NO_2 observations, Lyon, France 2022

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Aidan Farrow[1], Chloe Le Floc'h[2], Florin Popescu[1]

[1]Greenpeace Research Laboratories, College of Life and Environmental Sciences, Innovation Centre Phase 2, University of Exeter, Exeter, United Kingdom. [2]Greenpeace France

Key Findings

Air Pollution Concentrations

- At the Croix-Rousse tunnel monitoring station, adjacent to Primary School Michel Servet, the WHO guideline and EU standard for annual mean nitrogen dioxide has been exceeded each year since at least 2015, even during the COVID -19 pandemic.
- During a short-term monitoring study, the WHO guideline for the 24-hour average concentrations of nitrogen dioxide were exceeded both inside and outside the school.
- Average nitrogen dioxide concentrations inside the school during school opening hours are higher than 24-hour average concentrations.

Causes of air pollution inside the school

- Analysis of Roadside and Background air quality monitors in Lyon suggests that road traffic is responsible for high air pollution concentrations near the Tunnel de la Croix Rousse exit.
- Nitrogen dioxide concentrations increase at times coincident with peak road-traffic congestion further suggesting that road traffic is an important driver of pollution concentrations inside the school.

Impact of air pollution

- EU Standards are exceeded, despite the EU standard for annual mean nitrogen dioxide now being considered inadequate for the protection of public health, as increased risk of mortality is known to result from exposure at much lower concentrations
- Children are particularly vulnerable to the effects of air pollution.

Introduction

The Primary School Michel Servet is located in central Lyon between a steep hillside and the river Rhône, it is located adjacent to the mouth of a road tunnel and close to several major roads. This report uses observations of nitrogen dioxide air pollution (Box 1) to investigate the possible impact of road traffic emissions from the Tunnel de la Croix Rousse and nearby major roads on the air quality at the school. Measurements from inside and outside of the school are analysed to assess the nitrogen dioxide concentrations experienced by children attending the school.

There are several roads with heavy traffic flows in the vicinity of the school. These major roads converge at the Pont de Lattre de Tassigny which is approximately 120m north-east of the school. A road tunnel, the Tunnel de la Croix Rousse, extends west from the Pont de Lattre de Tassigny. The entrance to this road tunnel is immediately adjacent to the northern boundary of the school property (Figure 1).

Box 1: What is Nitrogen Dioxide (NO_2)

When fuels are burned in air the heat produced causes atoms of nitrogen in the air and in the fuel to oxidise. This causes the emission of gases called nitrogen oxides which include Nitric Oxide (NO) and Nitrogen Dioxide (NO_2), collectively referred to as NOx. NOx pollution can react with water to form acid rain, and with other substances to form particulate matter air pollution and smog. The health impacts of exposure to nitrogen oxides include cardiovascular diseases, exacerbated symptoms of asthma, chronic obstructive pulmonary disorder and other respiratory diseases (Anderson et al. 2007, Guarnieri & Balmes 2014).

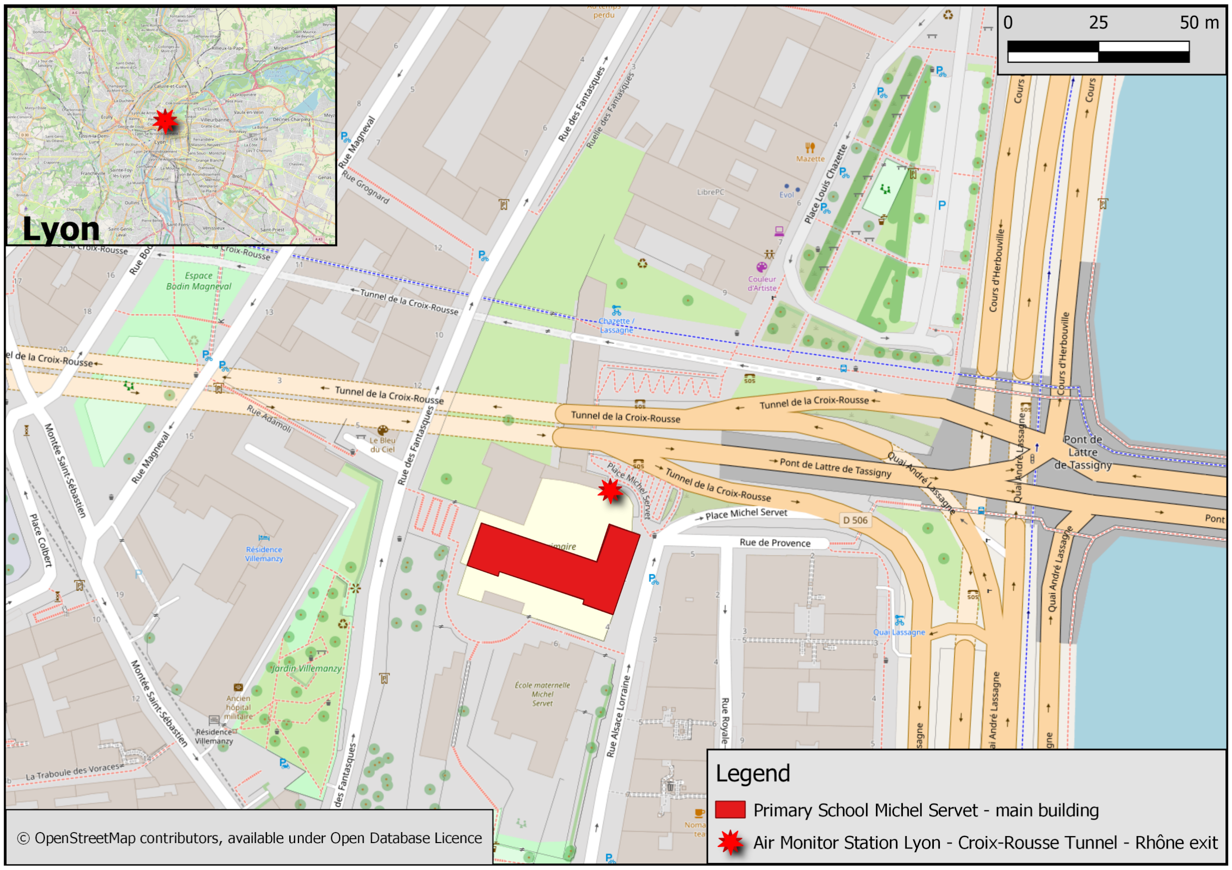

Figure 1. Lyon Air Quality Monitoring Station and Michel Servet Primary School

Exposure to air pollution is associated with adverse health effects, and research suggests that children are particularly at risk (Garcia et al, 2019, Achakulwisut et al, 2019). Therefore, organisations that are responsible for public health publish air quality guidelines and standards. The World Health Organisation (WHO) guidelines for air quality were updated in 2021 after a detailed review of the latest scientific research. The WHO recommends guidelines for annual-mean and 24-hour average NO_2 concentrations (WHO, 2021) as well as a 1-hour average NO_2 concentration (WHO, 2006). These guidelines are designed to assist decision makers when setting local environmental standards. EU Directive 2008/50/EC provides legal standards for air quality in France. These regulations set thresholds for the annual-mean and 1-hour average concentration of NO_2 (EU, 2008). The EU regulations are substantially weaker than the WHO's Air Quality Guidelines. The WHO Guidelines are derived from a much more recent review of scientific advances in our understanding of air pollution health effects. The EU standard for annual mean NO_2 can now be considered inadequate for the protection of public health, as increased risk of mortality is known to result from exposure at much lower concentrations (e.g. Stieb et al 2021). The WHO guideline and the current EU standards for NO_2 are shown in Table 1.

Table 1: World Health Organisation Air Quality Guidelines (2021) and EU Air Quality Standards (2008)[1]

Pollutant	WHO Guideline	EU Standard	Averaging period
NO_2 (µg/m^3)	10	40	Annual
	25*	-	24-hour
	200	200	1-hour

* Not to be exceeded on more than 3-4 days each year

Source: EU (2008), WHO (2006), WHO (2021)

Methods

Lyon air quality monitoring network

A network of air quality monitoring stations is operated in Lyon by Atmo Auvergne-Rhône-Alpes (Atmo), which is the observatory association approved by the Ministry of Ecological and Solidarity Transition for monitoring and information on air quality in the Auvergne-Rhône-Alpes region. The network has nine roadside and background air quality monitoring stations described as being located in 'urban' settings. One of these stations, the station at Saint Just, ceased operating in 2017 and is not included here.

[1] In 2015 Commission Directive (EU) 2015/1480 amended several annexes to previous air quality directives of the European Parliament and of the Council to provide details of reference methods, data validation and sampling points for the assessment of ambient air quality. The air quality standards themselves were not updated by this directive

The Lyon Tunnel Croix Rousse air monitoring station is part of the monitoring network. It is a roadside air quality monitor and is located within the premises of the Primary School Michel Servet. It is positioned between the exit of the road tunnel and the school buildings (Figure 1). The monitor is positioned on a wall which separates the school from the roadway and its inlet is at an elevation of approximately 6m above the road surface. Measurements of air pollutants including PM_{10}, NO_2 and NO are available from the Atmo website (Atmo, No Date).

Observations from the Lyon Tunnel Croix Rousse monitor are used in the analysis to describe air quality outside of the Primary School Michel Servet buildings; the monitor is referred to as the 'Croix-Rousse tunnel' monitor.

AQMesh multi sensor air quality monitor

AQMesh pods (Environmental Instruments Ltd, UK, www.aqmesh.com) are self-contained units that measure ambient concentrations of gaseous air pollutants (in this case SO_2 , NO, NO_2 and O_3) and environmental variables (temperature, relative humidity and atmospheric pressure). Data are gathered using electrochemical gas sensors and are processed by a proprietary algorithm which corrects for cross-interferences and for the effect of temperature and relative humidity.

When using AQMesh units or any other electrochemical gas sensors to estimate air pollutant concentrations, it is best practice to perform a field calibration to improve the accuracy of results and validate the measurements made. The AQMesh instrument was co-located with the Croix-Rousse tunnel monitor and a cross-calibration was used to calculate scaling factors that were then applied to the data collected using the AQMesh. Full details of this field calibration are provided in Appendix 1.

On the 25th of March 2022, after the field-calibration, the AQMesh instrument was deployed inside a classroom in the main building of the Michel Servet Primary School. Here measurements of SO_2 , NO, NO_2 and O_3 were made directly in the classroom environment experienced by the school students. Measurements are continuing in the classroom and results for the period 25th of March to 16 May 2022 are presented here. A power supply interruption prevented measurements being made during the period 25th-29th of April 2022 . Observations from this monitor are used in the analysis to describe air quality inside of the school buildings, the monitor is therefore referred to as the 'Indoor' monitor.

Traffic congestion data

Satellite navigation provider TomTom provides traffic congestion statistics for Lyon online (TomTom, 2022). The congestion data use a percentage index derived from average journey times. For example a 10% congestion level reported by TomTom indicates that average journey times are 10% longer than during baseline non-congested conditions. The congestion data are used to identify the timing of peak congestion levels in Lyon.

Results

Lyon air quality monitoring network

The annual mean NO_2 concentration observed between 2015 and 2021 at each of Lyon's 8 urban air quality monitoring stations is presented in Table 2.

These results, which cover the most recent seven years of data (including 5 years prior to the COVID-19 pandemic), reveal that annual average NO_2 concentrations exceed WHO guideline levels at all locations and that the EU standard has been exceeded at all roadside locations in that time. This EU standard was only exceeded at stations in roadside settings. At the Croix-Rousse tunnel and Peripheral monitoring stations, which are adjacent to major roads, the WHO guideline and EU standard were exceeded in all seven years. The Traffic Jaures and Villeurbanne Place Grandclement roadside monitoring stations are adjacent to significantly smaller roads.

The EU standard was not exceeded at any urban background station in any of the years analysed. Comparison of the results from roadside and urban background monitoring stations indicates that road traffic is responsible for a large contribution to the total NO_2 concentration close to major roads in Lyon. This is likely to be the case at the Croix-Rousse tunnel and Peripheral monitoring stations where the monitoring site is adjacent to major roads and the tunnel portal. Annual mean NO_2 concentrations away from the busiest roads are clustered between 16 and 42 μg/m^3, whereas results at the Croix-Rousse tunnel and Peripheral monitoring stations are notably higher, falling between 55 and 78 μg/m^3 in years that were unaffected by COVID-19 restrictions. This suggests that traffic emissions are a significant factor at these sites. The lowest annual mean concentrations were recorded during 2020 and 2021 when COVID-19 restrictions and reductions in road traffic influenced NO_2 and NO concentrations (Atmo, 2021c). In 2020, the station at the exit of the Croix-Rousse tunnel recorded a sharp reduction in NO_2 concentration, as did the other stations in the Lyon air monitoring network, particularly in the 2nd quarter, which is mainly due to the decline in activities (and therefore traffic) during the first confinement period linked to COVID-19 (Atmo, 2021b).

Between 2015 and 2021, the average difference between annual mean NO_2 concentrations at roadside and background locations for all monitoring stations in Lyon was between 16 and 30 μg/m^3. This increment alone is greater than the WHO guideline concentration of 10 μg/m^3 and indicates that traffic emissions in Lyon could be responsible for an important contribution to the total burden of NO_2 in roadside locations across the city. Investigations into the contribution of roads to nearby NO_2 concentrations support this conclusion (Atmo, 2021a).

Table 2. Annual mean NO_2 concentrations at air quality monitoring stations in urban areas of Lyon between 2015 and 2021 (μg/m^3)*

Station	**Type**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Croix-Rousse tunnel	Roadside	**55.0**	**62.0**	**73.4**	**57.1**	**65.0**	**42.3**	**43.4**
Traffic Jaures	Roadside		**41.0**	**41.7**	34.7	36.9	30.5	
Peripheral	Roadside	**78.0**	**71.0**	**70.7**	**66.3**	**62.0**	**48.5**	**49.4**
Villeurbanne Place Grand Clément	Roadside	**42.0**	39.0	38.4	34.4		30.6	25.4
East Lyon	Urban background	23.0	23.0	21.9		21.2		16.3
Peninsula	Urban Background			32.0				
Centre	Urban Background	30.0	28.0	28.4	24.8	23.7	21.3	18.3
Gerland	Urban background	34.0	32.0	31.4	29.6	29.3	22.9	22.7
Average (R)	Roadside	**58.3**	**53.3**	**56.1**	**48.1**	**54.6**	38.0	39.4

Average (UB)	Urban background	29.0	27.7	28.4	27.2	24.7	22.1	19.1
Average road increment (R - UB)	Roadside - Urban Background	29.3	25.6	27.6	20.9	29.9	15.9	20.3

*Concentrations exceeding the EU Standard for annual mean nitrogen dioxide concentrations shown in **bold**, all concentrations shown exceed the WHO Guideline.
Source: Atmo, https://www.atmo-auvergnerhonealpes.fr/donnees/acces-par-station (Accessed 27/05/2022)

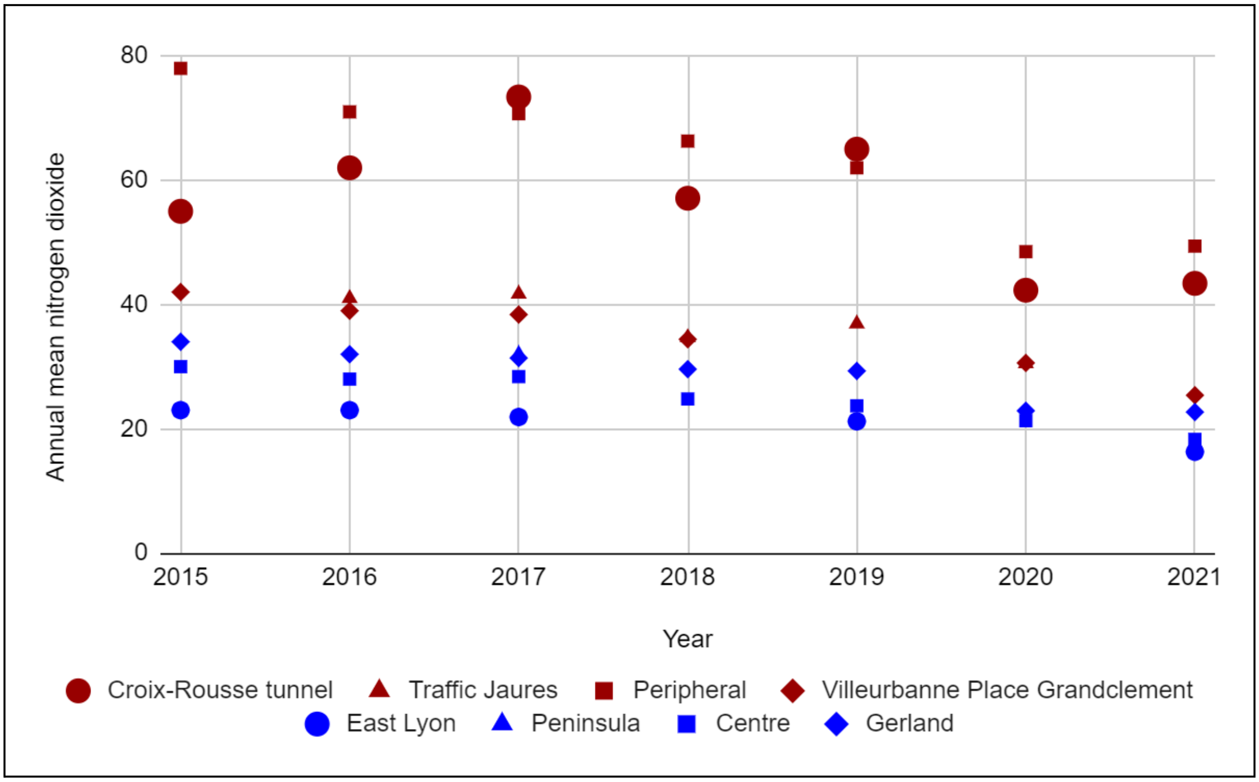

Figure 2. Annual mean NO_2 concentrations at roadside (red) and background (blue) air quality monitoring stations in urban areas of Lyon between 2015 and 2021 ($\mu g/m^3$). Source: Atmo, https://www.atmo-auvergnerhonealpes.fr/donnees/acces-par-station (Accessed 27/05/2022)

Annual mean NO_2 concentrations measured at most monitoring stations in urban Lyon show a very gradual trend toward lower annual mean concentrations (Table 2, Figure 2). In some cases, such as at the Croix-Rousse tunnel monitor, interannual variability is large relative to the long term trend. Concentrations were lowest during 2020 and 2021 when short-lived reductions in road traffic emissions can be attributed to COVID-19 restrictions. The underlying long-term trend is thought to be driven by the renewal of the road vehicle fleet operating in Lyon (Atmo, 2016) and by the actions implemented by Lyon Municipality through Plan Oxygène, such as lower speed limits and low emission zones (Métropole de Lyon, 2021, Atmo, 2021b). Newer vehicles coming into use follow Euro standard regulations which have achieved lower NOx emissions.

Annual mean NO_2 concentrations measured by the Croix-Rousse tunnel monitor at the primary school Michel Servet between 2015-2019 show little discernible trend, although lower concentrations were recorded during 2020 and 2021 (Table 2, Figure 2). The year 2017 recorded atypically high concentrations of NO_2 which may be the result of road closures in Lyon (Atmo, 2021b). The annual mean NO_2 concentrations at the Croix-Rousse tunnel monitor have continued to exceed regulatory standards. The lower concentrations recorded during spring 2020 provide an indication of the air quality that might be achieved if road traffic at the Croix-Rousse tunnel was drastically reduced.

Primary School Michel Servet

During the monitoring period, between 28th March 2022 and 16th May 2022 the measured average NO_2 concentrations were 30.1 and 19.0 μg/m^3 at the Croix-Rousse tunnel and indoor monitors respectively (Table 3).

To understand the air quality experienced by students, a subset of observations made during school opening hours is considered separately. The School Hours Only subset include observations made from Monday to Friday (36 days), between 08.00-19.00hrs. These hours are selected to include all hours when classrooms may be in use for lessons or extracurricular activities (Ecole primaire Michel Servet, No date).

During school hours the monitoring period average NO_2 concentrations were 43.4 and 24.1 μg/m^3 at the Croix-Rousse tunnel and indoor monitors respectively (Table 3).

The WHO recommends that 24-hour average concentrations of NO_2 do not exceed 25 μg/m^3 on more than 3-4 days each year (Table 1). During the 49 day monitoring period, between 28th of March 2022 and 16th of May 2022, 31 days exceeded the WHO guidelines for the 24-hour average concentrations of NO_2 at the Croix-Rousse tunnel monitor and 7 days exceeded at the indoor monitor. The highest 24-hour average measured was 73.9 µg/m^3 at the Croix-Rousse tunnel and 44.2 µg/m^3 at the indoor monitor (Table 3). Even accounting for measurement uncertainty at the indoor monitor (+/- ~10 µg/m^3), the WHO's health-based guidelines are likely to have been breached during the 49 day monitoring period. Details of the AQMesh measurement uncertainty are presented in the appendix.

The maximum measured 1-hour NO_2 concentrations were 156.4 and 65.5 µg/m^3 at the Croix-Rousse tunnel and indoor monitor respectively (Table 3). Both EU standards and WHO guidelines state that 1-hour NO_2 concentrations must not exceed 200 µg/m^3 (Table1), thus no observations breaching the 1-hour NO_2 EU standard nor the WHO guideline were made.

Table 3. Summary of NO_2 observations at the Primary School Michel Servet from 28 March 2022 - 16th May 2022

Statistic	Units	Croix Rousse Tunnel Monitor (outdoor)	AQMesh Monitor (indoor)	Relevant WHO Guideline	Relevant EU Standard
Environment	-	Outside Air	Indoor Air	-	-
Monitoring Period Average	µg/m^3	30.2	19.0	-	-
Monitoring Period Average (School hours only)	µg/m^3	43.4	24.1	-	-
Monitoring Period 24-hour Maximum	µg/m^3	73.9	44.2	25	-
Number of days exceeding WHO 24-hour Guideline	Days	31	7	3-4*	-
Monitoring Period 1-hour Maximum	µg/m^3	156.4	65.5	200	200
Monitoring Period 1-hour Maximum (School hours only)	µg/m^3	156.4	65.5	200	200

*The guideline concentration must not be exceeded on more than 3-4 days each year

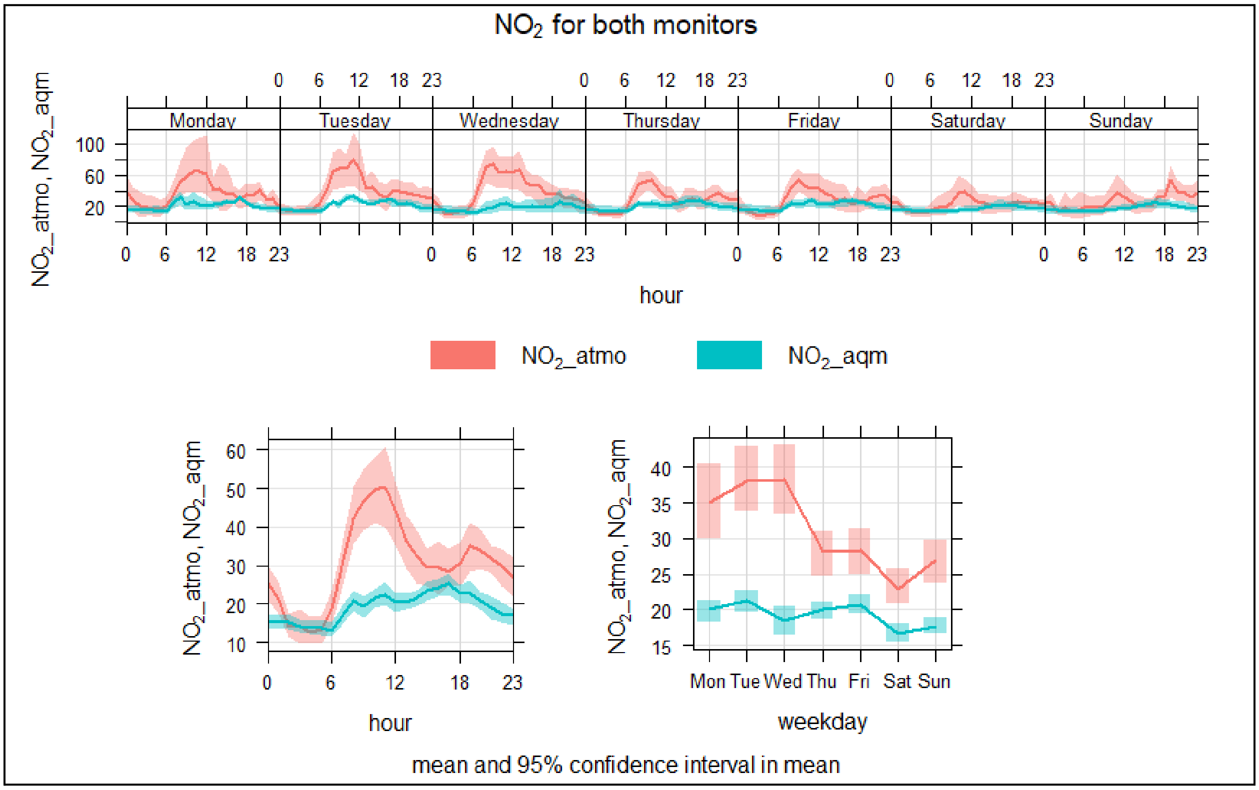

Figure 3. Summary of NO_2 observations (mean and 95% confidence interval) at the Primary School Michel Servet for the Croix-Rousse tunnel monitor (Red) and indoor AQMesh monitor (Blue) (μg/m^3) between 28th March 2022 and 16th May 2022

Lyon road traffic data show that peak weekday traffic congestion during 2019 and 2020 was at 8-9am and 5-6pm. At weekends, peak congestion occurs at approximately 11am and 6pm (TomTom, 2022). These periods of high traffic congestion are correlated with increasing NO_2 concentration measured by both air monitors (Figure 3), further suggesting that road traffic is an important driver of pollution concentrations inside the school.

During the daily morning NO_2 peak at 8-9am there is a corresponding NO peak with greater amplitude (Figure 4). NO is a more reactive gas than NO_2 which oxidises to NO_2 over time. Therefore, the ratio of NO to NO_2 observed by the Croix-Rousse tunnel monitor suggests that a nearby emission source, such as traffic using the Croix-Rousse tunnel, is responsible for these peak hour pollutant concentrations.

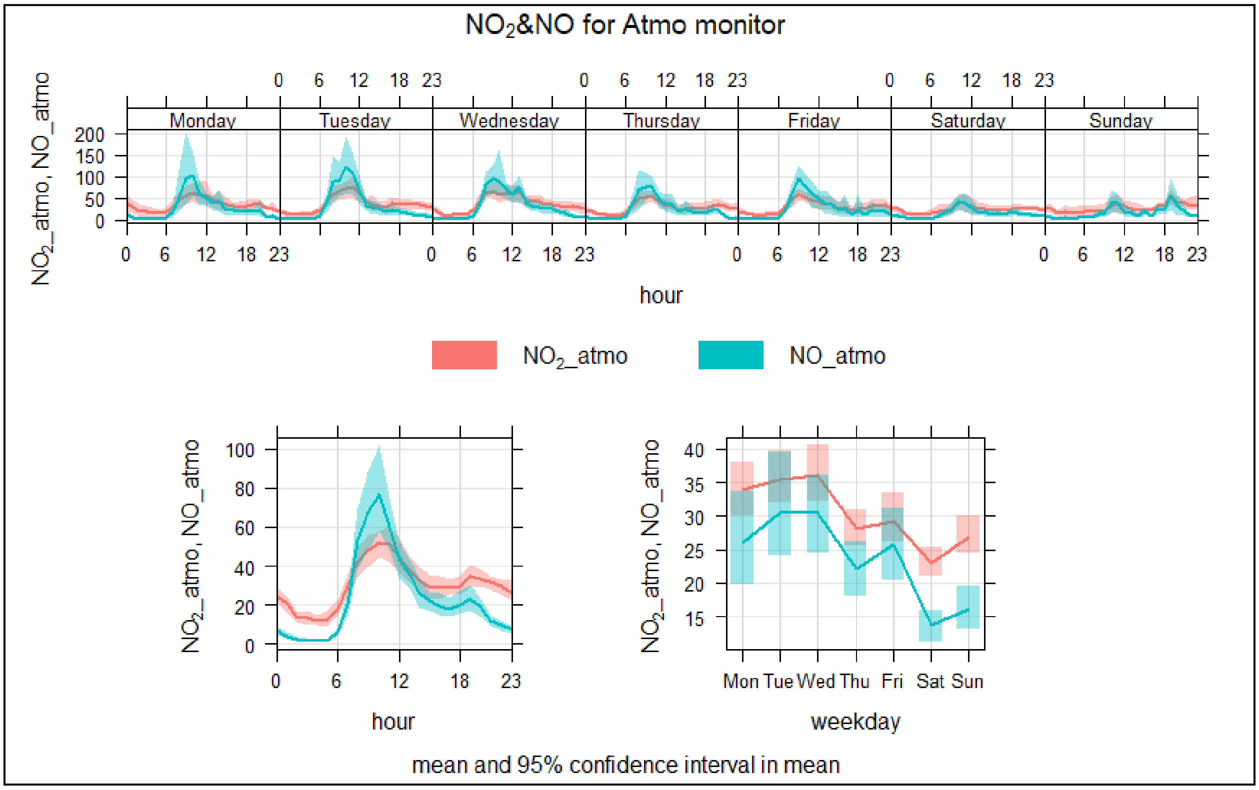

Figure 4. Summary of NO (Blue) and NO_2 (Red) observations (mean and 95% confidence interval) at the Primary School Michel Servet for the Croix-Rousse tunnel monitor (µg/m^3) between 28th March 2022 and 16th May 2022

Conclusions

NO_2 data from a short-term monitoring campaign at Primary School Michel Servet and long-term observations from air pollution monitors across Lyon was used to investigate air quality at the school.

The short term monitoring campaign began on 28th March and data analysed through to the 16th May 2022. The WHO guideline for 24-hour average concentrations of NO_2 was exceeded on several occasions both inside and outside the school during this period. Average NO_2 concentrations measured inside the school during school opening hours were higher than those measured over a 24-hour period.

NO_2 concentrations measured inside the main building of Primary School Michel Servet during the 49 days of monitoring exceeded the 24-hour WHO guideline 7 times.
NO_2 concentrations measured in the northern courtyard of the Primary School Michel Servet

by the Croix-Rousse tunnel monitor during the 49 days of monitoring exceeded the 24-hour WHO guideline 31 times. Measurements from this location reveal that the WHO guideline and EU standard for annual mean NO_2 have been exceeded each year since at least 2015, even during the COVID-19 pandemic.

Analysis of hourly NO_2 concentrations revealed that concentrations increase at times coincident with peak road-traffic congestion. This suggests that road traffic is an important driver of pollution concentrations at the school.

A comparison of air quality data from Roadside and Background air quality monitors in Lyon provided evidence that road traffic is responsible for high air pollution concentrations near the Tunnel de la Croix Rousse exit.

References

Achakulwisut et al (2019) - Pattanun Achakulwisut, Michael Brauer, Perry Hystad, Susan C Anenberg, Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO2 pollution: estimates from global datasets, The Lancet Planetary Health, Volume 3, Issue 4, 2019, Pages e166-e178, ISSN 2542-5196, https://doi.org/10.1016/S2542-5196(19)30046-4

Anderson et al (2007) - Anderson, H., et al. *Quantitative systematic review of short term associations between ambient air pollution (particulate matter, ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide), and mortality and morbidity*. London, Department of Health. Available at: https://www.gov.uk/government/publications/quantitative-systematic-reviewof-short-term-associations-between-ambient-air-pollutionparticulate-matter-ozone-nitrogen-dioxide-sulphur-dioxide-and-carbon-monoxide-and-mortality-and-morbidity (2007).

Atmo (No Date) - Atmo Auvergne-Rhône-Alpes. Accès aux données de mesure. https://www.atmo-auvergnerhonealpes.fr/donnees/telecharger (Accessed 27/05/2022) No Date

Atmo (2016) -Atmo Auvergne-Rhône-Alpes. Étude de la qualité de l'air sur le secteur de la Croix-Rousse (Lyon 1er et 4ème) Rapport de synthèse - Mesures et Modélisation - 2014-2015. rapport_synthese_etudexrousse_2014-2015_vrevmlvaldch_def.pdf (atmo-auvergnerhonealpes.fr) (Accessed 09/06/2022)

Atmo (2021a) - Atmo Auvergne-Rhône-Alpes. CAPI - Communauté d'Agglomération Porte de l'Isère Evaluation de la qualité de l'air autour d'axes de circulation structurants du territoire (A43 et RD1006) Bilan des campagnes de mesure réalisées entre 2019 et 2020. https://www.atmo-auvergnerhonealpes.fr/sites/aura/files/medias/documents/2021-10/atmo_synthese_mesures_2019-2020_capi_20201203.pdf (Accessed 08/06/2022)

Atmo (2021b) -Atmo Auvergne-Rhône-Alpes. Synthèse de la qualité de l'air aux abords du tunnel de la Croix-Rousse Analyse des données de 2014 à 2020. **Atmo-Nom du Rapport (atmo-auvergne rhone alpes.fr)** (Accessed 09/06/2022)

Atmo (2021c) - Atmo Auvergne-Rhône-Alpes. Bilan de la qualité de l'air 2020 en Auvergne-Rhône-Alpes atmo_bilan_2020_web-maj-sept-2021.pdf (atmo-auvergnerhonealpes.fr) (Accessed 10/06/2022)

Ecole primaire Michel Servet (No Date) - Ecole primaire Michel Servet https://ecoleprimairemichelservet.blogs.laclasse.com/informations-administratives/les-horaires/ (Accessed 08/06/2022)

EU (2008) - Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

Garcia et al (2019) - Garcia E, Berhane KT, Islam T, et al. Association of Changes in Air Quality With Incident Asthma in Children in California, 1993-2014. JAMA. 2019;321(19):1906–1915. doi:10.1001/jama.2019.5357

Guarnieri & Balmes (2014) - Guarnieri M, Balmes JR, Outdoor air pollution and asthma, The Lancet, Volume 383, Issue 9928, 2014, Pages 1581-1592, ISSN 0140-6736, https://doi.org/10.1016/S0140-6736(14)60617-6.

Métropole de Lyon (2021) - Métropole de Lyon. Plan Climat Air Énergie Territorial Point d'étape 2021 https://www.grandlyon.com/fileadmin/user_upload/media/pdf/environnement/20220223_pcaet_point-etape.pdf (Accessed 09/06/2022)

Stieb et al (2021) - Stieb, D.M., Berjawi, R., Emode, M., Zheng, C., Salama, D., Hocking, R., Lyrette, N., Matz, C., Lavigne, E. and Shin, H.H., 2021. Systematic review and meta-analysis of cohort studies of long term outdoor nitrogen dioxide exposure and mortality. PloS one, 16(2), p.e0246451.

TomTom (2022) - TomTom. *Lyon in Traffic Index 2021.* *https://www.tomtom.com/en_gb/traffic-index/lyon-traffic/#statistics* (Accessed 08/06/2022)

WHO (2006) – The World Health Organization. *Air Quality Guidelines: Global Update 2005 : Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide.* (2006).

WHO (2021) – The World Health Organization. *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.* 2021. https://apps.who.int/iris/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO (accessed 2022-02-08)

Appendix

Field-Calibration of the AQMesh

The AQMesh air quality monitoring instrument uses electrochemical sensors to determine ambient concentrations of trace gases. The sensors are sensitive to the environment, including the effects of temperature and humidity. Raw data gathered by the electrochemical gas sensors is processed by a proprietary algorithm which corrects for these effects using temperature, relative humidity and atmospheric pressure measurements also made by the AQMesh monitor.

A local field-calibration was conducted by colocating the AQMesh with the Croix-Rousse tunnel monitor. The colocation allowed comparison with a reference quality instrument to determine scaling factors which were then applied to the AQMesh measurements. The Croix-Rousse tunnel reference monitor is located on the northern side of the Primary School Michel Servet courtyard, close to the entrance to the Croix-Rousse tunnel and reports hourly concentrations of PM_{10}, NO and NO_2 as main pollutants.

The AQMesh pod was co-located with the reference monitor between 10th of February 2022 and 24th of March 2022, although data collection was interrupted due to a battery failure during this time (Figure A1). The local field-calibration was performed for NO and NO_2 on the 15th of March 2022 and hence data are used from 16th March in the report analysis.

Pre-calibration results from the co-location are shown in Figures A1 and A4 for NO and NO_2. The relationship between the AQMesh and reference monitor results is shown in Figures A2 and A5 which indicates that the AQMesh monitor was in moderately good agreement with the Croix-Rousse tunnel reference monitor for NO (R^2=0.58) and NO_2 (R^2=0.44) .

The scaling factors shown in Table A1 were then applied to the AQMesh monitoring results to improve the performance of the instrument during its deployment at the Michet Servet Primary School in Lyon. The scaled results of the field-calibration are shown in Figures A3 and A6 for NO and NO_2, respectively.

Table A1: Comparison of AQMesh and Croix-Rousse tunnel reference monitor data (ppb)

	NO	NO_2
Slope	0.697	0.682
Intercept	7.739	-0.359

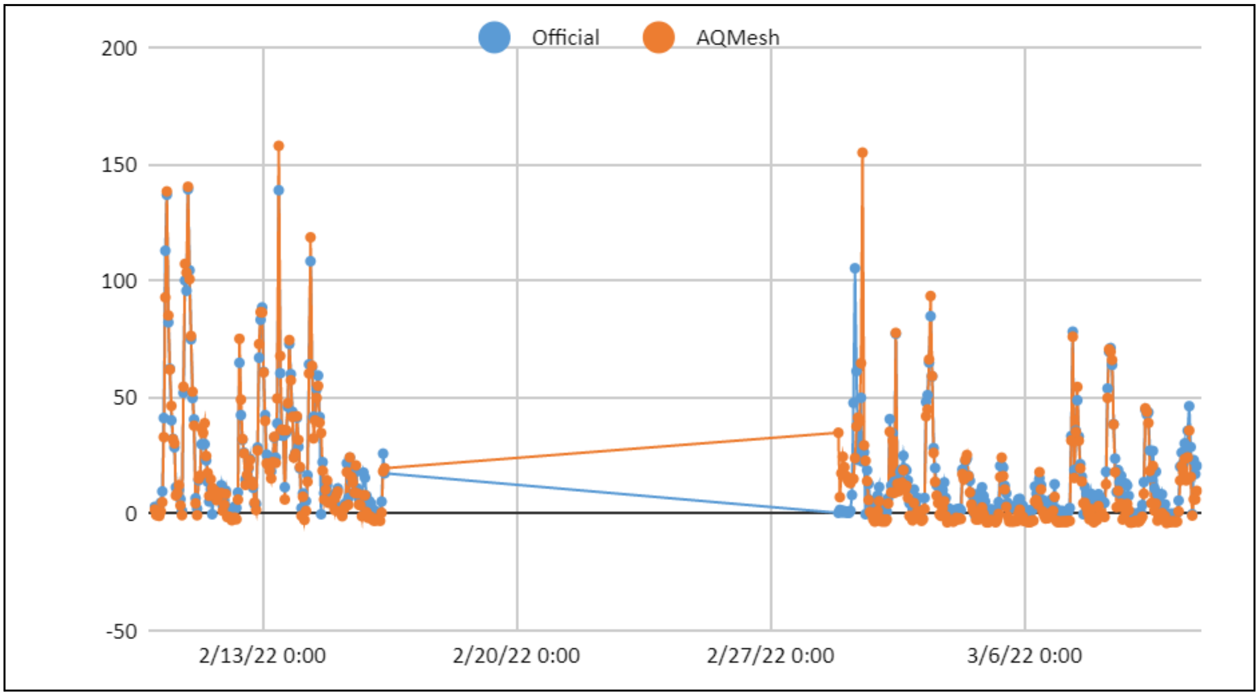

Figure A1: Measured NO concentration (ppb) from AQMesh (pre-calibration) and reference monitor

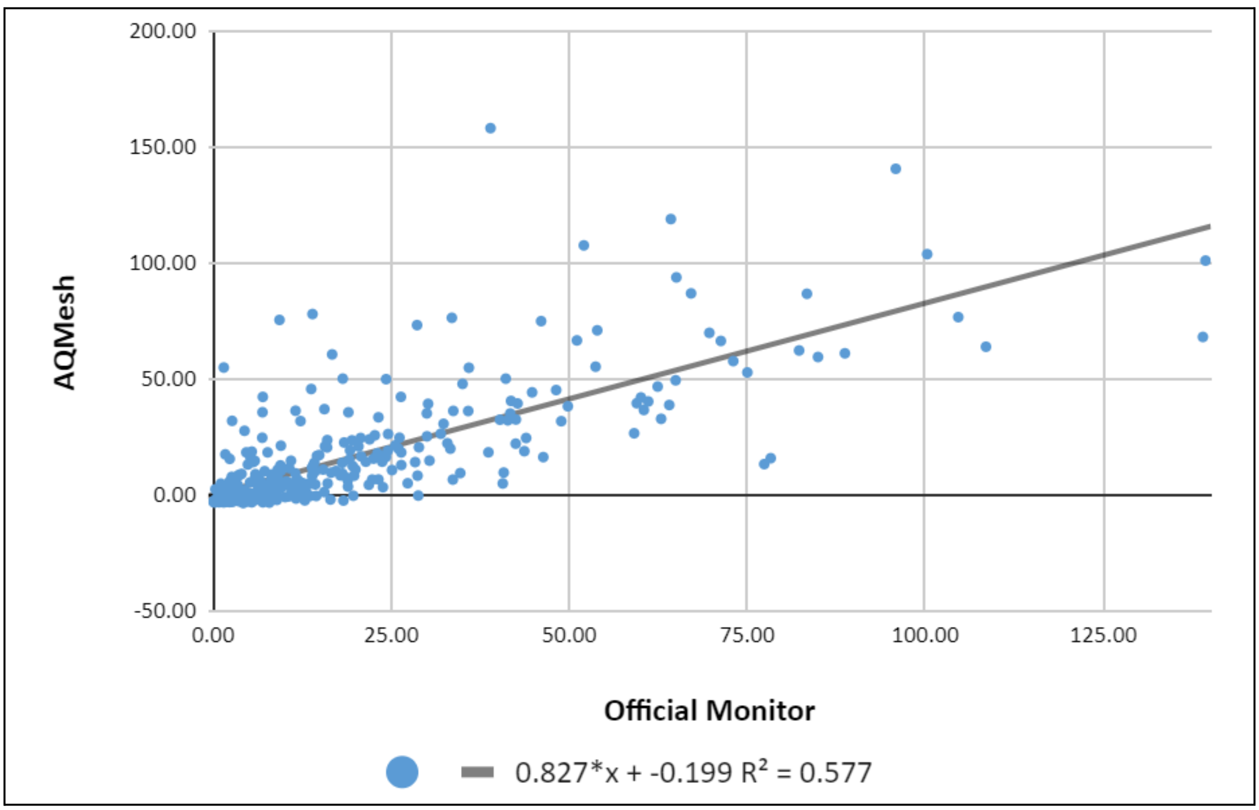

Figure A2: Comparison of AQMesh and reference monitor measured NO concentration (ppb)

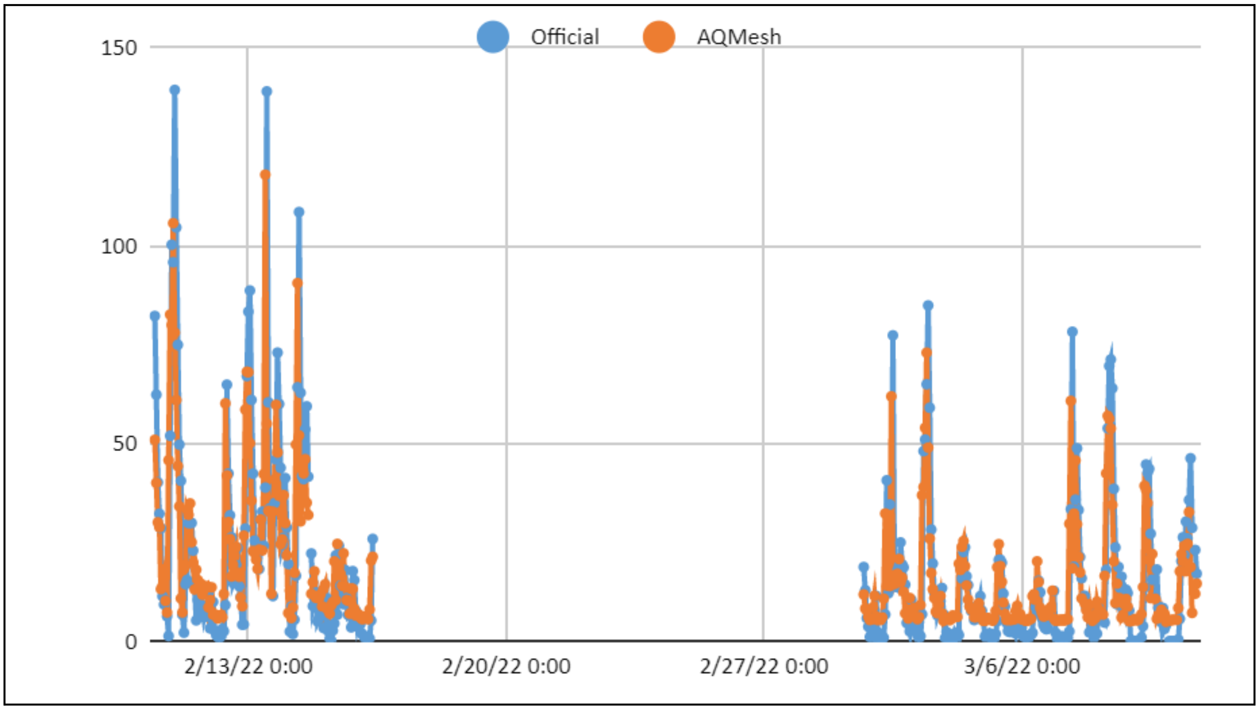

Figure A3: Measured NO concentration (ppb) from AQMesh (adjusted) and reference monitor

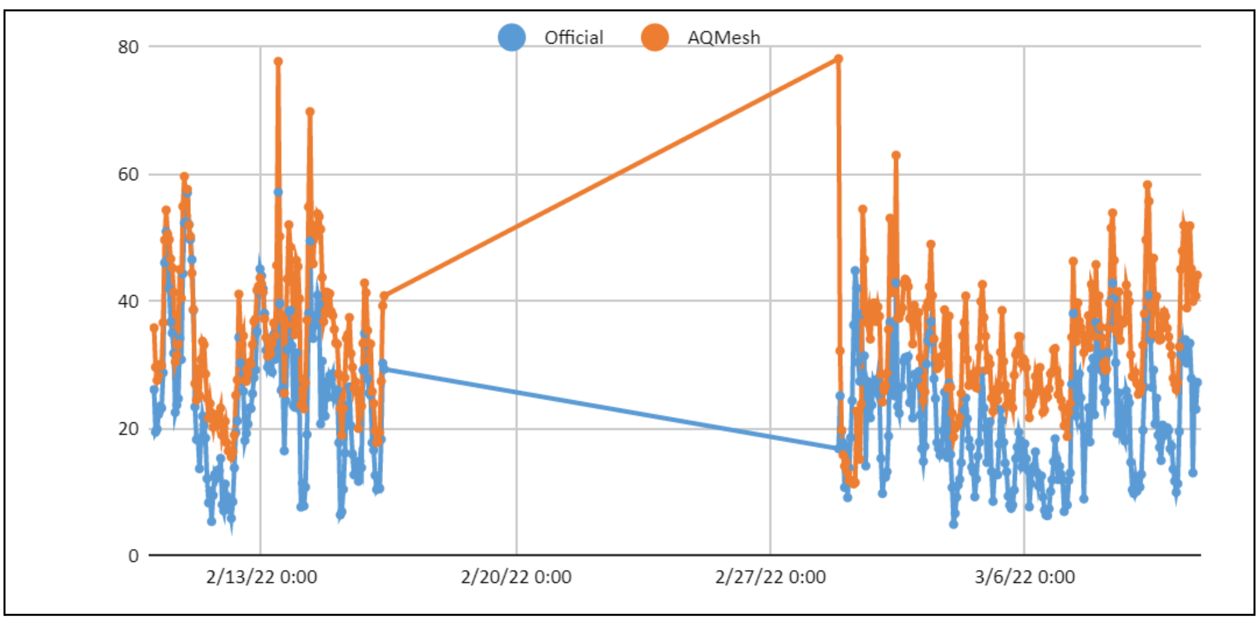

Figure A4: Measured NO_2 concentration (ppb) from AQMesh (pre-calibration) and reference monitor

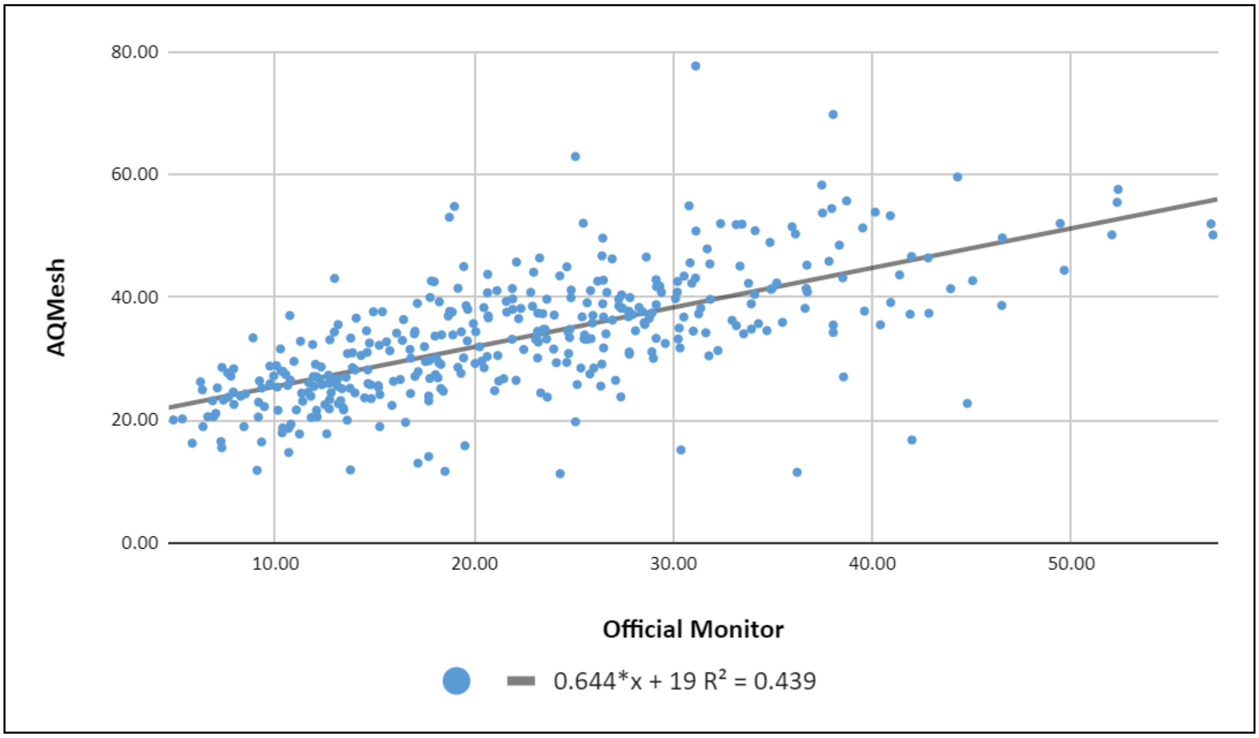

Figure A5: Comparison of AQMesh and reference monitor measured NO_2 concentration (ppb)

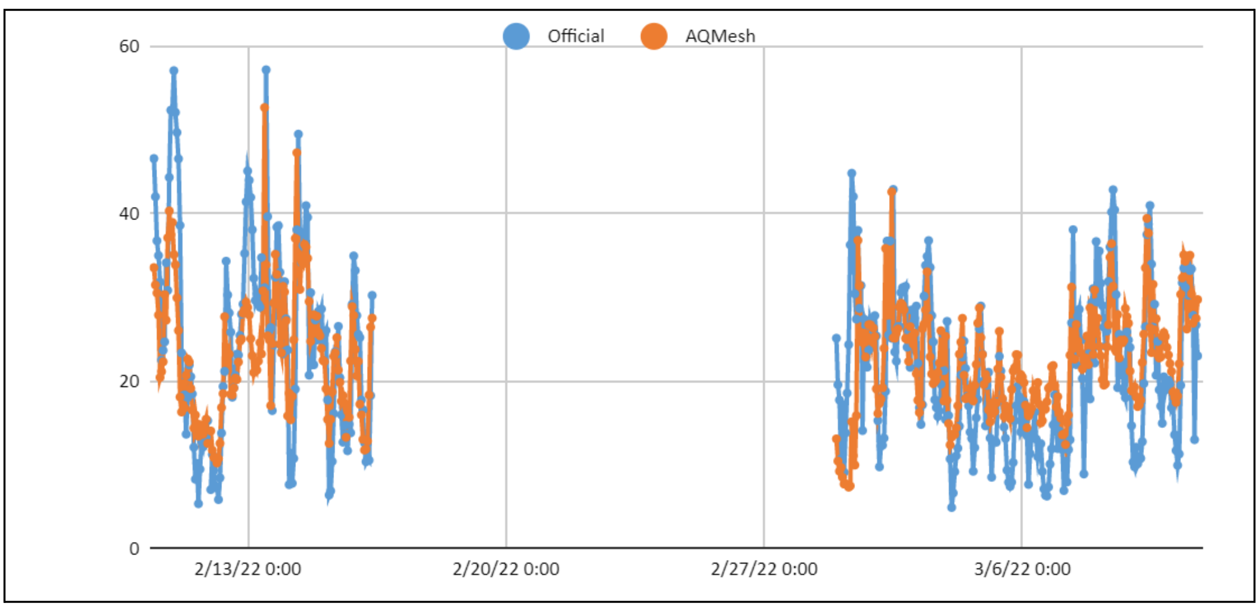

Figure A6: Measured NO_2 concentration (ppb) from AQMesh (adjusted) and reference monitor