors, a request was made for data that included hourly data over the full 24-hour period for each day. Suffolk County Council resupplied the data in annual excel spreadsheets with a tab per week and hourly readings for the entire 24-hour period. Hourly total flow traffic volumes for the analysis period were combined from Excel spreadsheets into a single csv file to be used during the analysis.

6.4.4 DEFRA air quality monitoring sites

DEFRA own around 300 Environment Agency managed monitoring sites across the UK to monitor air quality (DEFRA, no date). Three sensors nearest to the Zephyr sensor (locations shown in Figure 4 detailed in Table 6) were chosen to provide data for comparison as detailed in Table 7 below:

Site	Location	Sensor data available during analysis time period	Data used during analysis
Wicken Fen	Near Cambridge Latitude/Longitude: 52.298500, 0.290917	O_3 NO NO_2 SO_2 PM_{10} (from 7/6/22) $PM_{2.5}$ (from 7/6/22) Wind direction & speed Temperature	Hourly: NO_2 PM_{10} (from 7/6/22) $PM_{2.5}$ (from 7/6/22)
Lakenfields	Norwich Latitude/Longitude: 52.614823, 1.302686	O_3 NO NO_2 PM_{10} $PM_{2.5}$ Wind direction & speed Temperature	Hourly: NO_2 PM_{10} $PM_{2.5}$
St Osyth	Near Clacton on Sea Latitude/Longitude: 51.777874, 1.049010	O_3 NO NO_2 PM_{10} (from 1/4/22) $PM_{2.5}$ (from 1/4/22) Wind direction & speed Temperature	Hourly: NO_2 PM_{10} (from 1/4/22) $PM_{2.5}$ (from 1/4/22)

Table 7: DEFRA Air Quality Monitoring Sites and data analysed

Three csv files for each site were downloaded (2020, 2021, 2022). For each file, header rows, unwanted columns and dates outside the analysis period were removed and timestamps amended to match other sensors' format. Resultant files were combined into the two 12-month periods applied for the analysis. This resulted in six csv files used during analysis.

6.4.5 Missing/incomplete data

There were no data files supplied for the Zephyr sensor for February and March 2021, and no data for 22-26 March 2022. Within the supplied files, each particulate was missing approximately 3,800 readings, equating to around 6% of the total 64,000 readings (Table 8).

Particulate	Number of missing readings	Total readings	Percentage of total readings
$PM_{2.5}$	3,778	63,986	5.9%
PM_{10}	3,778	63,986	5.9%
PM_1	3,778	63,986	5.9%
NO_2	3,881	63,986	6.1%

Table 8: Zephyr sensor missing data

There was no data supplied for June 2021 for the NO_2 diffusion tubes.

Of the 14,578 traffic volume data readings, 14 were missing. The missing readings showed a pattern of occurring once a month at approximately the same time of day. Suffolk County Council's transport department confirmed that it is likely that this is when the sensor battery is changed, and the data downloaded.

Whilst it could have been possible to filter out or fill in missing data, it was decided to leave the data as recorded, as Pandas has the capability to handle missing data in its statistical analysis.

6.5 Findings of the case study data analysis

6.5.1 Comparison with Air Quality Objectives

DEFRA have published national air quality objectives and target values for the protection of human health (DEFRA, 2023h) (see Section 3). The case study compared the Zephyr sensor data with the DEFRA objectives to assess whether any exceedances of objectives occurred during the analysis period. The findings are shown in Table 9.

Pollutant	Objective	Concentration measured as	Zephyr Sensor 20/21	Zephyr Sensor 21/22
PM_{10}	50 μg/m^3 not to be exceeded more than 35 times a year	24 hour mean	There were no occasions when the PM_{10} 24-hour mean exceeded 50 μg/m^3	There were 2 days when the PM_{10} 24-hour mean exceeded 50 μg/m^3
PM_{10}	40 μg/m^3	annual mean	16.06 μg/m^3	14.98 μg/m^3
$PM_{2.5}$	20 μg/m^3	annual mean	12.19 μg/m^3	12.68 μg/m^3
NO_2	200 μg/m^3 not to be exceeded more than 18 times a year	1 hour mean	There were no occasions when NO_2 1-hour mean exceeded 200 μg/m^3	There were no occasions when NO_2 1-hour mean exceeded 200 μg/m^3
NO_2	40 μg/m^3	annual mean	25.56 μg/m^3	21.43 μg/m^3

Table 9: DEFRA national air quality objectives and targets

All objectives have been met during the analysis period according to the data collected by the Zephyr sensor.

6.5.2 PM_{10} Exceedances

Investigation was undertaken into the two consecutive days when PM_{10} exceeded 50 µg/m^3 on 21 and 22 March 2022 (Section 6.5.1). Humidity can affect PM_{10} readings, therefore particulates and ambient humidity were examined around those dates.

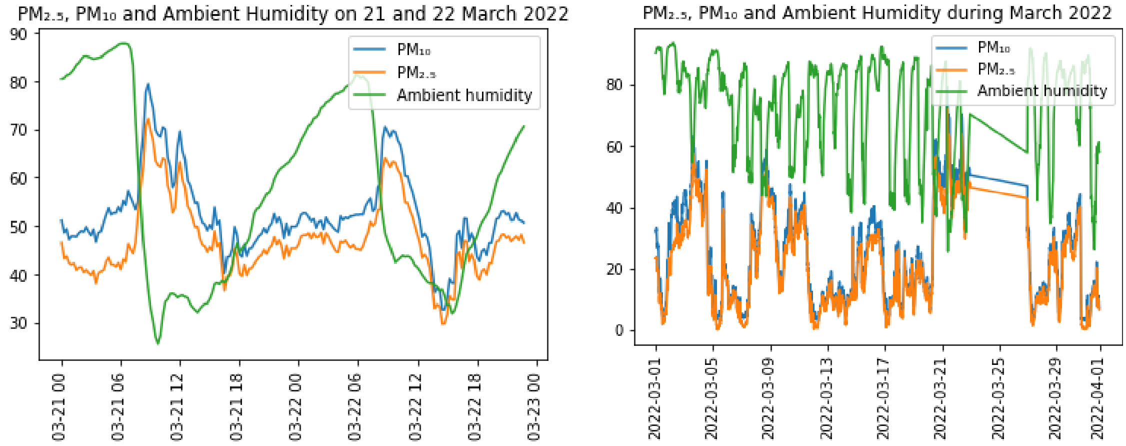
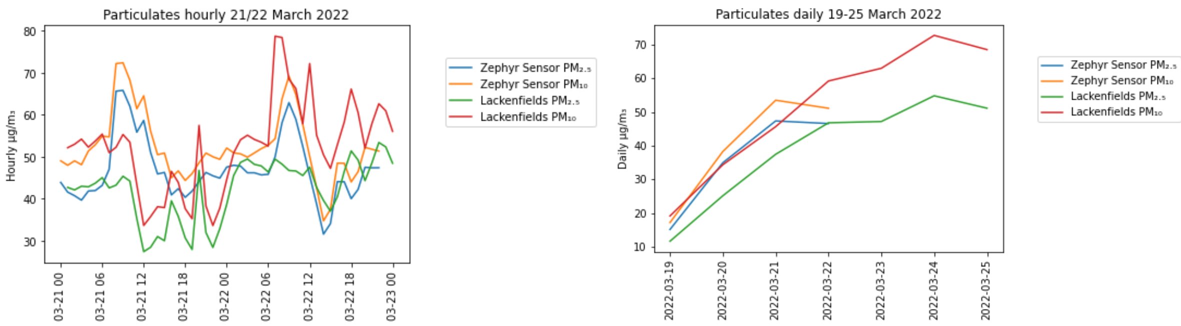


Figure 6: Particulates and Ambient Humidity March 2022

From inspection of the timeseries graphs, high humidity did not appear to be the cause of the exceedances.

Comparison was made with regional DEFRA air quality monitoring. These also showed an increase in particulates during March 2022, indicating that the cause may be more widespread beyond Bury St Edmunds. In March 2022 several large storms carried clouds of Saharan dust to Europe (Pratt, 2022). Only one DEFRA monitoring site (Lakenfield) recorded PM data during this time period, and has been investigated further (Figure 7). Visual correlation between these sites during this period indicates these two consecutive days of PM_{10} objective exceedance can be related to the international migration during the dust cloud event.



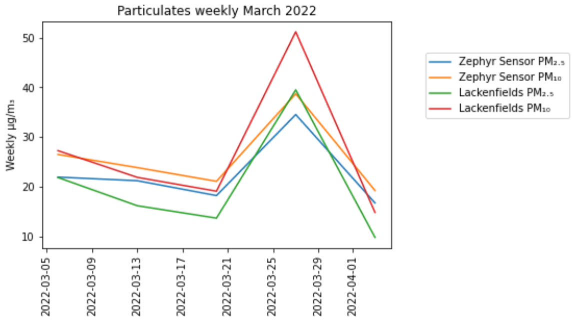
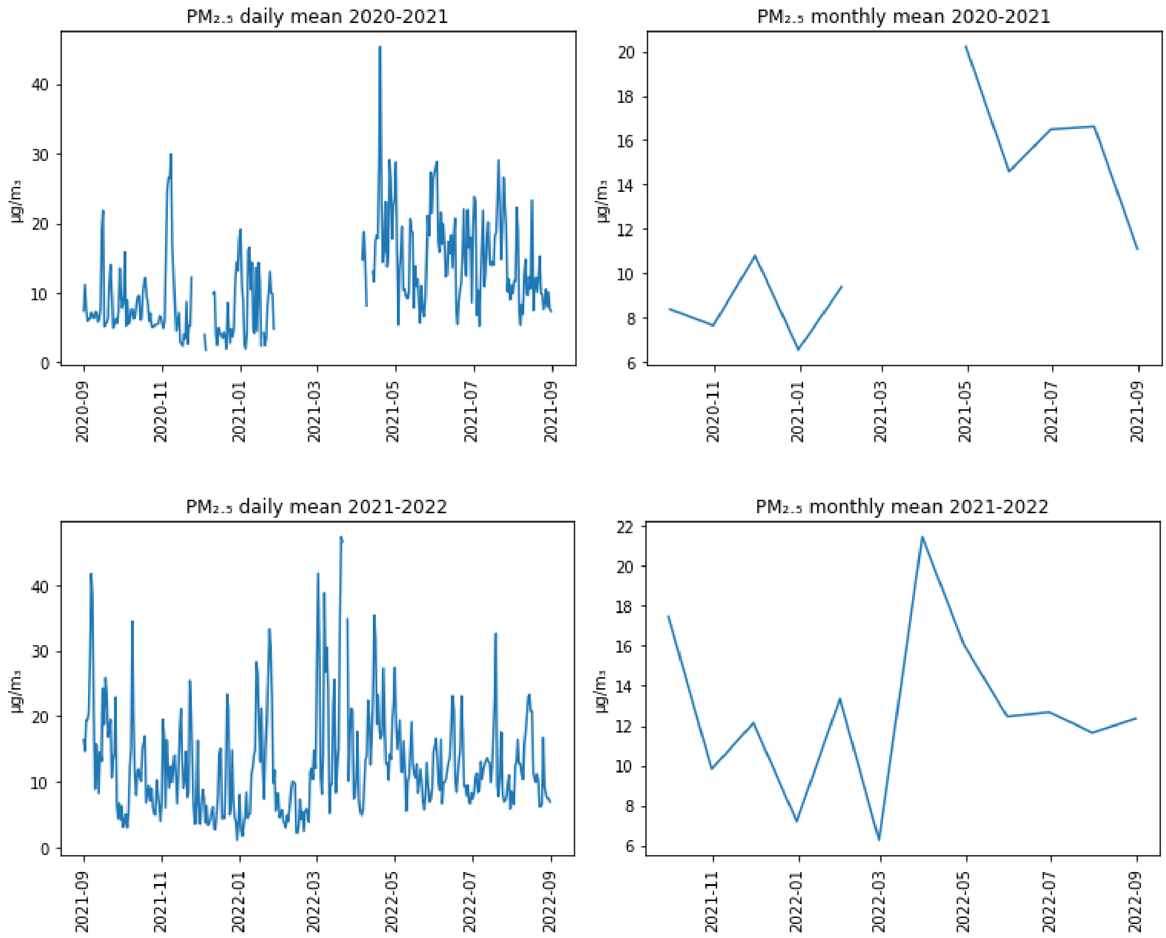


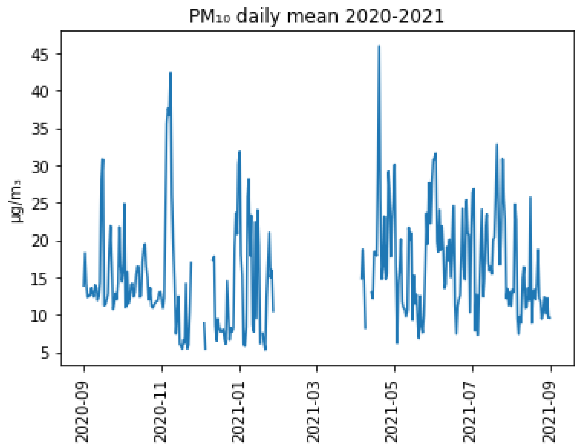
Figure 7: Zephyr sensor and Lakenfield DEFRA particulate readings, March 2022

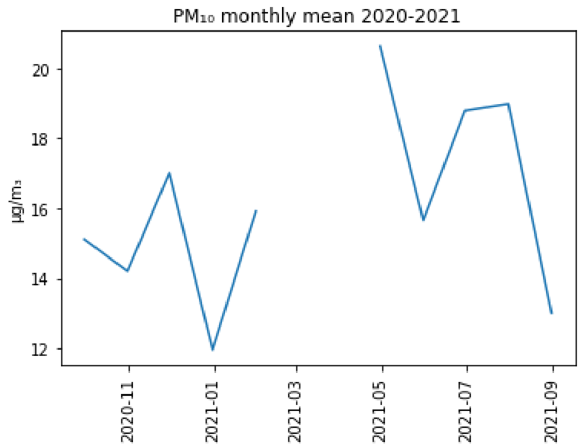
The Zephyr sensor produced no data from 23 to 26 March 2022. Further investigation would be required to ascertain whether this could be linked to the high concentrations of particulates experienced during the preceding dust cloud event.

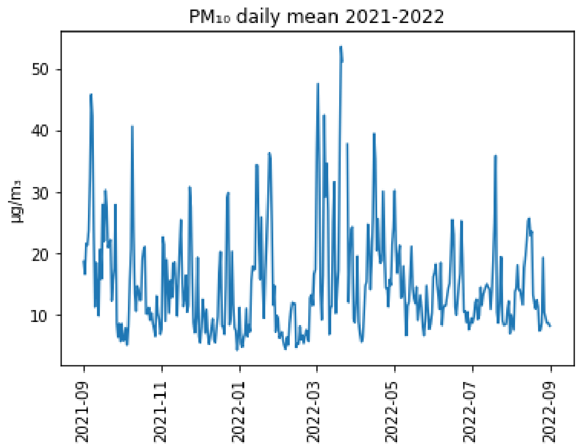
6.5.3 Analysis of particulate data: $PM_{2.5}$, PM_{10} and PM_1

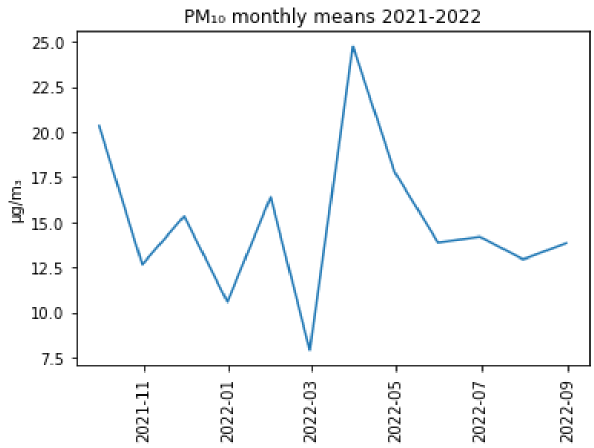
In line with the project focus on variations and sources of particulate data, timeseries plots of the data through the period have been created. These graphs below show the daily and monthly averages for $PM_{2.5}$, PM_{10} and PM_1 for the two years of the analysis period.




PM₁₀ daily mean 2020-2021
μg/m₃
45
40
35
30
25
20
15
10
5
2020-09
2020-11
2021-01
2021-03
2021-05
2021-07
2021-09


PM₁₀ monthly mean 2020-2021
μg/m₃
20
18
16
14
12
2020-11
2021-01
2021-03
2021-05
2021-07
2021-09


PM₁₀ daily mean 2021-2022
μg/m₃
50
40
30
20
10
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09


PM₁₀ monthly means 2021-2022
μg/m₃
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09

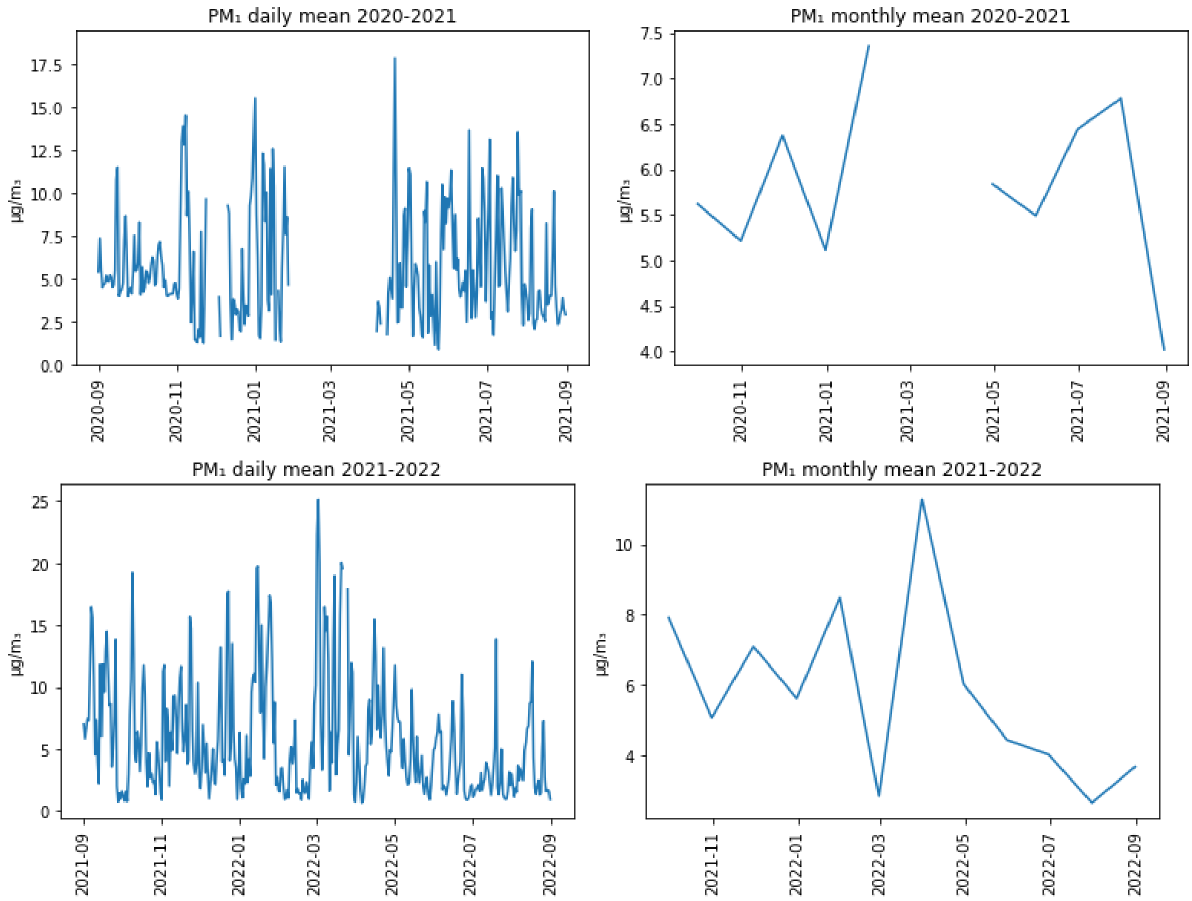
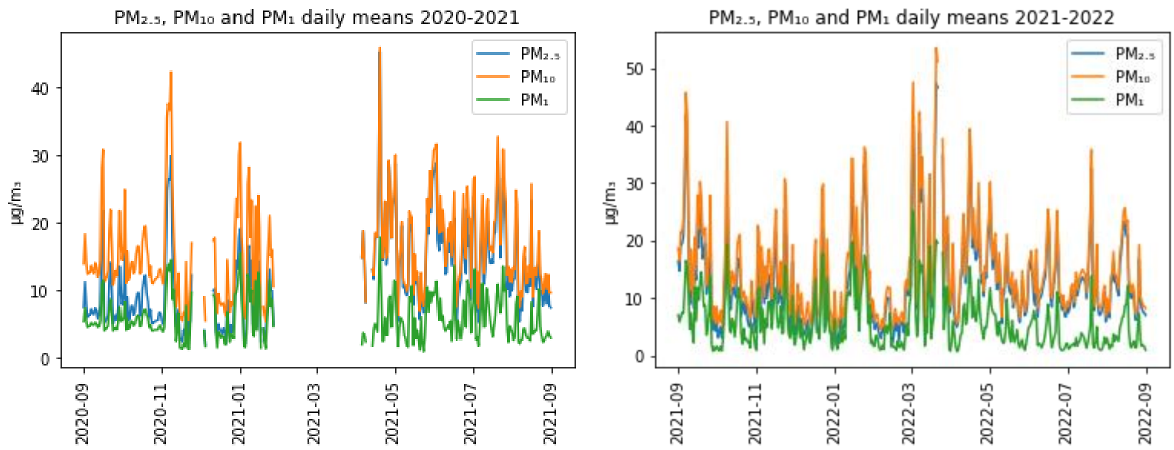


Figure 8: $PM_{2.5}$, PM_{10} and PM_1 daily and monthly means for 2020/2021 and 2021/2022

Visually, there appears to be a strong correlation between $PM_{2.5}$, PM_{10} and PM_1 as shown over both year periods and also a selected one month period in the graphs below. This correlation is explored further in Section 6.5.10.



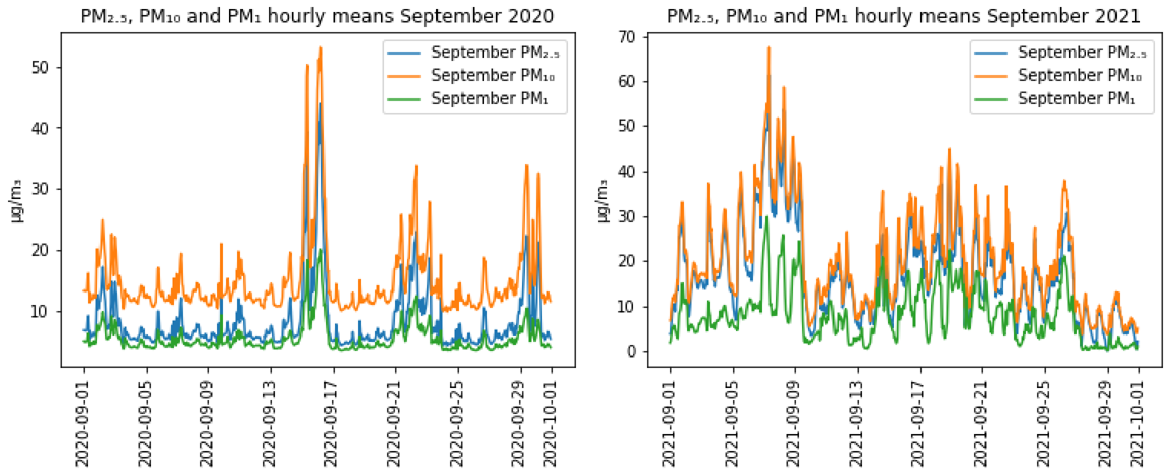


Figure 9: Correlation between $PM_{2.5}$, PM_{10} and PM_1

Across the period, visually values appear to have fallen. It is considered that there may be drift in the calibration of the sensor, with values being measured more accurately towards the start of the monitoring period.

$PM_{2.5}$ and PM_{10} are presented on a scatterplot to show the strong correlation. A line of best fit (least squares polynomial fit) has been added.

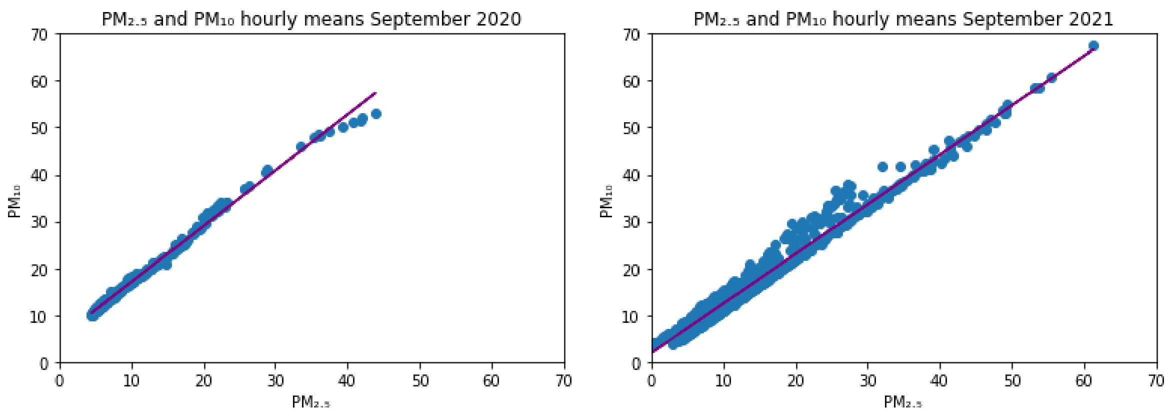


Figure 10: Scatterplots of $PM_{2.5}$ and PM_{10}, September 2020 and 2021

6.5.4 Comparison with NO_2 diffusion tube data

West Suffolk Council undertake monitoring for NO_2 using diffusion tubes at 66 sites in 2021 (West Suffolk Council, 2022), processed by an external specialist with quality assurance / quality control. Therefore, the Zephyr sensor data was compared to the diffusion tube data. As described in Section 6.4.2, NO_2 diffusion tube data from the diffusion tube co-located with the sensor is referenced as ‘TayfenDT adjusted’. Diffusion tube data is presented as a monthly mean, so a monthly mean has been calculated from the Zephyr sensor data for comparison.

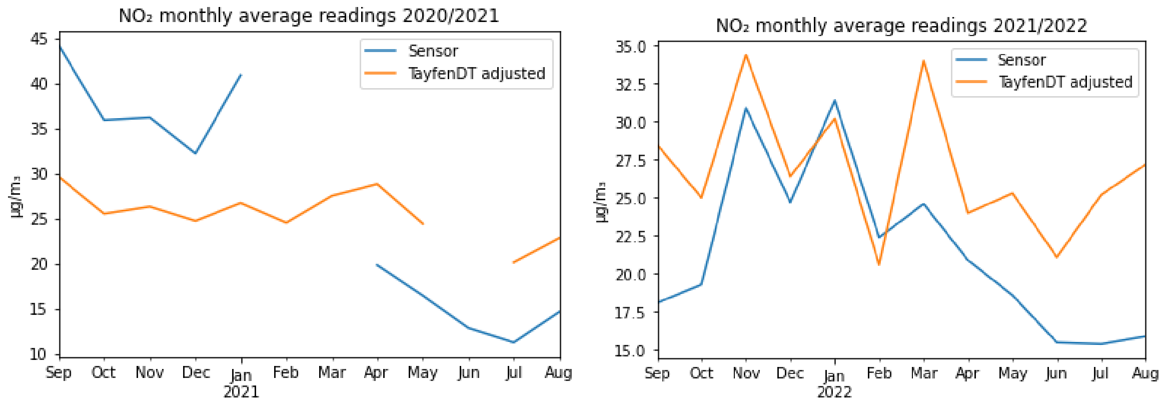


Figure 11: Comparison of Zephyr sensor and NO_2 diffusion tube data

These indicate visually a correlation between sensor data and measured monthly NO_2 means.

There were two periods of national lockdown during the analysis period (Institute for Government, 2021). These were plotted against the NO_2 diffusion tube data to assess impact of lockdown on measured NO_2 concentrations.

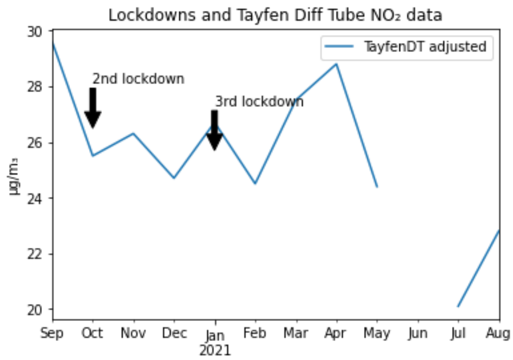


Figure 12: Lockdown dates and NO_2 data

Whilst there appears to be a reduction in NO_2 during the lockdown periods, variation in NO_2 concentrations also occur outside of the lockdown periods.

6.5.5 Impact of bonfire night on measured particulate matter

Analysis was undertaken of the time periods around bonfire night 2020 and 2021 to ascertain whether an increase in particulate matter was recorded.

In 2020, bonfire night was on a Thursday. Thus, the period Friday 23 October to Sunday 15 November was examined to include the weekends preceding and following bonfire night, when firework and bonfire events were most likely to have taken place, as well as the weekends preceding and following the event period, to provide reference readings during weekends when fewer events were likely. In 2021, the period Friday 22 October to Sunday 14 November was examined.

2020 2021

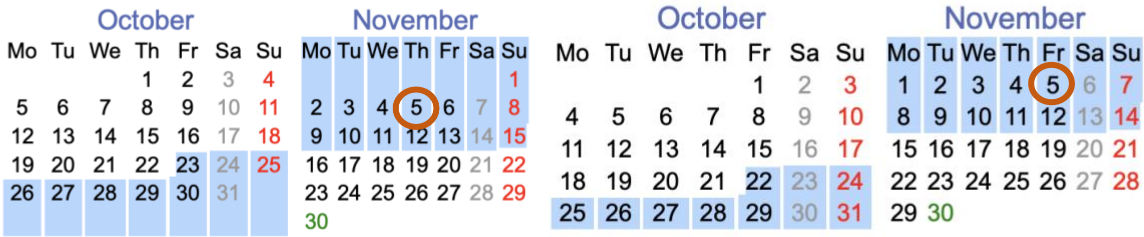


Figure 13: Analysis periods around bonfire night

The following graphs show a marked increase in PM_1, $PM_{2.5}$ and PM_{10} between 4 to 9 November for both years.

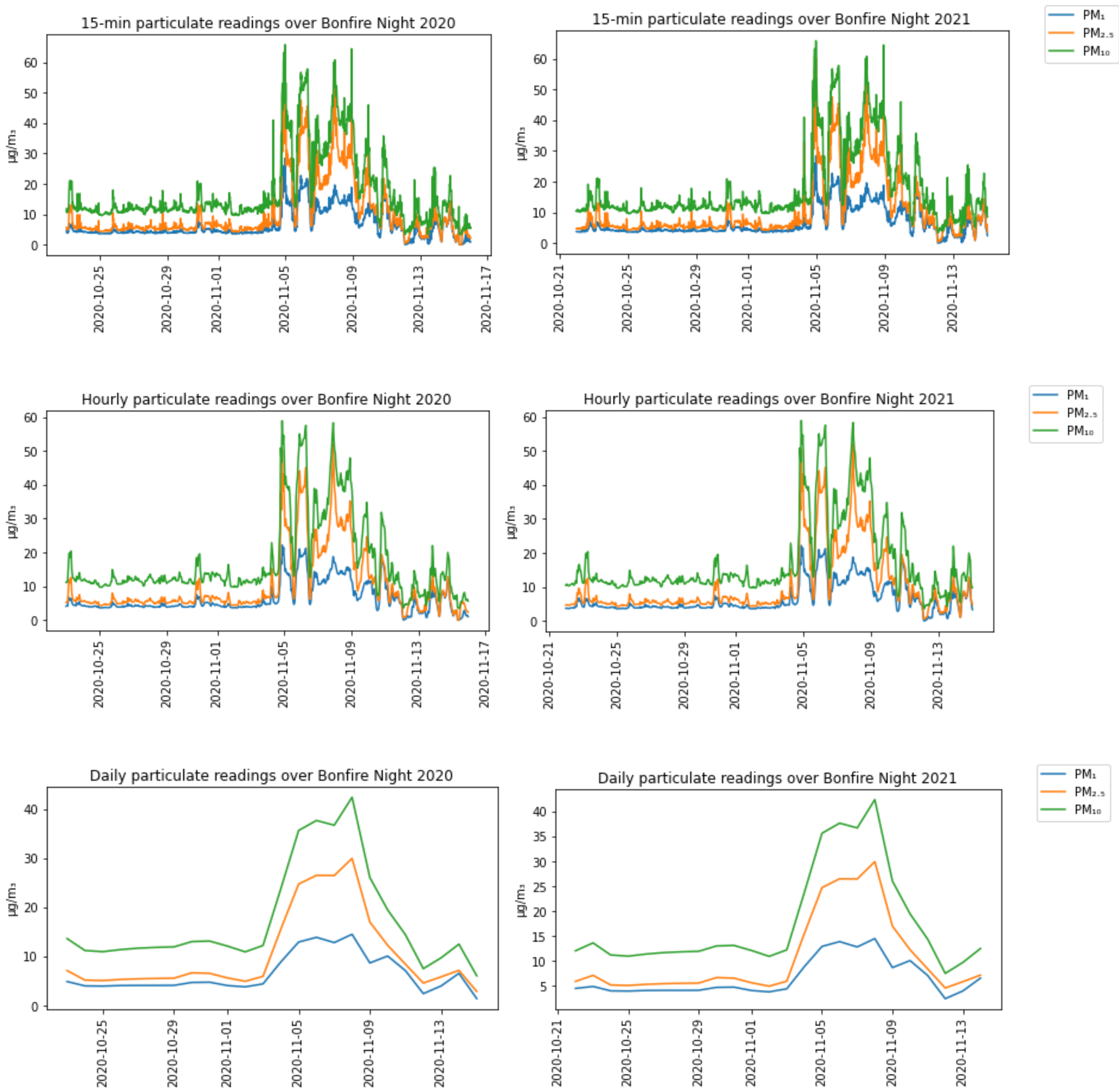


Figure 14: Particulate readings over Bonfire Night periods

DEFRA national air quality objectives state that PM_{10} (24-hour mean concentration) should not exceed 50 µg/m^3 more than 35 times a year. Therefore, the PM_{10} daily averages were examined to assess whether they were close to exceeding the objective (Table 10). There were no exceedances, however the readings exceeded 30 µg/m^3 between 5 and 8 November each year.

Date	PM_{10} 24-hour mean concentration	Date	PM_{10} 24-hour mean concentration
2020		**2021**	
		22 Oct	12.04
23 Oct	13.62	**23 Oct**	13.62
24 Oct	11.20	**24 Oct**	11.20
25 Oct	10.96	**25 Oct**	10.96
26 Oct	11.38	**26 Oct**	11.38
27 Oct	11.68	**27 Oct**	11.68
28 Oct	11.83	**28 Oct**	11.83
29 Oct	11.94	**29 Oct**	11.94
30 Oct	13.01	**30 Oct**	13.01
31 Oct	13.12	**31 Oct**	13.12
1 Nov	12.10	**1 Nov**	12.10
2 Nov	10.93	**2 Nov**	10.93
3 Nov	12.22	**3 Nov**	12.22
4 Nov	23.76	**4 Nov**	23.76
5 Nov	35.61	**5 Nov**	35.61
6 Nov	37.64	**6 Nov**	37.64
7 Nov	36.68	**7 Nov**	36.68
8 Nov	42.36	**8 Nov**	42.36
9 Nov	26.02	**9 Nov**	26.02
10 Nov	19.45	**10 Nov**	19.45
11 Nov	14.39	**11 Nov**	14.39
12 Nov	7.50	**12 Nov**	7.50
13 Nov	9.71	**13 Nov**	9.71
14 Nov	12.49	**14 Nov**	12.49
15 Nov	6.06	**15 Nov**	

Table 10: PM_{10} 24-hour mean concentrations during bonfire night period

Bonfire night events appear to have increased particulates between 4 to 9 November during both years, with PM_{10} readings exceeding 30 µg/m^3 between 5 and 8 November, but remaining below the DEFRA objectives of 50 µg/m^3.

6.5.6 Comparison of Zephyr sensor with regional DEFRA monitoring sites

The case study compared readings from the Zephyr sensor with regional DEFRA data. Data from the three live DEFRA monitoring sites nearest to Bury St Edmunds (described in Section 6.4.4, at distances of between 35km and 77km) were compared with the Zephyr sensor for $PM_{2.5}$, PM_{10} and NO_2 as shown in the figures below. Monthly averages were used to enable inclusion of West Suffolk Council NO_2 diffusion tube data.

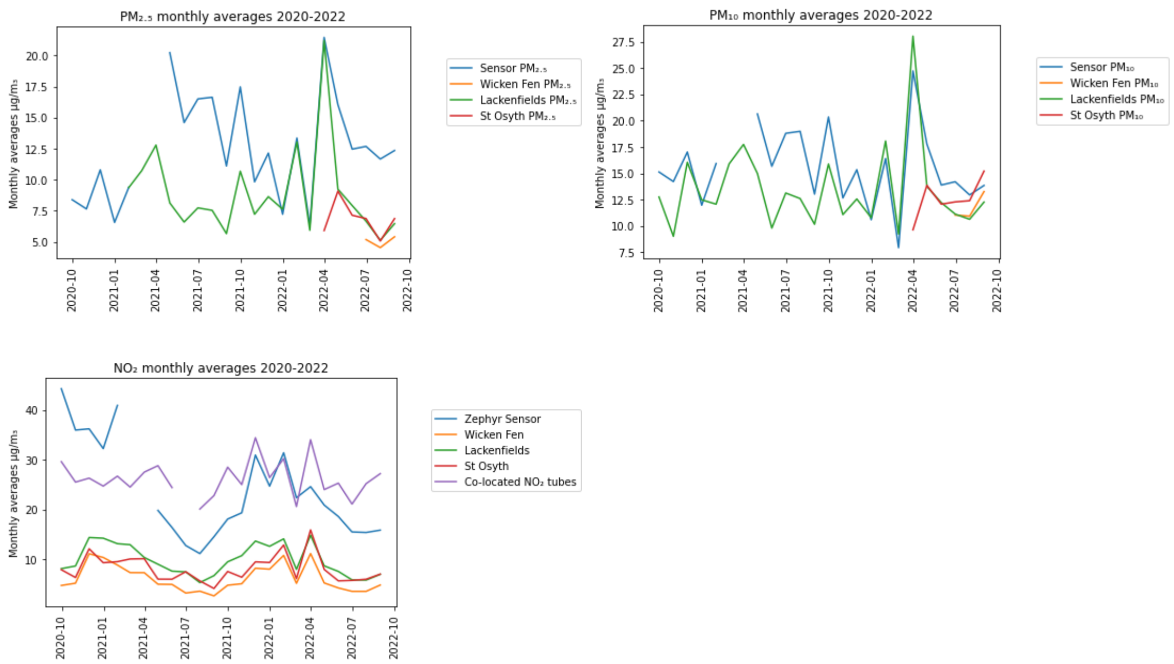


Figure 15: Comparison of Zephyr sensor with DEFRA sensors for $PM_{2.5}$, PM_{10} and NO_2

Whilst the Zephyr sensor generally shows higher volumes of particulates and NO_2 than the DEFRA sensors, time-series patterns are seen across the sensors.

6.5.7 Traffic data analysis

Traffic data has been provided by Suffolk County Council for a nearby traffic sensor (at 322m distance, Table 6 and Figure 3). A summary of the variation in hourly traffic volumes is shown in the boxplot and histogram below (Figure 16). The histogram represents the count of hours during which traffic volumes were encountered.

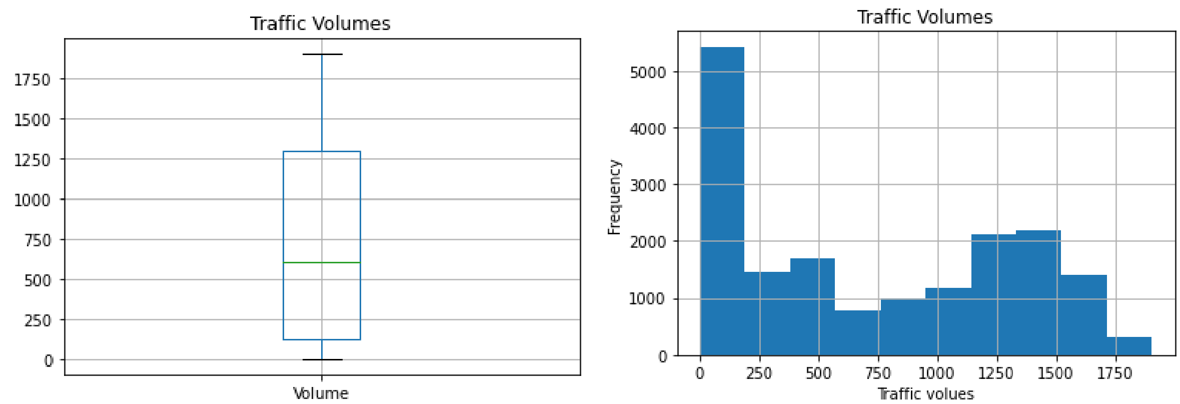


Figure 16: Summary of the hourly traffic volumes

Boxplots were also produced to visualise weekly traffic variation for each year (1 September to 31 August) (week number 36 represents 1 September) (Figure 17).

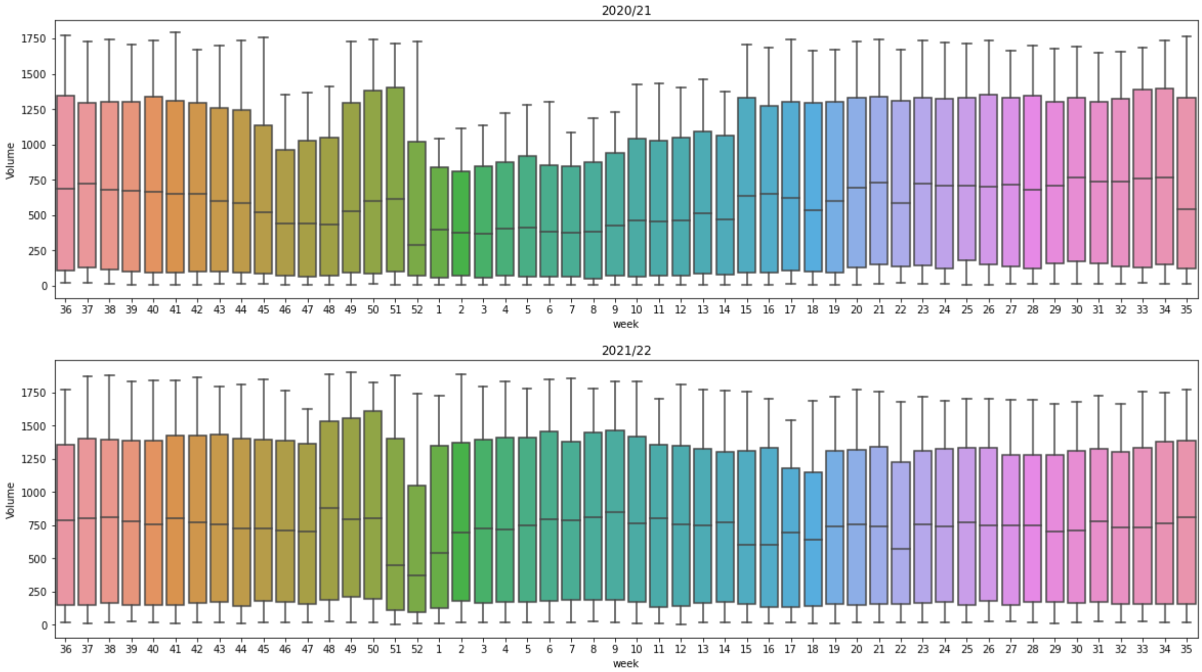


Figure 17: Boxplot of traffic patterns for each year

The two periods of national lockdown were plotted against the traffic volume data and show that traffic volumes during these periods were reduced as expected (Figure 18).

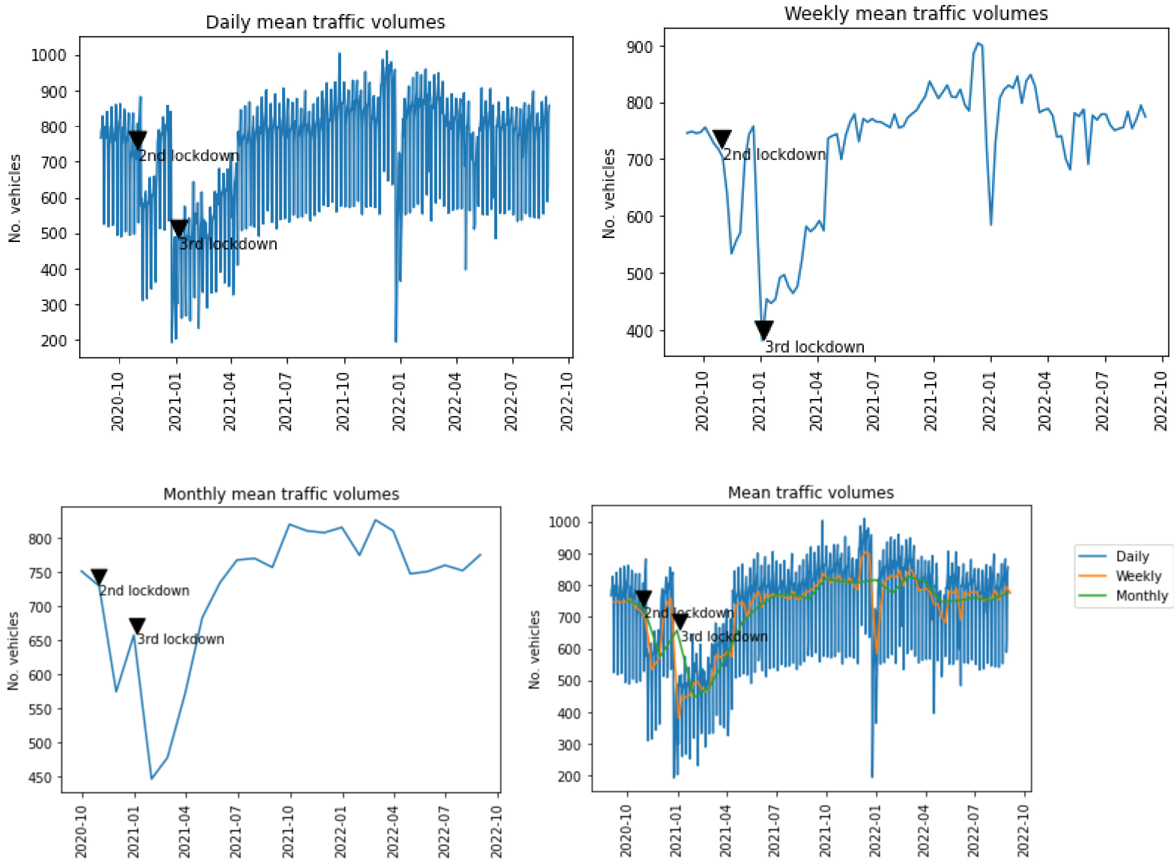


Figure 18: Variation in Traffic Volumes

Traffic data for December for each year was examined in more detail to assess the Christmas/New Year volumes for each year.

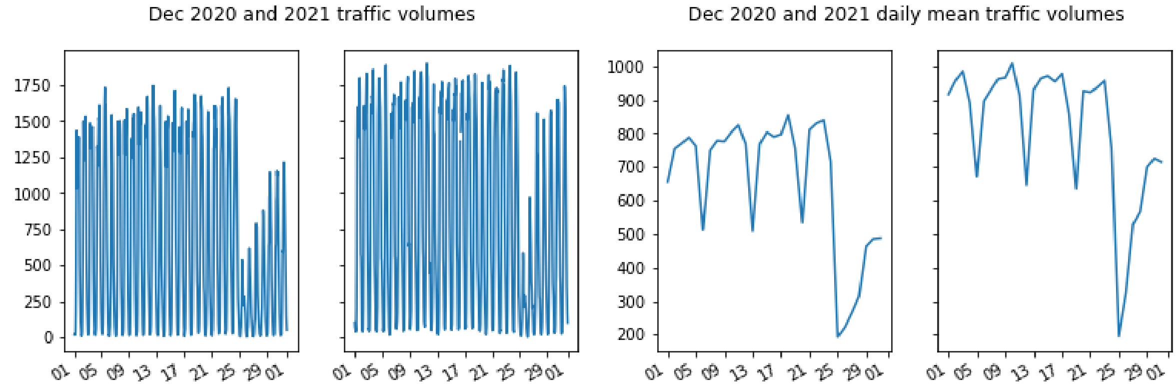


Figure 19: December 2020 and 2021 traffic volumes

Similar patterns for December for each year can be seen, with quieter periods over/just after Christmas as expected. December 2020 had lower traffic volumes than December 2021, potentially as a result of the impact of COVID-19 and associated lockdowns.

6.5.8 Air quality and traffic correlation

It is known that NO_2 concentrations are closely associated with local traffic (see West Suffolk Council, 2022 for an example discussion), and this was explored with timeseries (Figure 20) and scatterplot (Figure 21) representations.

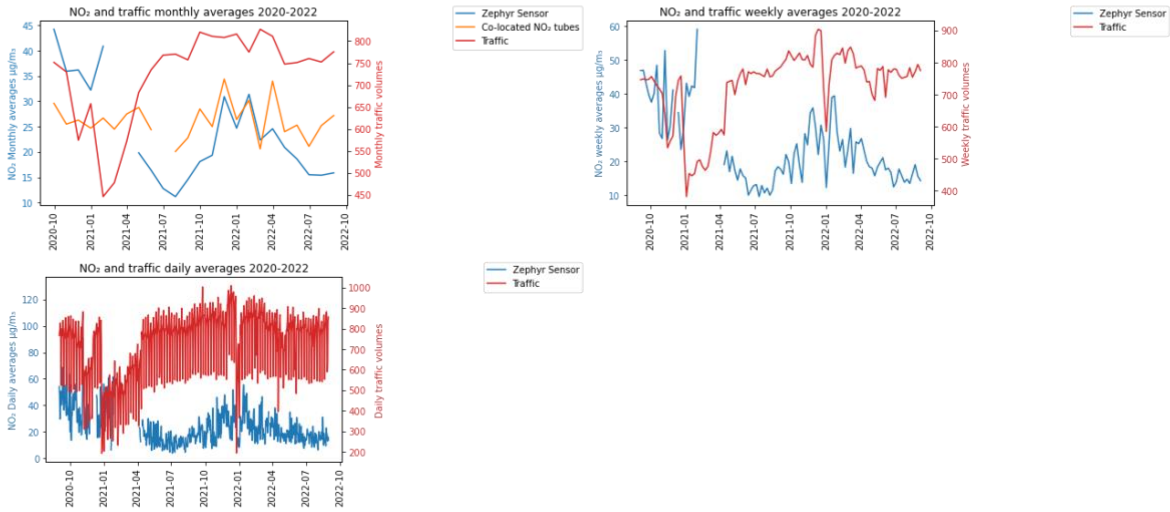


Figure 20: NO_2 and Traffic volume

These do not appear to show a strong correlation between NO_2 readings and traffic volumes on these timeframes.

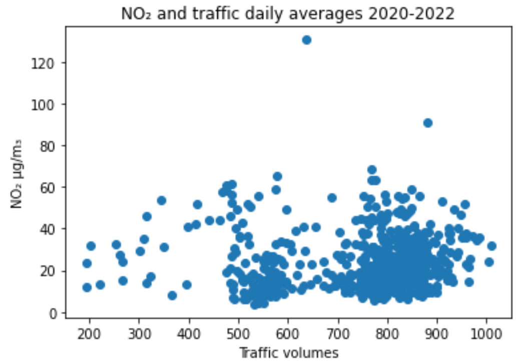


Figure 21: Scatterplot of NO2 and traffic volume

Traffic volume was also compared with particulate measurements as timeseries and scatterplots.

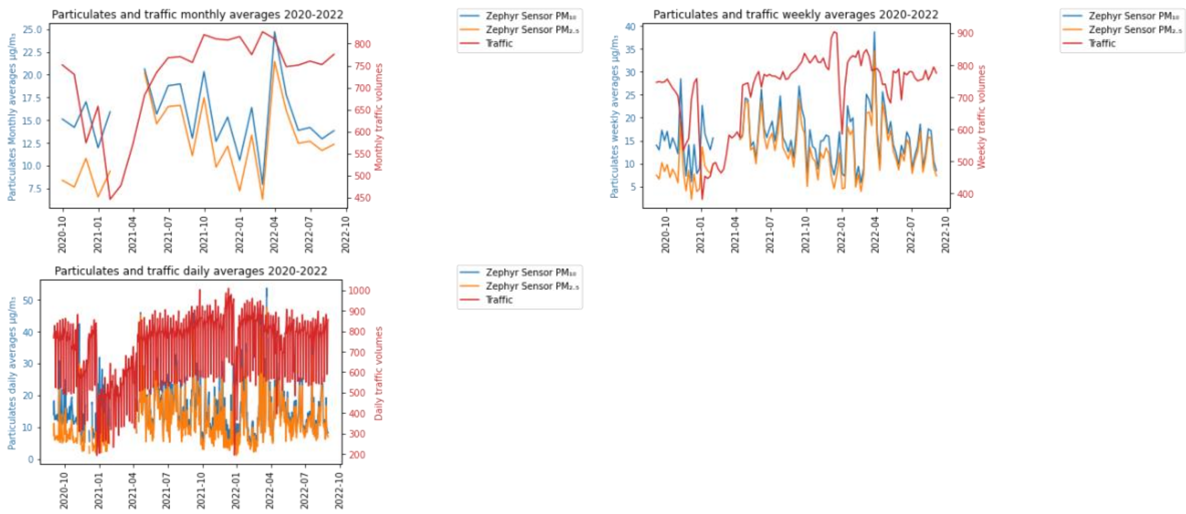


Figure 22: Particulates and Traffic Volumes

Again, the above graphs do not show a strong correlation between particulate readings and traffic volumes, which was also confirmed using scatterplots.

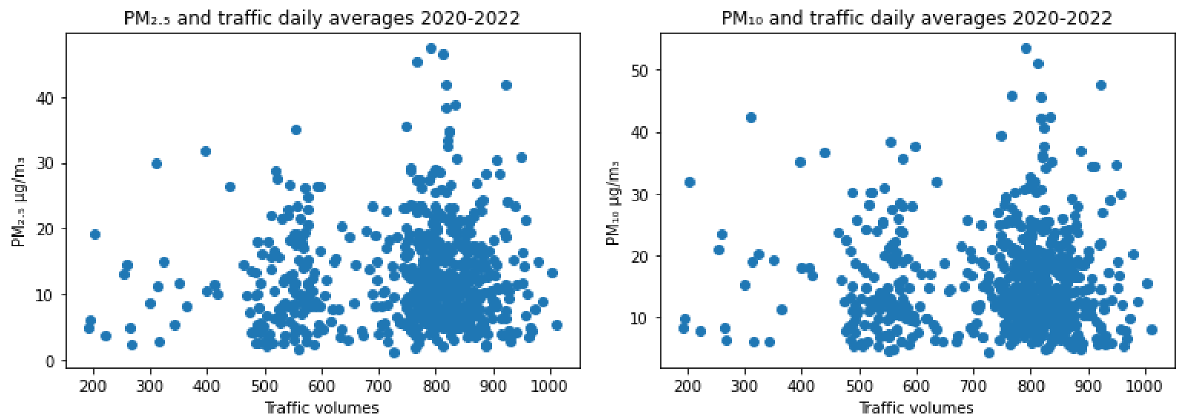


Figure 23: Scatterplots of particulates and traffic volumes

6.5.9 Road Closures

Further exploration of the impact of local traffic on air quality was undertaken by examining periods of road closures, at which point it is assumed that no road traffic was occurring. Roadworks and traffic interventions data is accessible via the one.network Historical Map. There were two road closures on Tayfen Road adjacent to the Zephyr sensor location during the analysis period. Suffolk County Council's access to historical roadwork data on the one.network platform (one.network, 2023) confirmed the dates and times as:

- 6 January 2022 9.36am - 11.30pm
- 25 April 2022 1.30pm - 6 May 2022 11.59pm

Readings from the Zephyr sensor were analysed to assess whether NO_2 and particulates appear to be reduced during the road closures.

6.5.9.1 6 January Road Closure

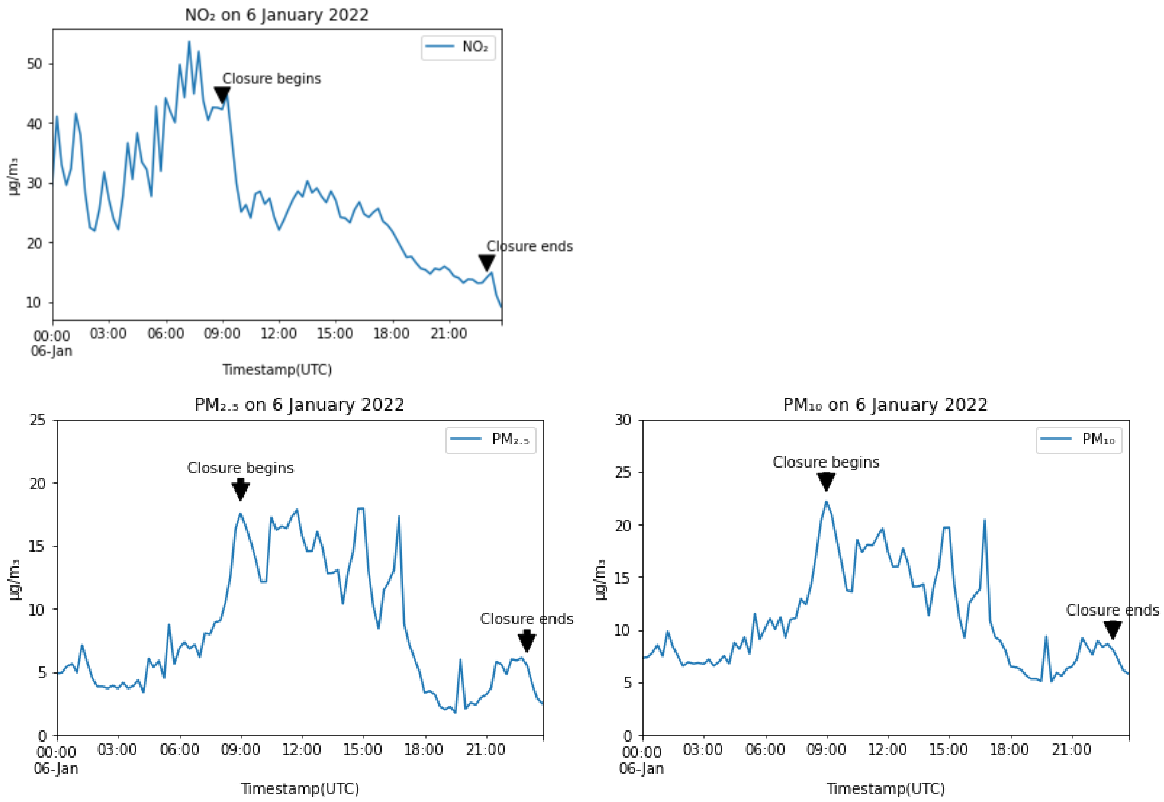
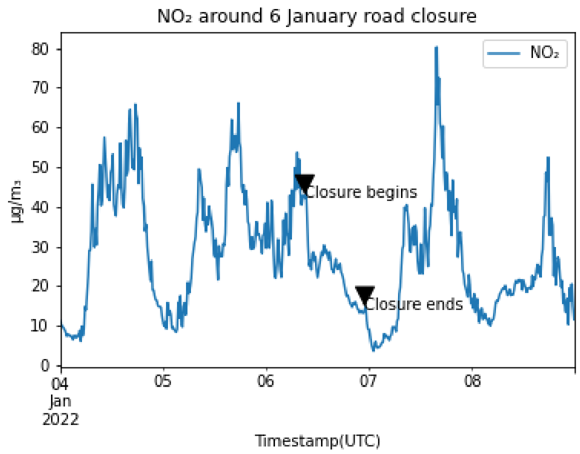


Figure 24: NO_2 and particulate readings on 6 January 2022

There is no apparent reduction in particulate readings, with a potential increase during this period, however NO_2 readings show a general decline throughout 6 January.

The five-day period around the closure (4 to 9 January) was examined for trends (Figure 25). Particulate trends do not appear to decline during this period; in fact it could be argued that they increase. This may be caused by the construction activities related to the reason for the road closure. It also appears that an afternoon peak of NO_2 is not present on 6 January whilst there are not vehicles on the adjacent road.



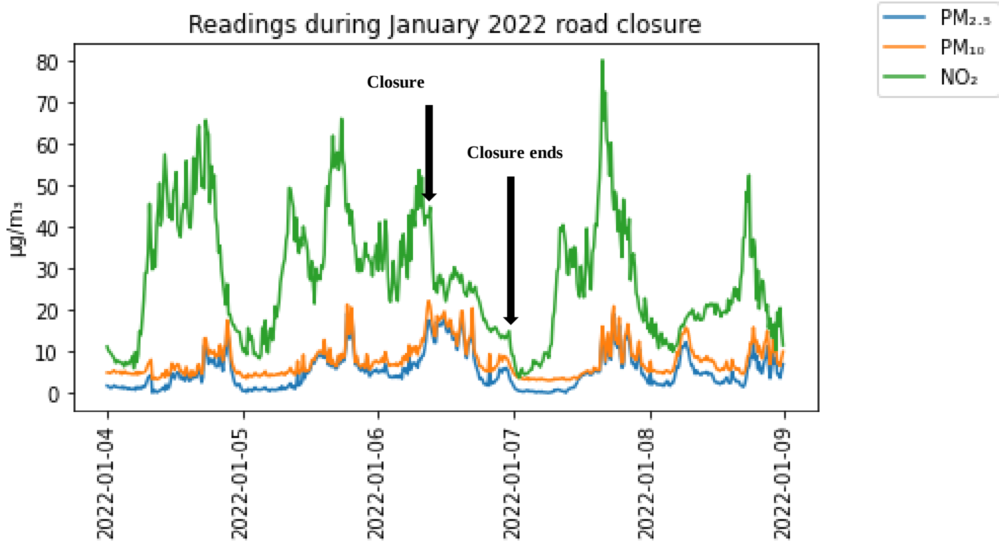


Figure 25: Readings for the five-day period around 6 January closure

6.5.9.2 April/May Road Closure

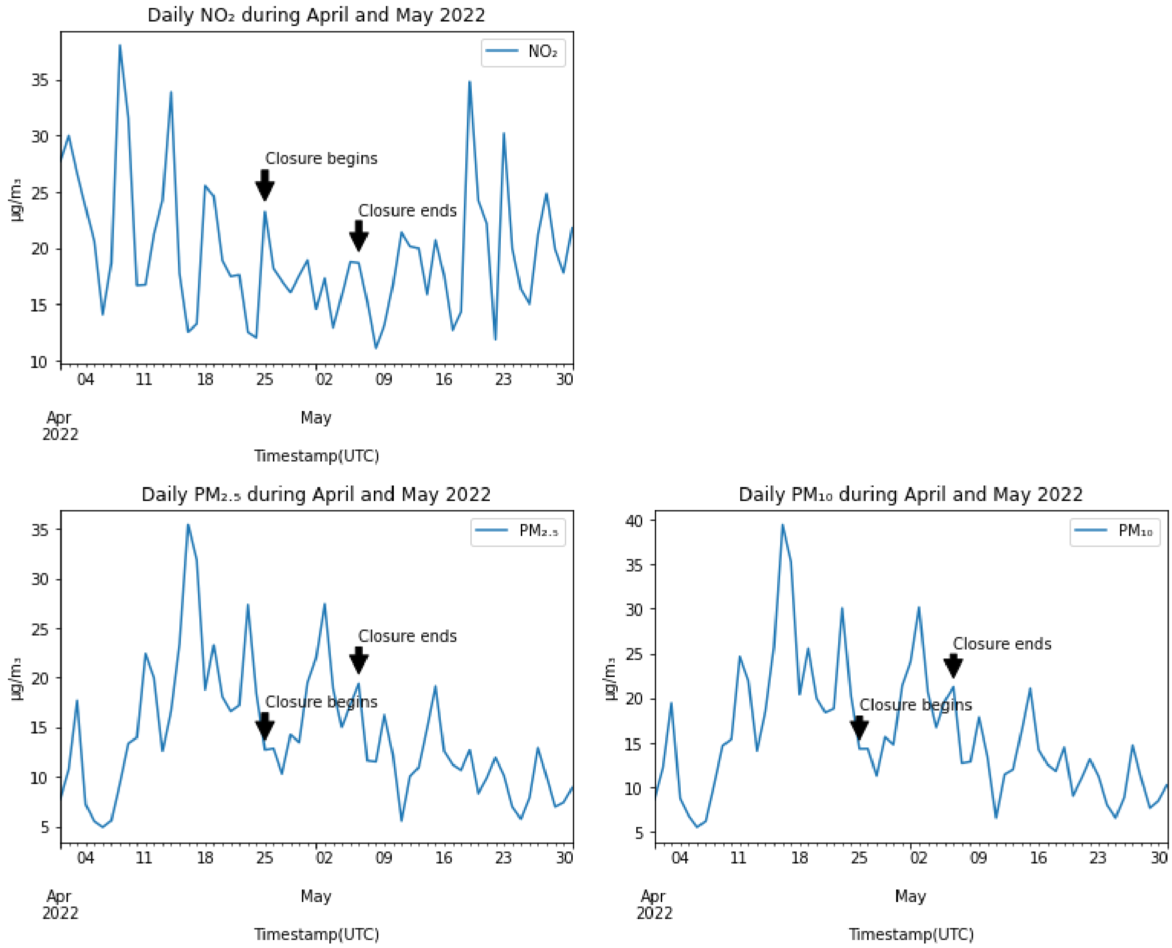


Figure 26: NO_2 and particulate readings during April to May 2022

Again, there appears to be no reduction in particulate readings, however it could be considered that NO_2 readings appear to gradually fall throughout the April/May closure, with gradual return to typical values following reopening of the road. Further statistical investigation of this data could present additional understanding.

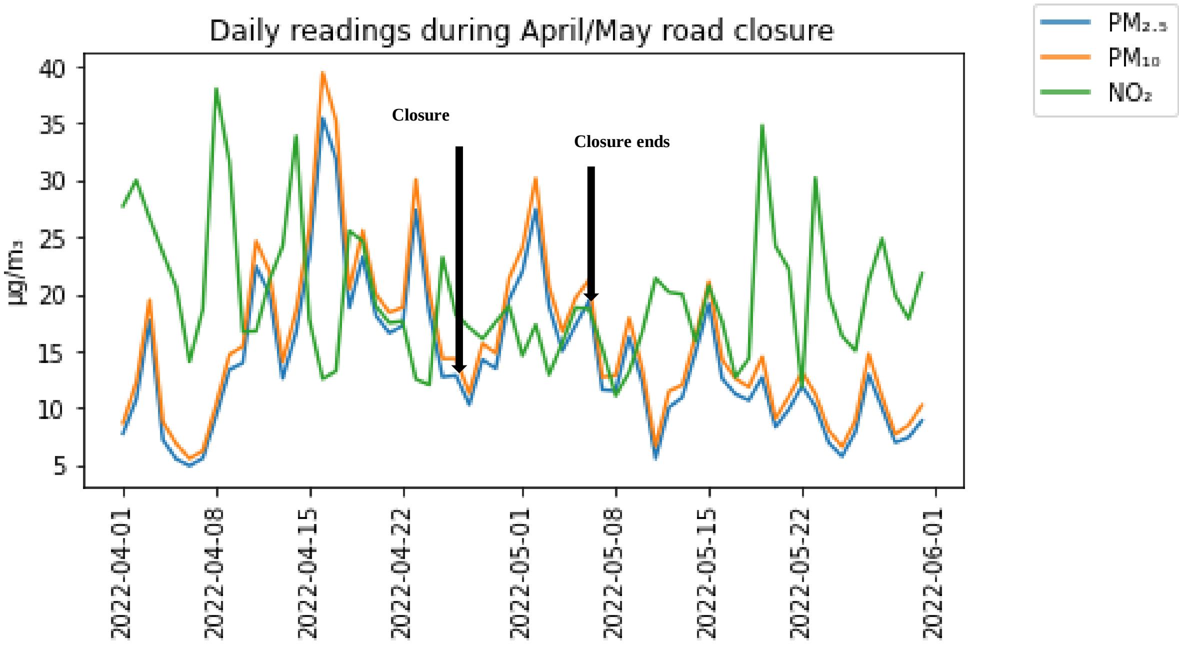


Figure 27: Daily average readings for the April/May closure

Road closure and traffic volume data indicate that whilst local traffic is understood to contribute to local NO_2 concentrations, particulate matter concentrations do not appear to be significantly impacted by local traffic.

6.5.10 Multi-data correlations

Hourly traffic volumes were combined with Zephyr sensor and DEFRA site readings (resampled to hourly mean readings) to further examine whether any correlation could be seen between traffic, particulates and NO_2.

A correlation matrix was calculated (Table 11). This is a statistical technique to evaluate the relationship between traffic volumes and all other variables. The table below shows the "correlation coefficient" whereby 1 is considered a strong relationship between the variables, 0 a weak relationship and -1 a strong inverse relationship. As can be seen, no strong relationships were identified; NO_2 readings from the Zephyr sensor have the strongest relationship with the Compiegne Way traffic volumes.

Traffic Volume	1.000000
Zephyr NO_2	0.239653
Zephyr $PM_{2.5}$	0.163081
Wicken Fen PM_{10}	0.153585
St Osyth PM_{10}	0.139170
Zephyr PM_{10}	0.098630
Lakenfields NO_2	0.001297
Wicken Fen $PM_{2.5}$	-0.020154
Lakenfields PM_{10}	-0.039628
St Osyth $PM_{2.5}$	-0.049163
St Osyth NO_2	-0.068410
Wicken Fen NO_2	-0.105730
Lakenfields $PM_{2.5}$	-0.106260

Table 11: Correlation matrix for Traffic Volumes

A correlation matrix heatmap (Figure 28) was also produced to visualise relationships between all readings that were available as hourly readings. Darker green boxes show strong relationships; an example can be seen confirming the Zephyr sensor $PM_{2.5}$ and PM_{10} correlation. Several of the particulate readings across multiple sensors show correlation coefficient results over 0.5, confirming that PM concentrations is a regional or wider issue. However, traffic volume appears to have no strong relationships, its strongest appears to be with NO_2 readings from the Zephyr sensor.

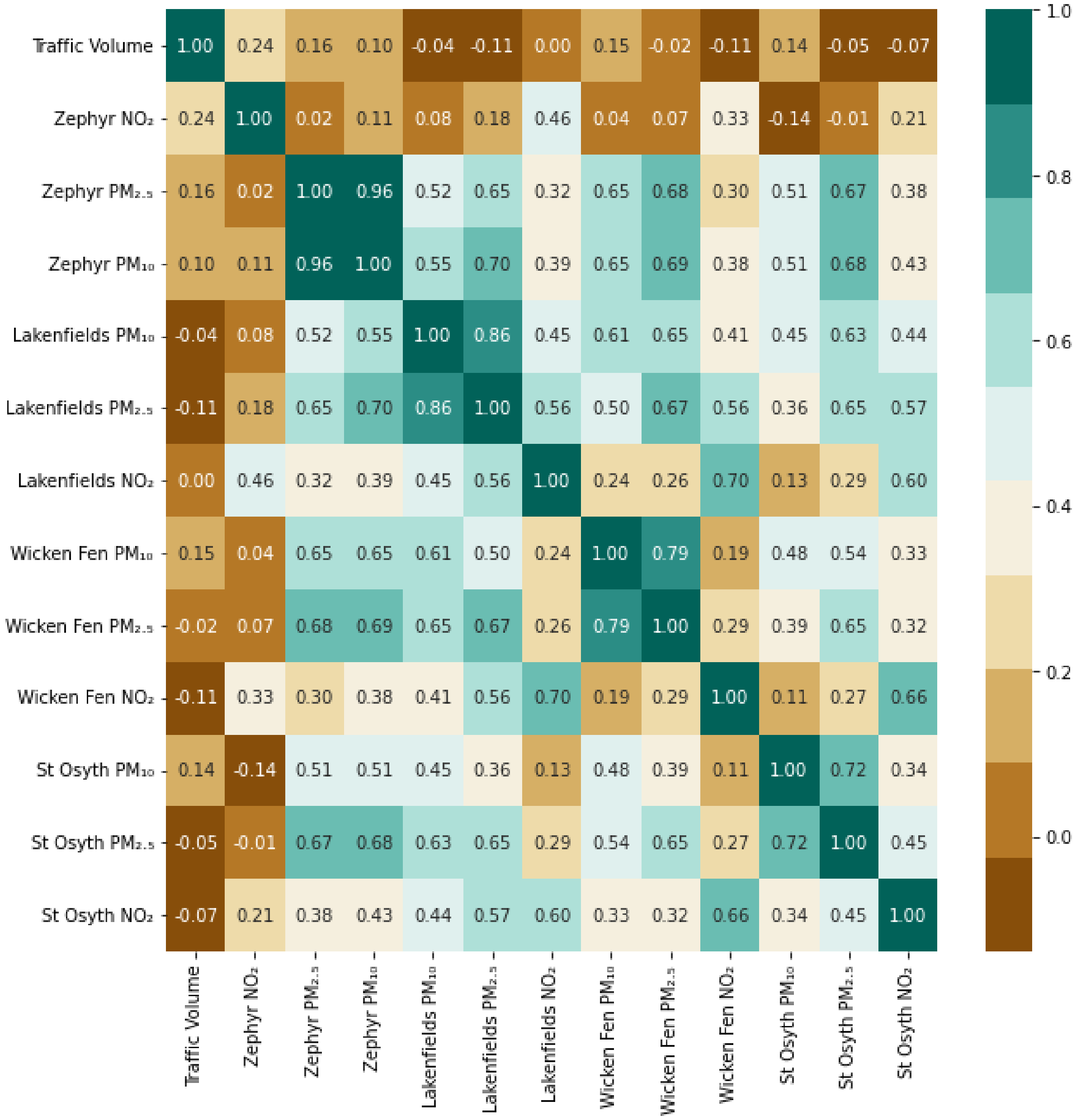


Figure 28: Correlation matrix heatmap

6.6 Conclusions from case study data analysis

This case study analysed data from seven sources for the two-year period 1 September 2020 to 31 August 2022. It focussed primarily on a Zephyr Air Quality Sensor in Bury St Edmunds, installed as part of a planning condition, and on particulates ($PM_{2.5}$ and PM_{10}), NO_2 and traffic volumes.

The data provided required a substantial amount of cleansing and preparation in order for it to be analysed in depth using Python data analysis tools.

It found that the Zephyr sensor had three periods of data missing, and within the data supplied approximately 6% of readings were missing. Further investigation would be required to establish the cause of the missing data.

The Zephyr sensor data showed similar levels of readings when compared to the nearby NO_2 diffusion tubes and generally higher levels of readings than those recorded by the regional DEFRA monitoring sites. There are several occasions where time-series patterns are seen across the sensors.

All sensors recorded a significant increase in particulates during March 2022 which appears to have been caused by a Saharan dust cloud.

The dust cloud event appears to have caused the only two exceedances of DEFRA national air quality objectives and target values of 50 µg/m^3 (24 hour mean) for PM_{10}. However, this remained below the target of no more than 35 exceedances a year, and all other objective/targets for $PM_{2.5}$, PM_{10} and NO_2 were met at the Zephyr sensor location for the 2-year period analysed.

There appears to be a strong correlation between $PM_{2.5}$ and PM_{10} data at all locations analysed. However, a strong relationship could not be found between traffic volumes and particulates. The international dust cloud event had a greater impact on particulate readings than local traffic volumes, as may be expected due to particulate sources and concentrations as previously described in Section 3.1.

Bonfire night events appear to have increased particulates between 4 to 9 November during both years, with PM_{10} readings exceeding 30 µg/m^3 between 5 and 8 November, but remaining below the DEFRA objectives of 50 µg/m^3.

There were two periods when the road adjacent to the Zephyr sensor was closed during the analysis period. NO_2 readings appear to be reduced during the road closure periods. Particulates did not reduce during these periods, and may have increased during the January road closure.

7 Conclusion

The exploration of a case study of a planning condition requesting air quality monitoring, the environmental and policy context and analysis of the case study data has indicated that local traffic conditions have an impact on local NO_2 but less immediate impact on local particulate matter concentrations. Particulate matter in the UK comes from a number of sources, can migrate for significant distances and times, and varies from year to year due to meteorological and other conditions.

Air pollution is the lead environmental health impact, with UK and EU policy driving reduction in particulate matter and increase in understanding of concentrations and sources. A ten-stage guide for incorporation of air quality monitoring has been proposed to cover from initial identification of a concern, specification of a monitoring and reporting protocol, and provision of data in a usable format to the local authority.

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