Elizabeth St. School Street Pilot Study

Jersey St Luke's Street School Trial

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1 Executive Summary

The Government of Jersey commissioned Ricardo to aid in their School Street Pilot Scheme at St Luke's Primary School in St Saviour by providing and reporting the Quality Assurance and Quality Control (QA/QC) services for their air quality monitoring data.

This study monitored Nitrogen Dioxide (NO_2), Particulate Matter 10 (PM_{10}) and Particulate Matter 2.5 ($PM_{2.5}$) concentrations at St Luke's Primary School for five weeks prior to the implementation of the school street pilot scheme (20th March until 23rd April) and five weeks during the scheme (24th April until 28th May). During the monitoring period, a low-cost automatic Clarity NO_2 and PM sensor was installed outside of St Luke's Primary School on Elizabeth Street and two non-automatic diffusion tubes were deployed, one of which was installed in St Luke's early years playground and the other was installed roadside of Route du Fort, on the exterior of the early years playground perimeter wall.

The objectives of the study were to determine:

i. if the closure of Elizabeth Street during the school street scheme resulted in a reduction in NO_2, PM_{10} or $PM_{2.5}$ concentrations, and if driver attitudes changed after the study, in that Elizabeth Street was travelled less;

ii. if there was any noticeable change in air quality concentrations on the A17 La Route Du Fort during the school street pilot scheme, as potentially more traffic used A17 when they could not travel through Elizabeth Street due to restrictions imposed, and;

iii. if there would be a difference between A17 roadside NO_2 concentrations and in St Luke's playground (closest to A17) to advise whether any mitigation is needed to protect the school's students;

Quality Assurance and Quality Control (QA/QC) was applied to the low-cost sensor and the two diffusion tubes as per guidance from the LAQM.TG(22) and advice published by Air Quality Expert Group (AQEG) on the Defra UK air website.

Results from the NO_2 diffusion tubes indicated that NO_2 concentrations decreased by up to 19.6% during the school street scheme. Further analysis showed that NO_2 concentrations measured in the St Luke's School playground were 41.67% lower than those measured roadside of Route du Fort, indicating the effectiveness of the wall between the playground and the road at reducing NO_2 concentrations. NO_2 concentrations measured at the St Luke's School playground are shown to be below the Air Quality Limit Values and Objectives annual mean of 40 µg m^{-3} but greater than the WHO annual mean limit value of 10 µg m^{-3} during the monitoring period.

NO_2 concentrations measured by the Clarity low-cost sensor show that the WHO NO_2 24-hour mean of 25 µg m^{-3} and hourly mean of 200 µg m^{-3} were not exceeded during the monitoring period. Overall, NO_2 concentrations were shown to decrease during the school street scheme. Analysis of diurnal profiles show that overall NO_2 concentrations were similar or lower at drop off times (07:30 to 09:30) but similar or slightly higher at pick up times (14:30 to 16:30) during the school street scheme. Overall mean NO_2 concentrations decreased by 5.66% at drop off times during the school street scheme and the occurrence of high value outliers decreased significantly. Once outliers were discounted, the range of NO_2 concentrations at drop off times during the school street scheme was smaller and lower which further indicates an overall decrease in NO_2 concentrations. NO_2 concentrations at pick up times during the school street scheme were shown to increase by a small percentage. However, further investigation highlighted a reduced range of values at pick up times during the scheme, when outliers were discounted, which may indicate that there were more frequent low NO_2 concentrations and that the few outliers elevated the overall mean concentration. The overall decrease in NO_2 concentrations during the School Street Pilot Scheme is likely due to decreases in road traffic as a result of the school street scheme. Other factors that may contribute to decreases in NO_2 concentrations include seasonal variation and changes to traffic patterns due to public school holidays.

Raw PM_{10} and $PM_{2.5}$ data measured by the Clarity sensor indicate that PM_{10} and $PM_{2.5}$ concentrations showed an overall decrease during the school street scheme. Investigation of PM_{10} and $PM_{2.5}$ concentrations at drop off and pick up times indicated a slight increase in concentrations. However, further investigation has highlighted that PM concentrations were also elevated during the scheme when the restrictions were not being implemented and some periods of elevated data were also noted during a comparison with the Osiris monitor at Jersey Howard Davis Park. This indicates that elevated data could be a result of other contributing factors in the area or regionally elevated PM due transboundary pollution episodes. Analysis of normalised PM data highlighted a decrease in occurrences of high concentrations of PM_{10} and $PM_{2.5}$ during the implementation of the school streets scheme. This indicates a reduction in exposure to potentially harmful elevated PM concentrations.

The recommendations following the conclusion of this study are:

- Capturing the "after" effects of study to determine if driver attitudes towards Elizabeth Street had changed;
- Continue monitoring data to highlight difference that seasonal variations may cause in pollutant concentrations;
- Encouraging road users to use active travel options such as walking, cycling or using the bus, where possible to reduce pollutant emissions;
- Further investigation to understand if traffic is reducing due to the restrictions or diverting to a different area;
- Undertake a comparative analysis of the results of this study to the traffic data collected independently during the scheme;
- Further monitoring carried out at St Luke's School using a low-cost sensor, focusing in and around the early years playground;

Contents

2 Introduction

2.1 Background

The Government of Jersey commissioned Ricardo to aid in their School Street Pilot Scheme at St Luke's Primary School in St Saviour by providing and reporting the Quality Assurance and Quality Control (QA/QC) services for their air quality monitoring data.

Jersey define a School Street as a road outside of a school with a temporary restriction on motorised traffic access during school term drop off (07:30 – 09:30) and pick up (14:30 – 16:30) times [1]. During these times, the street becomes a pedestrian and cycle only zone with no motorised vehicles permitted unless exempt such as residents, teachers and emergency vehicles. The School Street pilot scheme aims to provide safe walking and cycling facilities to allow children to walk and cycle to school as well as reducing the impact of 'the school run' on the environment including improving air quality. These aims are directly in line with the pledges by the Government of Jersey made in the Common Strategic Policy 2023 to 2026 [2]. More information on the School Street pilot scheme can be found here.

Elizabeth Street, a narrow one-way street outside of St Luke's Primary School, was chosen for the pilot scheme due to concerns over traffic volumes, air quality and safety. The initial scope of the study was to monitor:

- five weeks prior to implementation of the school street pilot scheme (20th March until 23rd April);
- five weeks during (24th April until 28th May);
- and five weeks after (29th May until 30th June).

However, positive public relations of St Luke's school street pilot scheme encouraged the Government of Jersey to extend Elizabeth Street closure until the end of the school term (21st July 2023) (Figure 1), therefore this report details the findings from the initially scoped five weeks prior (20th March until 23rd April) and five weeks during (24th April until 28th May) the school street pilot scheme.

Air quality was assessed before and during the school street pilot scheme through automatic and non-automatic monitoring techniques to assess whether there were notable changes in air quality in and around St Luke's Primary School as a result of the scheme. Further evaluation was carried out in comparison to Air Quality Objectives and, the Daily Air Quality Index. The main pollutants of concern for this study were Nitrogen Dioxide (NO_2), Particulate Matter 10 (PM_{10}) and Particulate Matter 2.5 ($PM_{2.5}$). Traffic data around St Luke's School during the School Street scheme were also collected independently to this study, although this information was outside the scope of this study and therefore has not been included. Further investigation could be made to compare the results of this report to the traffic data collected.

Figure 1. Elizabeth Street Closing Times Sign

2.2 Aims and Objectives

During school drop off and pick up times, it was noted that Elizabeth Street gets congested with traffic, this street is narrow and in close proximity to St Luke's Primary School. Therefore, the Government of Jersey carried out an air quality monitoring study consisting of monitoring 'business as usual' conditions for five weeks before the school street pilot scheme, five weeks during Elizabeth Street road closure and five weeks post scheme to determine:

i. if the closure of Elizabeth Street during the school street scheme resulted in a reduction in NO_2, PM_{10} or $PM_{2.5}$ concentrations, and if driver attitudes changed after the study, in that Elizabeth Street was travelled less;

ii. if there was any noticeable change in air quality concentrations on the A17 La Route Du Fort during the school street pilot scheme, as potentially more traffic used A17 when they could not travel through Elizabeth Street due to restrictions imposed, and;

iii. if there would be a difference between A17 roadside NO_2 concentrations and in St Luke's playground (closest to A17) to advise whether any mitigation is needed to protect the schools students;

These aims will be used to assess the School Street pilot scheme as a whole which will directly support the aims outlined in the Common Strategic Policy, to reduce the effect of the 'school run' on the environment including improving air quality.

In order to carry out this study, a combination of automatic and indicative non-automatic air quality monitoring equipment was utilised (Figure 2). An automatic Clarity Nitrogen Dioxide and Particulate Matter (NO_2/PM) low-cost air quality sensor was installed outside of the school in preparation for the study, on Elizabeth Street, on 27th February 2023. To further investigate the potential change in NO_2 throughout the study, two non-automatic diffusion tubes were deployed in March 2023 for six months; one was installed in St Luke's early years playground (close to the

A17) and the other was installed roadside of Route du Fort, on the exterior of the early years playground perimeter wall. Particulate matter data was also collected from the automatic Osiris monitor at Jersey Howard Davis Park (JER6).

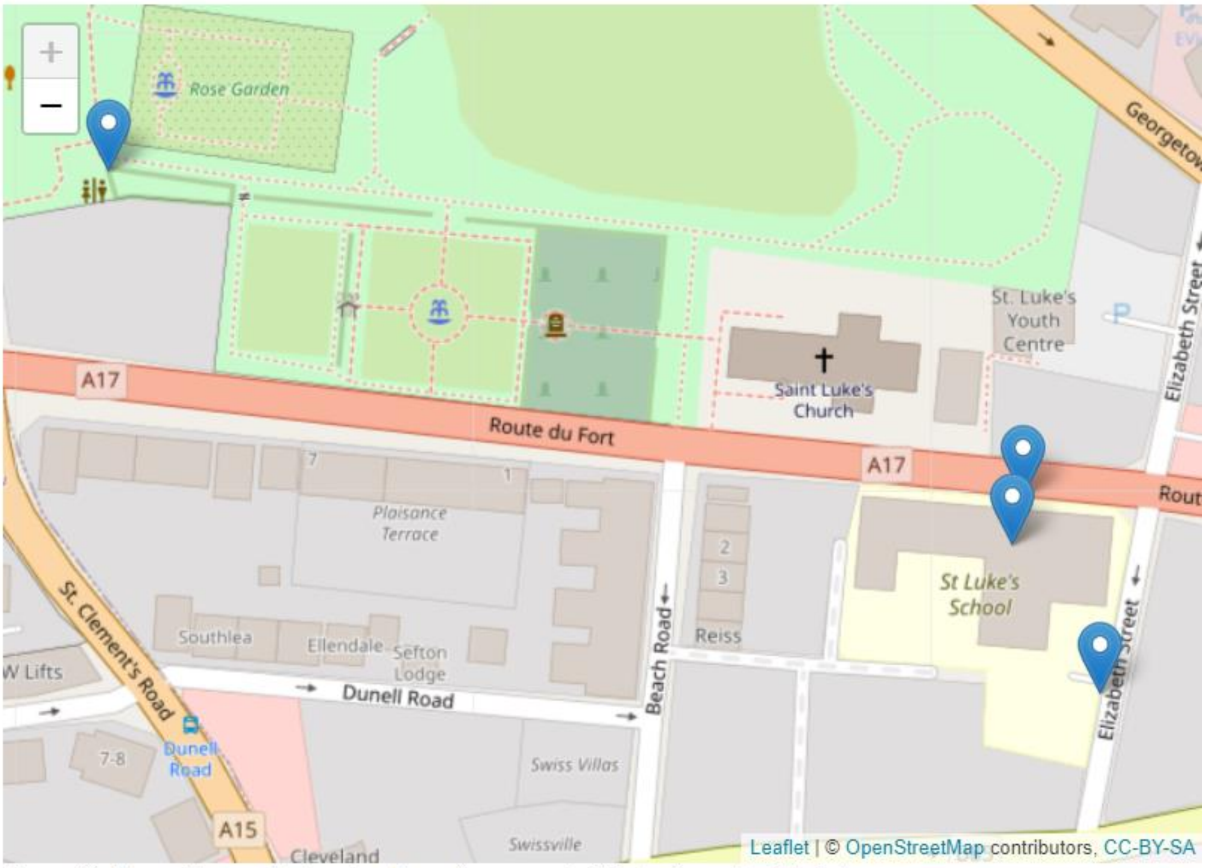

Figure 2. Air quality monitoring locations (hover and click to view site details)

3 Details of the Monitoring Study

For the purpose of this study, the Government of Jersey expanded their longstanding air quality monitoring network, consisting of one automatic NO_2 monitor on Beresford Street and 25 non-automatic NO_2 diffusion tube samplers, to incorporate two additional non-automatic NO_2 diffusion tubes and one automatic monitoring location for NO_2, PM_{10} and $PM_{2.5}$. Jersey also operates a growing network of low-cost air quality sensors, one of which, a Clarity Node-S, has been utilised in this study. Although the Government of Jersey's current air quality network includes a suite of four hydrocarbons (benzene, toluene, ethylbenzene and xylenes), the pollutants are outside the scope of this study and will not be reported.

In addition to the monitoring sites detailed above, the Government of Jersey also run two indicative automatic Osiris particulate matter (PM) monitors on the island, one of which (Howard Davis Park) was utilised in this report (Figure 2).

3.1 Pollutants Monitored

3.1.1 Nitrogen Oxides (NOx)

Combustion processes emit a mixture of oxides of nitrogen - NO and NO_2 - collectively termed NOx. NO is described as a primary pollutant (meaning it is directly emitted from source). NO is not known to have any harmful effects on human health at ambient concentrations. However, it undergoes oxidation in the atmosphere to form the secondary pollutant NO_2. NO_2 has a primary (directly emitted) component and a secondary component, formed by oxidation of NO.

NO_2 can have a wide range of effects on human health, dependent on exposure times and concentrations. Short-term exposure can inflame and irritate airways. In addition, exposure can lead to reduced lung function and increased risk of respiratory illnesses, especially childhood asthma. NO_2 is also involved in the formation of photochemical smog and acid rain and may cause damage to crops and vegetation.

Ambient concentrations of NO_2 are likely to be highest in the most built-up areas, especially where traffic is congested, or where buildings either side of the street create a 'canyon' effect, impeding the dispersion of vehicle emissions. NO_2 concentrations are also likely to drop off with distance from roads.

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

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The term "PM_{10}" is used to describe particles with an effective size less than 10 µm and "$PM_{2.5}$" particles less than 2.5 µm. The main sources of airborne particulate matter in the UK are combustion (industrial, commercial and residential fuel use). The next most significant source is road vehicle emissions. PM concentrations are likely to drop off with distance from roads.

These are of greatest concern with regard to human health, as they are small enough to penetrate deep into the lungs. They can cause inflammation and a worsening of the condition of people with heart and lung diseases. In addition, they may carry surface absorbed carcinogenic compounds into the lungs. Larger particles, meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation.

3.2 Air Quality Limit Values and Objectives

This report compares the results of the monitoring survey with air quality limit values and objectives 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.

3.2.1 World Health Organisation

The World Health Organisation (WHO) issued non-mandatory, advisory, guidelines for a variety of pollutants in 2005 using currently available scientific evidence on the effects of air pollution on human health. New, updated, guidelines were introduced in September 2021 [3] 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}. In light of the growing evidence of harm that PM_{10} and $PM_{2.5}$ can cause the Annual mean limits were reduced from 20 µg m^{-3} to 15 µg m^{-3} and 10 µg m^{-3} to 5 µg m^{-3} respectively.

3.2.2 European Community

Throughout Europe, ambient air quality is regulated by the most recent EC Directive on Ambient Air Quality and Cleaner Air for Europe 2008/50/EC [4]. This Directive (referred to as the Air Quality

Directive) sets limit values, which are mandatory, and other requirements for the protection of human health and ecosystems. Both NO_2 and benzene are covered by this Directive. 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.

3.2.3 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 [5] and its update EU/1480 [6] into UK law. It also placed a requirement on the Secretary of State for the Environment to produce a national Air Quality Strategy (AQS) containing standards, objectives and measures for improving ambient air quality. The original AQS was published in 1997, and contained air quality objectives based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) regarding the levels of air pollutants at which there would be little risk to human health. The AQS has since undergone a number of revisions, and as of the Environment Act 2021 must be reviewed at least every 5 years. These revisions have reflected improvements in the understanding of air pollutants and their health effects. They also incorporated new European limit values, 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 [7]. With the UK's exit from the EU the UK's AQS is no longer tied to that of the EU, however the current objectives are at least as stringent as the EC limit values.

3.2.4 Jersey Air Quality Strategy

The most recent Jersey Air Quality Strategy was published in 2013 [8] and is largely based on the WHO [9], EU[10] and UK [11] policies described above and its limit values are the same. As Jersey is not an EU member state there is no legal requirement to implement the EU Directive however, the Government of Jersey recognise the importance and relevance of the limit values to 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. The Government of Jersey have also published the 'Common Strategy Policy - 2023-2026' in 2022 [12]. This 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' on the environment.

3.2.5 Daily Air Quality Index

As well as the Air Quality Objectives, a Daily Air Quality Index (DAQI) is used to communicate information about current and forecast air quality to the public [13]. The Index is based on a scale of 1-10, divided into four bands (Low, Moderate, High and Very High): this provides a simple indication of pollution levels, similar to the pollen index. Low air pollution is between 1 and 3, Moderate is between 4 and 6, High is between 7 and 9, and Very High is 10 on the scale. This is intended to allow sensitive people to take any necessary action. Figure 3, 4 and 5 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 3. 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 4. 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 5. $PM_{2.5}$ DAQI Banding

3.3 Air Quality Monitoring

3.3.1 Monitoring Sites

This study supplemented Jersey's current air quality monitoring network, with the inclusion of an automatic low-cost sensor, Clarity, for NO_2, PM_{10} and $PM_{2.5}$; and two diffusion tubes for NO_2.

3.3.2 Monitoring Methods

3.3.2.1 NO_2 Diffusion Tubes

Palmes-type diffusion tubes were used for NO_2 (Figure 6). These consist of a small plastic tube, approximately 7 cm long. During sampling, one end is open and the other closed. The closed end contains an absorbent for the gaseous species (in this case NO_2) to be monitored. The tube is mounted vertically with the open end at the bottom. Ambient NO_2 diffuses up the tube during exposure and is absorbed as nitrite. The average ambient pollutant concentration for the exposure period is calculated from the amount of pollutant absorbed.

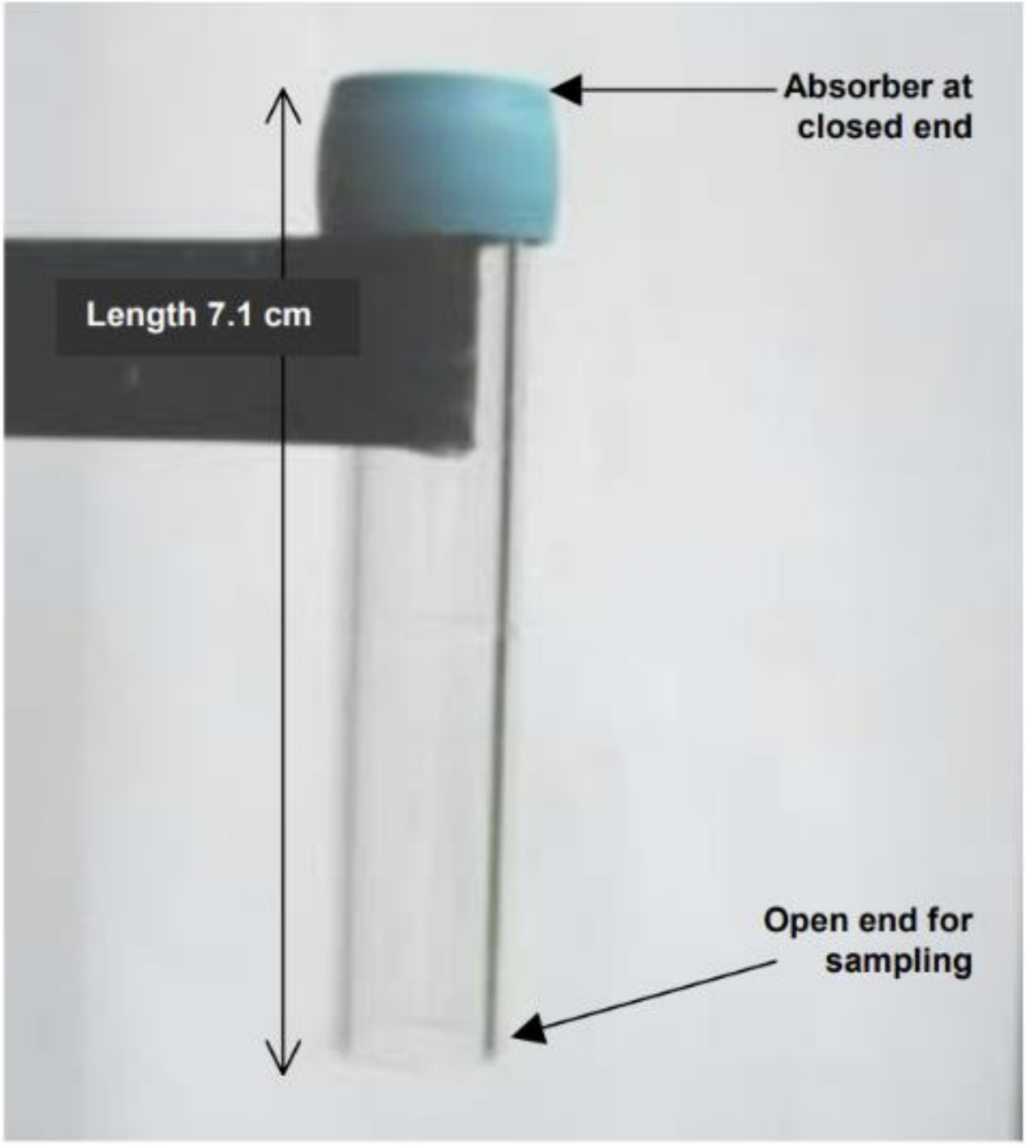

Figure 6. NO_2 diffusion tube

3.3.2.2 NO_2, PM_{10} and $PM_{2.5}$ Automatic Low-cost Sensor

Automatic monitoring of NO_2, PM_{10} and $PM_{2.5}$ was carried out using a low cost sensor known as Clarity Node-S. The Clarity sensor uses laser light scattering with remote calibration to collect $PM_{2.5}$ data and electrochemical cell with remote calibration to collect NO_2 data; noting that PM_{10} measurement data is created from estimate. Once the Node-S samples its first air quality measurements, the data are uploaded via 3G/4G LTE to the Clarity Cloud, where everything is processed and stored. The Clarity monitor used in this study was battery operated, powered via solar panel, and secured to a lamppost on Elizabeth Street outside of the school gates (see Figure 7).

Figure 7. Clarity sensor deployed on Elizabeth Street

3.3.2.3 Automatic Monitoring Stations

Particulate matter concentrations have also been collected using an Optical Scattering Instantaneous Respirable Dust Indication System (OSIRIS) monitor at Jersey Howard Davis Park (JER6) (Figure 8). This long-running automatic monitoring site is located in the Howard Davis Park and classified as an urban background site [14]. The site is 77 metres from the nearest road and 330 metres from the beach at Havre Des Pas.

Figure 8. The Osiris monitor at Jersey Howard Davis Park

4 QA/QC

4.1 QA/QC of Diffusion tube data

Diffusion tubes were prepared and analysed by Gradko International Ltd. They were supplied to the Water and Air Technical Officers of Jersey's Government, via Ricardo, who carried out the tube changing. The tubes were supplied in a sealed condition prior to exposure. After exposure, the tubes were again sealed and returned to Gradko for analysis. The UK Local Air Quality Management Technical Guidance LAQM.TG(22)[15] states that when using diffusion tubes for indicative NO_2 monitoring, correction should be made where applicable for any systematic bias (i.e. over-read or under-read compared to the automatic chemiluminescent technique; the reference method for NO_2). This study utilised the existing co-location diffusion tubes that are co-located with the automatic NO_2 monitoring site at Beresford Street Market, a local bias adjustment factor of 0.75 was calculated. Full QA/QC procedures for the co-location diffusion tubes and NO_2 chemiluminescent analyser can be found in the Annual Reports.

The LAQM.TG(22) states that the diffusion tube NO_2 data should be annualised if the data capture is below 75%. The reason for annualisation is to encapsulate the NO_2 concentrations throughout the year to account for seasonal and meteorological variation and its potential impacts on NO_2 concentrations. As this study was carried out over six specific months the annual data capture is 50%, despite the period data capture (six months) being 100% for each diffusion tube. However, annualisation was not carried out for this study as seasonal variation does not need to be accounted for in this instance.

Diffusion tube precision was assessed throughout this study where the triplicate tubes were sited. The calculated tube precision is presented in Figure 9. All months were classified as having good precision.

Checking Precision and Accuracy of Triplicate Tubes

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Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 μgm^{-3}	Tube 2 μgm^{-3}	Tube 3 μgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean	Period Mean	Data Capture (% DC)	Tubes Precision Check	Automatic Monitor Data
	Diffusion Tubes Measurements									**Automatic Method**		**Data Quality Check**	
1	01/03/2023	05/04/2023	21.4	20.8	21.8	21	0.5	2	1.3	16.9	100	Good	Good
2	05/04/2023	03/05/2023	19.9	20.8	20.4	20	0.5	2	1.1	15.4	100	Good	Good
3	03/05/2023	31/05/2023	18.3	17.6	18.0	18	0.4	2	0.9	14.3	100	Good	Good
4	31/05/2023	05/07/2023	18.8	20.0	19.9	20	0.7	3	1.6	15.0	99	Good	Good
5	05/07/2023	02/08/2023	19.3		19.6	19	0.2	1	1.5	12.6	100	Good	Good
6	02/08/2023	06/09/2023								12.1	100		Good
7													
8													
9													
10													
11													
12													
13													

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

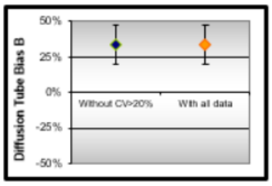
Overall survey --> Good precision | Good Overall
(Check average CV & DC from Accuracy calculations)

Site Name/ ID:

Precision 5 out of 5 periods have a CV smaller than 20%

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 5 periods of data
Bias factor A 0.75 (0.68 - 0.84)
Bias B 33% (19% - 47%)
Diffusion Tubes Mean: 20 μgm^{-3}
Mean CV (Precision): 2
Automatic Mean: 15 μgm^{-3}
Data Capture for periods used: 100%
Adjusted Tubes Mean: 15 (13 - 17) μgm^{-3}

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 5 periods of data
Bias factor A 0.75 (0.68 - 0.84)
Bias B 33% (19% - 47%)
Diffusion Tubes Mean: 20 μgm^{-3}
Mean CV (Precision): 2
Automatic Mean: 15 μgm^{-3}
Data Capture for periods used: 100%
Adjusted Tubes Mean: 15 (13 - 17) μgm^{-3}



Jaume Targa, for AEA
Version 04 - February 2011

If you have any enquiries about this spreadsheet please contact the LAQM Helpdesk at: LAQMHelpdesk@uk.bureauveritas.com

Figure 9. Local BIAS adjustment

A further check of the diffusion tube sampling regime was carried out with the use of a travel blank. The travel blank is a capped diffusion tube that is stored on-site and travels with the exposed diffusion tubes. The travel blank is then used to identify contamination of the samples that could occur during transportation and storage. The travel blanks used within this study showed no significant contamination of tubes during transportation and storage. For this reason, no data have been rejected due to contamination.

4.1.1 Calendar of Diffusion Tube Exposure Periods

The calendar of exposure periods used for the NO_2 is shown in Table 1, as per Defra's recommended exposure periods [16].

Table 1. Diffusion tube exposure periods

Month	Start Date	End Date	Duration (weeks)
January	04/01/2023	01/02/2023	4
February	01/02/2023	01/03/2023	4
March	01/03/2023	05/04/2023	5
April	05/04/2023	03/05/2023	4
May	03/05/2023	31/05/2023	4
June	31/05/2023	05/07/2023	5
July	05/07/2023	02/08/2023	4
August	02/08/2023	06/09/2023	5

4.2 QA/QC of automatic monitoring data

4.2.1 Osiris

Ricardo used their bespoke air quality data management system (MODUS) to manage and process indicative particulate matter (PM) data from the Osiris. MODUS is used by Ricardo across the Jersey air quality network, AURN and multiple other networks.

Ricardo's data management system provided:

• Automatic importing of data from the Osiris.

• Management and processing of raw data.

• Screening and scaling of raw data.

• Statistical analysis.

The Osiris data used in this report have been ratified. Data ratification reviews all calibration data, information from analyser services and repairs and any other information available for the particular site or analyser over the whole ratification period. Once all the ratification checks and corrections have been made then the data are re-loaded with a new status flag of "Ratified".

4.2.2 Clarity

4.2.2.1 Nitrogen Dioxide

Jersey is currently operating a Clarity Node-S air quality sensor which has been co-located with the Beresford Street automatic NO_2 monitoring site. This sensor was selected for this study at St Luke's School due to its ready availability and ease of installation. It was installed outside St Luke's School on 27th February 2023 and used a solar power supply. The time resolution was set to 5-minute intervals.

QA/QC was applied to this 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) and included:

• Co-location of the Clarity sensor at the nearest automatic site, from 01/01/2023 until 26/02/2023.

• The application of an NO_2 correction factor (0.845) to the raw data using the co-location data acquired, orthogonal regression analysis was carried out to help calculate a correction factor.

Figure 10 illustrates a time plot of the Beresford Street (JER08) automatic NO_2 against the NO_2 data from the Clarity sensor (AY8758Z7) during the first co-location. Noting that the Clarity sensor generally follows the automatic NO_2 monitor well and captures the daily peaks and troughs pattern of NO_2 from the local area. Figure 11 shows a positive linear association between the automatic monitor and Clarity co-location data.

A previous study undertaken by Ricardo undertook an assessment of uncertainty (U) of NO_2 measurements for low-cost clarity sensors which indicated that the data quality objective for Class 2 measurements – objective estimation (25% < U ≤ 75%) was met. 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).

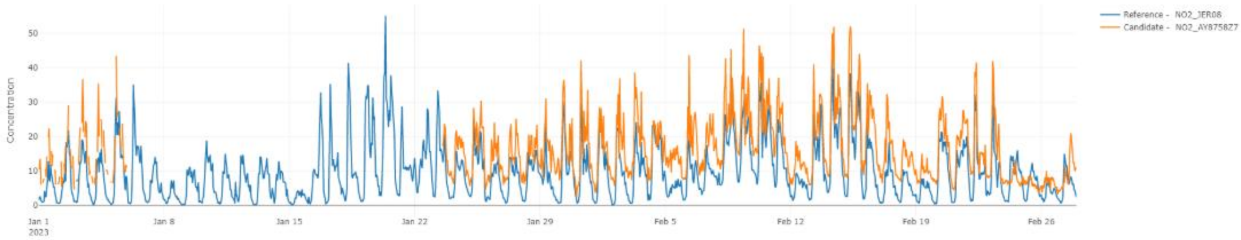


Figure 10. Time Plot

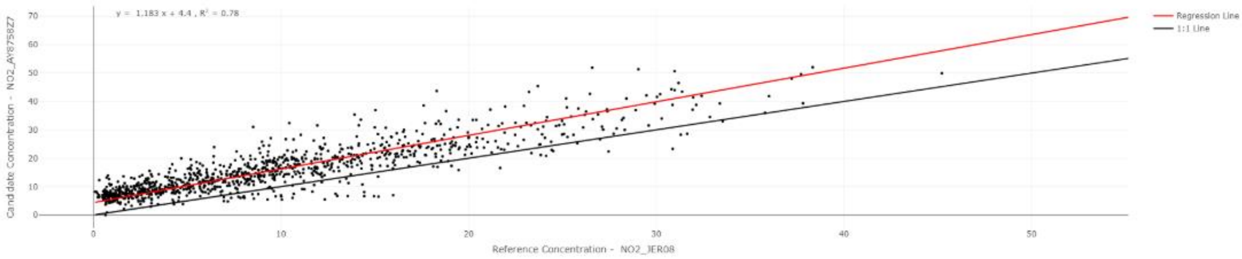


Figure 11. Scatter Plot

4.2.2.2 Particulate Matter

The Clarity sensor also monitors PM_{10} and $PM_{2.5}$, however as there is no reference PM air quality monitor present at Beresford Street, or any other reference PM monitor available, the PM data from the Clarity could not be co-located or ratified in the same way as the NO_2.A previous study undertaken by Ricardo to assess the uncertainty of measurements from a low-cost Clarity sensor could not assess the uncertainty of PM_{10} or $PM_{2.5}$ measurements due to the lack of reference analyser at Beresford Street. However, a comparison to the Osiris monitor at nearby Jersey Howard Davis Park (JER6) indicated that trends in PM data collected by the Clarity sensor are consistent with those measured at the automatic site. Therefore, the data is sufficient to highlight trends and investigate potential sources of pollution.

As the PM data could not be ratified in the same way as the NO_2, a combination of raw and normalised data has been used to allow analysis of trends before and during the school street pilot scheme. Normalisation is a statistical process used to evenly distribute data that was previously unevenly distributed whilst preserving the relationships between the original values. The PM_{10} and $PM_{2.5}$ data has been normalised between 0 - 1 using feature scaling normalisation. Normalised concentrations do provide relevant information regarding concentrations throughout the study.

5 Results and Discussion

5.1 NO_2 Diffusion Tube Results

NO_2 diffusion tube results are presented in Table 3. As previously discussed a bias adjustment factor of 0.75 has been applied to this diffusion tube data. LAQM.TG(22) states that bias adjustment factor should be applied to 'annual mean' NO_2 diffusion tube concentrations, though for this study the diffusion tube data was not annualised and bias was applied when applicable. As a full years worth of NO_2 diffusion data has not yet been captured for this study, the bias adjustment factor is based on the available year to date data (January - July).

Please note that even after application of a bias adjustment factor, diffusion tube measurements remain indicative only. Diffusion tubes are good as they are low cost and can be installed easily, but only provide a monthly snapshot of the air quality concentrations.

The data in Table 2 highlight that the bias adjusted mean NO_2 diffusion tube data collected between January and July 2023 do not exceed the Air Quality Limit Values and Objectives annual mean of 40 µg m^{-3}. It could therefore be extrapolated that it is unlikely that the annual mean will be exceeded in 2023. However, the bias adjusted mean NO_2 concentrations are shown to be higher than the WHO annual mean limit value of 10 µg m^{-3}. Therefore, it could be extrapolated that, in 2023, the WHO annual limit value is likely to be exceeded. All concentrations exhibit a downward trend as the sampling period enters the warmer summer months, where typically concentrations decrease in comparison to winter months due to meteorological conditions.

Table 2. NO_2 Diffusion Tube Results (µg m^{-3}) year to date (*monitoring began in March, **missing on collection)

	January	February	March	April	May	June	July	Raw Mean	BIAS Adjusted Mean
Central Market (1)	20.5	24.3	21.4	19.9	18.3	18.8	19.3	20.4	15.3
Central Market (2)	21.2	24.0	20.8	20.8	17.6	20.0	**	20.7	15.5
Central Market (3)	20.2	23.9	21.8	20.4	18.0	19.9	19.6	20.5	15.4
Playground La Route Du Fort	*	*	24.8	22.2	17.4	20.4	17.6	20.5	15.4
Perimeter Wall	*	*	39.0	37.9	30.4	34.1	34.8	35.2	26.4
Georgetown	33.7	40.5	33.5	33.9	33.5	29.3	27.8	33.2	24.9
Travel Blank	0.2	0.1	0.2	0.0	0.1	0.1	0.2	0.1	n/a

For Table 3, the average NO_2 concentrations from months March and April represent 'before' the school street pilot scheme (20/03/2023 - 23/04/2023) and the average NO_2 concentrations from the months May and June represent 'during' the pilot scheme (24/04/2023 - 28/05/2023), both of which have been bias adjusted using the above factor for any anomalies.

The diffusion tube located roadside of Route du Fort, on the perimeter wall of the early years playground, showed a decrease of 16.1% in bias adjusted period mean NO_2 concentrations when comparing before and during the implementation of the school street pilot scheme. This data indicates that NO_2 concentrations were lower along this road during the pilot scheme. One hypothesis of this study was that whilst Elizabeth Street was closed during the school street pilot scheme, more road users may travel on A17 La Route Du Fort. However, the decrease in NO_2 concentrations indicates that traffic may have also decreased along A17 La Route Du Fort during the school street pilot scheme. Reduced traffic may not be a direct result of the pilot scheme but could be caused by road users opting for more active travel options such as walking, cycling or using buses. It could also be the result of the downturn in road traffic due to the school public holidays, of which there were four days in May and a week for half-term in June [17].

The diffusion tube located in the playground of St. Luke's Primary School, also displayed a 19.6% decrease. Furthermore, the diffusion tube located at Georgetown also showed a decrease of 9.6%. Therefore, it is likely that this decrease in NO_2 concentrations may not be solely as a result of reduced road traffic. Generally, NO_2 concentrations tend to follow a seasonal cycle, with lower concentrations observed in summer and elevated concentrations in winter. This seasonal cycle is typical for urban areas when the highest levels of primary pollutants tend to occur in the winter months, when emissions may be higher, and periods of cold, still weather reduce pollutant dispersion. Therefore, seasonal variations could also be a contributing factor in the decrease of concentrations measured. Further analysis should be carried out to assess the impact of seasonal variations on NO_2 concentrations and if the pilot scheme has continued to impact driver attitude following the school street pilot scheme.

Further comparison of the diffusion tube results inside and outside of the playground highlight the effectiveness of the wall between the playground and Route du Fort road at reducing NO_2 concentrations within the playground. Across the diffusion tube sampling period (March to July), bias adjusted NO_2 concentrations in the playground were 41.67% lower than those measured by the diffusion tube on the perimeter of the playground, roadside of Route du Fort. This indicates that the wall between the playground and Route du Fort road significantly reduces overall NO_2 concentrations in the playground. Mitigation options such as adding a vegetation wall to the top of the existing stone wall may further aid a reduction in NO_2 concentrations in the early years playground.

Table 3. 'Before' and 'During' the school street pilot scheme period mean

Site	Before School Street		During School Street	
	Raw Mean	BIAS Adjusted	Raw Mean	BIAS Adjusted
Playground La Route Du Fort	23.5	17.6	18.9	14.2
Perimeter Wall	38.4	28.8	32.2	24.2
Georgetown	33.7	25.3	31.4	23.5

5.2 Clarity Sensor Results

5.2.1 NO_2

5.2.1.1 Time Series Plot

Figure 12 is a time series plot of the complete ratified Clarity NO_2 data, with the red highlighting the NO_2 data 'before' the school street pilot scheme began and the blue highlighting 'during' the scheme. The NO_2 concentrations measured during this study would not meet the WHO guideline annual mean limit of NO_2 concentrations of 10 µg m^{-3}. However, no data measured during this study exceeded the WHO Air Quality guideline 24-hour mean of 25 µg m^{-3} or hourly mean of 200 µg m^{-3}. NO_2 concentrations also remained in the 'Low' DAQI banding except for on one occasion on 25th April where concentrations peaked at 141 µg m^{-3} at 08:12, into the 'Moderate' band. As previously described within the diffusion tube results, NO_2 data can be influenced by major roads in close proximity to the monitoring location. Therefore, it should be noted that NO_2 concentrations measured by the clarity sensor are likely influenced by traffic on Route du Fort which is 42 metres to the North of the monitoring location.

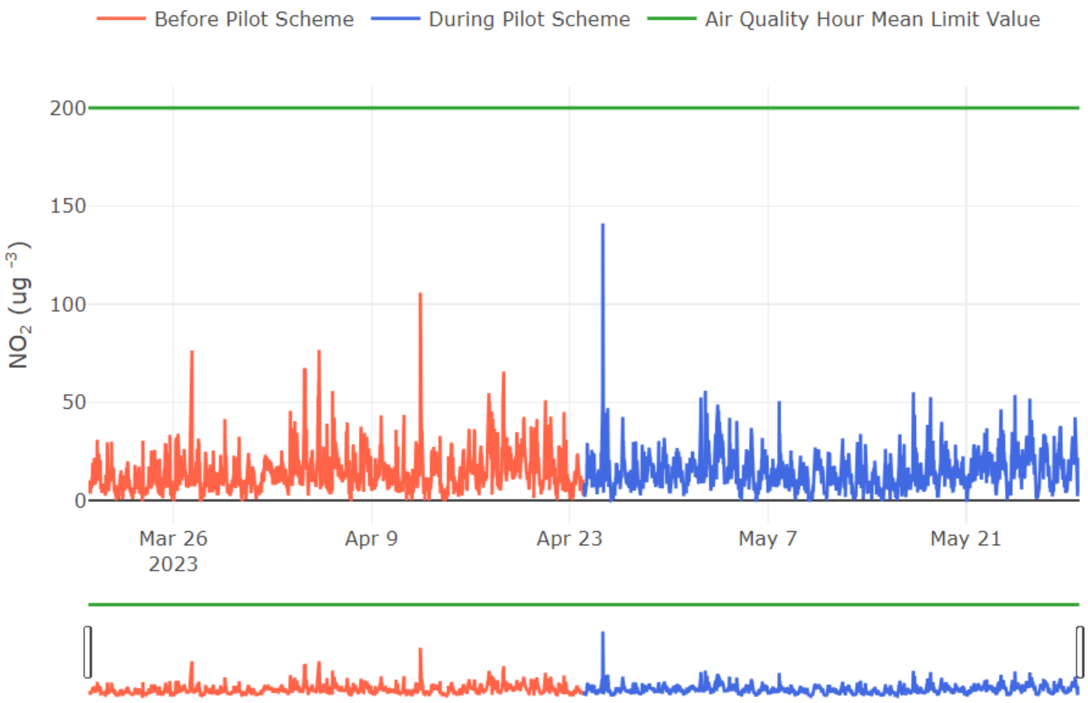


Figure 12. Time series of ratified Clarity NO_2 data

5.2.1.2 Time Variation Plot

The weekly time variation plot shown in Figure 13 illustrates a comparison in diurnal trends in data across the week, before and during the implementation of the school street pilot scheme. In general, weekly time variation plots usually illustrate that NO_2 concentrations are much more pronounced Monday to Friday and overall levels are lower over the weekend, particularly on Sunday when most commercial shops are closed. Concentrations tend to peak at rush hours in the morning, decrease during the middle of the day, then exhibit a less pronounced and broader evening road traffic rush-hour signature from early afternoon. This general pattern is evident in this study.

Overall, the diurnal profiles of ‘before’ and ‘during’ the pilot scheme are similar throughout the week. Data collected on Mondays are shown to be significantly lower during the school street pilot scheme compared to before the scheme between 03:00 and 21:00. On other days of the week, concentrations vary slightly. Generally, NO_2 concentrations during morning drop off times (7:30 to 9:30) Tuesday to Friday are similar between before and during the pilot scheme. Some days are slightly lower, and some are slightly higher. However, NO_2 concentrations at afternoon pick up times (14:30 to 16:30) are higher on Tuesdays, Wednesdays and Thursdays, during the school street pilot scheme compared to before the scheme. This increase in NO_2 concentrations measured at pick up times during the scheme may be attributed to higher background NO_2 levels which may be caused by a variety of factors such as the influx of tourists Jersey receives in summer months. NO_2 concentrations may also be influenced by the traffic on the major road located to the north of the monitoring location.

For the weekend, the school street pilot scheme was not operational, and the concentrations and diurnal patterns are similar in comparison.

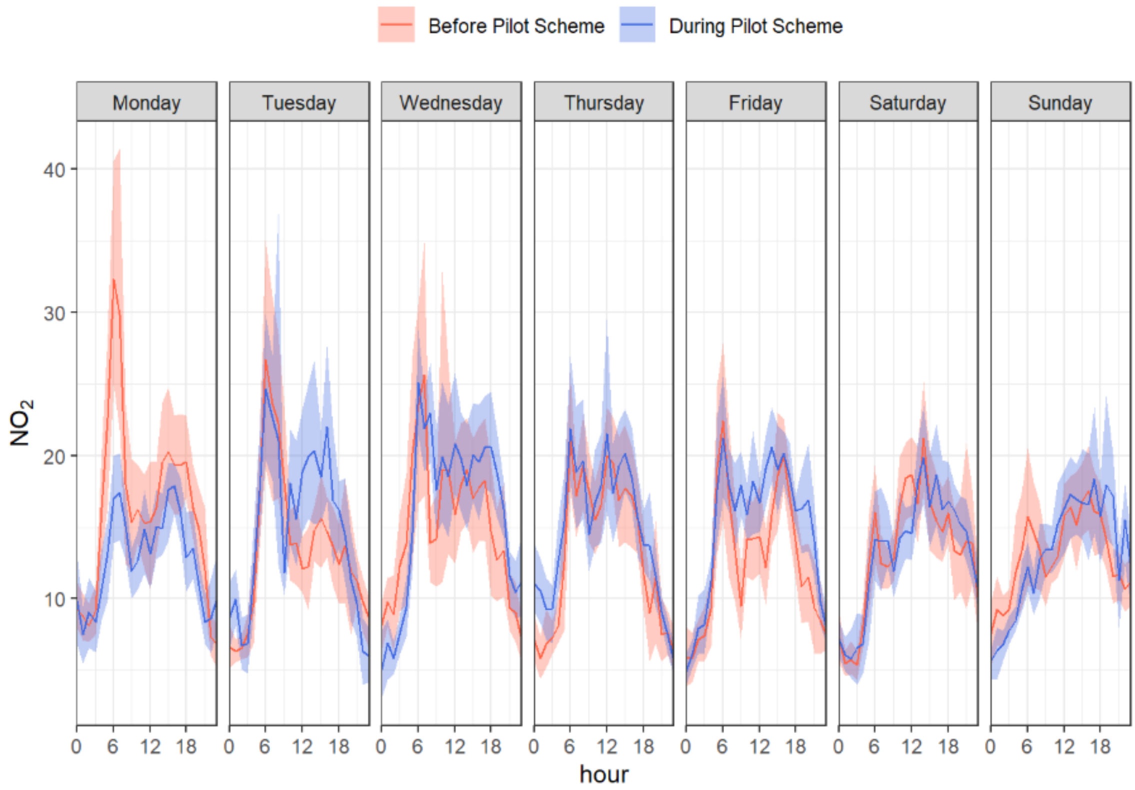


Figure 13. Time variation plot

5.2.1.3 Box Plot

Figure 14 highlights a comparison between NO_2 concentrations before and during the implementation of the school street pilot scheme at drop off (07:30 - 09:30) and pick up (14:30 - 16:30) times. The box plots summarise this data by highlighting the median, mean, distribution and outliers of each dataset. The median value is useful to identify the middle value in the dataset however it can smooth the influence of outliers on the dataset. As a result, mean values of each dataset have been assessed instead to better include the influence of outliers. A statistical analysis was also carried out to assess the statistical significance of difference between the datasets. A t-test was carried out to compare data collected during drop off times before and during this scheme, the results of which are shown below. The probability values (p-values) 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. This indicates that the difference between the results is small and may have been influenced by outliers or sampling errors. If the p-value is less than 0.05 then the difference between the means is statistically significant and therefore is not likely to have been influenced by outliers or sampling errors.

5.2.1.3.1 Drop Off

The mean NO_2 concentrations measured before the implementation of the school street pilot scheme was 16.44 µg m^{-3}, during the pilot scheme the median is shown to decrease to 15.51 µg m^{-3}, which shows a decrease in NO_2 concentrations of 5.66%. 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 5). These results indicate that the difference between the means could be due to chance. However, during the pilot study there are shown to be fewer high value outliers within the data collected where the maximum value measured before the pilot scheme was 76.36 µg m^{-3} compared to during the study where the maximum value is 49.61 µg m^{-3} which further indicates that NO_2 concentrations reduced during the school street scheme. Furthermore, once outliers are discounted, the range of NO_2 concentrations during the school street scheme is smaller and lower further highlighting the overall decrease in NO_2 concentrations during the school street pilot scheme.

5.2.1.3.2 Pick Up

Before the school street pilot study was implemented, the mean NO_2 concentration measured was 18.00 µg m^{-3} which was lower than median concentration of 18.61 µg m^{-3} measured during the scheme, indicating an increase of 3.39% during the scheme. The results of the statistical analysis, shown in Table 5, indicate that the difference between the means of these datasets is not statistically significant and therefore this difference between means may be due to chance. However, further investigation of the distribution of data at pick up times shows that when outliers are discounted, the range of data measured is between 0.39 µg m^{-3} and 37.09 µg m^{-3} which is lower than the range of data collected before the scheme (3.18 µg m^{-3} to 37.84 µg m^{-3}). This may indicate that there are more frequent low NO_2 concentrations during the scheme and that the few outliers are elevating the overall mean concentration.

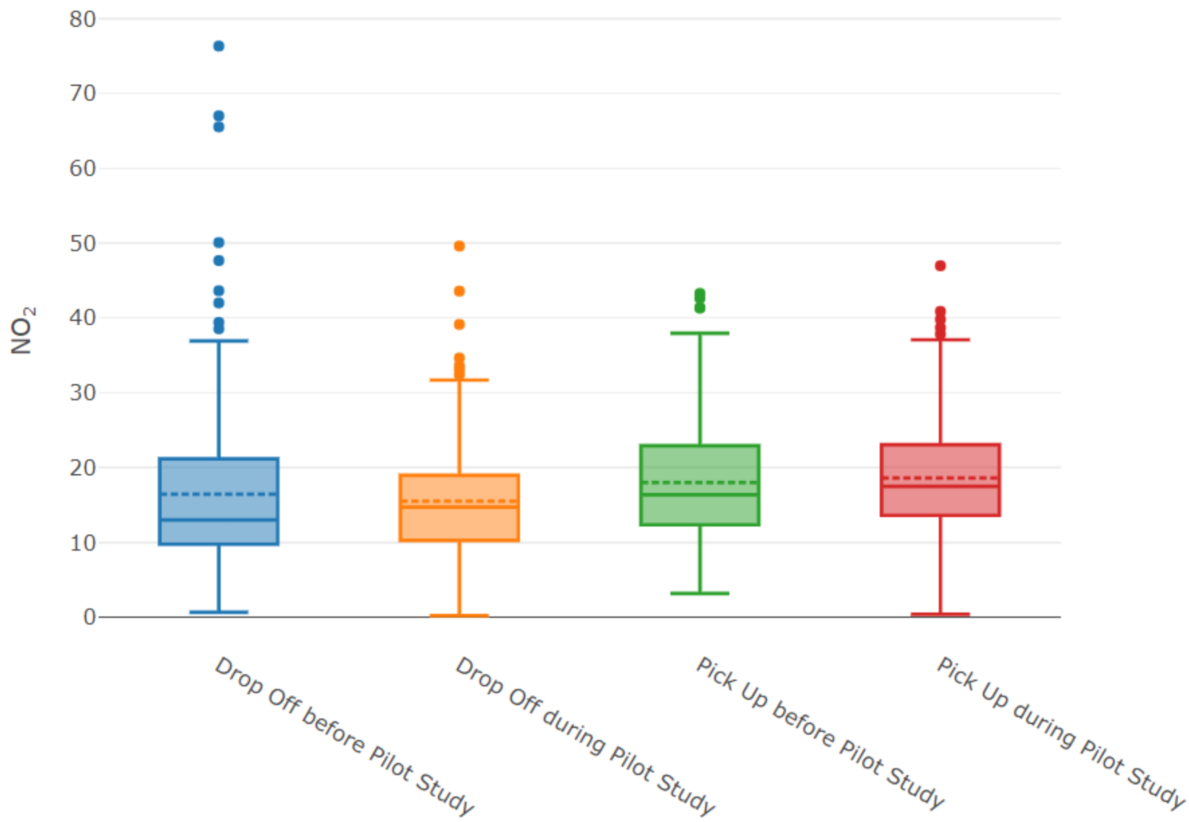


Figure 14. Box plot for drop off and pick up times

Table 4. Mean NO_2 concentrations and percentage change for before and during the implementation of the school streets pilot scheme for drop off (07:30 - 09:30) and pick up (14:30 - 16:30) times.

	Drop Off	Pick Up
Before School Street Scheme	16.44	18.00
During School Street Scheme	15.51	18.61
Percentage Change	-5.66%	+3.39%

Table 5. Results of the t-test for changes in mean values before and during the implementation of the school streets pilot scheme for drop off (07:30 - 09:30) and pick up (14:30 - 16:30) times. A p-value greater than the significance level of 0.05 indicates the difference between the means of the datasets are not statistically significant. If the p-value is less than 0.05 then the difference between the means is statistically significant.

	Drop Off	Pick Up
Calculated p-value	0.252	0.385
Significance level	0.05	0.05

5.2.2 Particulate Matter

As discussed above, the Clarity sensor also monitors PM_{10} and $PM_{2.5}$, however as there is no reference PM air quality monitor present at Beresford Street, or any other reference PM monitor available, the PM data from the Clarity could not be co-located or ratified in the same way. Therefore, a combination of raw and normalised data has been used to allow analysis of trends before and during the school street pilot scheme.

5.2.2.1 PM_{10}

5.2.2.1.1 Time Series Plot

Figure 15 illustrates raw PM_{10} data from the Clarity sensor, highlighting data before and during the school street pilot scheme. A comparison between PM_{10} data from the Clarity sensor and PM_{10} data from the Osiris monitor at Jersey Howard Davis Park (JER6) is shown in Figure 16. The raw data from the Clarity sensor is not directly comparable to ratified data from the Osiris monitor but this comparison is useful to show trends and peaks in both datasets. The PM_{10} data from the Clarity sensor shows periods of elevated data throughout the monitoring period. Several of these elevated periods are also seen in PM_{10} data from the Osiris monitor and are likely as a result of elevated regional PM_{10} data due to a combination of anthropogenic and natural PM sources with the location of the Osiris monitor in close proximity to the coast and within a tree-lined park. Section 3.1.2 of this report describes an expected drop off in PM concentrations with increased distance from roads, which is likely illustrated in Figure 15, where generally PM_{10} concentrations measured by the Osiris monitor are lower than those measured by the clarity sensor.

When comparing PM_{10} concentrations during drop off and pick up times, PM_{10} concentrations increased by 1.14% at drop off times (7:30 - 9:30) during the scheme. PM_{10} concentrations also increased at pick up times (14:30 -16:30) by 6.47%. However, PM_{10} concentrations also increased by 1.74% during monitoring period when the restrictions did not apply. Therefore, this increase in concentrations could be as a result of other PM sources. Particulate matter is a transboundary pollutant (pollutant that can be transported or chemically formed as air masses move from one country to another, not solely from road traffic). There is a potential contribution to particulate matter measurements from transboundary dust, sand and sea salt aerosols. However, the contribution of these particulate types is generally reliant on meteorological factors, in particular, increased wind speeds which are not assessed in this report. It is possible that the overall increase in PM at the Clarity sensor is not linked to the closure of Elizabeth Street but impacted by other contributing factors.

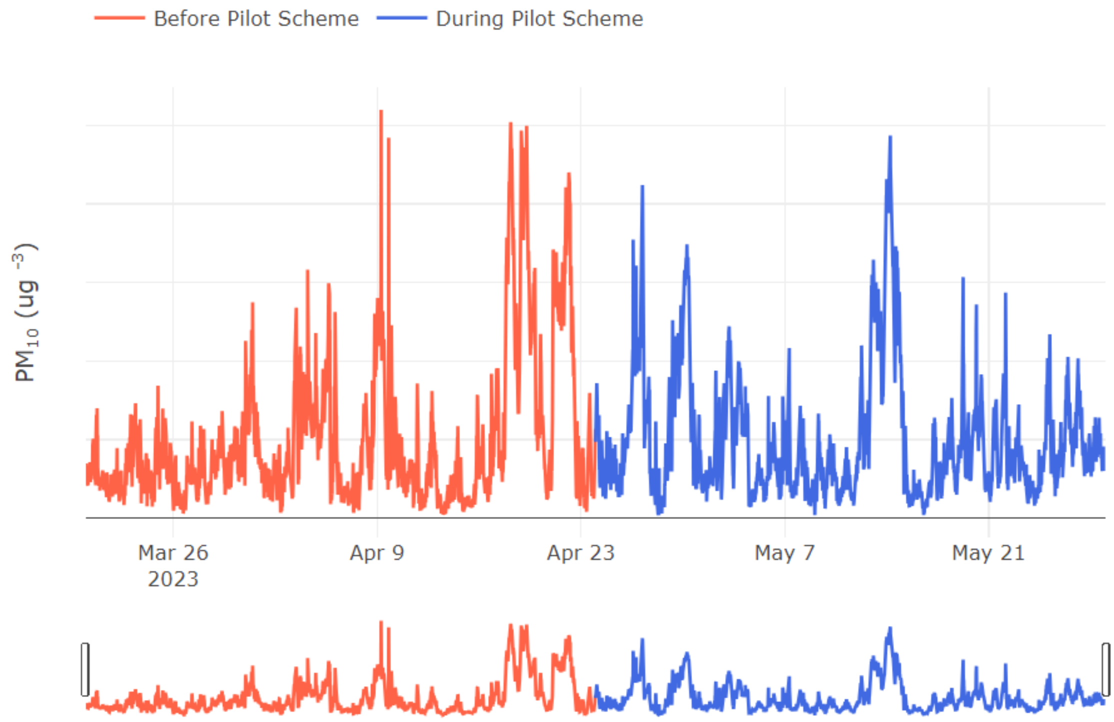


Figure 15. Time series of raw Clarity PM_{10} data

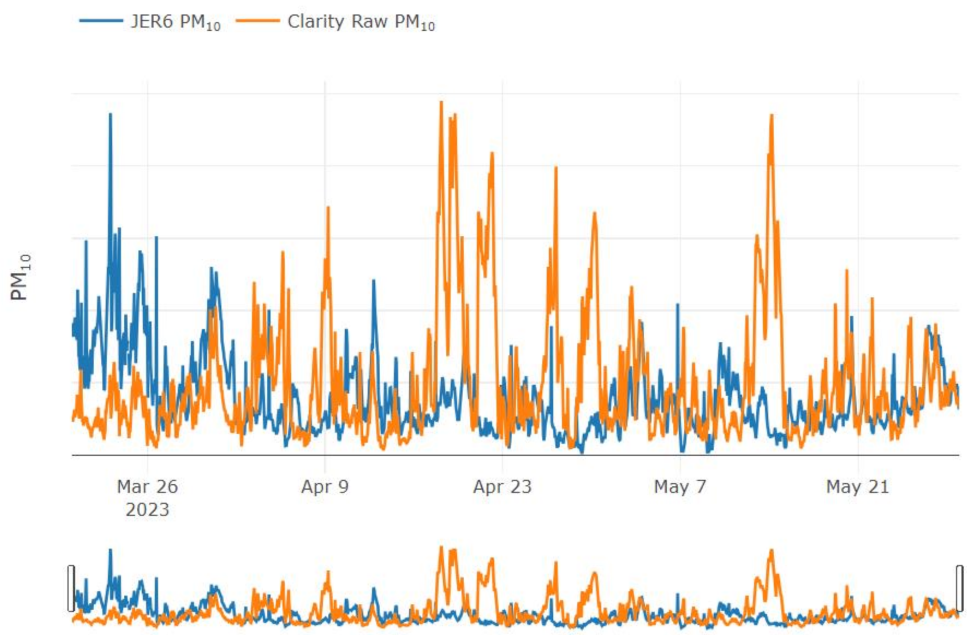


Figure 16. Time series of raw Clarity PM_{10} data and ratified PM_{10} data from the Osiris monitor at Jersey Howard Davis Park (JER6)

5.2.2.1.2 Normalised Data

Normalised data are used here 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'. 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.

Figures 17 and 18 highlight changes in PM_{10} concentrations before and during the school street pilot scheme. Before and during the pilot scheme, the highest frequency of PM_{10} concentrations occurs in the 'low' band. The frequency of PM_{10} concentrations within the 'high' band are shown to decrease by more than 50% during the implementation of the pilot scheme, decreasing from 72 values to 34 values within the 'high' band. Therefore, despite the analysis above showing a small increase in mean PM_{10} concentrations at drop off and pick up times during the school street scheme, the analysis of normalised PM_{10} data indicates that exposure to harmful high PM_{10} concentrations decreases during the school street pilot scheme.

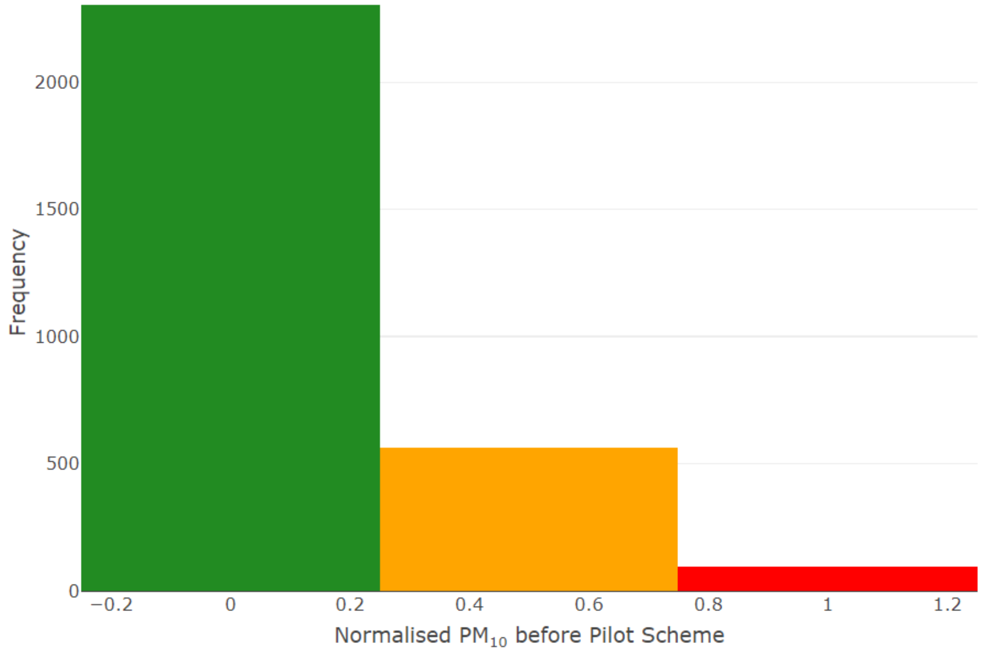


Figure 17. Normalised PM_{10} before the school street pilot scheme showing the frequency of PM_{10} concentrations within indicative 'low' (green), 'moderate' (orange) and 'high' (red) bands

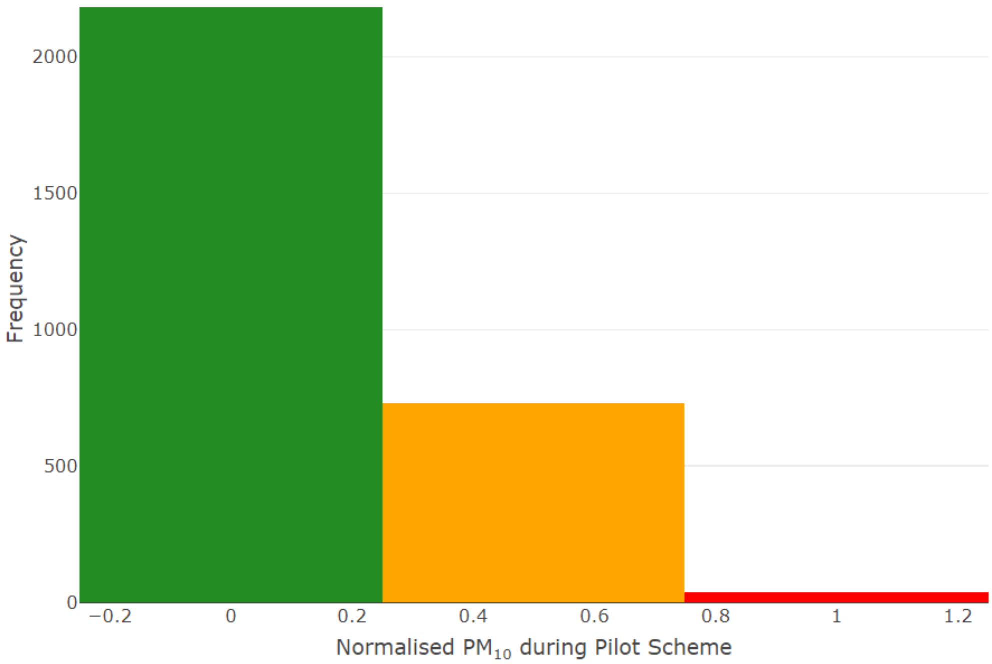


Figure 18. Normalised PM_{10} during the school street pilot scheme showing the frequency of PM_{10} concentrations within indicative 'low' (green), 'moderate' (orange) and 'high' (red) bands

5.2.2.2 $PM_{2.5}$

5.2.2.2.1 Time Series Plot

Raw $PM_{2.5}$ concentrations during the monitoring period are shown in Figure 19. Similar to the trends seen in PM_{10} data measured by the clarity sensor, elevated $PM_{2.5}$ concentrations are shown throughout the monitoring period. The raw data from the Clarity sensor is not directly comparable to ratified data from the Osiris monitor but this comparison is useful to highlight trends and peaks in both datasets as seen in Figure 20. This shows some periods of elevated $PM_{2.5}$ concentrations are seen in both datasets and therefore are likely a result of high regional PM concentrations. Elevated PM may be due to other anthropogenic PM sources or natural PM sources due to the location of the Osiris monitor within a tree-lined park, close to the coast. As expected, $PM_{2.5}$ concentrations measured by the Osiris monitor are lower than those measured by the clarity sensor which is likely due to the drop off in concentrations with distance from road that is described above.

An analysis of $PM_{2.5}$ concentrations measured at drop off (7:30 - 9:30) and pick up (14:30 -16:30) times has indicated that concentrations increased during the school street pilot scheme. $PM_{2.5}$ concentrations are shown to increase by 9.21% at drop off times and 13.37% at pick up times. However, during the monitoring period when the school street restrictions did not apply, $PM_{2.5}$ concentrations also increased by 8.09%. This indicates that the elevated $PM_{2.5}$ concentrations at drop off and pick up times may a result of other $PM_{2.5}$ sources or a transboundary movement of persistent $PM_{2.5}$. As previously described for PM_{10} concentrations, transboundary dust, sand and sea salt aerosols may contribute to elevated PM concentrations, although this contribution is dependent upon meteorological conditions, such as increased wind speeds.

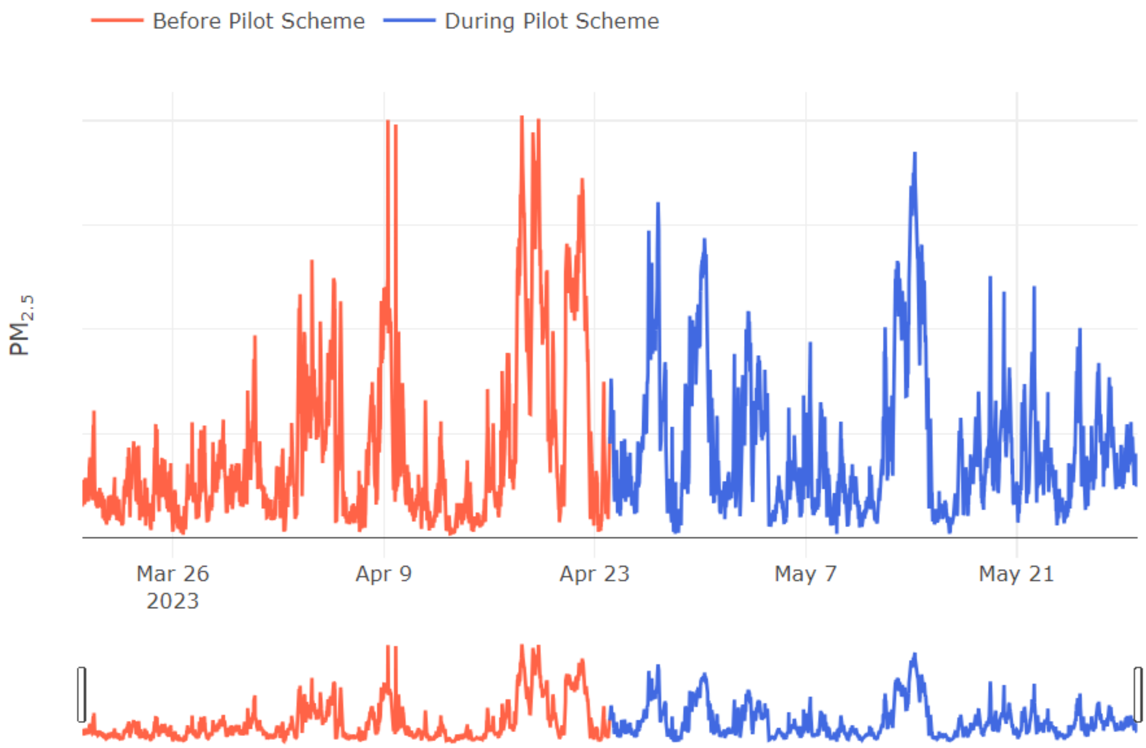


Figure 19. Time series of raw Clarity $PM_{2.5}$ data

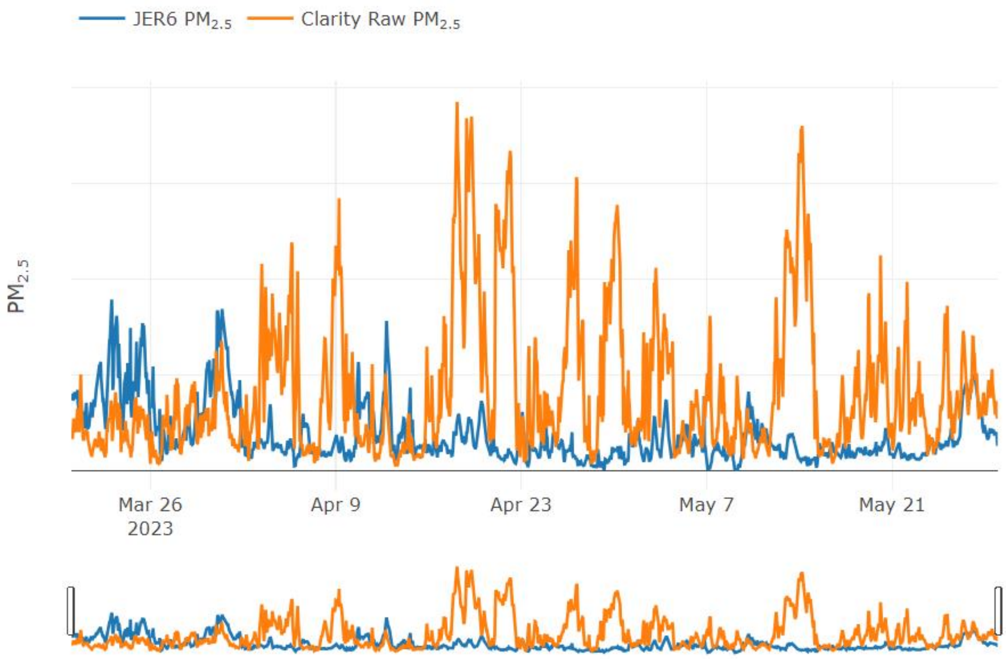


Figure 20. Time series of raw Clarity PM_{10} data and ratified PM_{10} data from the Osiris monitor at Jersey Howard Davis Park (JER6)

5.2.2.2.2 Normalised Data

As described above, frequency of normalised $PM_{2.5}$ data are also shown in Figures 21 and 22. Similar to the trends seen in PM_{10} data, the highest frequency of $PM_{2.5}$ concentrations occurs in the 'low' band for both before and during the school street pilot scheme. The frequency of values in the 'high' band, following the implementation of the school street scheme, decreases from 63 values to 23 values. This indicates a decrease in the highest concentrations of $PM_{2.5}$ during the school street pilot scheme. Therefore, there is a potential reduction in exposure to harmful high $PM_{2.5}$ concentrations during the scheme. Despite the indicated increase in mean $PM_{2.5}$ concentrations at drop off and pick up times during the school street pilot scheme, $PM_{2.5}$ concentrations measured during the school street pilot scheme indicated an overall decrease.

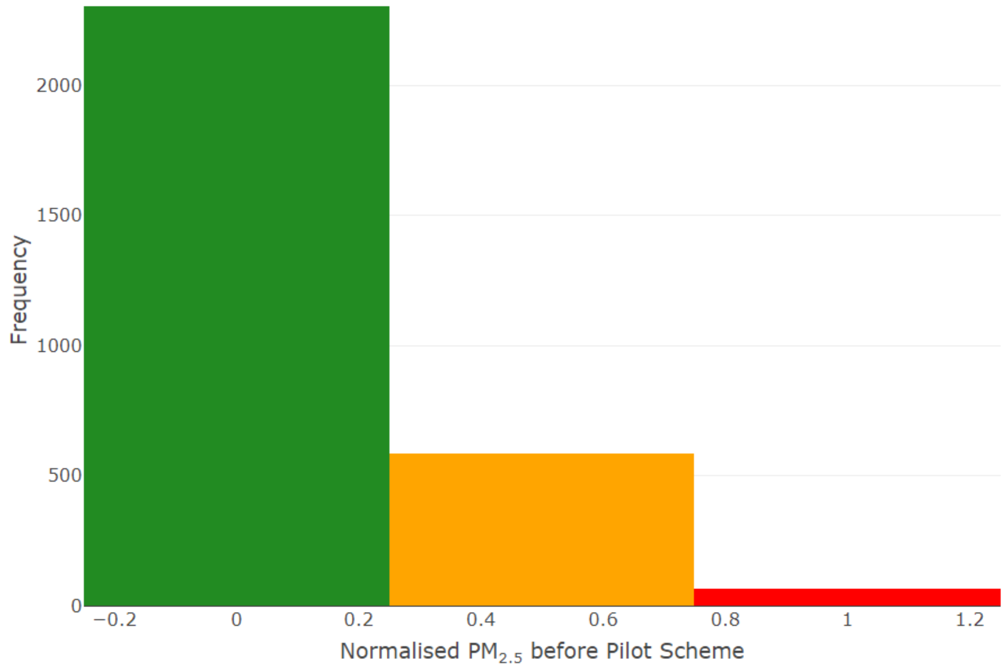


Figure 21. Normalised $PM_{2.5}$ during the school street pilot scheme showing the frequency of $PM_{2.5}$ concentrations within indicative 'low' (green), 'moderate' (orange) and 'high' (red) bands

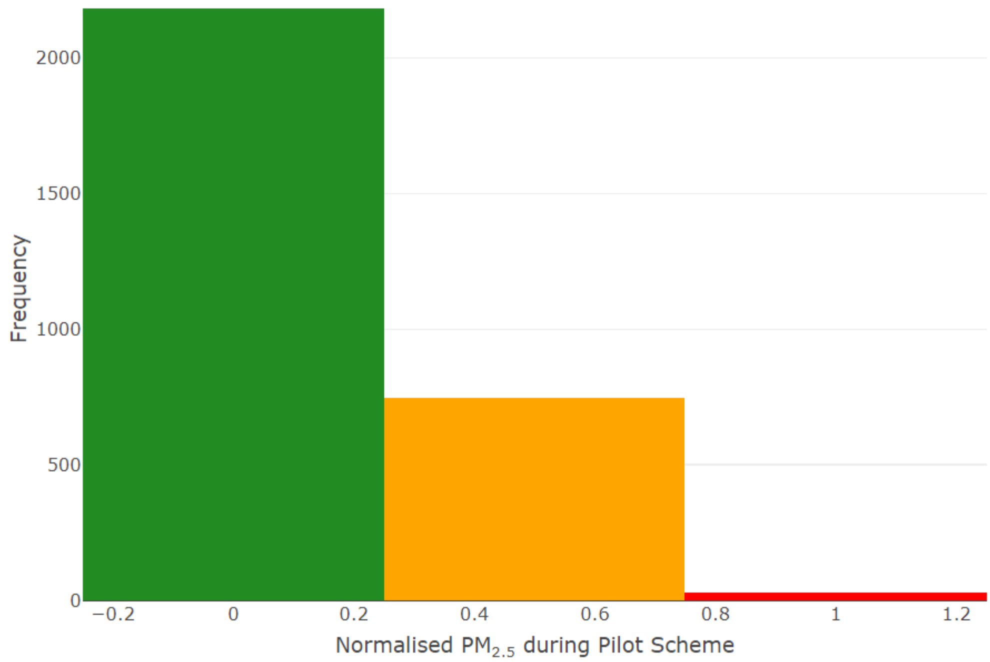


Figure 22. Normalised $PM_{2.5}$ before the school street pilot scheme showing the frequency of $PM_{2.5}$ concentrations within indicative 'low' (green), 'moderate' (orange) and 'high' (red) bands

6 Conclusions and Recommendations

In order to support the School Street Pilot Scheme at St Luke's Primary School, the Government of Jersey commissioned Ricardo to provide and report Quality Assurance and Quality Control services for their air quality monitoring data. With the addition of two NO_2 diffusion tubes and a low-cost Clarity sensor for NO_2, PM_{10}, and $PM_{2.5}$, this study enhanced Jersey's existing air quality monitoring network.

The automatic Clarity Nitrogen NO_2/PM air quality sensor was deployed on the 27th February 2023 outside of St. Luke's Primary School on Elizabeth Street. Furthermore, two non-automatic diffusion tubes were installed in March 2023 for a period of six months. One tube was deployed in St Luke's early years playground, while the other was installed outside the school premises, next to the A17.

The air quality monitoring study consisted of monitoring 'business as usual' conditions for five weeks before the school street pilot scheme, five weeks during Elizabeth Street road closure and five weeks post scheme to determine:

i. if the closure of Elizabeth Street during the school street scheme resulted in a reduction in NO_2, PM_{10} or $PM_{2.5}$ concentrations, and if driver attitudes changed after the study, in that Elizabeth Street was travelled less;

ii. if there was any noticeable change in air quality concentrations on the A17 La Route Du Fort during the school street pilot scheme, as potentially more traffic used A17 when they could not travel through Elizabeth Street due to restrictions imposed, and;

iii. if there would be a difference between A17 roadside NO_2 concentrations and in St Luke's playground (closest to A17) to advise whether any mitigation is needed to protect the schools students;

QA/QC was followed for diffusion tubes as per LAQM.TG(22). A local bias adjustment factor of 0.75 was calculated and applied to raw NO_2 data from the diffusion tubes. QA/QC was also applied to the Clarity 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) and included a co-location of the Clarity sensor at the nearest automatic site and the application of an NO_2 correction factor (0.845) to the raw data using the co-location data acquired, orthogonal regression analysis was carried out to help calculate a correction factor. Particulate matter data measured by the clarity sensor could not be co-located or ratified in the same way as the NO_2 data, therefore a combination of raw and normalised data is used in the analysis of PM concentrations.

NO_2 data from the diffusion tubes indicate a decrease in NO_2 concentrations of up to -19.6% during the school street pilot scheme. This could be attributed to a variety of factors, including a decrease in road traffic due to a change in driver attitudes during the scheme, leading to more active travel options, or a reduction in overall traffic due to school public holidays during May and June. Furthermore, NO_2 concentrations generally decrease during summer months due to changing meteorological conditions, which could also be a contributing factor to this decrease. Furthermore, a comparison between NO_2 concentrations measured in the playground and roadside of Route du Fort road, suggests that the wall between the playground and Route du Fort road reduces overall NO_2 concentrations in the playground by 41.67%.

During the monitoring period, NO_2 concentrations did not exceed the 200 µg m^{-3} hourly limit value or the 20 µg m^{-3} 24-hour average limit value outlined by the World Health Organisation.

Diurnal profiles of NO_2 concentrations measured by the low-cost Clarity sensor highlight a variety of changes in concentrations during the school street pilot scheme. NO_2 concentrations at drop off and pick up times are shown to decrease on Mondays during the scheme. Concentrations throughout the remaining weekdays are shown to be generally similar before and during the scheme at drop off times. However, at pick up times, NO_2 concentrations are shown to be similar to those measured before the scheme or slightly higher. This could be a result of increased background NO_2 concentrations during this time and not a result of the school street pilot study.

A box plot analysis of data before and during the school street pilot scheme was carried out and supported by a statistical analysis of results. This analysis highlighted a small increase in median values at both drop off and pick up times during the school street pilot scheme compared to before the scheme. Mean values at pick up times also showed a small increase of 3.39%.

However, at drop off times mean values decreased by 5.66% and high value outliers also decreased. This indicates that exposure to high concentration peaks in NO_2 decreased at drop off times. Furthermore, the range of values was lower at both drop off and pick up times when excluding outliers. This further indicates a reduction in high and potentially harmful concentrations during the scheme.

Statistical tests were carried out to test the statistical significance of differences between measurement before and during the school street pilot scheme. Both tests identified the difference between means measured before and during the school street scheme at drop off and pick up times were not statistically significant. This indicates that the differences between the results are small and may have been influenced by outliers or sampling errors.

Raw PM data from the Clarity sensor showed elevated periods throughout the whole monitoring period, irrespective of the school street pilot scheme. A further comparison of PM_{10} and $PM_{2.5}$ data against the PM data collected by the Osiris monitor at Jersey Howard Davis Park was carried out. This analysis highlighted that some of these periods of elevated data were also seen at Howard Davis Park and therefore could likely be periods of regionally elevated PM data, possibly caused by transboundary pollution episodes.

PM_{10} and $PM_{2.5}$ concentrations were shown to increase at drop off and pick up times during the school street pilot scheme. However, further investigation has indicated that PM_{10} and $PM_{2.5}$ concentrations were also elevated during this period when school street restrictions were not implemented. Therefore, it is possible that other sources are contributing to elevated PM in the area.

Analysis of normalised PM data highlighted a decrease in occurrences of high concentrations of PM_{10} and $PM_{2.5}$ during the implementation of the school streets scheme. This also indicates a reduction in exposure to potentially harmful PM concentrations.

Overall, the results indicate that pollutant concentrations decreased during the school street pilot scheme, despite some analyses indicating a small increase in concentrations when investigating solely drop off and pick up times.

This study also highlighted potential elevated pollutant concentrations in and around the early years playground at St Luke’s School. A further investigation with a low-cost sensor would give the ability to assess a wider range of pollutants at a higher resolution and further assess the potential elevated pollutant concentrations that children in the early years playground may be exposed to.

Future recommendations following this study:

- Capturing the “after” effects of study to determine if driver attitudes towards Elizabeth Street had changed;
- Continue monitoring data to highlight difference that seasonal variations may cause in pollutant concentrations;
- Encouraging road users to use active travel options such as walking, cycling or using the bus, where possible to reduce pollutant emissions;
- Further investigation to understand if traffic is reducing due to the restrictions or diverting to a different area;
- Undertake a comparative analysis of the results of this study to the traffic data collected independently during the scheme;
- Further monitoring carried out at St Luke’s School using a low-cost sensor, focusing in and around the early years playground;

7 References

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