Jersey Rouge Bouillon School and Wellington Road Air Quality Study

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1 Executive Summary

The Government of Jersey commissioned Ricardo to complete a short-term study measuring concentrations of pollutants at Rouge Bouillon School and on Wellington Road in Jersey. Similar studies have suggested elevated pollutant concentrations in certain areas are associated with school traffic at school entrances [1] and that children are exposed to these elevated concentrations when travelling to and from school [2].

The primary objective of the study was to assess pollutant exposure along main road and back street walking routes to and from Rouge Bouillon School and, on and around Wellington Road during drop off and pick up times. The secondary aim was to identify if there was any noticeable change in air quality concentrations at both monitoring locations during school drop off and pick up times. This study monitored Nitrogen Dioxide (NO_2), Particulate Matter 10 (PM_{10}) and Particulate Matter 2.5 ($PM_{2.5}$) concentrations at both monitoring locations. A low-cost Vortex IoT automatic monitoring sensor was installed at each monitoring location and a mobile Praxis Urban sensor, was used to measure pollutant concentrations along four popular walking routes around both monitoring locations during morning drop-off and afternoon-pick up times.

QA/QC was applied to the three sensors used in this study in line with advice published by Air Quality Expert Group (AQEG) on the Defra UK air website (AQEG advice on the use of 'low-cost' pollution sensors - Defra, UK).

During the monitoring period, NO_2 concentrations did not exceed the Air Quality Limit Values and Objectives hourly limit value of 200 µg m^{-3}. However, EU limit values are currently under review and are likely to be partially aligned with WHO air quality guideline limit values. Analysis of diurnal profiles highlight that NO_2 concentrations at Rouge Bouillon School generally follow the expected trend of higher concentrations during morning and evening rush hours indicating the influence of traffic on NO_2 concentrations at these times. However, NO_2 concentrations measured on Wellington Road are shown to be highest in the afternoon which may be influenced by idling traffic at afternoon pick up times. Further investigation showed that mean NO_2 concentrations were higher at drop off and pick up times compared to between these times at both monitoring locations. The range of data at drop off and pick up times were also greater, and outliers were also of higher value. Analysis of a pollution rose shows that NO_2 concentrations are elevated at low wind speeds which highlights that the primary sources of elevated NO_2 concentrations are nearby. This indicates that traffic is likely a significant source of elevated NO_2 concentrations. The building work currently taking place along Wellington Road may also be a potential source of elevated NO_2 concentrations.

Particulate matter data measured by the Vortex sensors could not be co-located or ratified in the same way as the NO_2 data. Therefore, absolute values are not reported and comparisons to the Air Quality Limit Values and Objectives are not made. Raw particulate matter (PM) data from the vortex sensors shows good agreeance with ratified PM data from the Osiris analyser at Jersey Howard Park with elevated periods being shown in both Osiris and Vortex datasets which indicates regionally elevated PM. Normalised PM data from the Vortex sensors showed that there was an overall low frequency of high PM_{10} and $PM_{2.5}$ concentrations at both monitoring locations during drop off and pick up times.

Spatial analysis of NO_2 and PM concentrations at Rouge Bouillon School and Wellington Road indicate highest concentrations of NO_2 were measured on main road routes at both sites. Results of spatial analysis of PM concentrations at both monitoring locations Rouge Bouillon School and Wellington Road, a pollution hot spot is identified in very close proximity to each monitoring location for all pollutants. This is likely caused by a high volume of vehicles passing along this road and also idling whilst waiting along this road during drop off and pick up times.

Future recommendations have been made as a result of the findings of this study, which are;

- Encouraging students to walk to school where possible to reduce motorised vehicle traffic on roads surrounding schools.
- Recommending students walk backstreet routes to school instead of main road routes to reduce exposure to elevated pollutant concentrations and increase student engagement to encourage walking of routes with better air quality where possible.
- Advising vehicle drivers to turn off engines when stationary on roads surrounding schools to reduce emissions from engine idling.
- Continue monitoring air quality at both locations in all weather conditions to investigate the impacts that weather conditions may have on traffic patterns and therefore air quality around schools.
- Explore the impact of the building work currently taking place on Wellington Road on pollutant concentrations.
- Investigate the possibility of implementing motorised vehicle restrictions along streets outside of Rouge Bouillon School and on Wellington Road during morning drop off times (7:30 - 9:30) and afternoon pick up times (14:30 to 16:30).
- Review school finish times with the aim to spread the traffic burden.
- Assess current school bus fleets and initiate programmes to replace the existing fleets with Euro 6 compliant vehicles.

Contents

2 Introduction

2.1 Background

The Government of Jersey commissioned Ricardo to complete a short-term study measuring concentrations of pollutants at two monitoring locations in St. Helier. The locations chosen were Rouge Bouillon School and a location on Wellington Road as representative of locations where elevated volumes of school related traffic have been highlighted. Studies have found links between traffic pollution and adverse health effects [3] and that children are exposed to higher levels of pollution when travelling to and from school [4]. The same study indicated that children walking on the main roads were exposed to more pollution than those walking on the back streets, this is supported by characterisation of the linear fall-off in NO_2 exposure with increasing distance from a major road [5]. The scope of the study is to monitor NO_2, PM_{10} and $PM_{2.5}$ concentrations at Rouge Bouillon School and on Wellington Road using static low-cost sensors, initially over three months. This will be supported be data from a mobile low-cost sensor taking measurements along popular main road and backstreet walking routes to and from Rouge Bouillon School as well as, on and around Wellington Road during morning drop-off and afternoon-pick up times.

Currently the Government of Jersey has a longstanding air quality monitoring network, consisting of one automatic NO_2 monitor on Beresford Street Market and 25 non-automatic NO_2 diffusion tube samplers, and two indicative automatic Osiris particulate matter (PM) monitors on the island. For this study, this network was expanded to incorporate two additional low-cost automatic monitoring locations for NO_2, PM_{10} and $PM_{2.5}$. Although the Government of Jersey's current air quality network includes monitoring of a suite of four hydrocarbons (benzene, toluene, ethylbenzene and xylenes), the pollutants are outside the scope of this study and will not be reported.

2.2 Pollutants Monitored

2.2.1 Nitrogen Oxides (NOx)

Combustion processes emit a mixture of oxides of nitrogen - NO and NO_2 - collectively termed NOx. NO is directly emitted from the source, therefore referred to as a primary pollutant. At ambient concentrations, NO is not known to have any harmful impacts on human health. However, in the atmosphere, it undergoes oxidation to form a secondary pollutant of NO_2. NO_2 is both a primary and secondary pollutant, being directly emitted and formed by the oxidation of NO. NO_2 is a respiratory irritant and, at high concentrations, is toxic. Additionally, it contributes to the formation of photochemical smogs and acid rain, and therefore may cause damage to crops and vegetation.

Ambient NO_2 concentrations are likely to be highest in built up areas. Especially in areas with high levels of traffic congestion, or where vehicle emission dispersion is impeded by buildings either side of the street that create a 'canyon' effect.

2.2.2 Particulate Matter 10 and 2.5 (PM_{10} and $PM_{2.5}$)

The source, particle size, and physical and chemical composition of airborne particulate matter vary widely. Particles with an effective size less than 10 µm are termed as PM_{10}. Additionally, particles measuring less than 2.5 µm are considered $PM_{2.5}$. Due to the small size of these particles, they are of greatest concern to human health, as they are small enough to deeply penetrate into the lungs. They have the potential to induce inflammation and worsen the condition of people suffering of heart and lung diseases. Furthermore, they may introduce carcinogenic compounds, that are absorbed onto the surface, into the lungs. Due to their size, larger particles are not readily inhaled and are removed from the air by sedimentation relatively effectively. In the UK, the main sources of airborne particulate matter in the UK are combustion (industrial, commercial and residential fuel use). Following these, road emissions are the next most significant source.

2.3 Air Quality Limit Values and Objectives

This report compares the results of the monitoring survey with air quality limit values and objectives which are applicable worldwide, in Europe and the UK. The majority of these guidelines are based upon an annual dataset. Therefore, a comparison of the results of this study to an annual limit value is not definitive but relevant to highlight whether the results of this study would meet the limit values.

2.3.1 World Health Organisation

In 2005, the World Health Organisation (WHO) issued non-mandatory, advisory guidelines for a variety of pollutants using currently available scientific evidence on the effects of air pollution on human health. Further to this, updated guidelines were introduced in September 2021[6] which significantly reduced the Annual mean limit of NO_2 from 40 µg m^{-3} to 10 µg m^{-3} and the 24 hour mean being reduced to 25 µg m^{-3}. PM_{10} and $PM_{2.5}$ Annual mean limits were also reduced from 20 µg m^{-3} to 15 µg m^{-3} and 10 µg m^{-3} to 5 µg m^{-3} respectively due to growing evidence of harm from these two pollutants.

2.3.2 European Community

Ambient air quality is regulated by the EC Directive on Ambient Air Quality and Cleaner Air for Europe (EU/2015/1480) [7] throughout Europe. This Air Quality Directive consolidated three previously existing Directives which set mandatory limit values and other requirements for the protection of human health and ecosystems. The Government of Jersey have agreed to meet the EU health limits. The Air Quality Directive contains limit values for NO_2 as follows:

- 200 µg m^{-3} as an hourly mean, not to be exceeded more than 18 times per calendar year. To have been achieved by 1st January 2010.
- 40 µg m^{-3} as an annual mean, for protection of human health. To have been achieved by 1st January 2010.

2.3.3 The UK Air Quality Strategy

The Environment Act 1995 required the UK to transpose the original EU Directive on Ambient Air Quality and Cleaner Air for Europe 2008/50/EC [8] and the subsequent update of EU/1480 [9] into UK law. It also placed a requirement on the Secretary of State for the Environment to produce a national Air Quality Strategy to contain standards, objectives, and measures for improving ambient air quality. In 1997, the original AQS was published which contained air quality objectives based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) concerning air pollution concentrations at which there would be minimal human health risks.

Since the publishing of the original Air Quality Strategy, it has undergone many revisions to reflect the improvements in understanding and air pollutants and their respective health effects, and as of the Environment Act 2023, the Air Quality Strategy must be reviewed at least every 5 years. Furthermore, new European limit values have been incorporated both for pollutants already covered by the Strategy and for newly introduced pollutants such as polycyclic aromatic hydrocarbons and $PM_{2.5}$ particulate matter. The latest version of the strategy was published by Defra on 28th April 2023 [10]. With the UK's exit from the EU the UK's Air Quality Strategy is no longer tied to that of the EU, however the current objectives are at least as stringent as the EC limit values.

2.3.4 Jersey Air Quality Strategy

The WHO[11], EU[12] and UK[13] policies described above served as the foundation for the most recent Jersey Air Quality Strategy, which was released in 2013[14]. As Jersey is not an EU member state there is no legal requirement to implement the EU directive. However, the importance and relevance of the limit values to Jersey is recognised by the Government of Jersey. The Jersey Air Quality Strategy works within the EU and UK limit values and puts in place a project plan and policies to ensure compliance. Following the updated WHO guidelines the government policy concerning air quality limit values is under consideration. In 2022, the Government of Jersey also published the 'Common Strategy Policy - 2023-2026' [15]. This strategy highlights seven priorities for change of which the Environment is one. Within the Environment priority, aims for improvements to air quality are outlined as well as reducing the impact of 'the school run environment'.

2.3.5 Daily Air Quality Index

The Daily Air Quality Index (DAQI) is used to communicate information about current and forecast air quality to the public [16]. Similar to the pollen index, the DAQI is based on a scale of 1 to 10, with four bands: Low, Moderate, High, and Very High. This gives a simple indicator of pollution levels. The scale places low air pollution between 1 and 3, moderate air pollution between 4 and 6, high air pollution between 7 and 9, and very high air pollution at 10. This is intended to allow sensitive people to take any necessary action. Figures 1, 2 and 3 highlight the Daily Air Quality Index for NO_2, PM_{10} and $PM_{2.5}$.

Nitrogen Dioxide

Based on the hourly mean concentration.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-67	68-134	135-200	201-267	268-334	335-400	401-467	468-534	535-600	601 or more

Figure 1: NO_2 DAQI Banding

PM_{10} Particles

Based on the daily mean concentration for historical data, latest 24 hour running mean for the current day.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	91-100	101 or more

Figure 2: PM_{10} DAQI Banding

$PM_{2.5}$ Particles

Based on the daily mean concentration for historical data, latest 24 hour running mean for the current day.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-11	12-23	24-35	36-41	42-47	48-53	54-58	59-64	65-70	71 or more

Figure 3: $PM_{2.5}$ DAQI Banding

3 Details of the Monitoring Study

3.1 Aims and Objectives

The aim of this study is to monitor exposure to pollution when travelling to and from school. In order to meet this, three important air pollutants were measured around Rouge Bouillon School and Wellington Road in Jersey. The results of the monitoring carried out are used to assess air quality outside of schools, particularly pollution levels during walks to and from school at morning drop-off and afternoon pick up times. This study was carried out alongside a complementary assessment of the school street trial taking place Elizabeth Street, outside St Luke's school, which has indicated increased levels of exposure to pollutants such as PM_{10} and $PM_{2.5}$ linked to school traffic at school entrances in certain areas. Comparison of results from this study to air quality objectives and the St Luke's school street trial will inform the possibility of potential mitigation decisions as well as highlighting the possibility for wider ranging follow on or longer-term monitoring.

3.2 Monitoring Sites

This study expanded Jersey's current air quality monitoring network, maintained by the Water and Air team, which is part of the Environment Department, to include two automatic low-cost Vortex sensors at Rouge Bouillon School and on Wellington Road. The Vortex sensors measured NO_2, PM_{10} and $PM_{2.5}$ concentrations at both monitoring locations. Furthermore, to measure NO_2, PM_{10} and $PM_{2.5}$ concentrations along popular walking routes around both monitoring locations, a mobile air quality monitoring system was utilised.

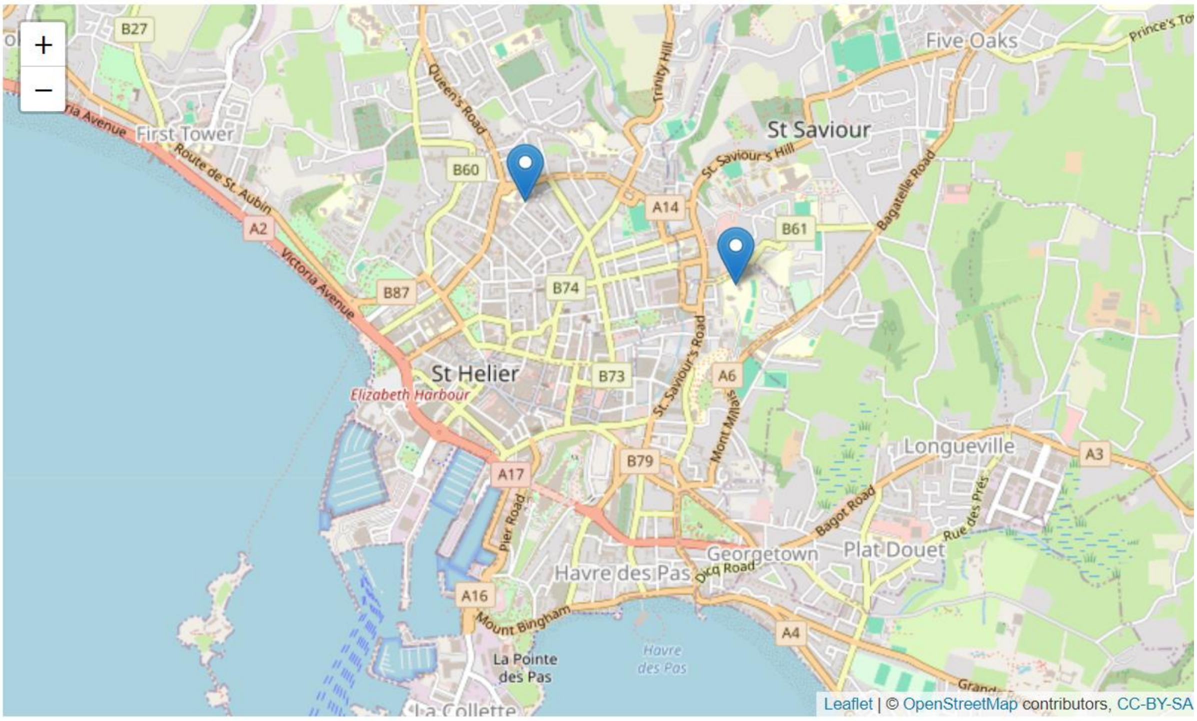

Figure 4: Static air quality monitoring locations

3.2.1 Monitoring Methods

3.2.1.1 Static Low-cost Automatic Sensors

Indicative monitoring of NO_2, PM_{10} and $PM_{2.5}$ concentrations was carried out using two low-cost sensors known as Vortex IoT - VTXAIR. The Vortex sensors measure NO_2 concentrations using an electrochemical cell with remote calibration. Particulate matter data is collected using an Optical Particle Counter (OPC) which uses laser light scattering to determine PM concentrations. Vortex sensors are certified as indicative by MCERTS for particle matter measurements. The data from these sensors is aggregated in 5-minute intervals. Temperature, pressure and relative humidity measurements were also collected which are essential in the QA/QC process.

One sensor was installed at the Rouge Bouillon School (Figure 5), and the other was installed at a location on Wellington Road (Figure 6). At Rouge Bouillon School, the sensor was originally installed in April but experienced a fault. The sensor began collecting data at this site on 28th June 2023. The Vortex sensor on Wellington Road was installed on 27th April 2023. Both sensors are currently still in place at each respective location at the time of this report being written. In this study, the period studied starts on 27th April to 30th September, however, there are significant data gaps in data collected from both sensors due to technical issues that occurred.

Figure 5: Vortex sensor deployed at Rouge Bouillon School

Figure 6: Vortex sensor deployed on Wellington Road

3.2.1.2 Mobile low-cost Automatic Sensor

Ricardo have developed a mobile air quality monitoring system utilising a Praxis Urban sensor which has the ability to measure a number of key pollutants. In this study the equipment was used to measure NO_2, PM_{10} and $PM_{2.5}$ concentrations along with GPS data. The Praxis Urban sensor is certified as indicative by MCERTS for particle matter measurements. A team of two Ricardo analysts utilised this mobile sensor unit to carry out journeys on foot, along popular walking routes to both Rouge Bouillon School and Wellington Road (Figure 7 and 8). For each monitoring location, two main road routes and two back street routes were walked. For Rouge Bouillon School, routes A and C are the main road routes and B and D are the backstreet routes. The main road routes walked at the location on Wellington Road are routes C and D, where the A and B are the backstreet routes. The routes monitored at each site averaged approximately 9 minutes per route. There are 7 schools within a 500-metre radius of Wellington Road, therefore any mitigations implemented will need to be a collective effort between all schools in the area.

This mobile sensor monitoring was carried out at drop off (07:50 to 09:00) and pick up times (13:50 to 16:00) at Rouge Bouillon School on 3^{rd} and 4^{th} July 2023 and at Wellington Road on 5^{th} and 6^{th} July 2023. It should be noted that on the 5^{th} July state schools were on strike, therefore only two schools were open in the immediate vicinity of Wellington Road.

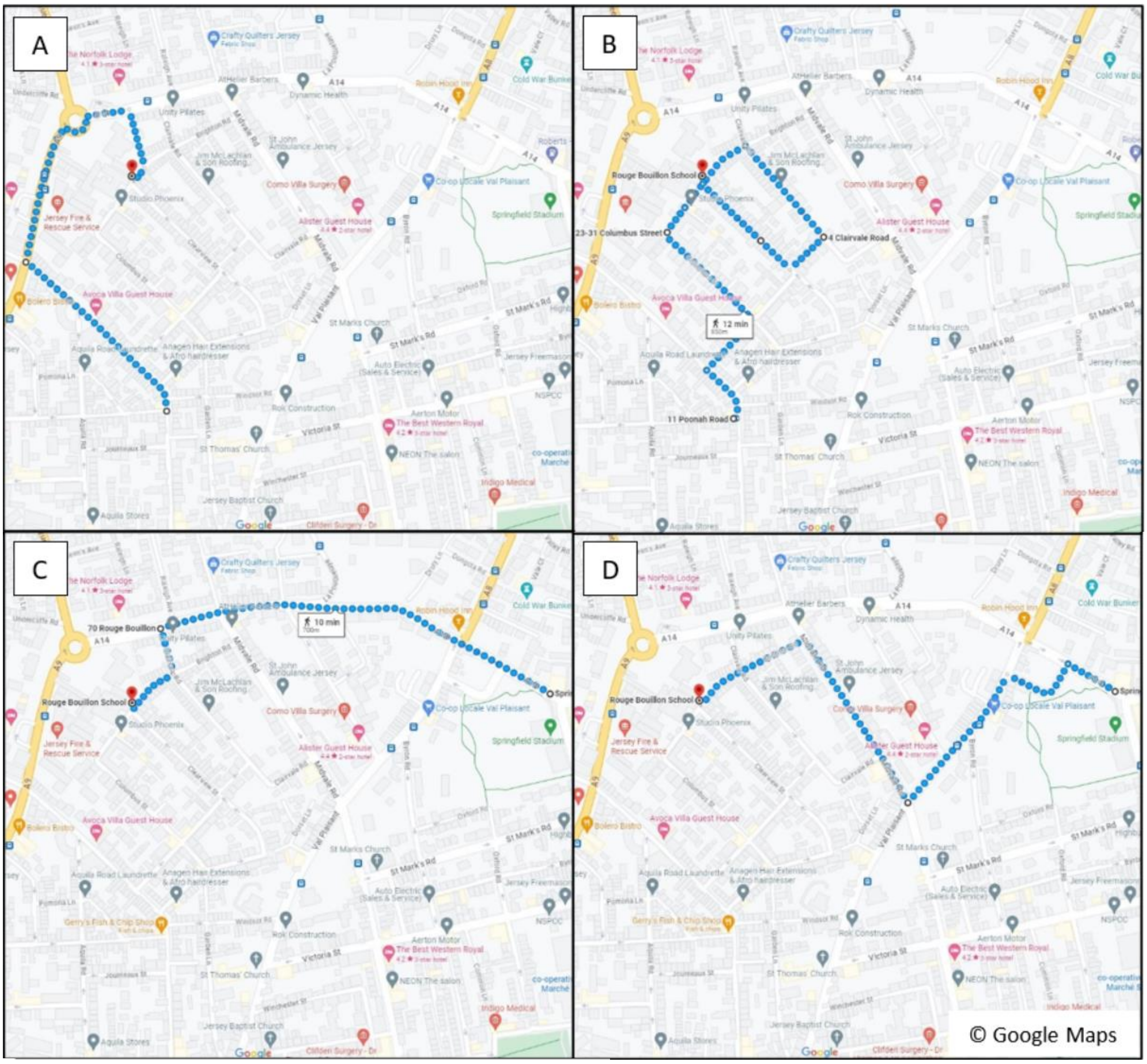

Figure 7: Four popular walking routes to Rouge Bouillon School

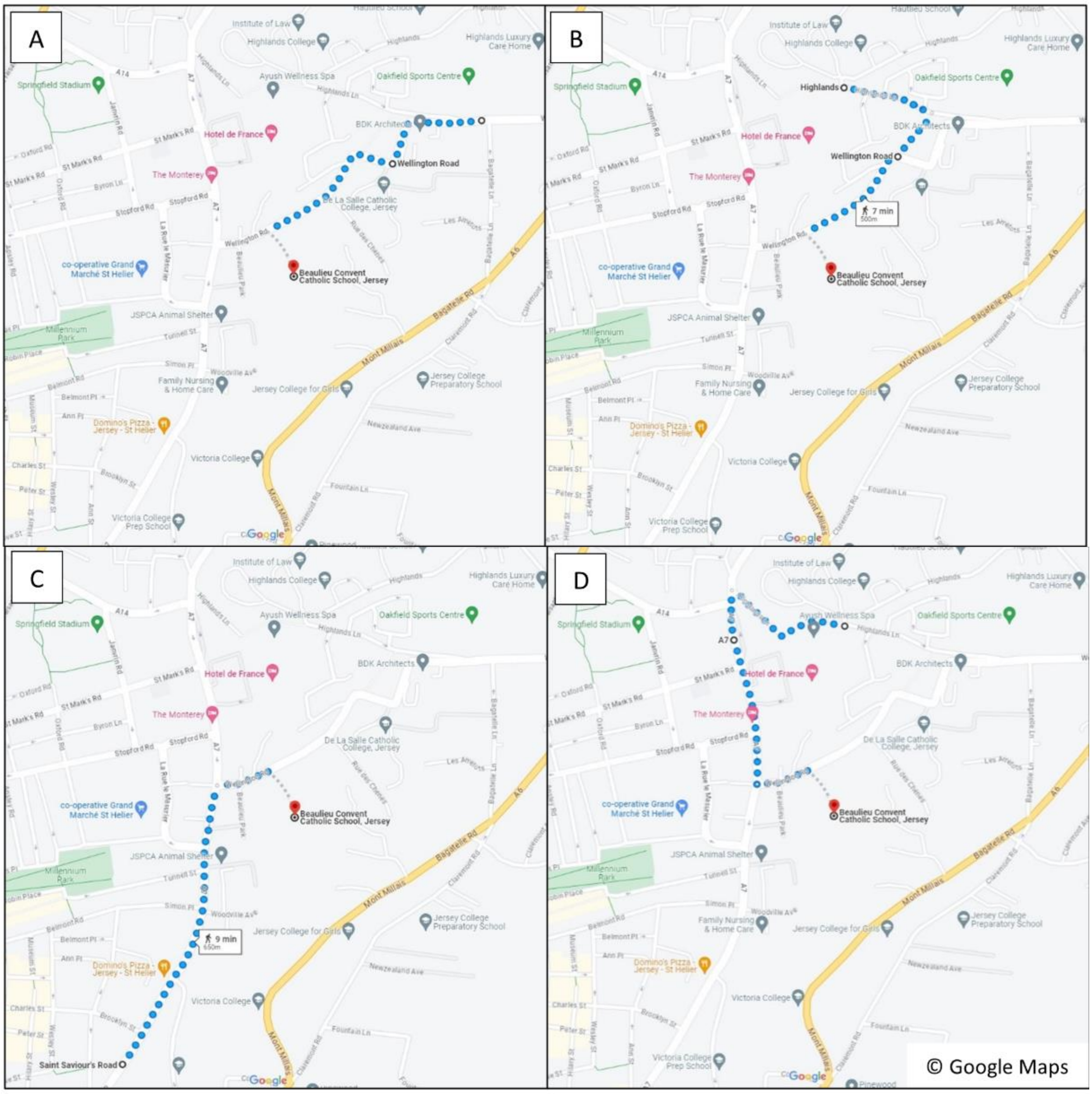

Figure 8: Four popular walking routes to Wellington Road

3.2.2 St Luke's School Street Pilot Study

Prior to this study, the Government of Jersey commissioned Ricardo to aid in their School Street Pilot Scheme at St Luke's Primary School in St Saviour. One of the aims of the St Luke's School Street Study was to determine if the temporary restrictions on motorised traffic access during school term drop off (07:30 – 09:30) and pick up (14:30 – 16:30) times produced any noticeable changes in air quality. A Clarity NO_2/PM sensor was installed outside of St Luke's Primary School on Elizabeth Street in February 2023 and two non-automatic diffusion tubes were deployed in March 2023 for six months for use in the study. The data from the St Luke's School Street Pilot Scheme are used in this report to provide comparison and inform recommendations.

In a previous study undertaken by Ricardo, two Vortex (VTXAir) sensors and one Clarity sensor were compared to assess the performance of the systems for monitoring air quality on the island of Jersey. This investigation concluded that there is no significant difference between Vortex and Clarity sensors in measuring NO_2 concentrations. However, for PM measurement variability increased, and additional co-location work would be required to evaluate measurement uncertainty. An assessment of uncertainty (U) of NO_2 measurements was carried out for both sensor types which indicated that the data quality objective for Class 2 measurements – objective estimation (25% < U ≤ 75%) was met for both sensor types. Therefore, absolute NO_2 concentrations are less certain but it is possible that the range of concentrations may be estimated (e.g. high, medium or low concentrations). As there is no PM reference analyser at Beresford Street Market, no assessment of PM_{10} or $PM_{2.5}$ uncertainty could be made. The critical importance of ongoing QA/QC, including appropriate co-location studies with reference analysers was also highlighted.

4 QA/QC

QA/QC practices were applied to the three sensors used in this study in line with advice published by Air Quality Expert Group (AQEG) on the Defra UK air website (AQEG advice on the use of 'low-cost' pollution sensors - Defra, UK). Practices carried out as part of the QA/QC process include co-location of sensors with reference stations and calculation and application of correction factors derived from the data collected during these co-locations. To calculate the correction factor for each pollutant measured by each sensor, orthogonal regression analysis is carried out where correlation between the sensor and reference site is shown. Positive correlation shows that concentrations measured by the sensor are in good agreeance with the reference site and therefore the data is able to be used in accordance with best practice. No correlation or negative correlation highlight a poor agreeance between measurements.

4.1 Vortex

For this study, two Vortex sensors were chosen for the static automatic monitoring due to their ready availability and ease of installation. The sensors were co-located at Jersey Beresford Street Market for an extended period prior to installation at each monitoring location on 27th April 2023. The time resolution for both sensors was set to 5-minute intervals.

4.1.1 Nitrogen Dioxide

For NO_2 concentration measures, orthogonal regression analysis was carried out to aid calculation of a correction factor for each sensor. A correction factor of 1.468 was applied to NO_2 data collected from JERV1 Vortex sensor, and a correction factor of 2.075 was applied to JERV2 Vortex sensor. Figure 9 shows a time plot of NO_2 concentrations measured at Beresford Street against NO_2 data from Vortex sensors JERV1 SN0060 at Rouge Bouillon School and JERV2 SN0260 on Wellington Road during the co-location period between 1st January 2023 and 5th February 2023. Both Vortex sensors generally follow the reference station well, capturing daily variations as seen at Beresford Street. Both sensors were shown to have positive linear association with the automatic monitor at Beresford Street.

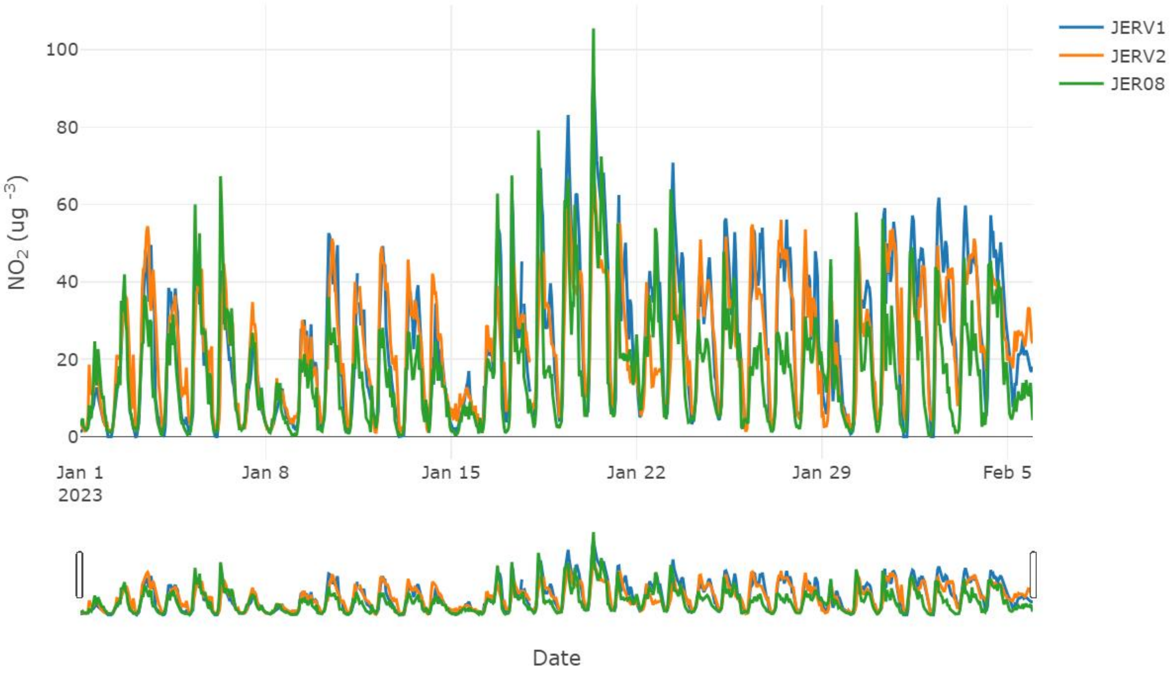

Figure 9: Time series of NO_2 data from Rouge Bouillon School (JERV1), Wellington Road (JERV2) and Jersey Beresford Street (JER08) during co-location period

4.1.2 Particulate Matter

As there is no reference PM air quality monitor present at Beresford Market Street, PM data from the Vortex sensors could not be co-located or ratified in the same way as the NO_2 data from these sensors. Therefore, the PM_{10} and $PM_{2.5}$ data has been normalised between 0 and 1. Normalised data provide relevant information pertaining to PM concentrations throughout this study, whereby '1' represents the highest range of concentrations and '0' indicates the lowest concentration. Normalised data are displayed in bandings, where data in band 0 to 0.25 are 'low', 0.25 to 0.75 are 'moderate', and 0.75 to 1.00 are 'high'. Using this method is indicative of changes in the frequency of PM measurements within these 'bands'. These bands are not associated with the DAQI bands but are used to illustrate the frequency of measurements within each band, relative to each other.

4.2 Praxis Urban

The mobile monitoring Praxis Urban BGX-666 sensor was set to collect data in 10 second intervals during this study to give high resolution results to aid assessment of the spatial distribution of pollutants along popular walking routes and potential hot spots along these routes. The sensor was serviced and calibrated by the manufacturer prior to use in this study and was subsequently co-located following completion of the air quality monitoring. The sensor was co-located at London Harlington, an AURN affiliated site, from 12th July 2023 to 9th August 2023.

4.2.1 Nitrogen Dioxide

Similar to the Vortex sensor, an orthogonal analysis of the co-location data was carried out to calculate a correction factor of 0.509 for NO_2 concentrations. A time plot of NO_2 data from London Harlington and the Praxis Urban mobile sensor (scsbgx666) during the co-location is shown in

Figure 10. Concentration measured by the Praxis Urban sensor compare well to the concentrations measured by the automatic monitor at London Harlington, displaying similar diurnal trends in data.

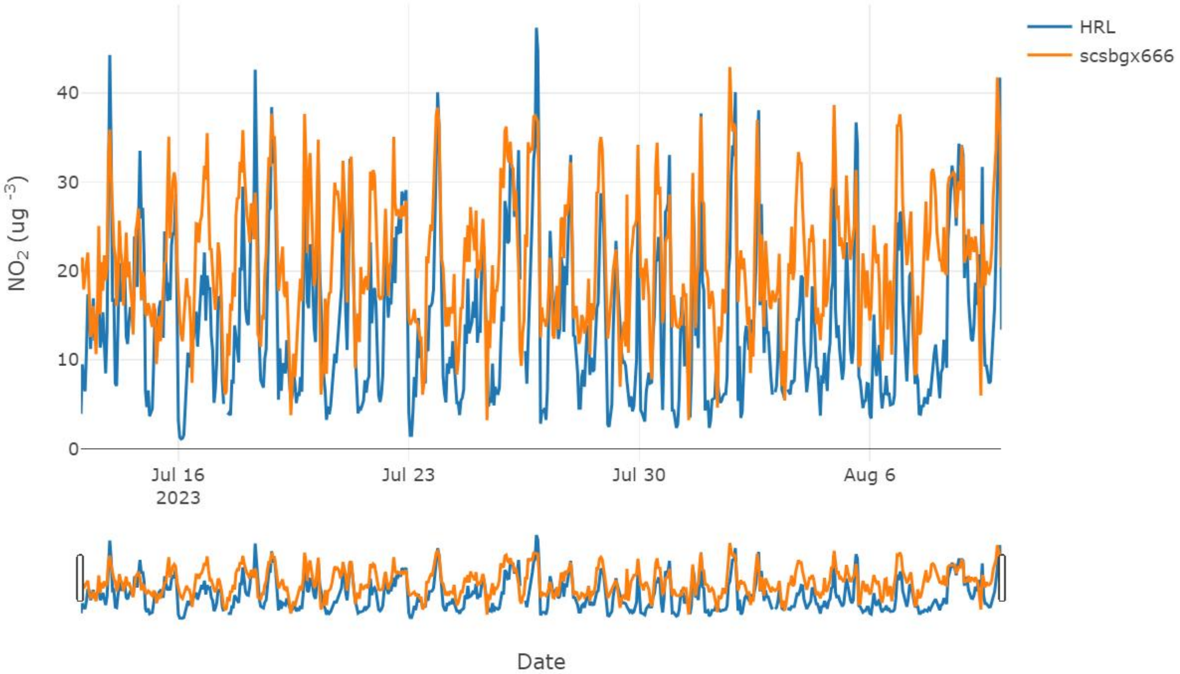

Figure 10: Time series of NO_2 data from scsbgx666 and London Harlington (HRL) during co-location period

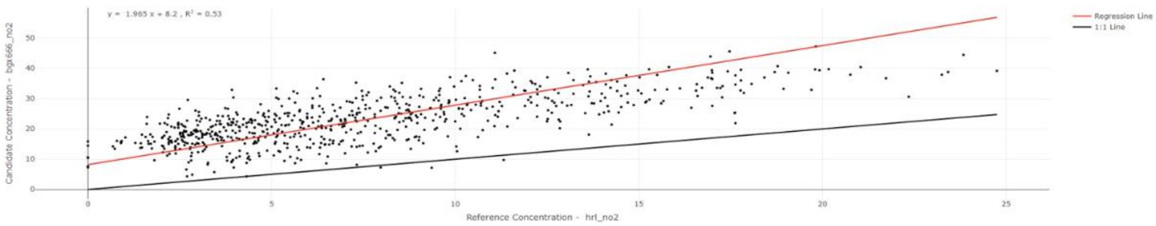

Figure 11: Scatter Plot showing correlation between NO_2 concentrations from scsbgx666 and London Harlington (HRL) during co-location period

4.2.2 Particulate Matter

The orthogonal analysis of the co-location data for both PM_{10} and $PM_{2.5}$ against London Harlington, calculated a correction factor of 0.901 for PM_{10} concentrations and 0.772 for $PM_{2.5}$ concentrations. Time plots of PM_{10} and $PM_{2.5}$ concentrations measured by the Praxis Urban sensor against London Harlington (Figure 12 and 13) show that PM concentrations compare well with London Harlington. Figure 14 and 15 show positive linear association between the Praxis Urban sensor and the reference site (London Harlington) for both pollutants.

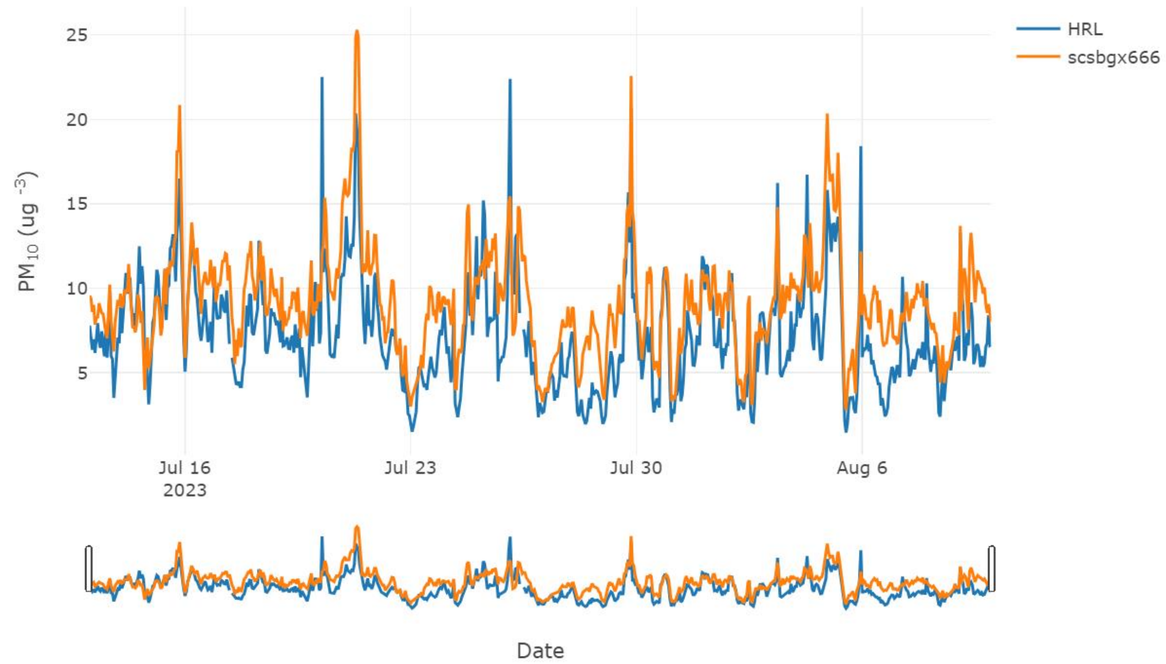

Figure 12: Time series of PM_{10} data from scsbgx666 and London Harlington (HRL) during co-location period

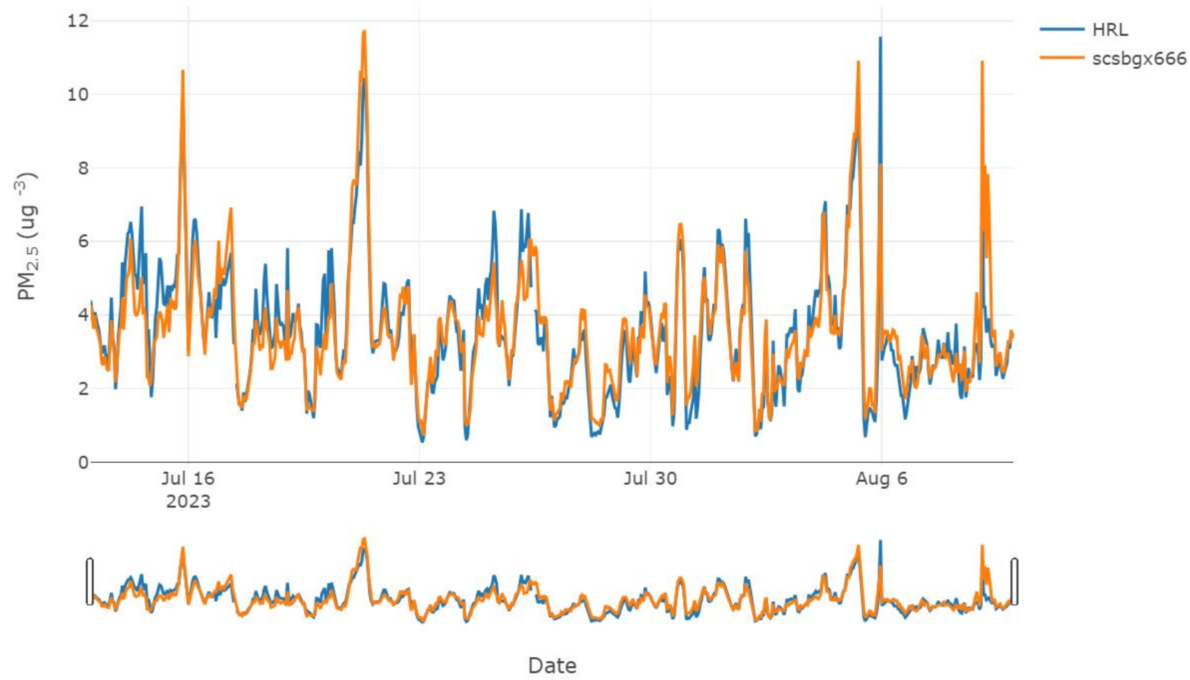

Figure 13: Time series of $PM_{2.5}$ data from scsbgx666 and London Harlington (HRL) during co-location period

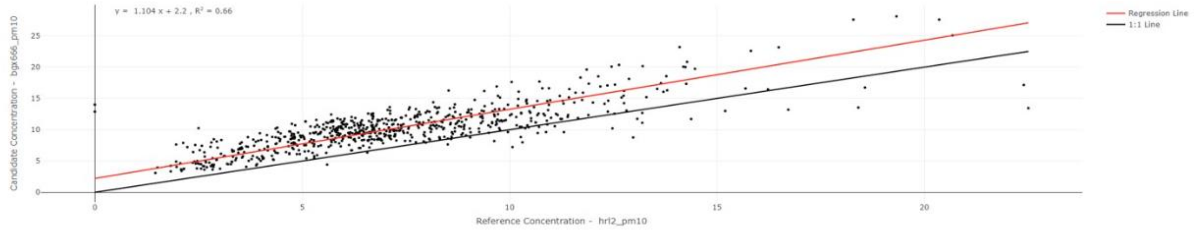

Figure 14: Scatter Plot showing correlation between PM_{10} concentrations from scsbgx666 and London Harlington (HRL) during co-location period

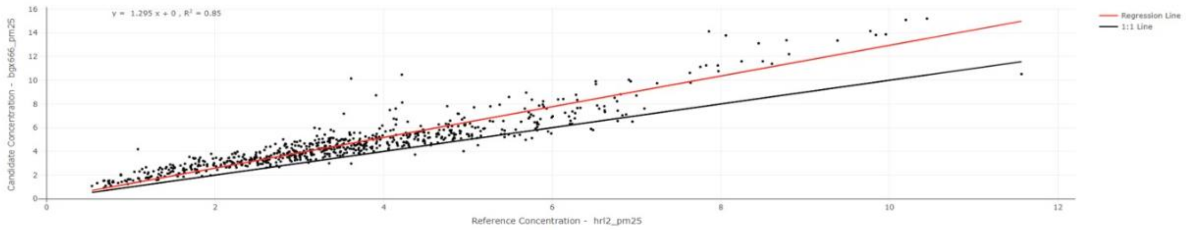

Figure 15: Scatter Plot showing correlation between $PM_{2.5}$ concentrations from scsbgx666 and London Harlington (HRL) during co-location period

4.3 Automatic Monitoring Stations

The following techniques were used for the automatic monitoring of NOx (i.e. NO and NO_2) and PM:

- NO, NO_2 – Chemiluminescence.
- PM_{10} - Fine Dust Analysis Systems (FIDAS) and Optical Scattering Instantaneous Respirable Dust Indication System (OSIRIS).
- $PM_{2.5}$ - Fine Dust Analysis Systems (FIDAS) and Optical Scattering Instantaneous Respirable Dust Indication System (OSIRIS).

The FIDAS analyser is located at London Harlington and was used solely for co-location of both Vortex sensors. Further information on these techniques and the associated QA/QC processes is provided in the most recent iteration of the Annual Jersey Air Quality Monitoring Report [17].

5 Results and Discussion

5.1 Static Vortex Sensor Monitoring

5.1.1 Nitrogen Dioxide

5.1.1.1 Time Series

Figure 16 shows hourly average NO_2 concentrations at both monitoring locations through period 27th April to 30th September. NO_2 concentrations measured at Rouge Bouillon School and on Wellington Road did not exceed the Air Quality Limit Values and Objectives hourly mean of 200 µg m-3. However, EU limit values are currently under review and are likely to be partially aligned with WHO air quality guideline limit values. NO_2 concentrations remained in the 'Low' DAQI band throughout the monitoring period of this study. Unfortunately, due to technical issues, there are significant gaps in the data which has limited analysis of the data sets.

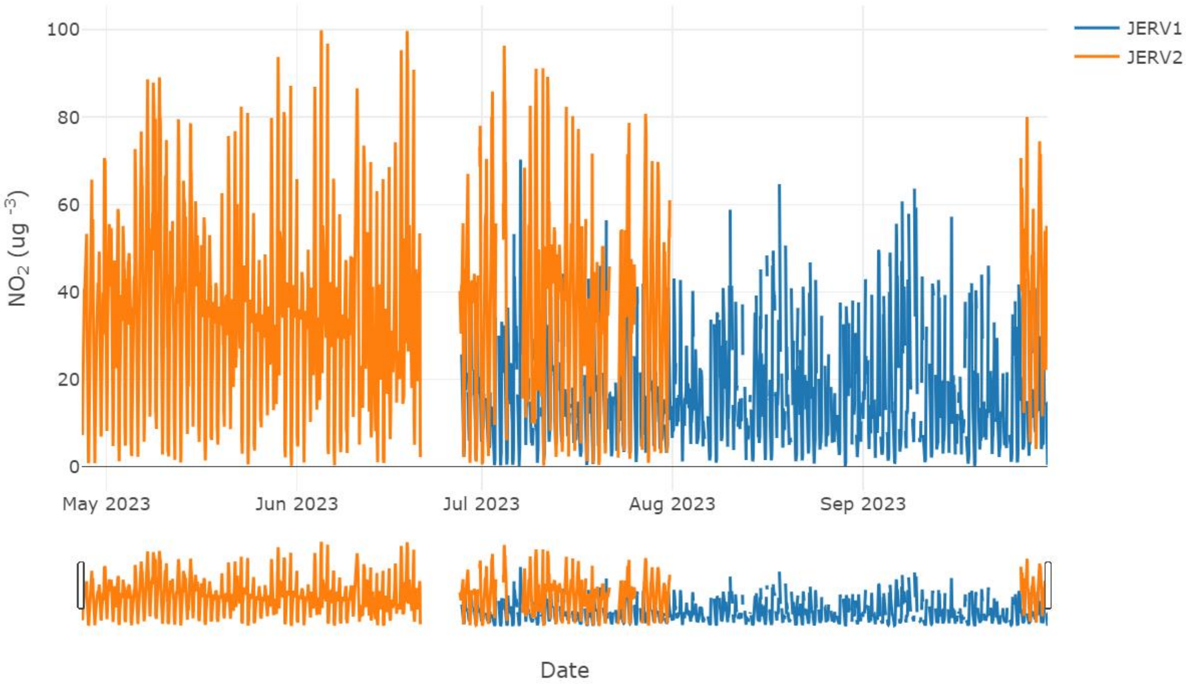

Figure 16: Time series of ratified hourly NO_2 data from Rouge Bouillon School (JERV1) and Wellington Road (JERV2)

5.1.1.2 Time Variation

In general, weekly time variation plots highlight NO_2 concentrations are more pronounced Monday to Friday, with overall concentrations lower over the weekend, especially on Sunday when most commercial shops are closed. Generally, concentrations tend to peak at rush hours in the morning, decreases in the middle of the day and then show a broader, less pronounced evening rush hour signature.

A weekly analysis of NO_2 data collected at Rouge Bouillon School and Wellington Road is shown in Figure 17. This general pattern is evident at Rouge Bouillon School. This pattern is likely the result of traffic flows on the A9 Road and Rouge Bouillon Road. Anecdotal evidence from the Ricardo analysts undertaking this monitoring noted that at drop off times traffic queued heavily when travelling East. Furthermore, at pick up times there was significantly less queueing of traffic due to reduced commuter traffic during these times. The roundabout between the A9 Road and Rouge Bouillon Road also facilitates good traffic flow compared to traffic lights.

On Wellington Road, the expected pattern is less evident. The peaks at morning rush hour are less pronounced compared to Rouge Bouillon School. NO_2 concentrations on Wellington Road are generally shown to highest in the afternoon or evening. Further anecdotal evidence from the Ricardo analyst team indicated that vehicles only briefly stopped along Wellington Road during school drop off times. However, at pick up times vehicles continue to wait along Wellington Road for longer periods with engines idling. Buses were also noted to wait longer at bus stands during the afternoon pick up periods. This evidence could therefore be linked to the increased concentrations of NO_2 that occur in the afternoons. Wellington Hill is a steep hill and therefore vehicles travelling up the hill are likely to be working harder and may produce more emissions as a result. Many students from other schools in the area also walk down Wellington Hill to get the school buses in the afternoon and are therefore also exposed to these elevated pollutant concentrations. Concentrations across the weekend are more elevated than expected, especially in the afternoon, this may be due to Wellington Hill being busy during weekends as it is one of the main roads that runs from North East Jersey into St Hellier. Other factors that could influence elevated NO_2 concentrations include weather conditions or increased traffic flow due to the influx of tourists that visit Jersey in summer months. The potential source of the elevated data until approximately 11PM on Mondays and Tuesdays is unknown and further investigation would be needed to potentially identify the cause of this data.

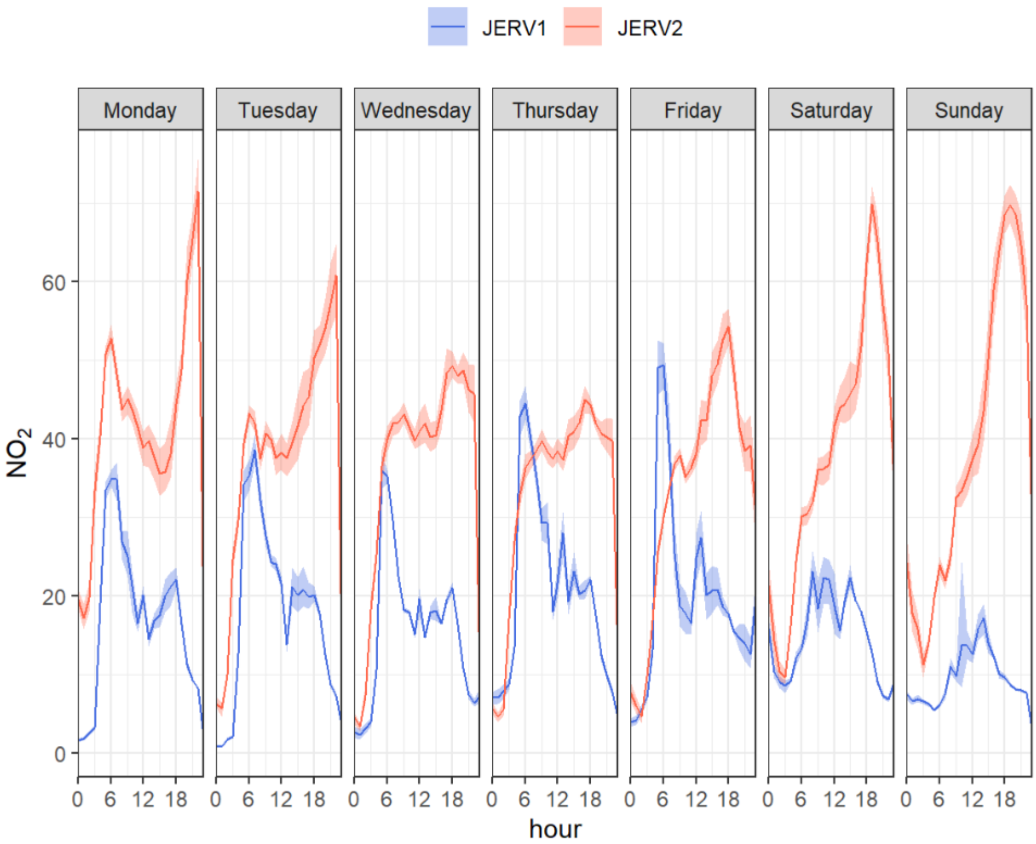

Figure 17: Time Variation plot of ratified NO_2 data from Rouge Bouillon School and Wellington Road

5.1.1.3 Box Plot

Figure 18 and 19 show box plots comparing NO_2 concentrations at drop off and pick up times (7:30 to 9:30 and 14:30 to 16:30) to NO_2 concentrations between drop off and pick up times (09:35 to 14:25) during the monitoring period. This analysis highlights the median, distribution and outliers of each data set. Further statistical analysis of these results is also applied to assess the statistical significance of the difference between medians of each data set using a t-test. The probability values (p-values) derived from this analysis are compared to a significance level of 0.05. If the p-value is greater than 0.05 then the difference between the means of the datasets is not statistically significant. If the p-value is less than 0.05 then the difference between the means is statistically significant.

At Rouge Bouillon School, NO_2 concentrations are shown to be highest at drop off and pick up times compared to between these times (Figure 18) which supports the pattern previously observed in the Time Variation plot above. The mean of NO_2 concentrations measured at drop off and pick up times was 23.26 µg m^{-3} compared to the mean of 20.31 µg m^{-3} of data measured between these times. The results of the statistical analysis show that the p-value is greater than the significance value of 0.05 which indicates there is no statistically significant difference between means of the datasets (Table 1). These results indicate that the difference between the means could be due to chance. However, the range of data measured at drop off and pick up times is also greater, and the outliers are of greater concentrations. This indicates that NO_2 concentrations are higher at drop off and pick up times which is likely a result of increased traffic at these times.

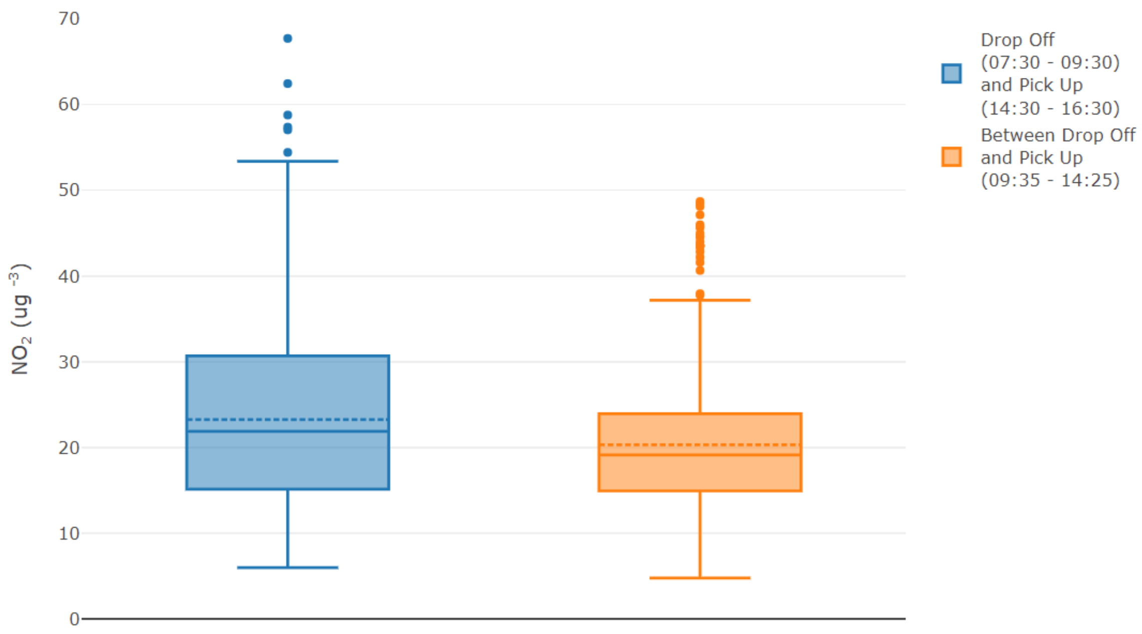

Figure 18: Box Plot showing variations in NO_2 concentrations at Rouge Bouillon School at Drop Off (07:30 to 09:30) and Pick Up times (14:30 to 16:30) and between Drop Off and Pick Up times (09:35 to 14:25)

Comparatively, there is a less noticeable difference between NO_2 concentrations at drop off and pick up times and between drop off and pick up times on Wellington Road. The mean of NO_2 concentrations measured at drop off and pick up times was 40.27 µg m^{-3}. Between drop off and pick up times, the mean of concentrations measured was 39.09 µg m^{-3}. The results of the statistical analysis indicate that p-value is less than 0.05 and therefore the difference between means is statistically significant and unlikely due to chance (Table 1). Despite the small difference between the means of each dataset, the range of data measured during drop off and pick up times is greater. Furthermore, the outliers at drop off and pick up times are also of higher value than outliers between drop off and pick up times. Therefore, the increased range and higher value outliers at drop off and pick up times are likely a result of increased traffic at these times.

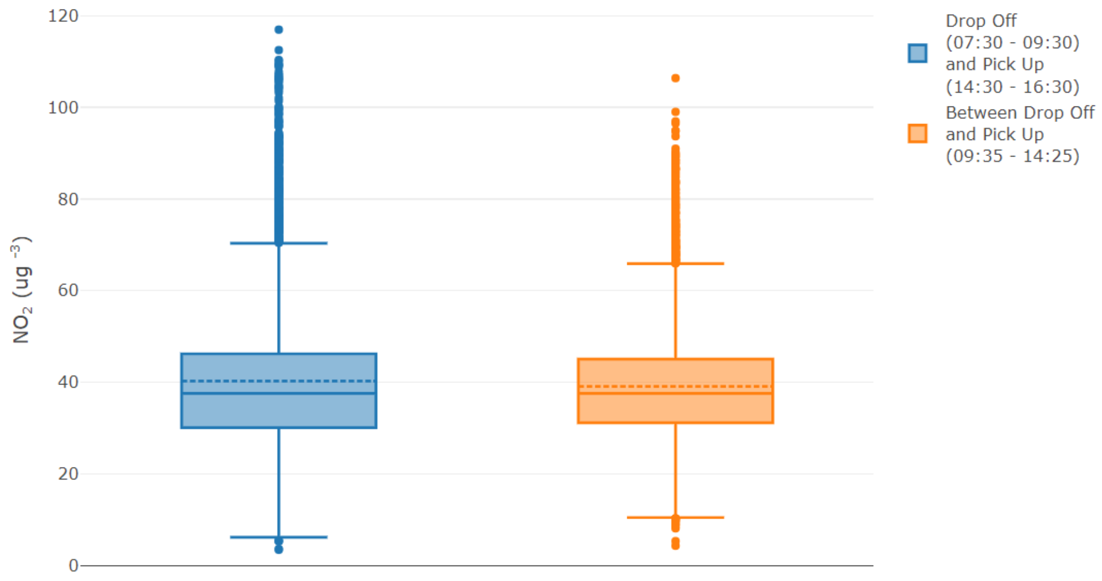

Figure 19: Box Plot showing variations in NO_2 concentrations at a location on Wellington Road at Drop Off (07:30 to 09:30) and Pick Up times (14:30 to 16:30) and between Drop Off and Pick Up times (09:35 to 14:25)

	Rouge Bouillon School	**Wellington Road**
Calculated p-value	2.5095	0.0003
Significance level	0.05	0.05

Table 1. Results of the t-test for changes in mean values at Rouge Bouillon School and Wellington Road for drop off (07:30 - 09:30) and pick up (14:30 - 16:30) times.

Figure 20 shows a bivariate 'Pollution Rose' plot of hourly mean NO_2 concentrations against corresponding wind speed and direction at Beresford Street automatic monitoring site. Pollution roses should be interpreted as follows:

- The wind direction is indicated as north, south, east and west.
- The wind speed is indicated by the distance from the centre of the plot: the concentric circles indicate wind speeds in 5 ms^{-1} intervals.
- The pollutant concentration is indicated by the colour (as indicated by the scale).

The plots do not show distance of pollutant emission sources from the monitoring site. However, in the case of primary pollutants such as NO, the concentrations at very low wind speeds are dominated by emission sources close by, while at higher wind speeds, effects are seen from sources further away.

Although Figure 20 is created using NO_2 data from Beresford Street monitoring site, it provides relevant information as to potential sources of elevated NO_2 concentrations on Wellington Road. NO_2 concentrations are shown to be elevated at calm, light wind conditions which indicates that the source of NO_2 is nearby. There is currently building work taking place along Wellington Road and therefore elevated concentrations between drop off and pick up times may be a result of this building work. Elevated concentrations are also shown to occur at higher wind speeds from the South Easterly and South Westerly directions. The sources of this elevated data in windier conditions could be the multiple main roads in these directions or possibly the result of a street canyon effect.

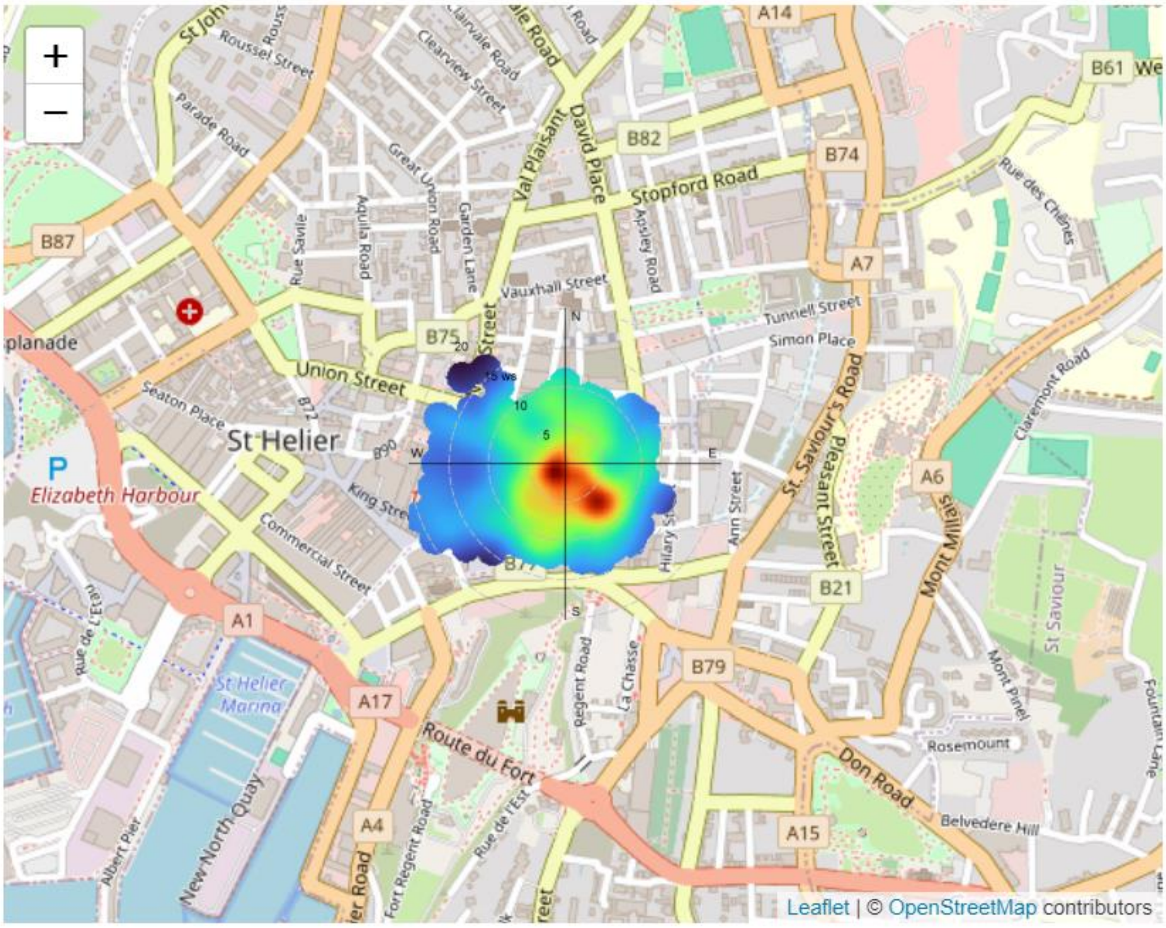

Figure 20: Pollution rose for NO_2 at Beresford Street, 2023

5.1.2 Particulate Matter

As previously discussed, there is no reference PM air quality monitor present at Beresford Market Street, therefore the PM data from the Vortex sensors could not be co-located or ratified in the same way as the NO_2 data from these sensors. As a result of this, a combination of raw and normalised data has been used to provide analysis. Raw data from the Vortex sensor has been compared to ratified data from the Osiris analyser at Jersey Howard Park to provide visualisation of trends across the monitoring period. Furthermore, data has been normalised between 0 and 1 which provides relevant information pertaining to the frequency of PM concentrations throughout this study, whereby ‘1’ represents the highest range of concentrations and ‘0’ indicates the lowest concentration.

5.1.2.1 Time Series

Figure 21 and 22 show a comparison between raw PM_{10} and $PM_{2.5}$ data from both Vortex sensors at Rouge Bouillon School and Wellington Road in comparison to ratified PM_{10} and $PM_{2.5}$ data from the Osiris analyser at Jersey Howard Davies Park. For the period where data is available from the Osiris analyser, the PM_{10} and $PM_{2.5}$ data is in good agreeance, with elevated periods being shown in both Osiris and Vortex datasets. Unfortunately, due to the Osiris analyser being away from site for calibration, no comparison can be made to the data collected at Rouge Bouillon School. Although the data shows that data collected at Rouge Bouillon School is generally lower than data measured at the location on Wellington Road and by the Osiris analyser. It should be noted that there is currently construction taking place on Wellington Road, which can be seen in Figure 6. This construction could contribute to additional particulate matter in the atmosphere, such as dust. However, as construction was occurring during the length of this study, it can be considered part of the background influences. If long term trends in particulate matter concentrations are assessed, then this construction work should be considered.

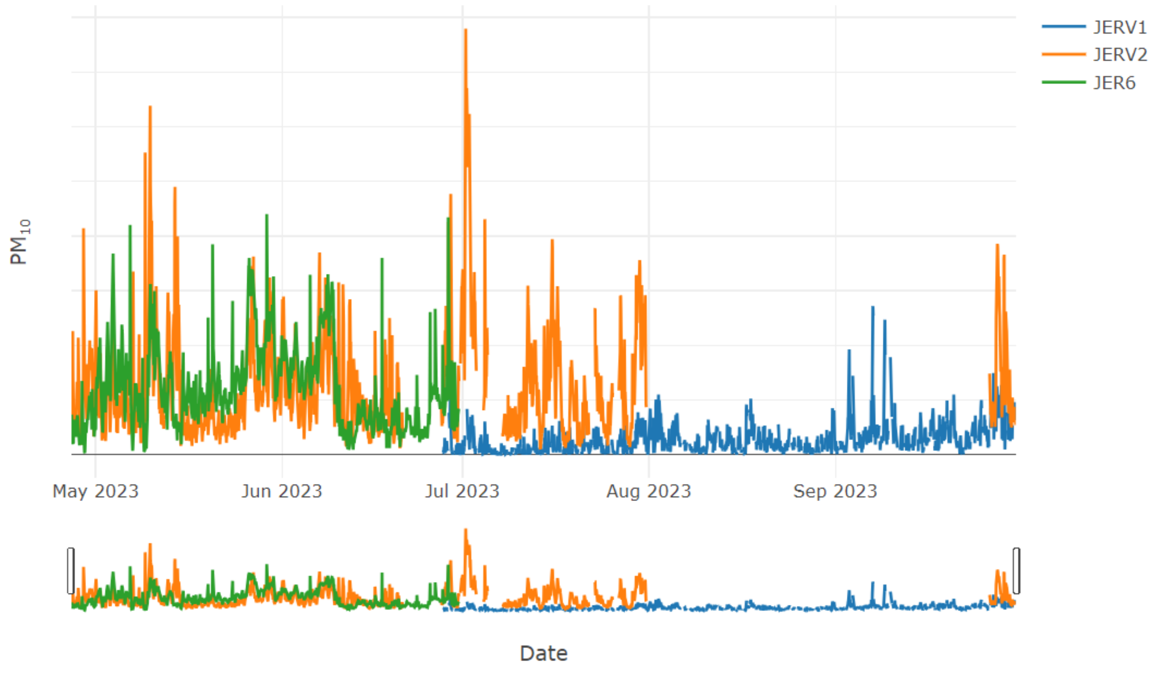

Figure 21: Time series of raw PM_{10} data from Rouge Bouillon School (JERV1) and Wellington Road (JERV2) and ratified PM_{10} data from Jersey Howard Park Osiris (JER6) during the monitoring period

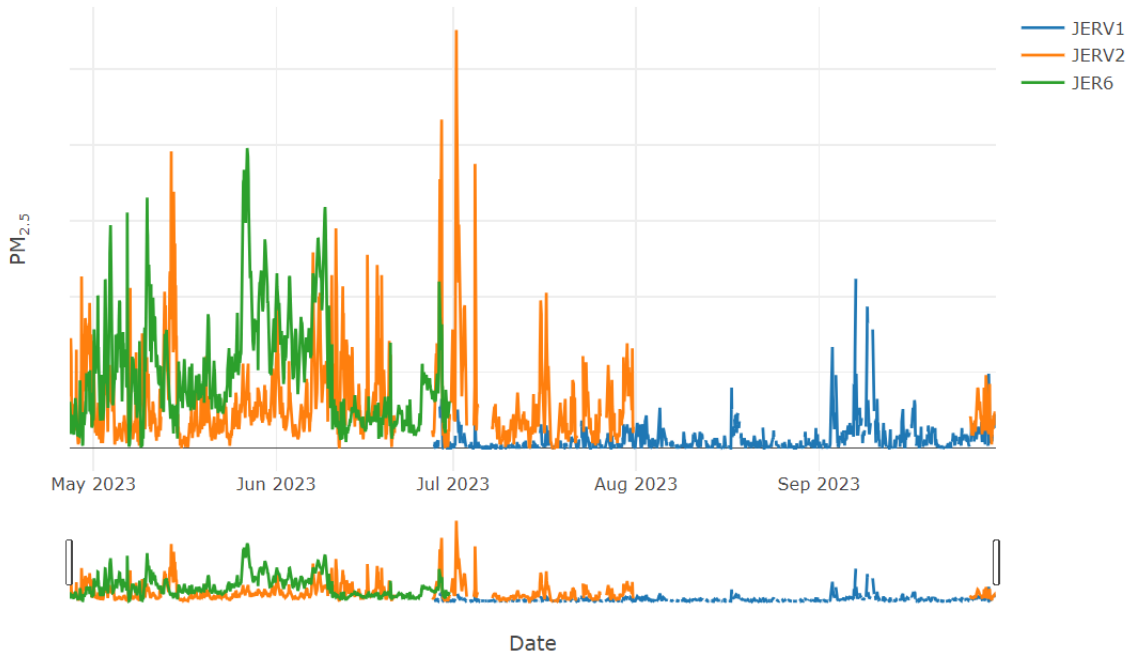

Figure 22: Time series of raw $PM_{2.5}$ data from Rouge Bouillon School (JERV1) and Wellington Road (JERV2) and ratified $PM_{2.5}$ data from Jersey Howard Park Osiris (JER6) during the monitoring period

5.1.2.2 Normalised Data

Normalised data are used in Figure 23 to 26 to show the frequency of PM_{10} measurements within bandings, where data in band 0 to 0.25 are ‘low’, 0.25 to 0.75 are ‘moderate’, and 0.75 to 1.00 are ‘high’. This method provides information regarding changes in the frequency of PM measurements in these ‘bands’. These bands are used to illustrate the frequency of measurements within each band relative to each other and are not associated with the DAQI bands.

Figure 23 and 24 show the frequency of PM_{10} concentrations at Rouge Bouillon School and on Wellington Road, within the bands described above. For both monitoring locations, it can be seen that the highest frequency of measurements occurs in the ‘low’ band, 94.67& and 85.98% respectively. Comparatively, both monitoring locations show less than 1% of measurements are within the ‘high’ band indicating that both locations have few PM_{10} measurements of high value relative to the data measured.

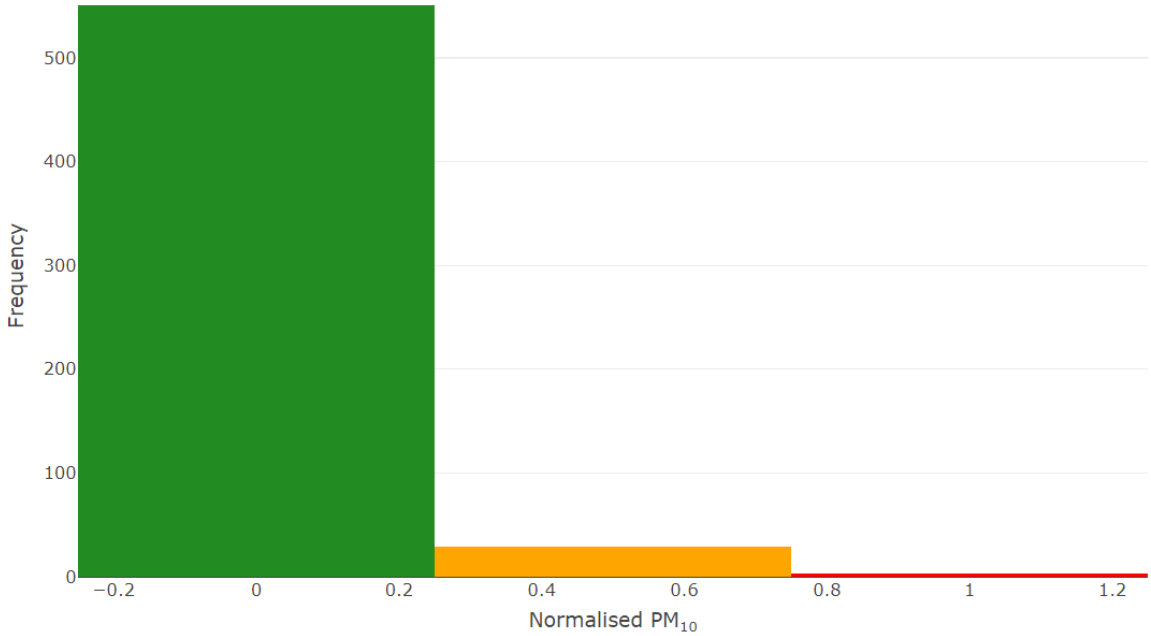

Figure 23: Normalised PM_{10} monitored at Rouge Bouillon School showing the frequency of PM_{10} concentrations within indicative ‘low’ (green), ‘moderate’ (orange) and ‘high’ (red) bands

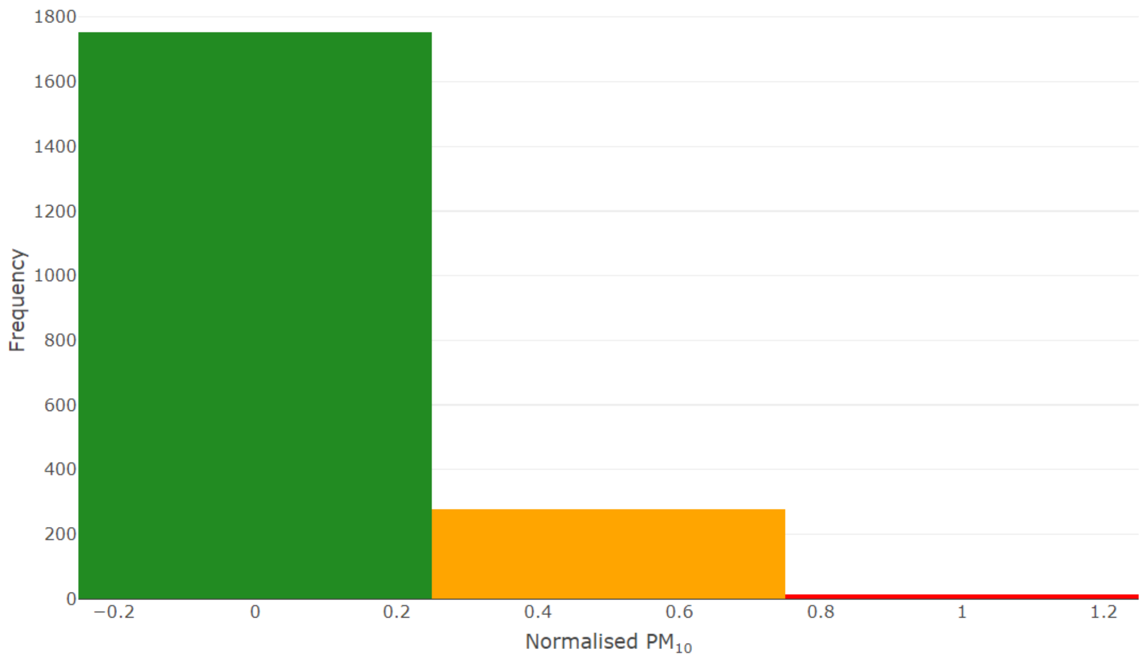

Figure 24: Normalised PM_{10} monitored at a location on Wellington Road showing the frequency of PM_{10} concentrations within indicative ‘low’ (green), ‘moderate’ (orange) and ‘high’ (red) bands

Normalised $PM_{2.5}$ from Rouge Bouillon School and Wellington Road are shown in Figure 25 and 26 respectively. At Rouge Bouillon School, 96.74% of values occur within the ‘low’ band. Similarly, on Wellington Road, 91.91% of values occur in the ‘low’ band. For both monitoring locations, the percentage of values within the ‘high’ band is 0.34%. Therefore, this indicates that there are few high values measured at both sites relative to each data set.

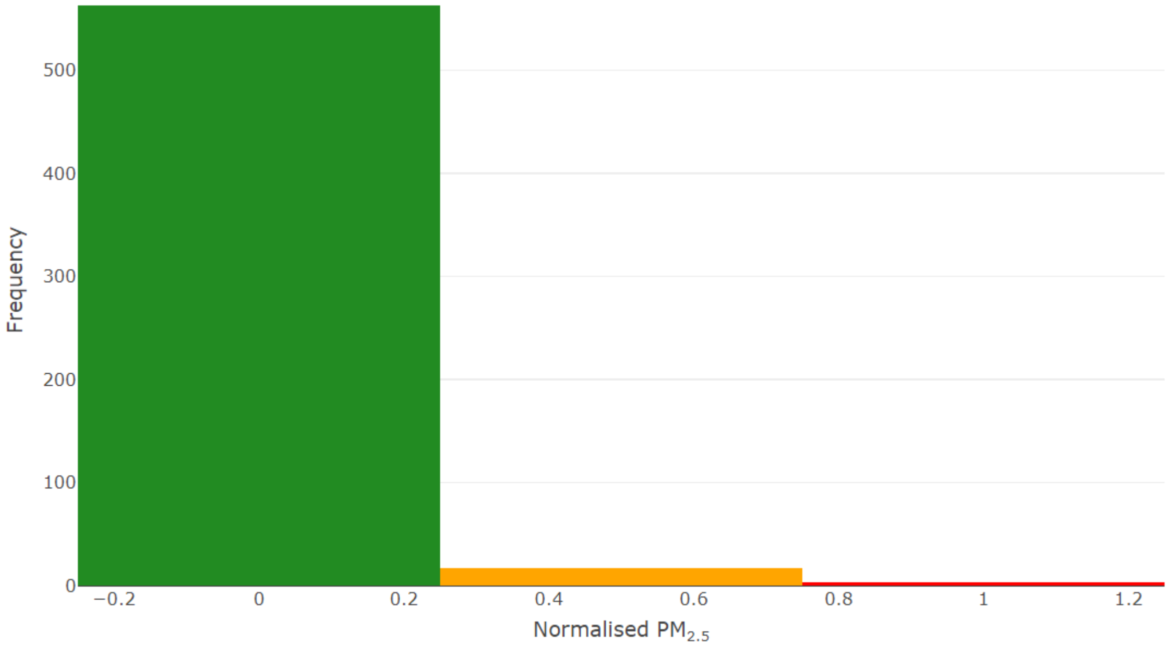

Figure 25: Normalised $PM_{2.5}$ monitored at Rogue Bouillon School showing the frequency of $PM_{2.5}$ concentrations within indicative ‘low’ (green), ‘moderate’ (orange) and ‘high’ (red) bands

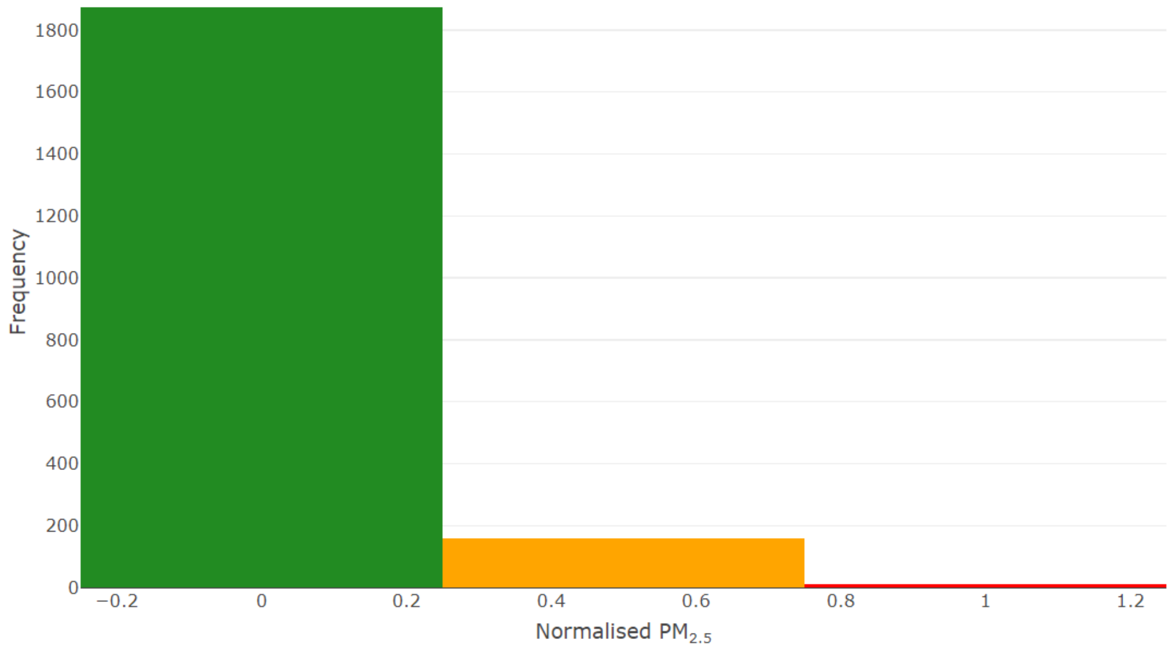

Figure 26: Normalised $PM_{2.5}$ monitored at a location on Wellington Road showing the frequency of $PM_{2.5}$ concentrations within indicative 'low' (green), 'moderate' (orange) and 'high' (red) bands

5.2 Mobile Praxis Urban Sensor Monitoring

5.2.1 Rouge Bouillon School

Figure 27, 28 and 29 show the results of the mobile monitoring at Rouge Bouillon School using the Praxis Urban sensor where the red marker on each map indicates the location of Rouge Bouillon School. Each pollutant is presented on a different plot and there is also a separate figure to highlight the walking routes taken to Rouge Bouillon School (Figure 30). Pollutant concentrations are shown in percentiles, whereby 0% shows lower pollutant concentrations and 100% indicates the highest concentration. As previously described, route A and C are the main road routes, and the backstreet routes are B and D.

NO_2 concentrations at Rouge Bouillon School are shown to be highest along Route A and C at both drop off and pick up times. The main road routes show the highest levels of NO_2, however route B also shows hot spots of elevated NO_2. Route D, to the east of the school, shows the lowest concentrations of NO_2 at both times.

Figure 28 shows PM_{10} concentrations measured Rouge Bouillon School. These results indicate more variable concentrations along all routes compared to NO_2. All routes indicate elevated PM_{10} concentrations at times, however overall the most polluted routes are also shown to be Route A and C. Route D shows the lowest concentrations at pick up times.

Similar to PM_{10} concentrations, $PM_{2.5}$ concentrations are shown to vary across each route (Figure 29). Measured $PM_{2.5}$ concentrations are shown to be highest along Route C but hotspots are also shown along sections of Great Union Road and the junction of the A9 and Great Union Road. Overall concentrations are also shown to be lowest along Route D as seen with NO_2 and PM_{10}.

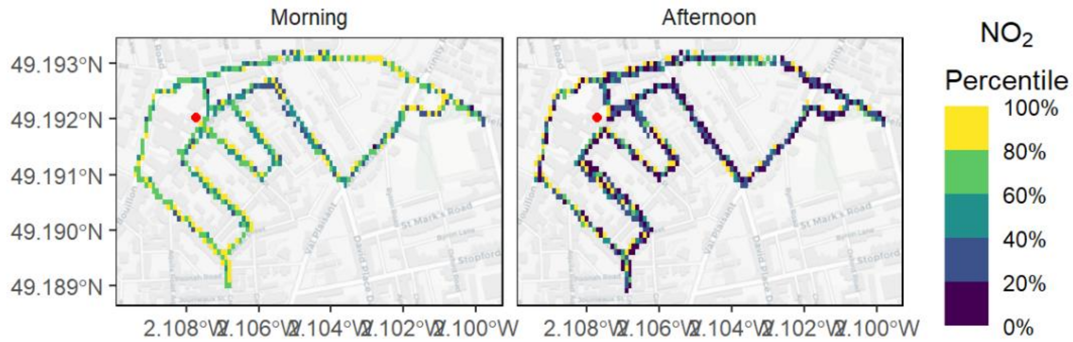

Figure 27: Map showing NO_2 concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times at Rouge Bouillon School

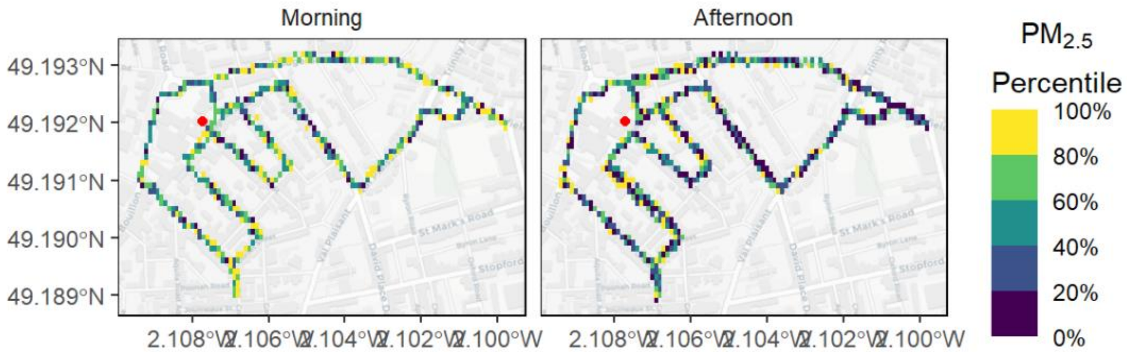

Figure 29: Map showing $PM_{2.5}$ concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times at Rouge Bouillon School

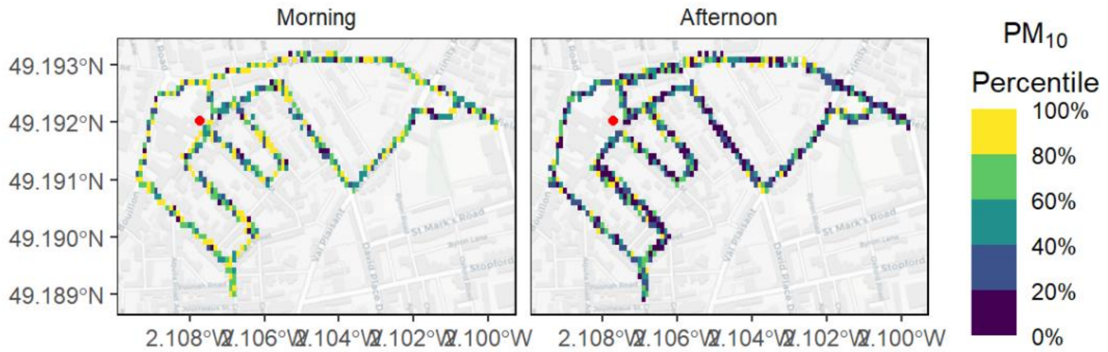

Figure 28: Map showing PM_{10} concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times at Rouge Bouillon School

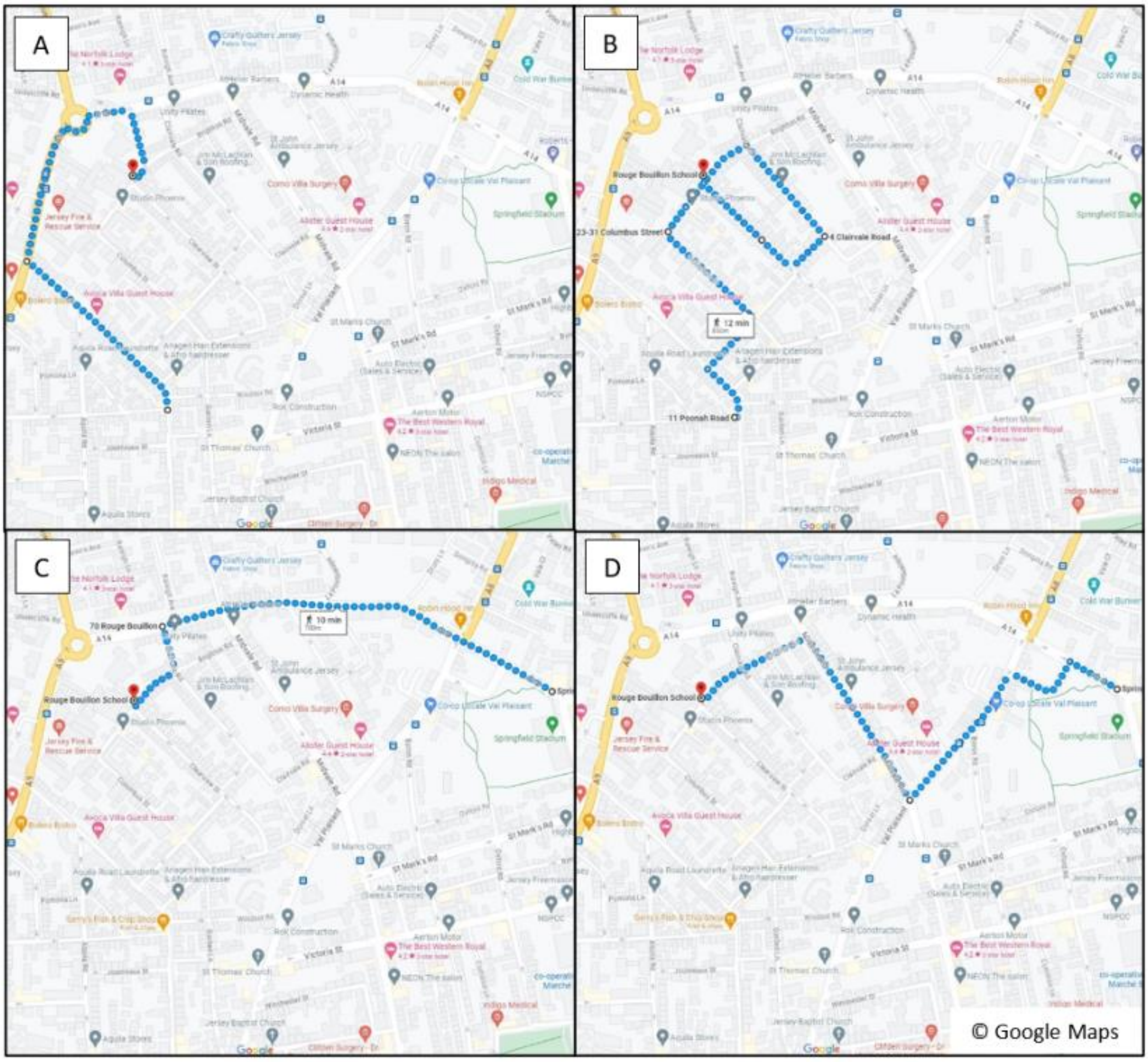

Figure 30: Four popular walking routes to Rouge Bouillon School

5.2.2 Wellington Road

The results of the mobile monitoring on Wellington Road using the Praxis Urban sensor are shown in Figure 31 to 33 where the red marker on each map indicates the location of the Vortex sensor. Each pollutant is presented on a different plot and there is also a separate figure to highlight the walking routes taken around Wellington Road (Figure 34). Pollutant concentrations are shown in percentiles, where the lowest concentration is 0% and the highest concentration is shown as 100%. Route C and D are the main road routes and Route A and B are the backstreet routes.

Analysis of NO_2 concentrations collected during monitoring on Wellington Road, show NO_2 concentrations are significantly higher along Route C and Route D, especially along the A7 and Wellington Road at both drop off and pick up times. Overall, NO_2 concentrations are shown to be highest a drop off times. However, analysis of NO_2 concentrations during afternoon pick up times also suggest there is a significant hotspot located on Wellington Road in close proximity to the sensor location. The Ricardo analysts undertaking this monitoring noted that at drop off times, vehicles were generally stationary for shorter periods compared to pick up times where vehicles tended to idle for longer periods of time. Therefore, the hotspot that is indicated on Wellington Road at pick up times is likely linked to the high volume of idling cars at this location at these times.

Spatial analysis of PM_{10} concentrations on Wellington Road indicate that elevated concentrations are spread along all routes (Figure 31). Concentrations of PM_{10} are generally shown to be highest along Route C as well as along the length of Wellington Road at both drop off and pick up times, although overall concentrations are highest at drop off times.

Similar to the trends observed for spatial variations in PM_{10} concentrations, $PM_{2.5}$ concentrations show high variability along each route. Overall, Route C shows the highest concentrations when compared to the other routes. Also, elevated concentrations can also be seen along the length of Wellington Road. Lowest concentrations are shown along Route A and B when excluding Wellington Road.

Similar to the hotspot of NO_2 concentrations on Wellington Road, a hotspot can also be seen for both PM_{10} and $PM_{2.5}$ concentrations at the sensor location of Wellington Road at pick up times. The anecdotal evidence from the Ricardo analysts, indicated a greater number of vehicles idling along this road at pick up times compared to drop off times. Therefore, the hotspots identified for each pollutant at pick up times may be as a result of idling vehicles.

Further anecdotal evidence suggests that approximate 50% of pupils arrive by bus or foot and the remaining 50% arrive by car. Furthermore 90% of the junior school pupils arrive to school by car. An alternative entrance to one of the schools on Wellington Road has been closed for construction for 18 months but is expected to re-open in 2024 which may result in a shift of up to 25% of the current traffic to this route.

The high spatial variability in PM concentrations measured at both monitoring locations may be result of traffic volume and congestion. However, particulate matter is a transboundary pollutant (a pollutant that can be transported or chemically formed as air masses move from one country to another). There is a potential contribution to particulate matter measurements from transboundary dust and sea salt aerosols. However, the contribution of these particulate types is generally reliant on meteorological factors, in particular, increased wind speeds. Wind speeds during this study were generally moderate with increased wind speeds in late May and early June, which may have increased the contribution of these particulate matter types during this period. Therefore, it is possible that the elevated PM concentrations along all routes, especially at morning drop off times, may not be solely a result of traffic.

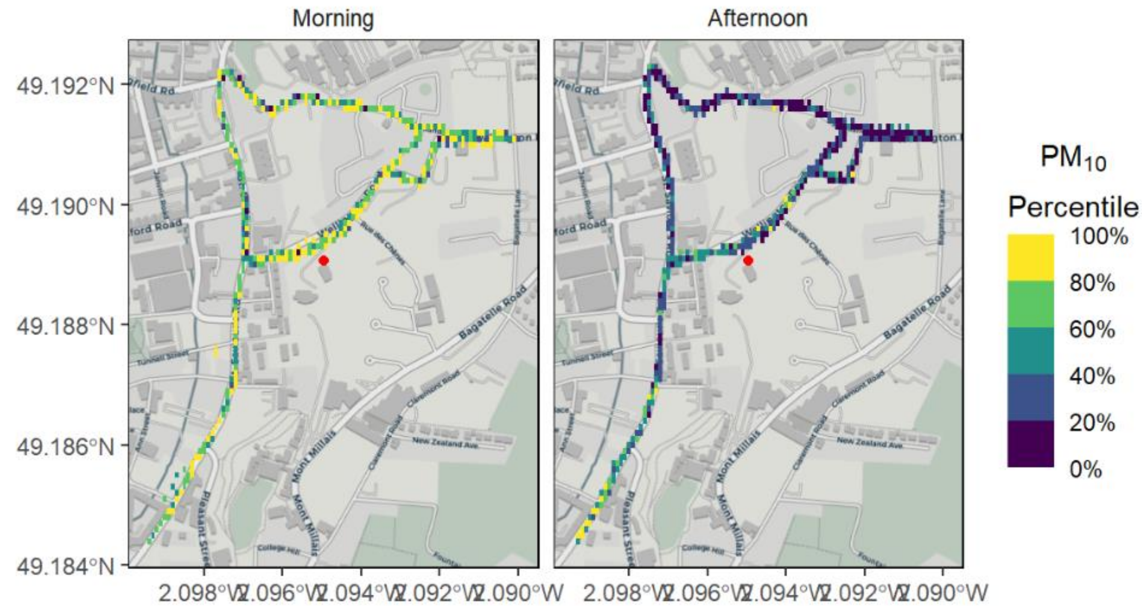

Figure 32: Map showing PM_{10} concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times on Wellington Road

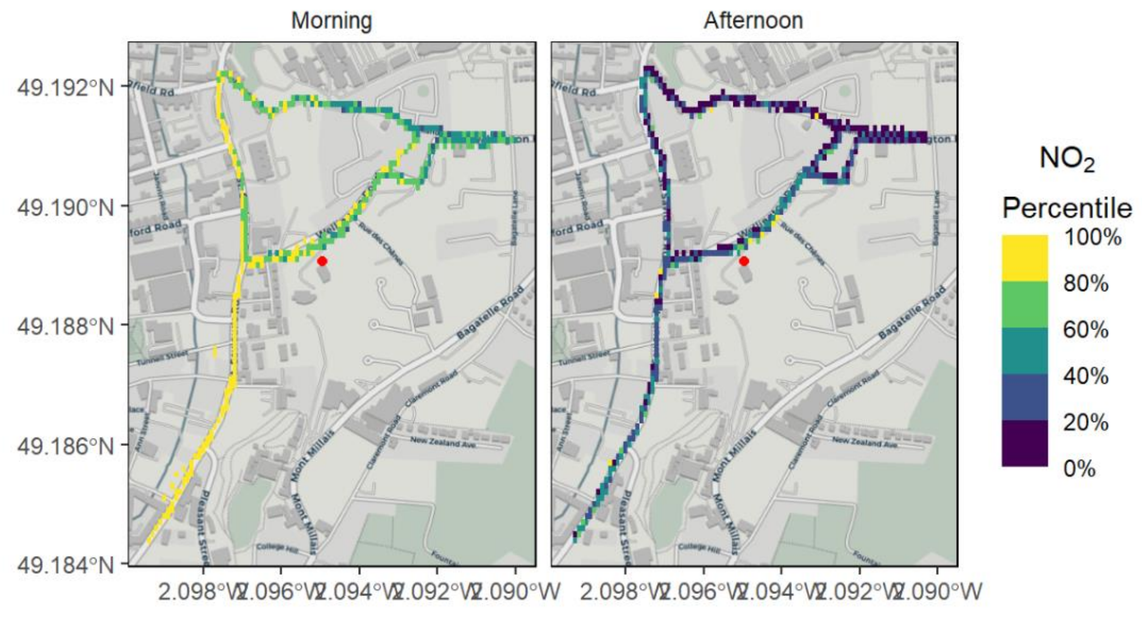

Figure 31: Map showing NO_2 concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times on Wellington Road

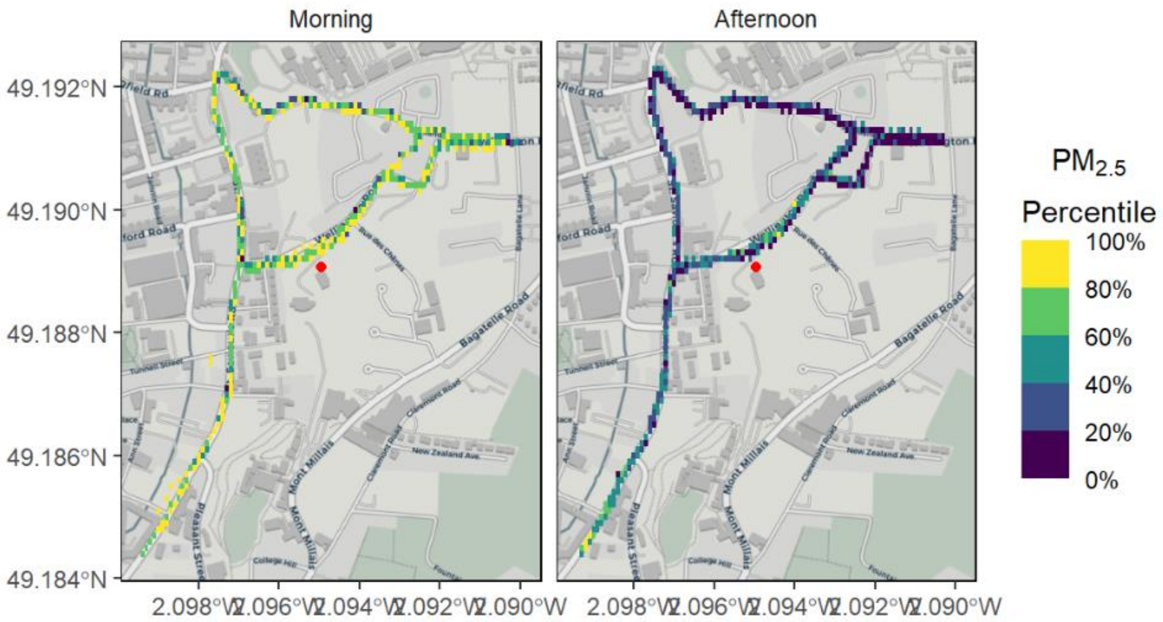

Figure 33: Map showing $PM_{2.5}$ concentrations measured during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times on Wellington Road

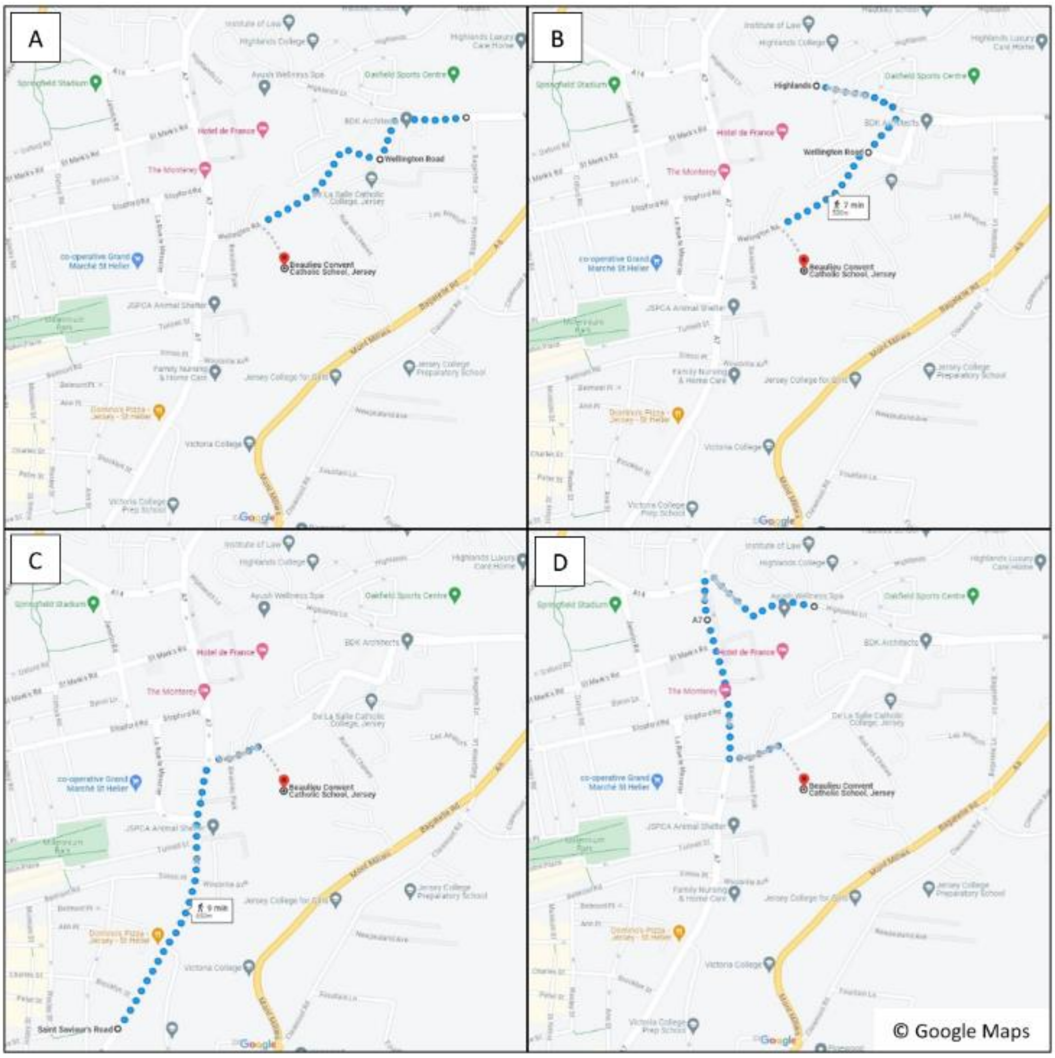

Figure 34: Four popular walking routes around Wellington Road

5.3 St Luke's School Street Pilot Scheme Comparison

The results of the St Luke's School Street Pilot Scheme indicated variable results for changes in pollutant concentrations as a result of the motorised vehicle restrictions implemented. Figure 34 shows the variable results of NO_2 concentrations during the pilot scheme, showing an overall decrease in concentrations on Mondays during the scheme however concentrations remained the same or slightly increased on other weekdays. However, normalised PM data showed a decrease in the frequency of high PM_{10} and $PM_{2.5}$ values when comparing before and during the pilot scheme.

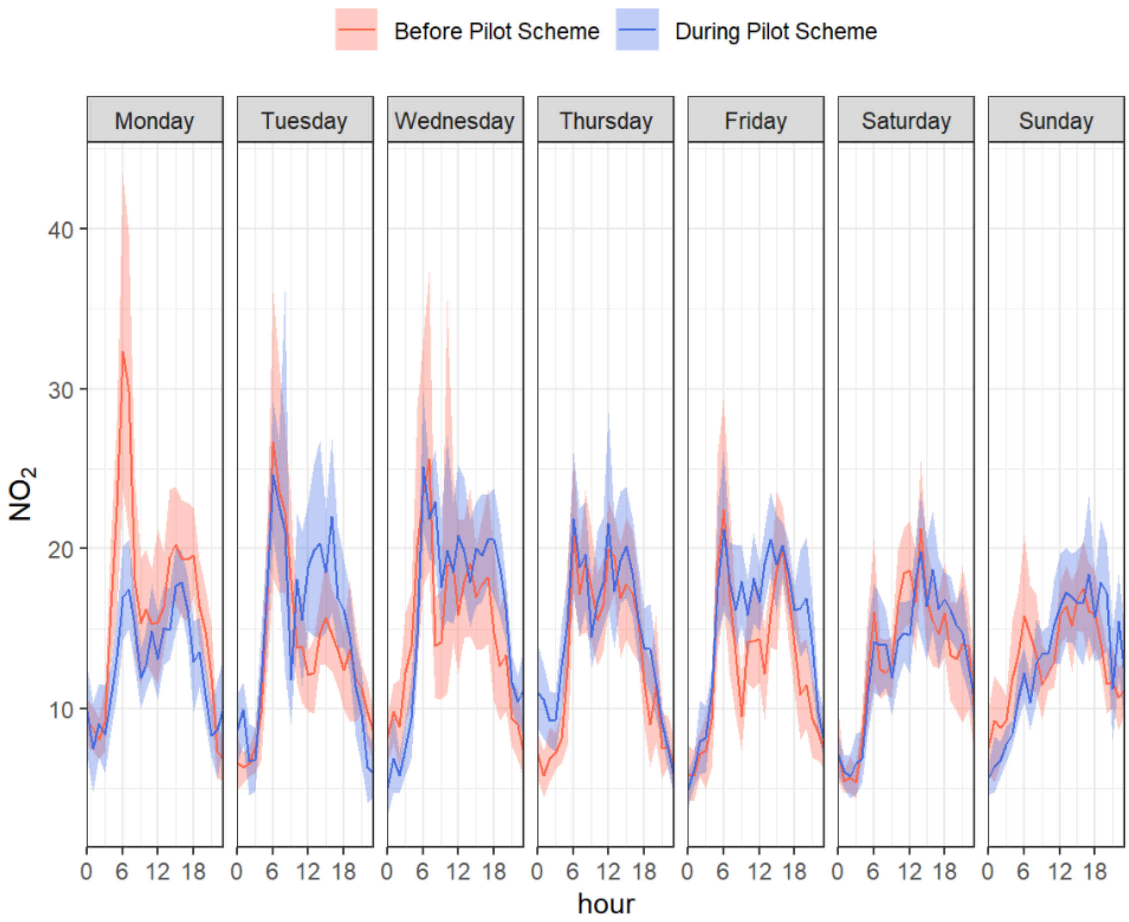

Figure 35: Time Variation plot of NO_2 data measured before and during the school street pilot scheme at St. Luke's School

Figure 35 indicates that overall NO_2 concentrations measured by the Clarity sensor at St Luke's school are lower than those measured by the Vortex sensor on Wellington Road. Therefore, this may indicate that similar restrictions to those imposed during the school street pilot scheme may be beneficial in reducing NO_2 concentrations on Wellington Road.

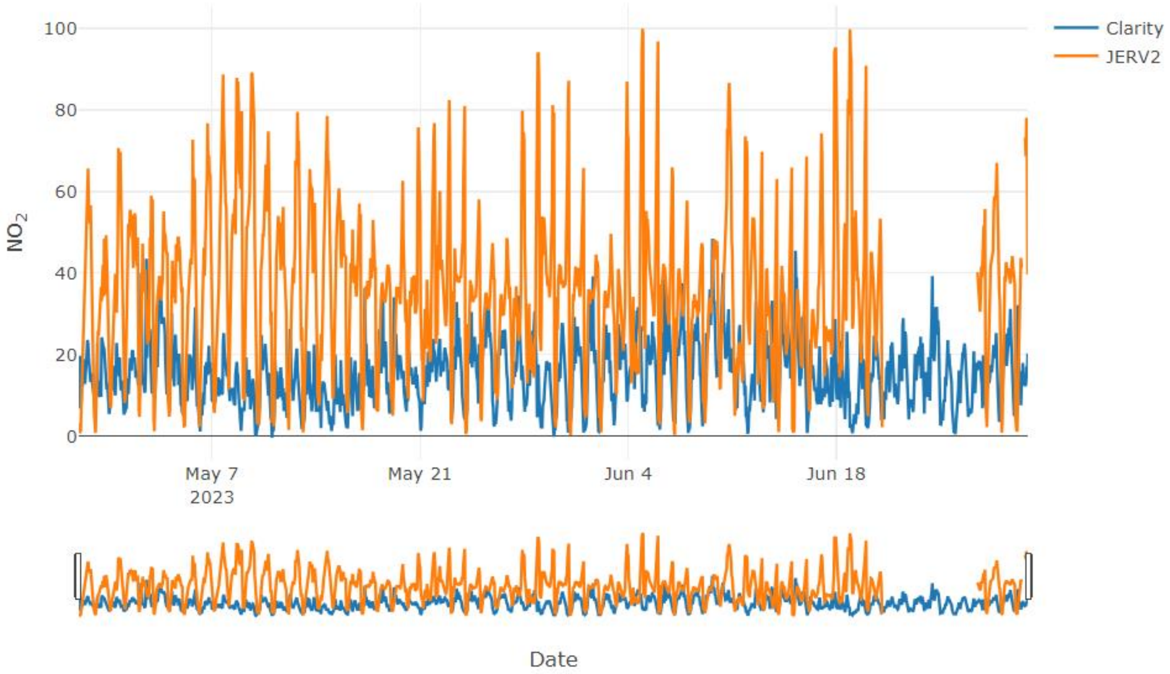

Figure 36: Hourly NO_2 data from Clarity sensor at St Luke's School and Wellington Road for period 28th April to 30th June

The Vortex sensor at Rouge Bouillon School only became operational on 27th June and the Praxis Urban sensor was only operational between 3rd July to 6th July. Therefore, it is not possible to compare these data sets to the Clarity sensor due monitoring periods not coinciding.

It is possible that implementing a restriction on motorised vehicles during school drop off and pick up times may decrease NO_2, PM_{10} and $PM_{2.5}$ concentrations around the monitoring locations. However, as PM is a transboundary pollutant, the closure of streets directly adjacent to schools may not decrease PM concentrations.

6 Conclusions and Recommendations

The Government of Jersey commissioned Ricardo to aid in investigating air quality around Rouge Bouillon School and Wellington Road by providing and reporting the Quality Assurance and Quality Control (QA/QC) services for their air quality monitoring data. This study supplemented Jersey's current air quality monitoring network, with the inclusion of a two static low-cost Vortex IoT - VTAIR sensors, and one mobile low-cost Praxis Urban sensor which measured NO_2, PM_{10} and $PM_{2.5}$.

The two automatic Vortex air quality sensor were installed at Rouge Bouillon School and a location on Wellington Road on 27th April 2023. The mobile Praxis Urban sensor was deployed for four days during the 3rd to the 6th of July 2023; two days of monitoring was carried out at each monitoring location.

The air quality monitoring study consisted of monitoring NO_2, PM_{10} and $PM_{2.5}$ concentrations at Rouge Bouillon School and Wellington Road. The primary aims of this study were to assess whether there are notable changes in air quality during morning drop off (7:30 to 9:30) and afternoon pick up (14:30 to 16:30) times as well as carry out spatial analysis to compare pollutant exposure on main road and back street walking routes.

QA/QC was applied to the Vortex sensors and Praxis Urban sensor data in line with advice published by Air Quality Expert Group (AQEG) on the Defra UK air website (AQEG advice on the use of 'low-cost' pollution sensors - Defra, UK). This included co-location of both Vortex sensors at the nearest automatic site (Jersey Beresford Street) and co-location of the Praxis Urban sensor at London Harlington. The co-location data acquired was then used in orthogonal regression analyses to aid with the calculation of correction factors for each sensor which were then applied to the data collected during this study.

From the Vortex time series analysis of hourly time intervals, concentrations at Rouge Bouillon School are generally lower than those measured at the location on Wellington Road. During the monitoring period, NO_2 concentrations did not exceed the 200 µg m^{-3} hourly limit value outlined by the World Health Organisation (WHO). However, the WHO 24-hour average limit value of 20 µg m^{-3} was exceeded 6 times at Rouge Bouillon School and 91 times at the Wellington Road location during the monitoring period.

The diurnal profiles from the Vortex NO_2 time variation plot for Rouge Bouillon School highlight that diurnal concentrations generally follow the expected trend of a peak at rush hours in the morning, followed by a decrease in the middle of the day and another broader, less pronounced peak during evening rush hours. However, NO_2 concentrations measured on Wellington Road do not follow this trend, showing highest concentrations in the afternoon which may be influenced by idling traffic on the road directly adjacent to this location at afternoon pick up times.

The box plot analysis of Vortex sensor data highlighted that NO_2 concentrations were higher during morning drop off and pick up times at both monitoring locations compared to between drop off and pick up times. At Rouge Bouillon School, NO_2 concentrations show a higher mean value with an increased range and outliers of higher values during drop off and pick up times. However, at the location on Wellington Road, the means of the two datasets were very similar but the range of the data set was greater, and the outliers were higher during drop off and pick up times. Pollution rose analysis has highlighted that elevated concentrations occur at low wind speeds, indicating that the building work currently taking place on Wellington Road are potentially a source of this elevated data.

Normalised PM data from the Vortex sensors showed that there was an overall low frequency of high PM at both Rouge Bouillon School and Wellington Road and raw data from Wellington Road compared well to ratified PM data from the Osiris analyser at Howard Park automatic monitoring site. It is worth noting that during this study, construction work was taking placed on Wellington Road. However, as this took places during the entire duration of the study, any additional particulate matter as a result of the construction can be considered a background influence.

Spatial analysis of NO_2 and PM concentrations at Rouge Bouillon School and Wellington Road indicate highest concentrations were measured along the main road walking routes compared to the backstreet walking routes. For both Rouge Bouillon School and Wellington Road, a pollution hot spot could be identified on the road close to each monitoring location for all pollutants. This is likely caused by a high volume of vehicles passing along this road and also idling whilst waiting along this road during drop off and pick up times.

The future recommendations following this study are;

- Encouraging students to walk to school where possible to reduce motorised vehicle traffic on roads surrounding schools.
- Recommending students walk backstreet routes to school instead of main road routes to reduce exposure to elevated pollutant concentrations and increase student engagement to encourage walking of routes with better air quality where possible.
- Advising vehicle drivers to turn off engines when stationary on roads surrounding schools to reduce emissions from engine idling.
- Continue monitoring air quality at both monitoring locations in all weather conditions to investigate the impacts that weather conditions may have on traffic patterns and therefore air quality around schools.

- Explore the impact of the building work currently taking place on Wellington Road on pollutant concentrations.
- Investigate the possibility of implementing motorised vehicle restrictions along streets outside of Rouge Bouillon School and along Wellington Road during morning drop off times (7:30 - 9:30) and afternoon pick up times (14:30 to 16:30).
- Review school finish times with the aim to spread the traffic burden.
- Assess current school bus fleets and intiate programmes to replace the existing fleets with Euro 6 compliant vehicles.

Due to the proximity of other schools in the area, any mitigations implemented should be done as a collective effort between schools to ensure traffic from the surrounding schools does not reduce the effectiveness of any mitigating actions that are implemented.

7 References

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