Air Quality Monitoring of
Barford Village and a quarry

By

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Abstract

This study is in response to concerns about the proposed establishment of a quarry near Barford village, close to Barford Primary School. This work is related to conducting air quality monitoring in this vicinity to establish some background air quality readings and study the effect of quarries on air quality. The selected quarry was randomly selected for the generic study of air quality near quarries and it is independent from Barford village; therefore, the quarry will not be named in this report. The monitoring aims to collect data on various pollutants, including PM10, PM25, NO2, and potentially SO2. The research findings are compiled in this report. This research is expected to provide valuable insights to inform future air quality analysis and any decision-making process.

The data collection and analysis will be carried out by an independent research team from Nottingham Trent University. The data is collected from various locations to provide a comprehensive assessment as follows:

1. Barford Primary School classroom: Air quality monitoring has been conducted at the school in Barford Village. This location is significant as it represents an area where children and staff spend a significant portion of their time. The selected classroom was facing the green fields west of the school.
2. Main Road (Barford Road): Data collection will also extend to a main road in the vicinity within the village. Main roads often experience high levels of traffic and emissions, making them important reference points for understanding the baseline of air quality in the area. The monitoring equipment we used on the west side of the road.
3. Residential House on the village main road (Barford Road): Air quality monitoring will be carried out at a residential house within the area. This aspect of the research will help to assess how nearby residents may be affected by changes in air quality. The house was on the east side of the road.
4. Quarry: because there is currently no active quarry in the area and due to the necessity of such data, the data will be collected from a randomly selected quarry with similar conditions to ensure the realism of the study.

This information will be crucial for comparing air quality near the proposed Quarry near Barford village.

1. Introduction

The quarrying sector holds a significant role in fostering development by ensuring a consistent and sufficient supply of raw materials for construction purposes. However, it also causes a considerable adverse impact on the environment and gives rise to health concerns in nearby areas. Indicators for air pollutant emissions within quarrying sector encompass a range of substances. These, depending on the type of query, include emissions of sulphur oxides (SOx), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), ammonia (NH3), carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), and fine particulate matter (PM2.5 and PM10) (Fugiel *et al.*, 2017).

In Europe, over 2.7 billion tons of aggregates are annually produced across 25,000 quarries scattered throughout the continent. The operation of open-cast quarries has a direct and wide-ranging impact on the environment, particularly on the surroundings (e.g., vegetation and soil), due to its inherently extensive nature (Dentoni *et al.*, 2023).

The United Kingdom ranks among the highest in Europe when it comes to particulate and gas emissions originating from the mining and quarrying sector (Fugiel et al., 2017). Table 1 provides a comparative overview, displaying the percentage of these emissions in the UK in relation to other European countries (Fugiel et al., 2017).

	CO	CO2	PM2.5	PM10	NMVOC	Sox	Nox	NH3	CH4
GG	0.5	0.4	1.3	0.7	0.1	0.2	0.9	0	8.1
CZ	0.8	4.7	4.2	4.1	1.2	2.8	2.6	0	33.5
DK	0.7	2.5	0.4	0.4	5	0.1	0.7	0	1
DE	0.2	1.1	2.4	7.7	0.1	0.7	0.5	0	7.5
ES	1.1	1.1	2.8	3.8	0.8	1.1	1.2	0	1.8
FR	0.1	0.4	2.1	7.9	0.1	0.6	0.6	0	0.1
OT	0.6	0.5	0.4	0.3	0.7	0	0.6	0	1.5
NL	0.2	1.5	0.1	0.1	7.9	0.4	1.2	0	4.9
PL	0.3	0.6	2.2	5.2	2.3	0.2	0.3	0	31.6
FI	0	0.4	0.3	0.6	0	0.3	0.2	0	0
UK	2.4	4.2	2.8	7.4	12.9	1.6	5.6	0	6.6
NO	13.3	26.9	8.8	22.6	35.9	2.2	20	0	15

Figure 1 amount of particulate and gas emissions from mining and quarrying sectors in UK comparing to other European countries (Fugiel et al., 2017).

2. Methodology

The aim of this work is to experimentally monitor air quality in three different locations in Barford village and a fourth location in a randomly selected quarry of similar nature to the proposed one near Barford village. This will allow to establish an understanding of air quality in the village and possible effect of quarries on the local areas.

2.1 Monitoring Equipment.

In this study, Aeroqual devices are utilised, each comprising a logger and a monitoring head. A total of four devices were used, with two dedicated to monitoring particulate matter. These two particulate matter heads were designed to measure both PM10 and PM2.5 levels. The other two heads are to measure NOx and SOx levels, see Figure 2. To ensure a comprehensive data collection, the loggers were programmed to record readings at intervals of every 2 minutes. This setup allowed for the continuous collection of data over a span of several days, ensuring a robust dataset for analysis.

Figure 2: This figure shows some of the divices used in this study.

2.2 Monitoring Devices Setup

Barford Primary School

Two portable air quality monitoring devices, designed to track NO2 levels and particulate matter (both PM10 and PM2.5), have been placed in the school premises in a classroom for a duration of four days. The two monitoring devices are positioned in a classroom with a window that faces in the direction of the planned quarry site as shown in Figure 3.

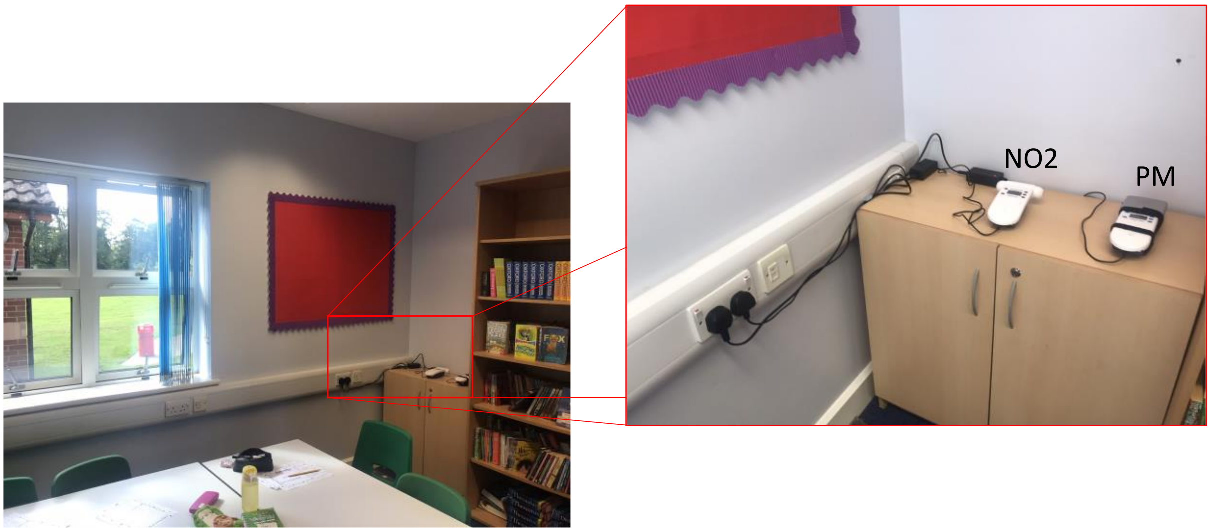


Figure 3: Two Particulate Matter (PM10 & PM2.5) and NO2 monitoring devices in the school.

Main Road (Barford Road)

On the main road of the village, two devices were positioned to measure particulate matter and SO_2 levels. As illustrated in Figure 4, these two monitoring devices were affixed to the roof of a vehicle to capture air quality data as other vehicles passed by. The data was collected from a fixed point, which is believed to be the busiest section of the road.

Figure 4: The two devices on the top of the vehicle to monitor air quality in the main road.

House on Barford Road

A nearby house within the vicinity was chosen for air quality monitoring over a span of several days. This house is situated along the same main road and faces the direction of the proposed Quarry. For this monitoring task, a single device designed to measure particulate matter was installed at the house, as depicted in Figure 5.

Figure 5: The Particulate Matter Device at a Residential house.

Quarry:

To understand the impact of any quarry on the air quality in the surrounding area within wind direction, three portable air quality monitoring devices were employed nearby a randomly selected quarry. The quarry is not named in this report as it is arbitrary selected. These devices were operational during quarry's operational activities in two occasions in two different days. Among the three devices, two were designated for measuring Particulate Matter, while the third was utilized to monitor NO2 levels.

Note: It's essential to maintain the anonymity of the specific quarry being studied in this research, including its location and name, as the study's focus is not on evaluating this particular quarry.

Figure 6: Three air quality monitoring devices used at an existing Quarry.

3. Data Analysis

3.1 Barford Primary School

Data collection at the school covered four days, commencing at 10:00 am on the first day and concluding at 11:00 am on the last day. Figure 7 and Figure 8 display the recorded PM (PM10 & PM2.5) and NO2 data from the school over the four days of the experiment. The figures illustrate a consistent pattern where data recorded during school hours consistently registers higher values compared to non-school hours. This pattern suggests that the increased readings are likely attributed to the presence of students and staff. However, it's important to note that several other factors may be contributing to this phenomenon, including the possibility that doors are frequently open, leading to increased air circulation and, consequently, a higher influx of pollutants into the classroom. Also, the window is normally open during daytime and most likely to be closed at the end of working day for security reasons.

It's evident that most of the readings stay within a relatively stable range, except for an abnormality observed on the third day and partially on the fourth day. Specifically, during a short timeframe between 13:40 and 12:30, a significant and sudden increase in the recorded readings occurred, indicating the presence of an unusual event. However, it's important to note that the fourth day exhibits consistently higher readings across the entire dataset.

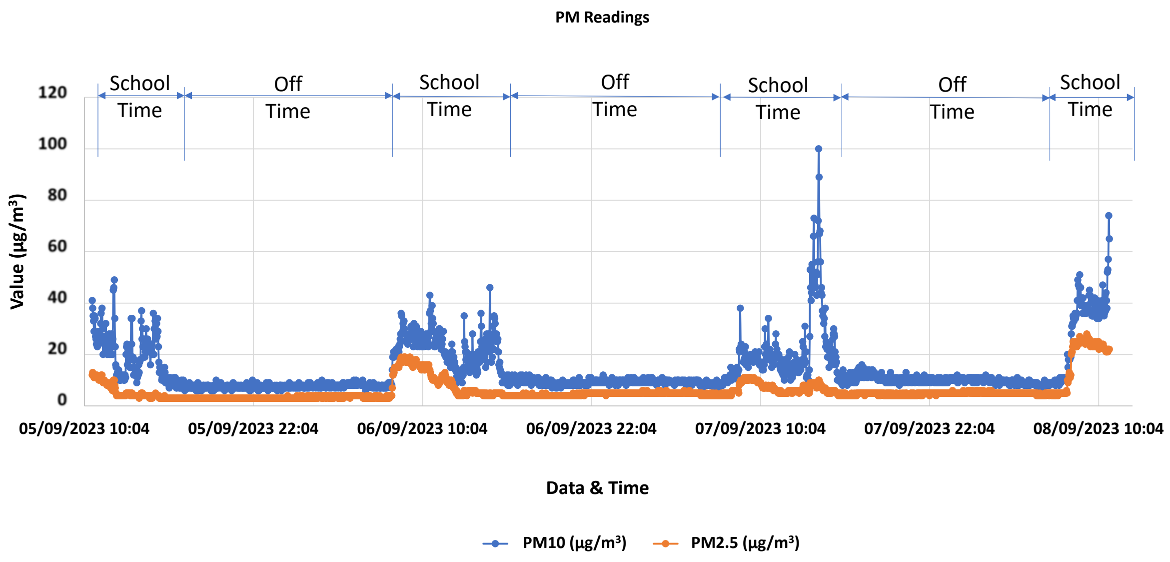


Figure 7: School Air Quality Data - PM10, PM2.5 Over Four Days

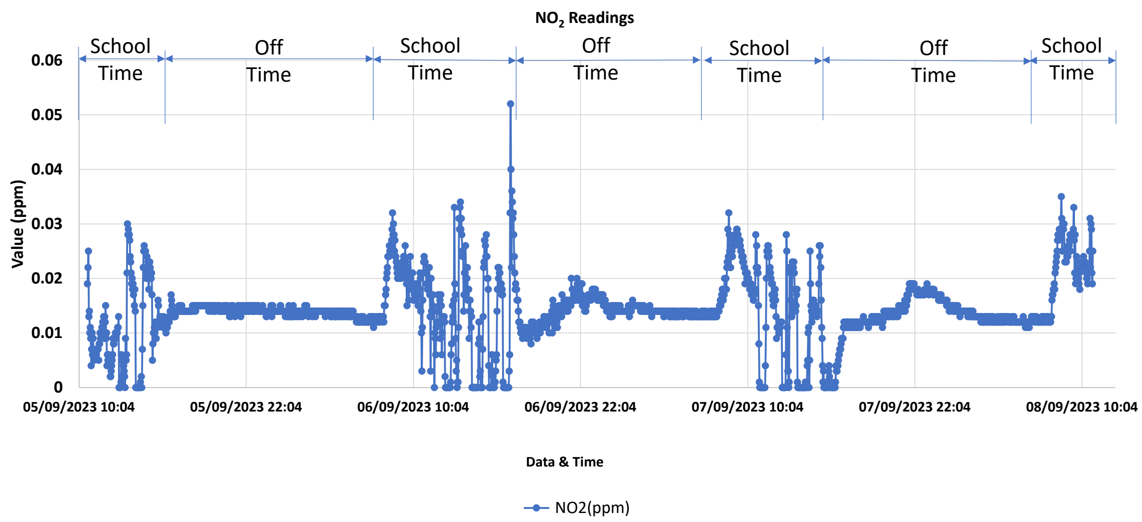


Figure 8: School Air Quality Data - NO_2 Over Four Days

Upon calculating the daily averages, as illustrated in Figure 9 and Figure 10, it becomes evident that the highest levels of air pollution were recorded on the last day confirming the previous observation.

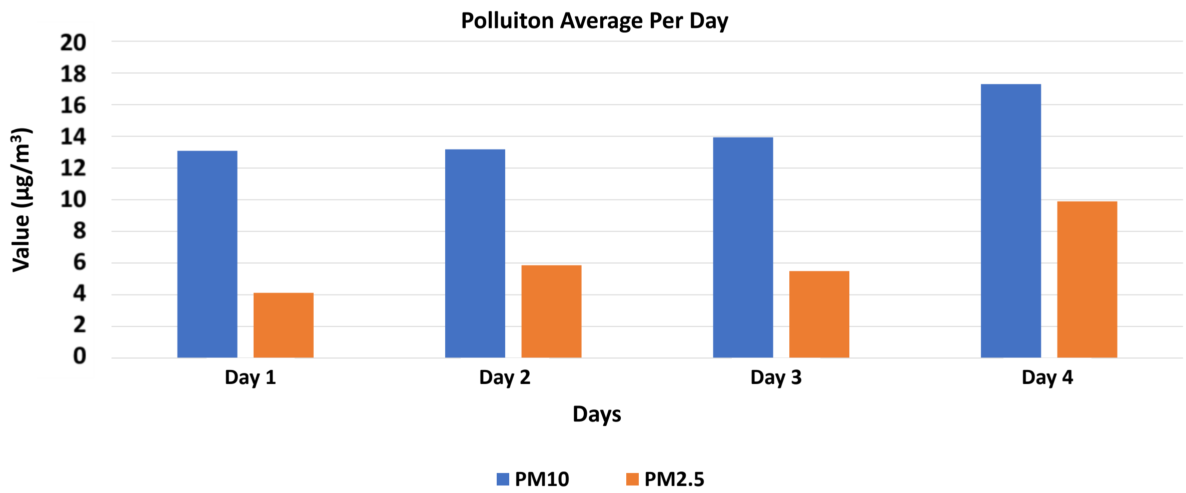


Figure 9: Daily Average Air Pollution - PM10 and PM2.5

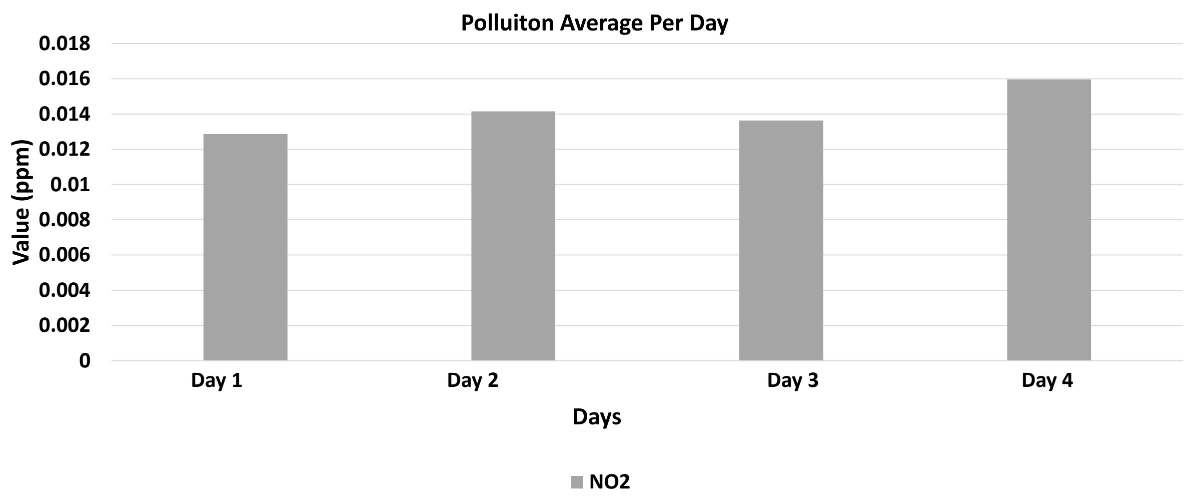
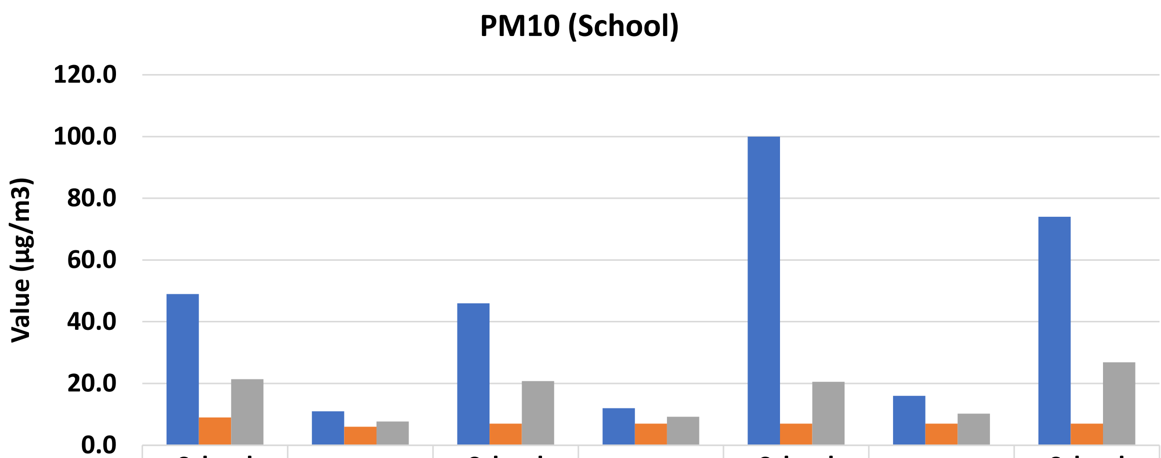


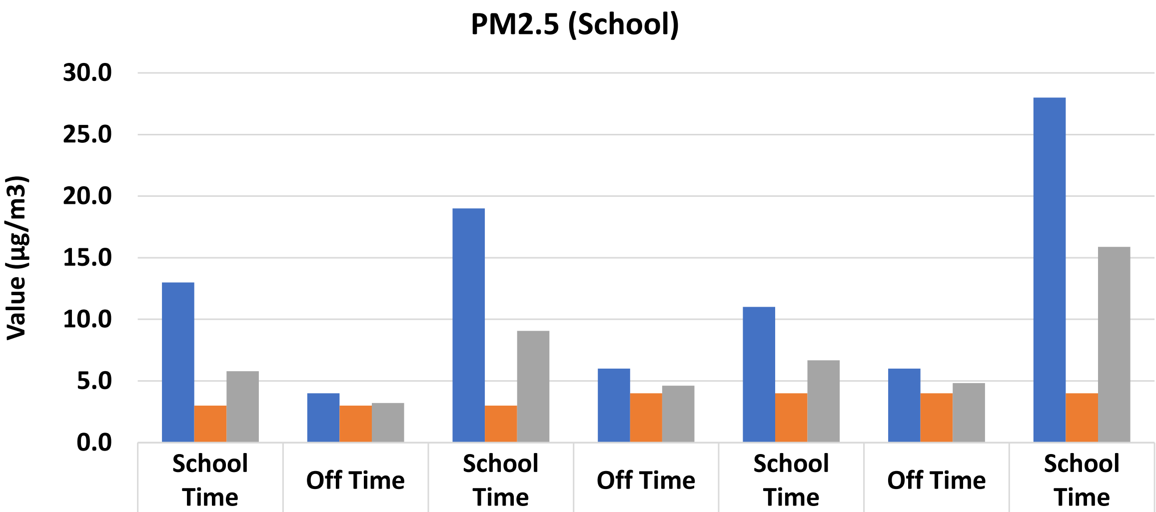
Figure 10: Daily Average Air Pollution - PM10, PM2.5, and NO2

In the two graphs, Figure 11 and Figure 12, the data illustrates the maximum, minimum, and average values for each of the particulate matter components (PM10 and PM2.5). The PM10 graph reveals that the maximum reading occurred on the school time of the third day, while the PM2.5 graph indicates that the maximum reading was observed on the school time of the fourth day. However, the averages for both PM10 and PM2.5 consistently show that the highest average levels were recorded on the school time of the fourth day.



	School Time	Off Time	School Time	Off Time	School Time	Off Time	School Time
Max	49.0	11.0	46.0	12.0	100.0	16.0	74.0
Min	9.0	6.0	7.0	7.0	7.0	7.0	7.0
Average	21.4	7.7	20.8	9.2	20.5	10.2	26.9

Figure 11: Data analysis for PM10 at the school.



	School Time	Off Time	School Time	Off Time	School Time	Off Time	School Time
Max	13.0	4.0	19.0	6.0	11.0	6.0	28.0
Min	3.0	3.0	3.0	4.0	4.0	4.0	4.0
Average	5.8	3.2	9.1	4.6	6.7	4.8	15.9

Figure 12: Data analysis for PM2.5 at the school.

The NO2 data as shown in Figure 13 displays a notable pattern of consistency in readings throughout the monitoring period. However, there is significant variability in readings during school hours, with wide fluctuations observed within the range of 0 to 0.035. The data stabilizes during non-school hours to slightly fluctuate only at values confined between 0.01 and 0.02.

Furthermore, it's worth noting a distinct peak in NO2 levels on the second day, occurring just after school hours at 17:03. This peak indeed appears as a transient event in the data and may be considered an outlier, especially as it did not persist for a significant duration.

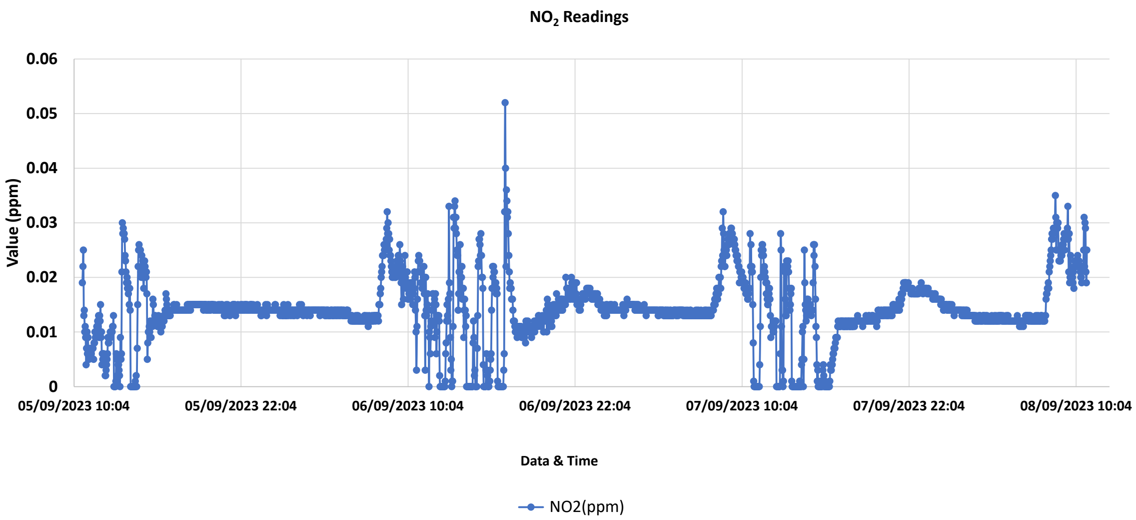
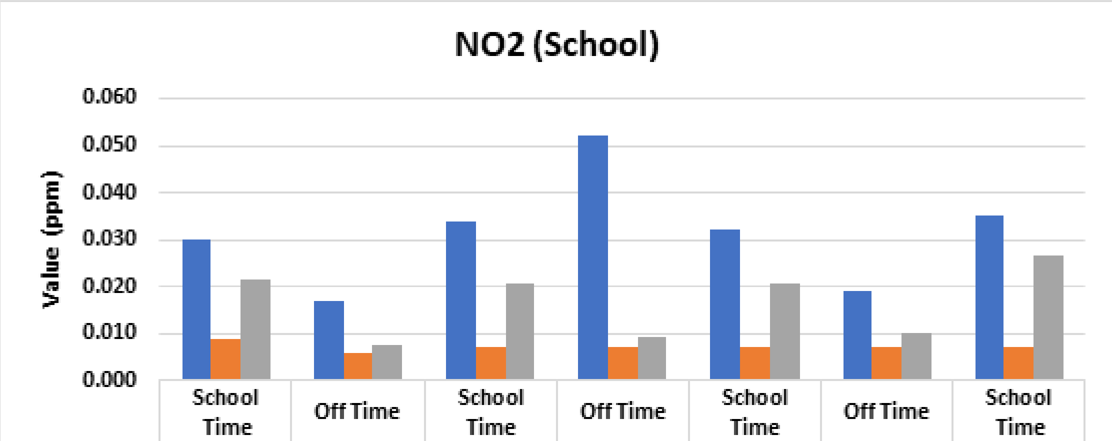


Figure 13: Results of NO2 at the school

Figure 14 effectively illustrates the range of NO2 readings at the school, including the maximum, minimum, and average values. The data indicates overall consistency in NO2 levels across the various periods. However, a notable exception occurs during the off time of the second day, where the maximum value notably spikes upward. As previously explained, this spike corresponds to the transient peak observed on the second day.



	School Time	Off Time	School Time	Off Time	School Time	Off Time	School Time
Max	0.030	0.017	0.034	0.052	0.032	0.019	0.035
Min	0.009	0.006	0.007	0.007	0.007	0.007	0.007
Average	0.021	0.008	0.021	0.009	0.021	0.010	0.027

Figure 14: Data analysis for NO2 at the school.

When visually representing the data in the form of heat maps for the four consecutive days, as displayed in Figure 15 for PM10, Figure 16 for PM2.5, and Figure 17 for NO2, a consistent pattern emerges. It becomes evident that the highest readings consistently align with school hours with higher levels during rush hours, underscoring the impact of school activities and road traffic on air quality during the monitoring period.

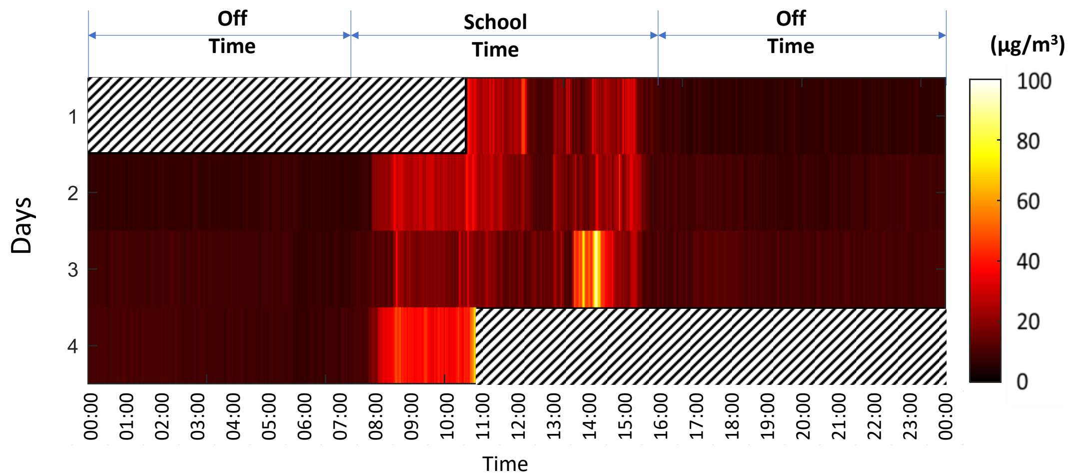


Figure 15: Visual Representation of PM10 Readings at the School.

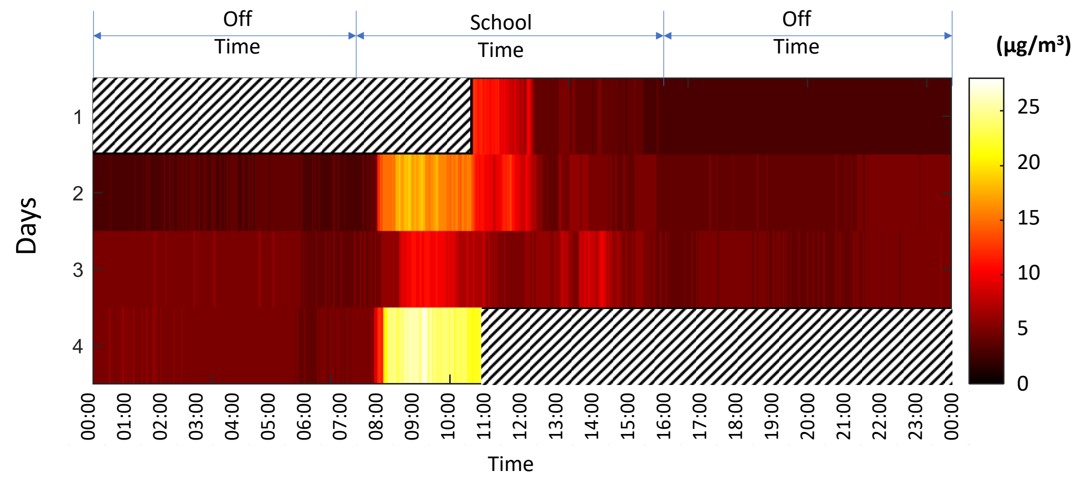


Figure 16: Visual Representation of PM2.5 Readings at the School

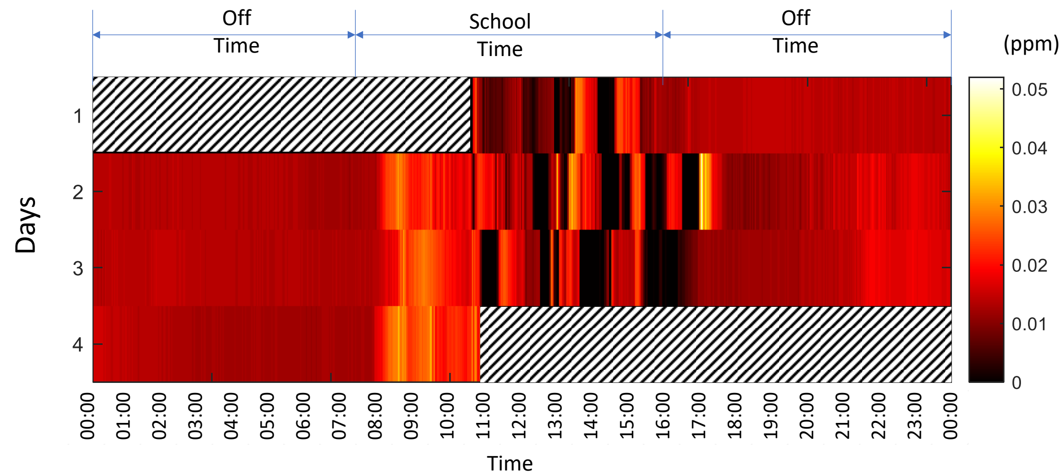


Figure 17: Visual Representation of NO2 Readings at the School

3.2 The House on Barford Road

A house on the main road of the village has been selected to collect air quality data from. The monitoring process ran in parallel with the school monitoring activity and extended over four days as well. It commenced at 13:00 pm and concluded on the fourth day at 12:00 pm. Only particulate matter (PM10 & PM2.5) was monitored at this selected house to measure the impact of traffic from the main road on air quality of the house.

As shown in Figure 18, the collected data covers the entire designated time span. The data does not exhibit a uniform pattern; however, it does reveal higher readings during the daytime. it is obvious that there are occasional spikes occurring during the daytime in the data, suggests that the traffic on the road may indeed be influencing the air quality around the house, leading to increased particulate matter levels during daytime hours.

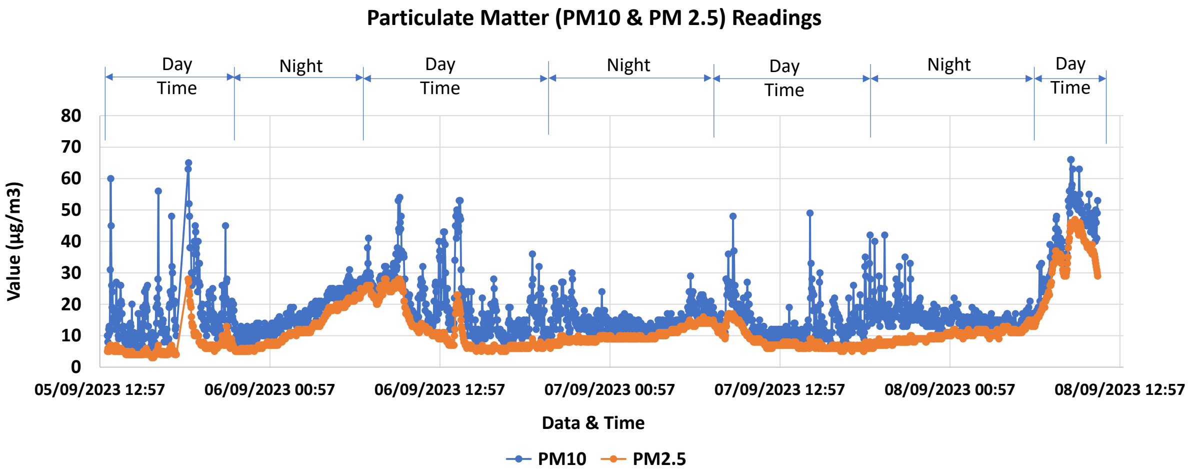


Figure 18: The house Air Quality Data - PM10 and PM2.5 Over Four Days

Upon calculating the averages for both PM10 and PM2.5, it becomes evident that the fourth day exhibits higher levels of particulate matter. Furthermore, a closer examination of the data reveals that for PM10, the minimum reading occurred on the third day at 15.0 µg/m^3, while the maximum was recorded on the fourth day at 25.0 µg/m^3. In the case of PM2.5, the minimum reading was observed on the first day at 6.0 µg/m^3, and the maximum reading occurred on the fourth day at 19.0 µg/m^3.

These variations highlight the fluctuations in particulate matter levels throughout the monitoring period, with the fourth day consistently showing higher levels in both PM10 and PM2.5.

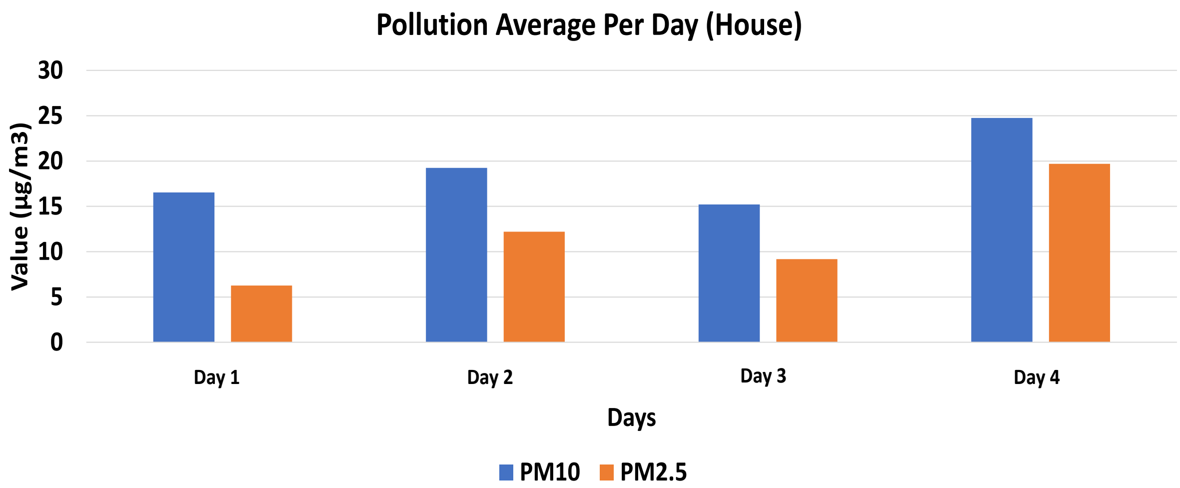


Figure 19: Average of the PM10 & PM2.5 in four days

Figure 20 and Figure 21 provide visual representations of the data for both PM10 and PM2.5 collected at the house over the course of four days, allowing for a day-by-day comparison. As previously mentioned, both figures clearly indicate that the highest readings for both PM10 and PM2.5 occurred on the fourth day. This visual presentation facilitates an easy and direct comparison of each day's data.

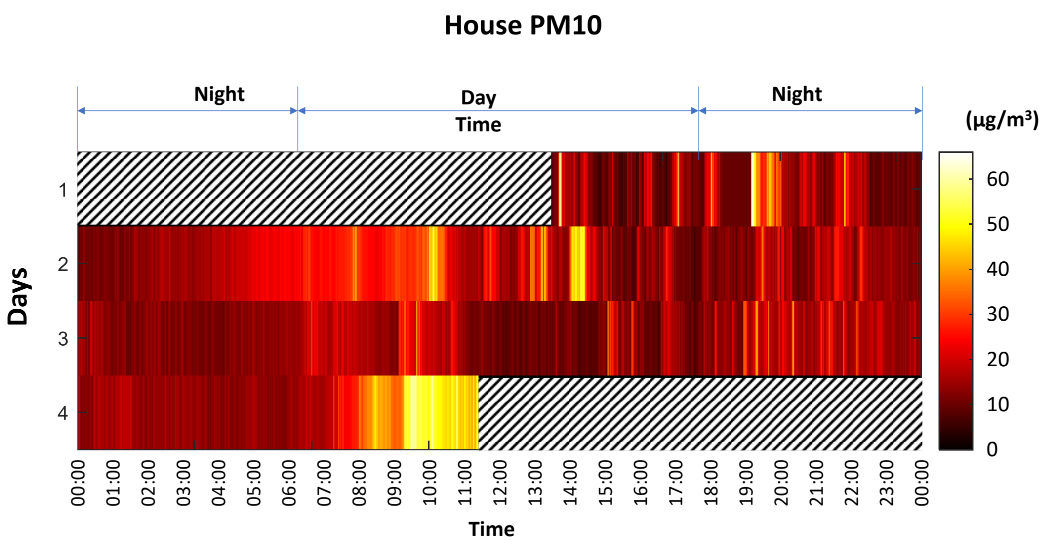


Figure 20: Visual Representation of PM10 Readings at the house

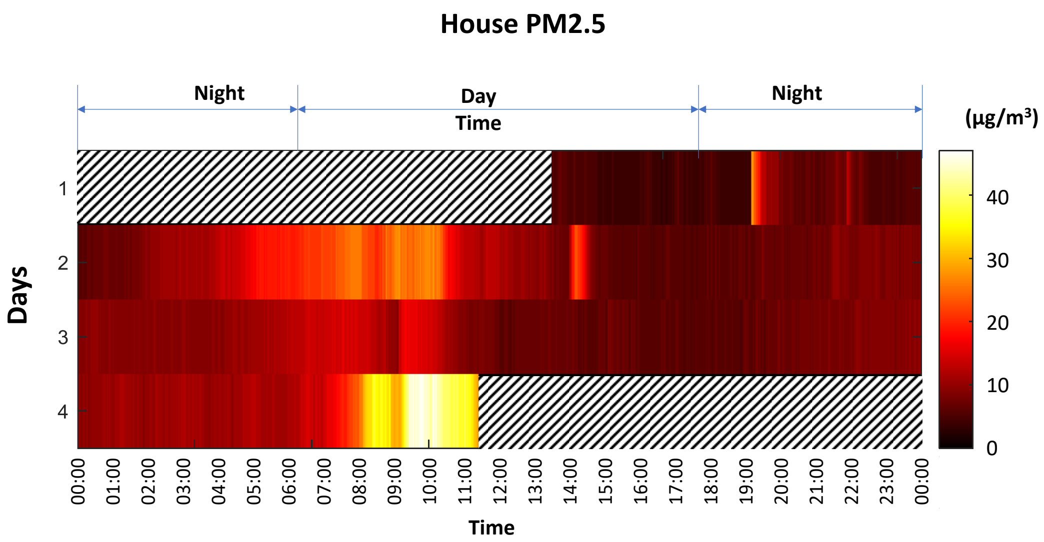


Figure 21: Visual Representation of PM2.5 Readings at the house

3.3 Main road (Barford Road)

Air quality monitoring was conducted on the main road of the village, where both the school and the selected house are situated. This monitoring process extended for nearly two hours, running from 10:33 am to 12:23 pm. It involved the use of monitoring devices for particulate matter (PM10 & PM2.5) and SO2. During this duration, the monitoring point on the main road observed the passage of approximately 5 cars per minute, including a few trucks and tractors.

Figure 22 provides a visual representation of the recorded readings for both particulate matter (PM10 & PM2.5) and SO2 during this monitoring period. The graph demonstrates that particulate matter levels decreased over time, despite their initial higher readings at the outset of the experiment. Conversely, the SO2 levels displayed an increase during the latter half of the testing period.

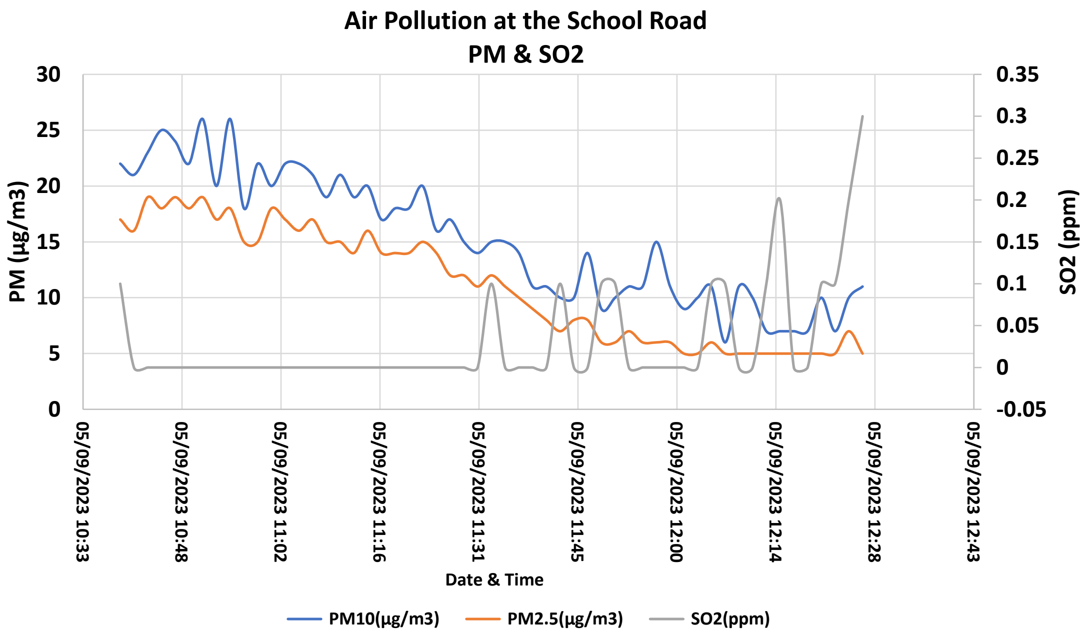


Figure 22 results of the monitoring the PM10, PM2.5 and SO2 in the main road.

3.4 Quarry

Trial 01:

This is a pilot assessment and was conducted at the selected quarry to evaluate air quality in an environment resembling the proposed Quarry near Barford. The trial extended for an hour during the operation of the quarry.

In this assessment, three devices were utilized, comprising two particulate matter monitoring devices whereas each one will read both PM10 and PM2.5. and one device for monitoring NO2. The monitoring process started from almost 0.5 km away from the quarry and then moved towards the quarry site to be close as much as 0.1 km from the centre of the quarry. The devices were configured to capture readings at two-minute intervals.

Particulate Matter (PM10 & PM2.5):

Figure 23 and Figure 24 present the data for particulate matter from both devices, plotted on a map near the quarry. The figures show the average of the readings from both devices. The figures depict the results using a colour scale, with the minimum values represented in blue and gradually transitioning to the maximum values shown in red. The average minimum value for PM10 was 18.0 µg/m^3, while the average maximum value was 581.0 µg/m3. In the case of PM2.5, the average minimum recorded was 9.0 µg/m^3, with an average maximum of 156.0 µg/m^3.

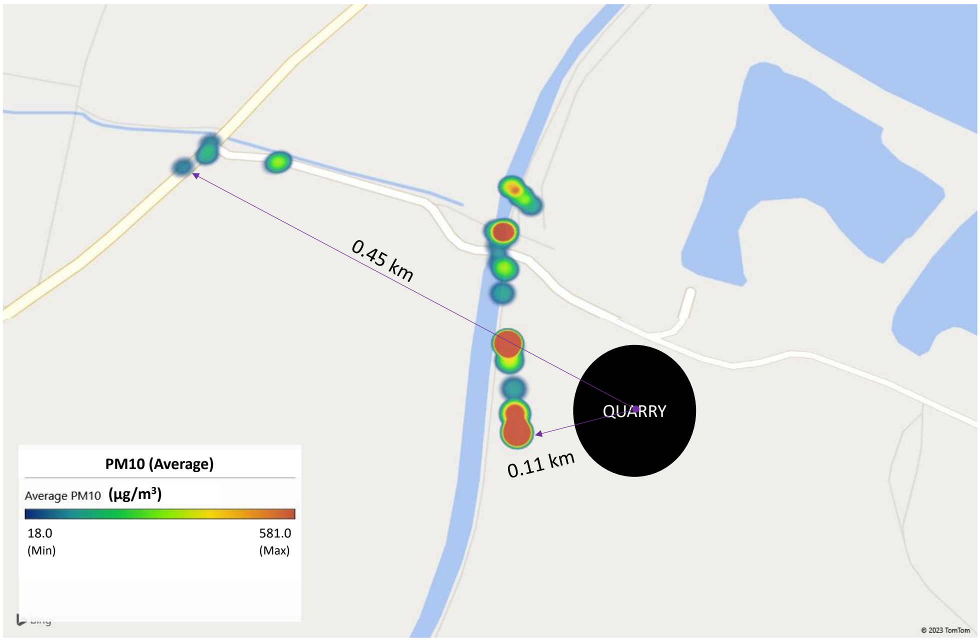


Figure 23: A map shows the location of the average PM10 readings taken by both devices.

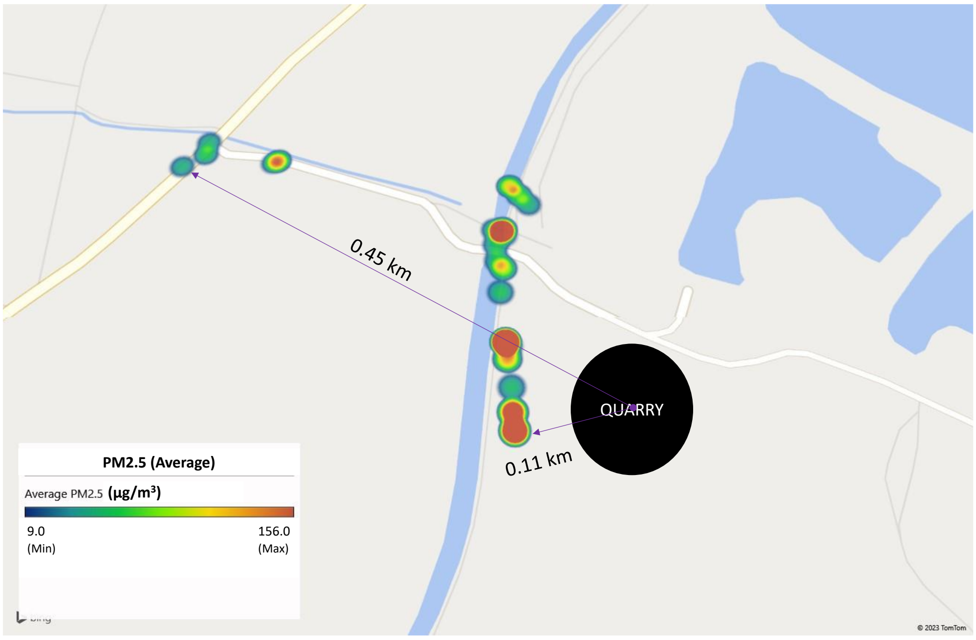


Figure 24: A map shows the location of the average PM2.5 readings taken by both devices.

By conducting a correlation analysis between the distance and the Particulate Matter readings, it was observed that pollution levels increased as the monitoring location moved closer to the quarry, as evident in both Figure 25 and Figure 26

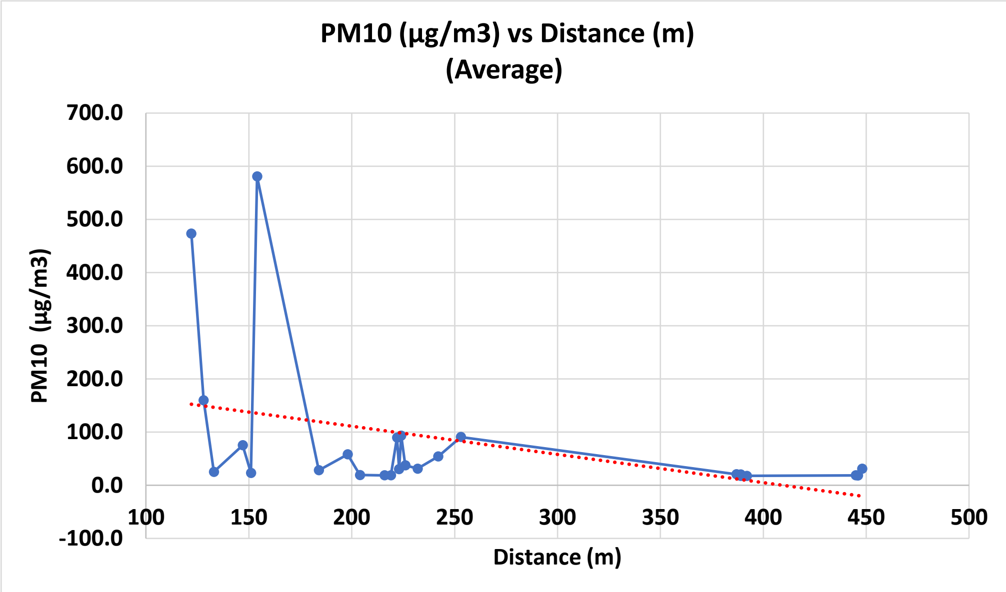


Figure 25: PM10 vs Distance

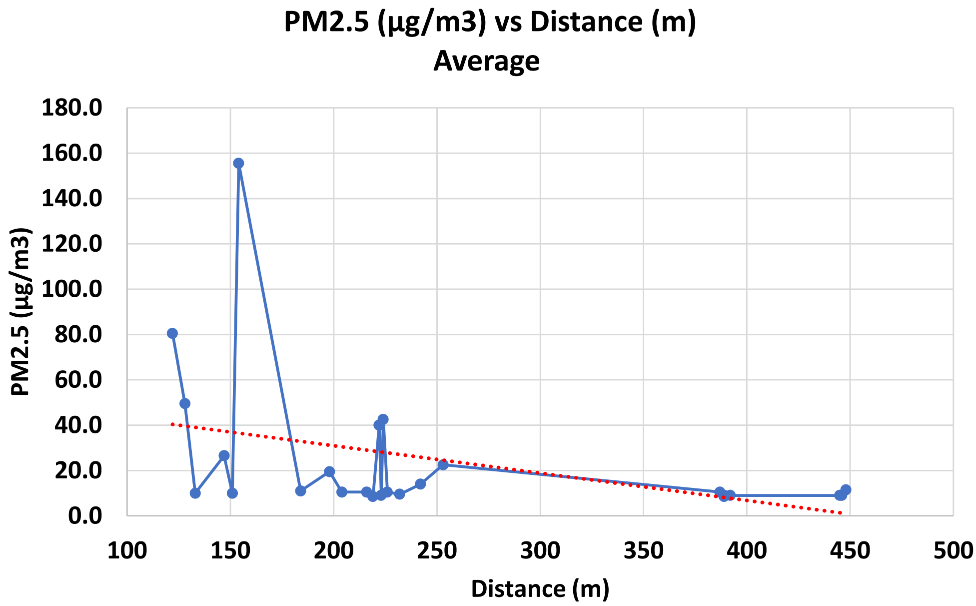


Figure 26: PM2.5 vs Distance

Nitrogen Dioxide (NO_2)

In addition to PM monitoring devices, an NO2 monitoring device was employed. The readings captured by the NO_2 monitoring device are illustrated in Figure 27. As in the previous figures, this graph uses a colour scale, with blue denoting minimum values and red indicating maximum values. The recorded data ranged from a minimum value of 0.016 ppm to a maximum value of 1.139 ppm. It's important to note that the area in question was not characterized by heavy traffic, which is typically a significant source of NO2 emissions.

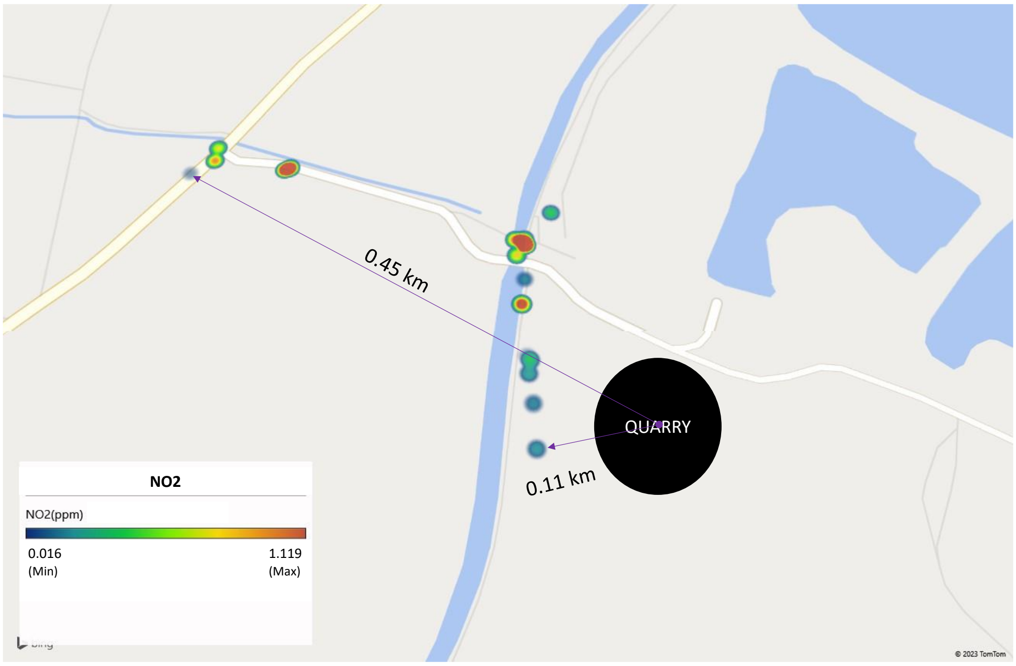


Figure 27: A map shows the location of the NO2 readings.

After conducting a correlation analysis between the levels of NO2 and the distance from the quarry, it was determined that there is no discernible relationship between these factors. Figure 26 shows this lack of correlation.

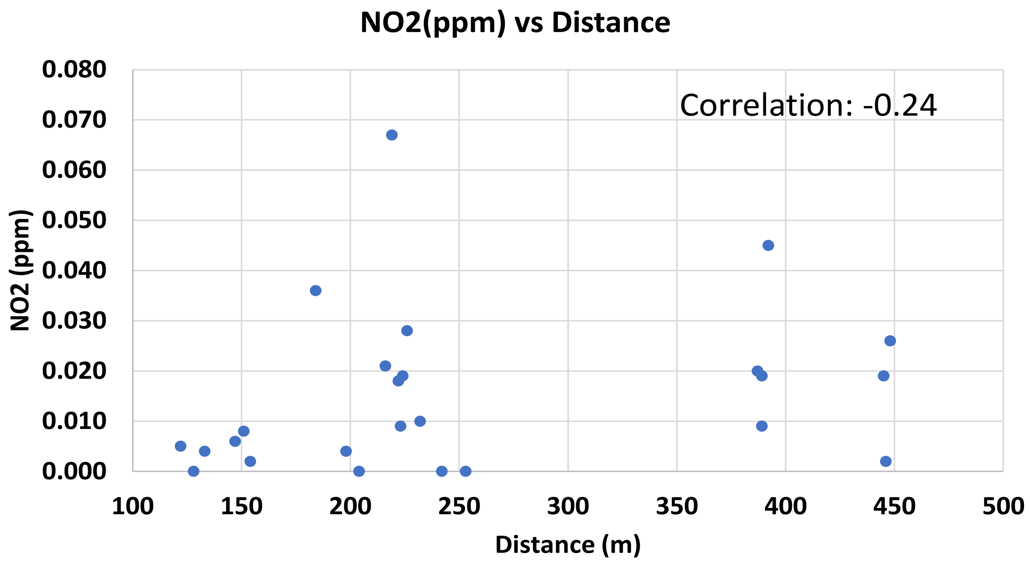


Figure 28: NO2 vs Distance

Trial 2:

During this trial, four monitoring devices were employed, including two for Particulate Matter (PM10 & PM2.5), one for Nitrogen Dioxide (NO2), and one for Sulphur Dioxide (SO2). The trial spanned a five-hour duration, from 11:00 to 16:00. It's worth mentioning that the Quarry was in operation and actively producing gravel, yet no dust was visibly present. The wind direction was westward, and the wind speed was relatively low.

Figure 29 depicts the four devices utilized for data collection. Devices labelled as no. 1 and no. 2 are designated for measuring particulate matter, no. 3 is dedicated to NO2 measurement, and no. 4 is specifically designed for SO2 measurement.

Figure 29: The four devices use to collect data.

For the first four hours, the devices were stationed at a fixed point located 0.65 km away from the quarry as shown in Figure 30. They were positioned on the west side of the quarry, facing the current wind direction on the day of the trial.

Figure 30: The four-monitoring devices in operation at the fixed point.

In the last hour, the four devices were hand-held and transported along a path within the vicinity. The movement began from the initial position and proceeded towards the quarry, reaching a distance as close as 0.1 km from the quarry. They then returned to the same initial position using a different route. This round-trip movement was repeated twice along the same path for data collection.

Figure 31 displays the fixed point marked within a yellow circle, where the four devices were set up to collect data for four hours. It also illustrates the path used to collect data in the last hour. The blue spots represent the first round of data collection, while the orange spots indicate the second round. Each round lasted approximately half an hour.

It's important to note that during this trial, there were ongoing farming activities on the south side of the data collection area. Figure 32 illustrates a tractor in operation during the data collection period. These agricultural activities have had an impact on the results.

Figure 34 presents the entire dataset plotted on a single graph. The data distinctly illustrates a notable spike in the last hour, attributed to farming activities.

Figure 31: This map shows the fixed point in yellow circle and the path used to collect data in the last hour.

Figure 32: Tractor in operation at the south of the data collection area.

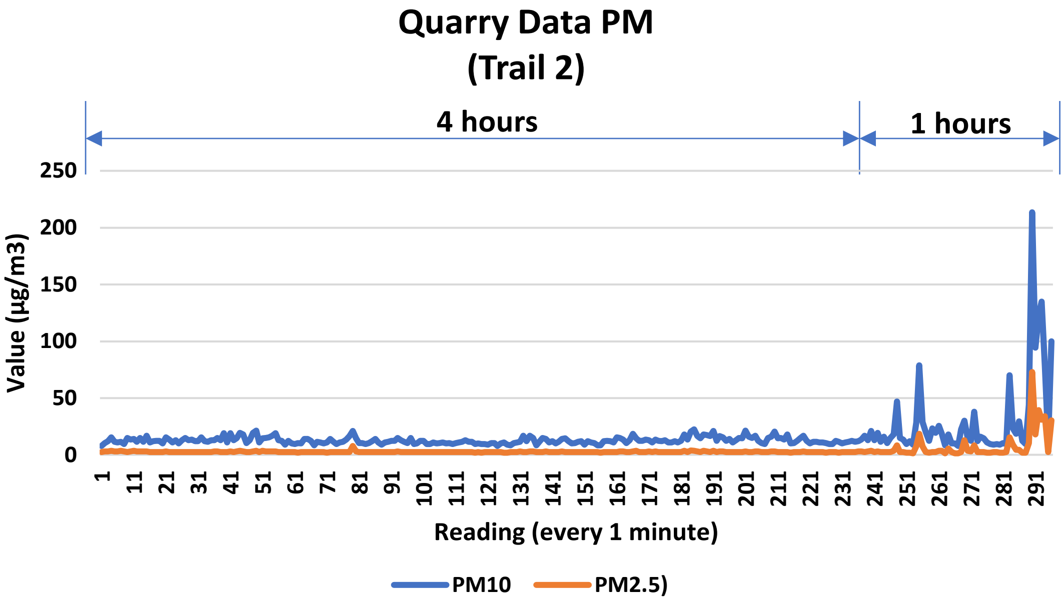


Figure 33: PM data collected during the trail 2 at the Quarry

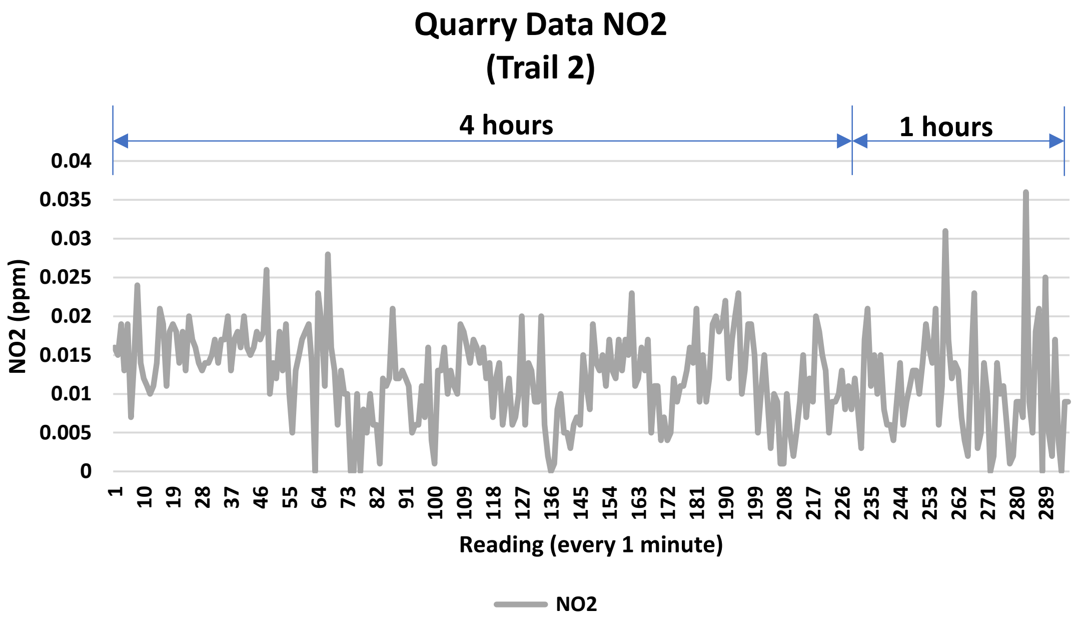


Figure 34: No2 data collected during the trail 2 at the Quarry.

Figure 33 and Figure 35 present the data collected during the initial four hours from the fixed point. It's important to note that the wind was characterized by low-speed conditions during this period. However, it's worth mentioning that the SO2 device recorded consistently at 0 values indicating a technical error throughout the entire trial. As a result, the SO2 data will be excluded from the analysis.

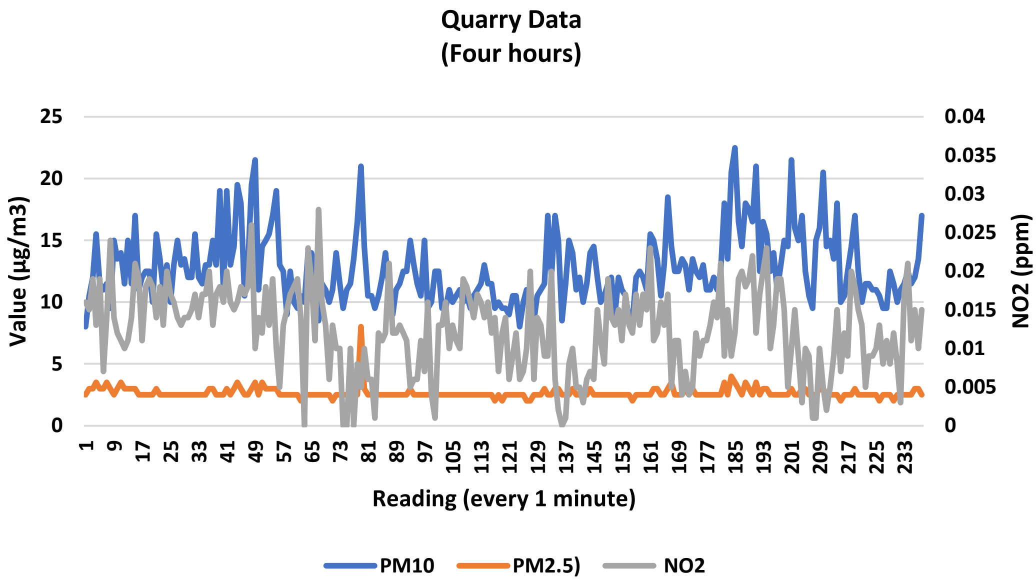
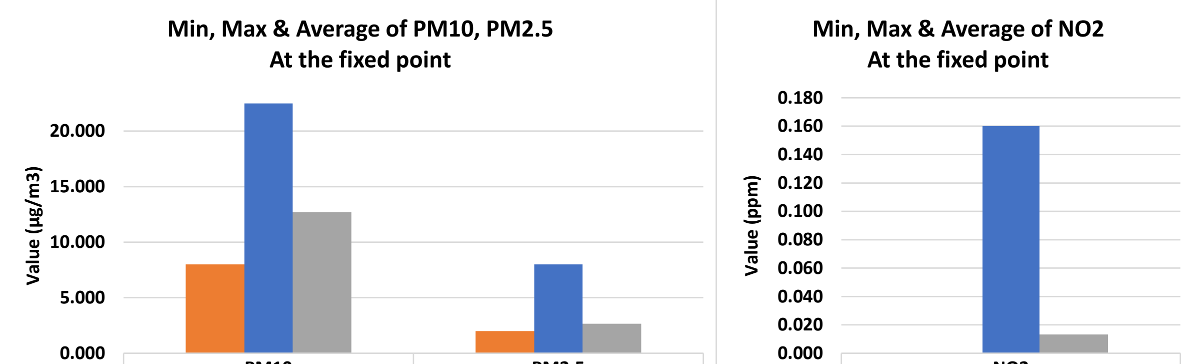


Figure 35: First four hours readings (Quarry)

Figure 36 illustrates the minimum, maximum, and average values of the data measured in the vicinity of the quarry during the second trial. PM10 shown a minimum value of 8.0 µg/m^3, a maximum value of 230.0 µg/m3, and an average of 13.0 µg/m^3. PM2.5 recorded a minimum of 2.0 µg/m3, a maximum of 8.0 µg/m3, and an average of 3.0 µg/m3. NO2 showed a minimum value of 0.00 ppm, a maximum value of 0.023 ppm, and an average of 0.012 ppm.



	PM10	PM2.5
Min	8.000	2.000
Average	12.708	2.649
Max	22.500	8.000

	NO2
Min	0.000
Average	0.013
Max	0.160

Figure 36: Minimum, Maximum & averages of pollution data at the fixed point (Quarry).

Figure 37 shows the data collected during the last hours in which there were two rounds as mentioned before. The figure indicates that the readings are higher during the last hour compared to the data collected in the first four hours. This increase could be attributed to the fact that the data was collected from a point closer to the Quarry, despite the presence of some farming activities.

Figure 38 illustrates the minimum, maximum, and average values of the data measured in the vicinity of the quarry during the last hour. PM10 shown a minimum value of 8.0 µg/m3, a maximum value of 214.0 µg/m3, and an average of 30.0 µg/m3. PM2.5 recorded a minimum of 2.0 µg/m3, a maximum of 73.0 µg/m3, and an average of 8.0 µg/m3. NO2 showed a minimum value of 0.00 ppm, a maximum value of 0.036 ppm, and an average of 0.011 ppm.

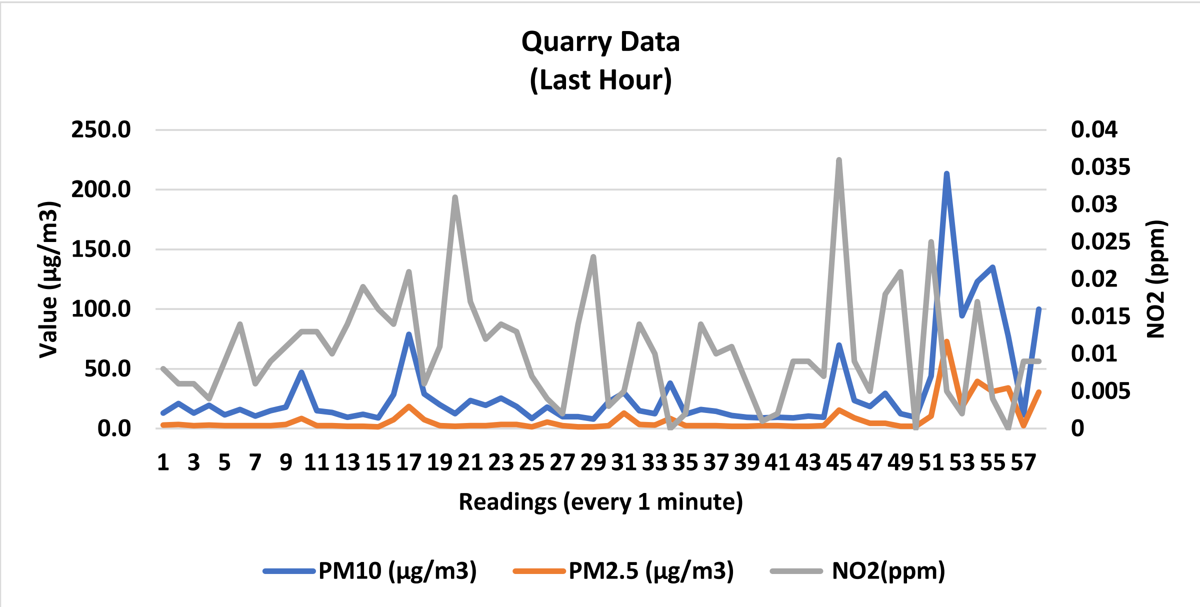
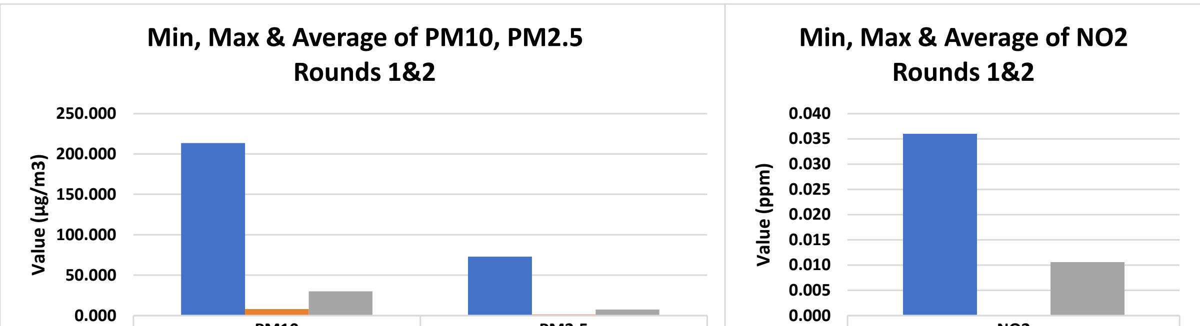


Figure 37: the data collected in the last hour in two rounds (Quarry).



	PM10	PM2.5
Max	213.500	73.000
Min	8.000	1.500
Average	30.086	7.534

	NO2
Max	0.036
Min	0.000
Average	0.011

Figure 38: Minimum, Maximum & averages of pollution data of the last hour (round 1&2; Quarry)

The results for each type of pollutant have been graphically represented on maps to provide a visual depiction of pollutant levels. The colour scales on the maps reflect values of pollution, transitioning from minimum values in blue to maximum values in red.

In this study, three different maps were created to represent the pollutants measured. Figure 36 displays the result map for PM10, Figure 37 shows the result map for PM2.5, and Figure 38 presents the results for NO2.

The particulate matter maps clearly indicate some impact from farming activities; nevertheless, they still reveal that readings closer to the quarry are higher than those further away. This pattern is also observed in the NO2 map, although it exhibits less variability in values between closer and farther readings.

Figure 39: PM 10 colour map (Quarry)

Figure 40: PM2.5 colour map (Quarry)

Figure 41: NO2 colour map (Quarry)

Summary

Figure 42 presents a summary of the findings in the four locations in terms of average readings. The average pollution on the road or in the house in Barford village are similar in terms of PM2.5; and the house PM10 average was slightly higher, but this could be related to the difference in monitoring times (more values for the house) including the rush hour near the school. The School itself has pollution average less than the other locations in the village which could be related to being on the west side facing the fields. The quarry readings were sensitive to distance from the quarry, but PM10 average was the highest among all tests.

Final note: Every experimental work has its own limitations. The purpose of this study, within the given time and resources, was to provide a comparative measurement of air pollution, particularly PM10 and PM2.5 and understand the average and variation of air quality readings in different locations and scenarios. Many factors affect pollution levels including distance from source, wind direction, environmental factors such as green areas, etc.

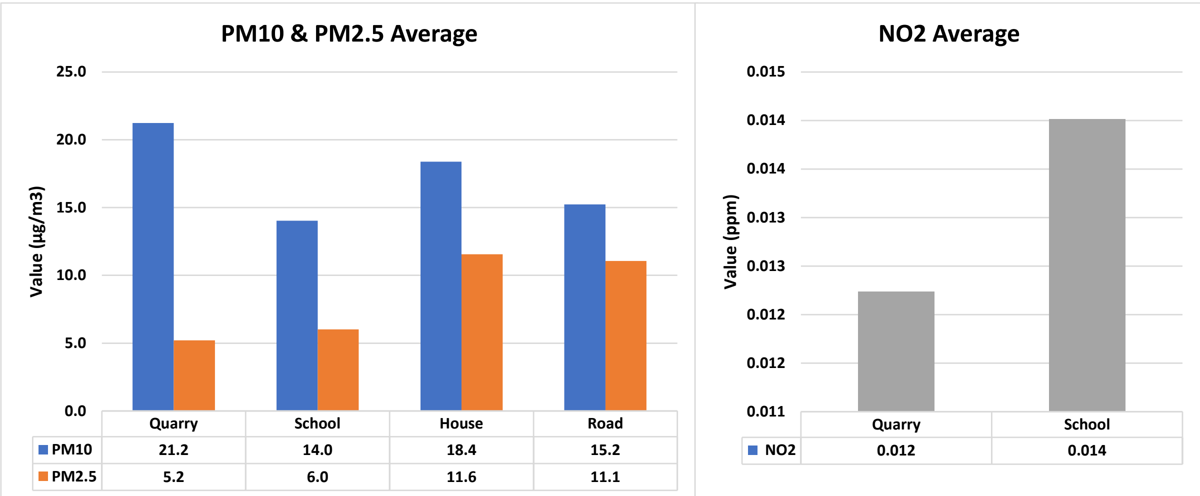


Figure 42: Summary of findings (average readings).

References:

Dentoni, V. *et al.* (2023) 'A comprehensive methodology for the visual impact assessment of mines and quarries', *Environmental Impact Assessment Review*. Elsevier Inc., 102(June), p. 107199. doi: 10.1016/j.eiar.2023.107199.

Fugiel, A. *et al.* (2017) 'Environmental impact and damage categories caused by air pollution emissions from mining and quarrying sectors of European countries', *Journal of Cleaner Production*, 143, pp. 159–168. doi: 10.1016/j.jclepro.2016.12.136.

Appendix 1

PPM to mg/m^3 and ug/m^3

Based on https://support.aeroqual.com/Wiki/Conversion_factor

Sensor	PPM conversion to mg/m^3	PPM conversion to ug/m^3
Ammonia	0.7	700
Carbon dioxide	1.96	1960
Carbon monoxide	1.25	1250
Chlorine	3.16	3160
Formaldehyde	1.34	1340
Hydrogen	0.082	82
Hydrogen sulphide	1.52	1520
Methane	0.72	720
Nitrogen dioxide	2.05	2050
Non-methane hydrocarbon	2.5	2500
Ozone	2.14	2140
Particulate matter	n/a	n/a
Perchloroethylene	6.78	6780
Sulphur dioxide	2.86	2860
Volatile organic compounds	2.5	2500

The Air Quality Standards Regulations (UK)

https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-particulate-matter-pm10-and-pm25