

Vortex Air Quality Sensor Performance - Southwark

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1 Background

This is a summary report for Vortex IoT for the period 01/04/2021 to 21/09/2021 assessing the performance of six nitrogen dioxide (NO₂) and ozone (O₃) sensors. The sensors form part of a small network in Southwark, London and provide data at a time averaged resolution of 5-minutes. Nearby reference sites, which provide 15-minute average data, were used for comparison to the sensors. Sensor system data is aggregated to 15-minute, hourly and daily averages for the comparisons with reference data. Analyses have been carried out using sensor data as supplied by Vortex IoT - no further adjustments have been carried out by Ricardo.

2 Monitoring stations

The map below (Figure 1) shows the sensor network (blue markers) and reference sites (red markers) used for this assessment. Further details of the sites are summarised in Table 1.

Southwark Borough Council operate five [automatic air quality monitoring sites](#) (reference), in addition to the six sensor sites. The closest of these reference sites to the sensor network is Southwark - Lower Road. In addition to the Southwark reference network, two Automatic, Urban and Rural Network (AURN) reference sites (London N. Kensington and London Bloomsbury) were utilised for comparing O₃ concentrations.

Figure 1: Location map of air quality monitoring sites



Table 1: Site information summary

Site Name	Type	Pollutants Measured	Latitude	Longitude
SW-AQM-01	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49664	-0.05256
SW-AQM-02	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49702	-0.05091
SW-AQM-03	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49784	-0.04952
SW-AQM-04	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49562	-0.05155
SW-AQM-05	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49451	-0.04993
SW-AQM-06	Sensor	NO ₂ , O ₃ , PM ₁₀ , PM _{2.5}	51.49741	-0.05394
Southwark - Lower Road	Reference	NO ₂ , PM ₁₀ , PM _{2.5}	51.49656042	-0.053050447
Southwark - Vicarage Grove	Reference	NO ₂ , PM ₁₀ , PM _{2.5}	51.47358035	-0.087781854
Southwark - A2 Old Kent Road	Reference	NO ₂ , PM ₁₀ , PM _{2.5}	51.48049949	-0.059552893
Southwark - Elephant and Castle	Reference	PM ₁₀ , PM _{2.5}	51.4931557	-0.101527038
Southwark - Tower Bridge Road	Reference	NO ₂ , PM ₁₀ , PM _{2.5}	51.50139067	-0.078203437
London Bloomsbury	Reference	NO ₂ , O ₃ , SO ₂ , PM ₁₀ , PM _{2.5}	51.52229	-0.125889
London N Kensington	Reference	NO ₂ , O ₃ , SO ₂ , CO, PM ₁₀ , PM _{2.5}	51.52105	-0.213492

2.1 Air Quality Strategy Objectives

The [European Air Quality Directive](#) and [Fourth Daughter Directive](#) set out legal limits for different pollutants as Limit Values (LV), Target Values or Long Term Objectives to protect human health and have been transposed into UK law. Table 2 summarises the air quality strategy objectives for England for NO₂ and O₃ and shows the objectives in units of micrograms per cubic metre ($\mu\text{g m}^{-3}$) with the number of exceedances in each year that are permitted (where applicable). Note that due to the secondary and transboundary nature of O₃, this pollutant is not managed under the Local Air Quality Management regime as it is difficult to control concentrations at a local level.

Table 2: Air quality objectives, England

Pollutant	Metric	Type	Legal Value ($\mu\text{g m}^{-3}$)
NO ₂	1-hr	LV	200 (18 allowed)
NO ₂	Annual mean	LV	40
O ₃	Maximum daily running 8-hour mean	LV	100 (10 allowed)

3 Data Analysis

3.1 Summary statistics

Tables 3 and 4 present pollutant statistics for the period 01/04/2021 to 21/09/2021 for NO₂ and O₃, respectively. Note that at a data capture rate of at least 85% over a calendar year is required in order to directly compare statistics to the air quality objectives. However, the objectives do provide a useful reference point for the purposes of this assessment. It is also important to note that all data from reference sites were provisional at the time of carrying out this assessment and that statistics were calculated using hourly average data.

Sensor data capture rates for NO₂ and O₃ were >90% for all sensors except SW-AQM-01 (42.9%), with four out of six sensors achieving data capture rates of >98%. In general data coverage was comparable or better to what is seen in the provisional reference data sets.

For NO₂, mean concentrations measured by the sensor network were similar to that measured at the closest reference monitoring site - Southwark Lower Road. This similarity is mirrored in the peak hourly concentrations with maximum hourly concentrations of between 99.6 and 113.3 $\mu\text{g m}^{-3}$ measured by the sensor network, compared to 106 $\mu\text{g m}^{-3}$ measured at Southwark Lower Road. Mean and hourly O₃ concentrations were consistent with what is seen at the three reference sites.

Table 3: Summary of statistics for NO₂

Site	Mean ($\mu\text{g m}^{-3}$)	Data Capture (%)	Hourly Maximum ($\mu\text{g m}^{-3}$)	Hours Exceeding
SW-AQM-01	24.3	42.9	100.7	0
SW-AQM-02	25.3	99.5	113.3	0
SW-AQM-03	25.1	99.7	101.6	0
SW-AQM-04	25.3	99.1	102.7	0
SW-AQM-05	25.1	92.1	99.3	0
SW-AQM-06	24.9	98.9	103.4	0
Southwark - Lower Road	25.6	93	106	0
Southwark - Vicarage Grove	36.5	87.7	122.4	0
Southwark - A2 Old Kent Road	28.5	94.9	107.8	0
Southwark - Tower Bridge Road	37.2	46.2	241.8	10

Table 4: Summary of statistics for O₃

Site	Mean ($\mu\text{g m}^{-3}$)	Data Capture (%)	Hourly Maximum ($\mu\text{g m}^{-3}$)	8-Hour Exceedances
SW-AQM-01	49.6	42.9	148.1	6
SW-AQM-02	53.5	99.2	138.4	9
SW-AQM-03	53.9	99.1	152.2	9
SW-AQM-04	53.4	99	134.5	9
SW-AQM-05	53.5	92	140.3	8
SW-AQM-06	53.8	98.6	139.4	9
London Bloomsbury	48.8	98.9	139.1	5
London N. Kensington	57.4	95.5	149.9	0
Southwark - Elephant and Castle	58.4	94.9	154.6	14

3.2 Time series plot

The plots in Figures 2 to 7 show the time series of 15-min, hourly and daily average NO₂ and O₃ concentrations. For both NO₂ and O₃, the underlying trend in concentrations are consistent between all reference and sensor sites, even looking at 15-minute concentrations. Specifically, for NO₂ the sensors trend very closely to Southwark - Lower Road, the closest reference site.

Figure 2: Time series plot of 15-minute NO₂ concentrations

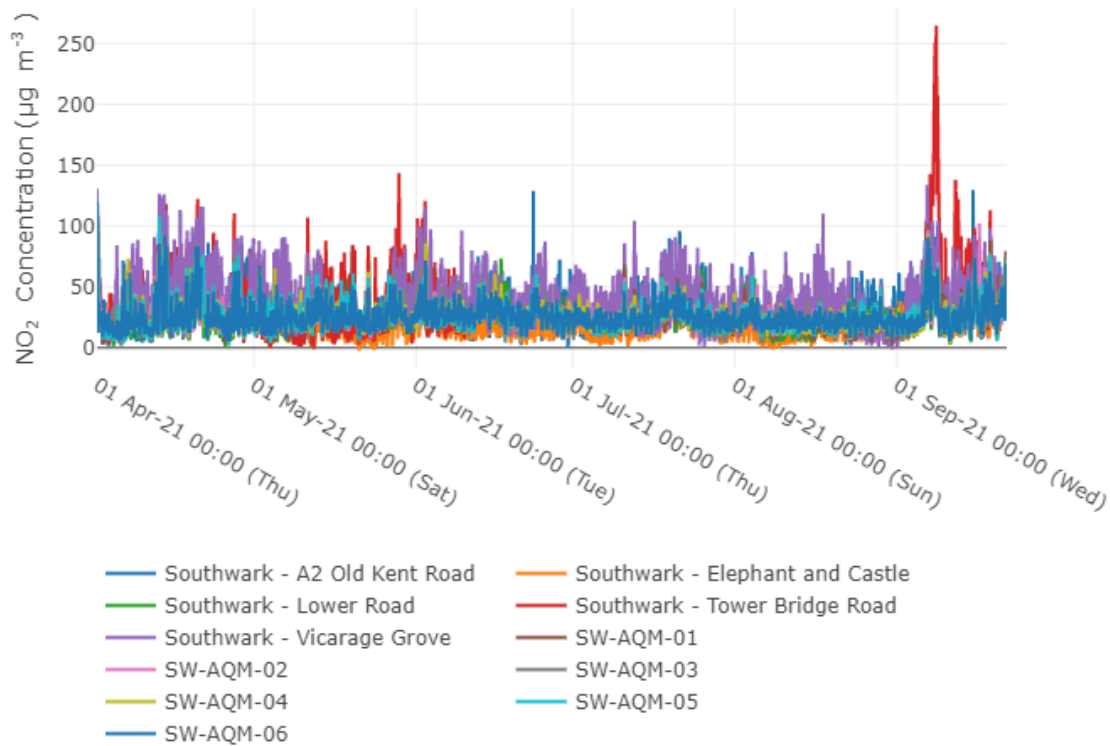


Figure 3: Time series plot of hourly NO₂ concentrations

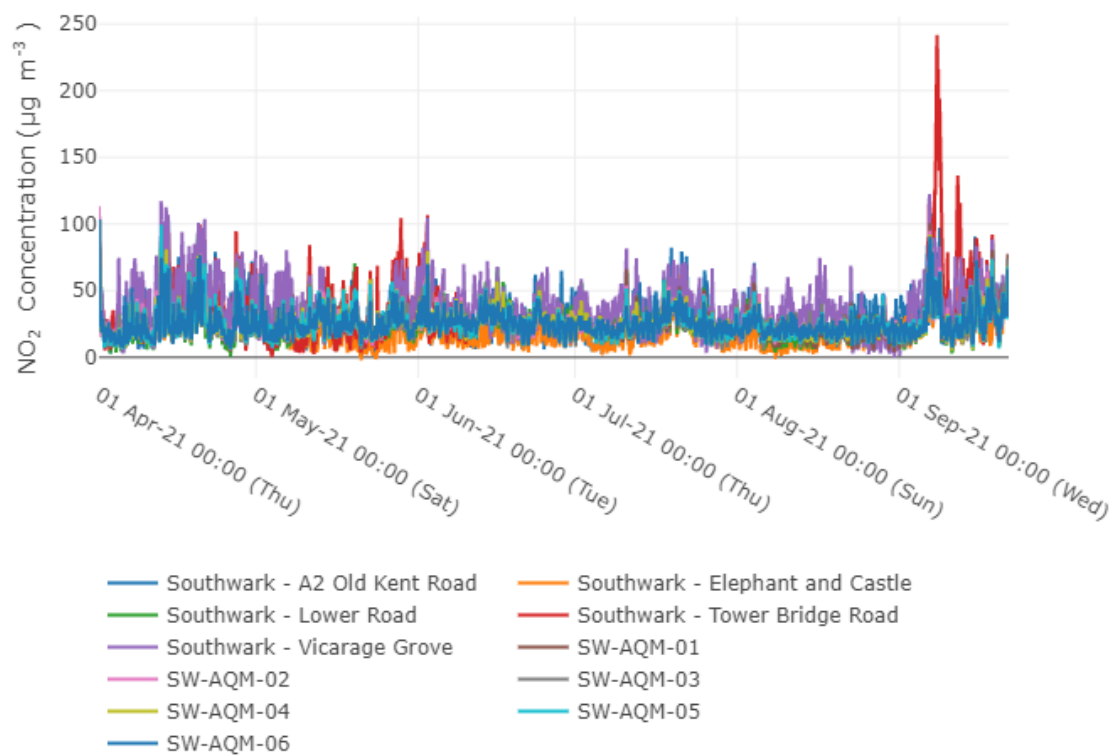


Figure 4: Time series plot of daily NO₂ concentrations

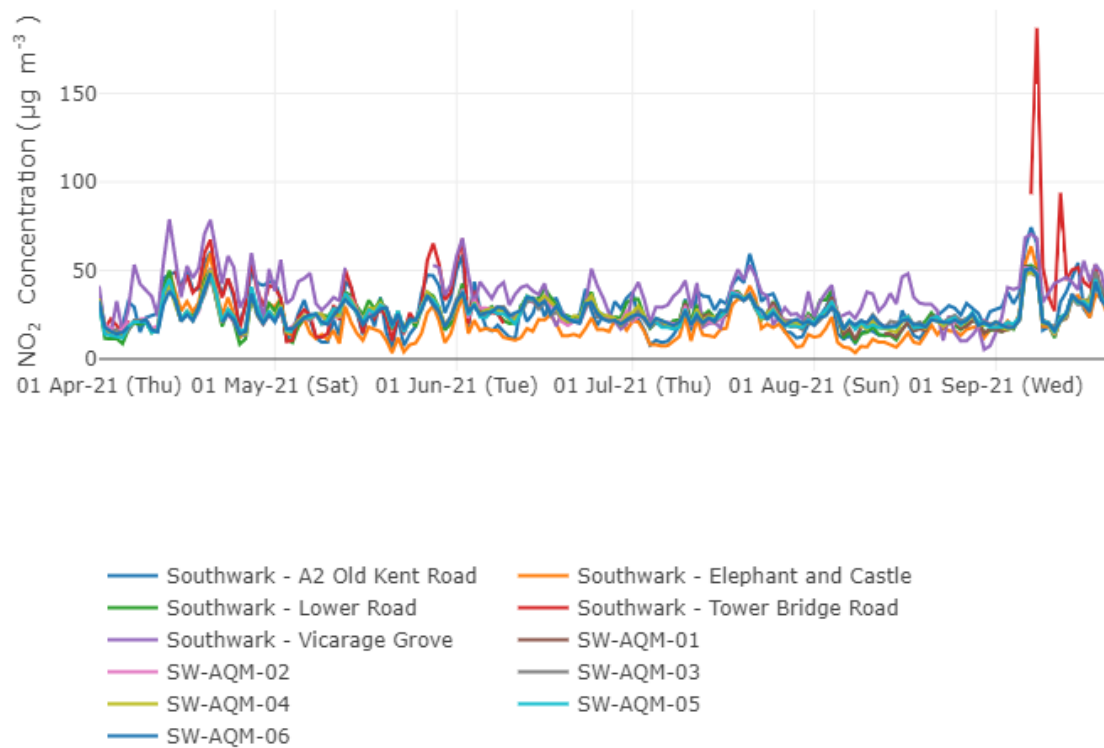


Figure 5: Time series plot of 15-minute O₃ concentrations

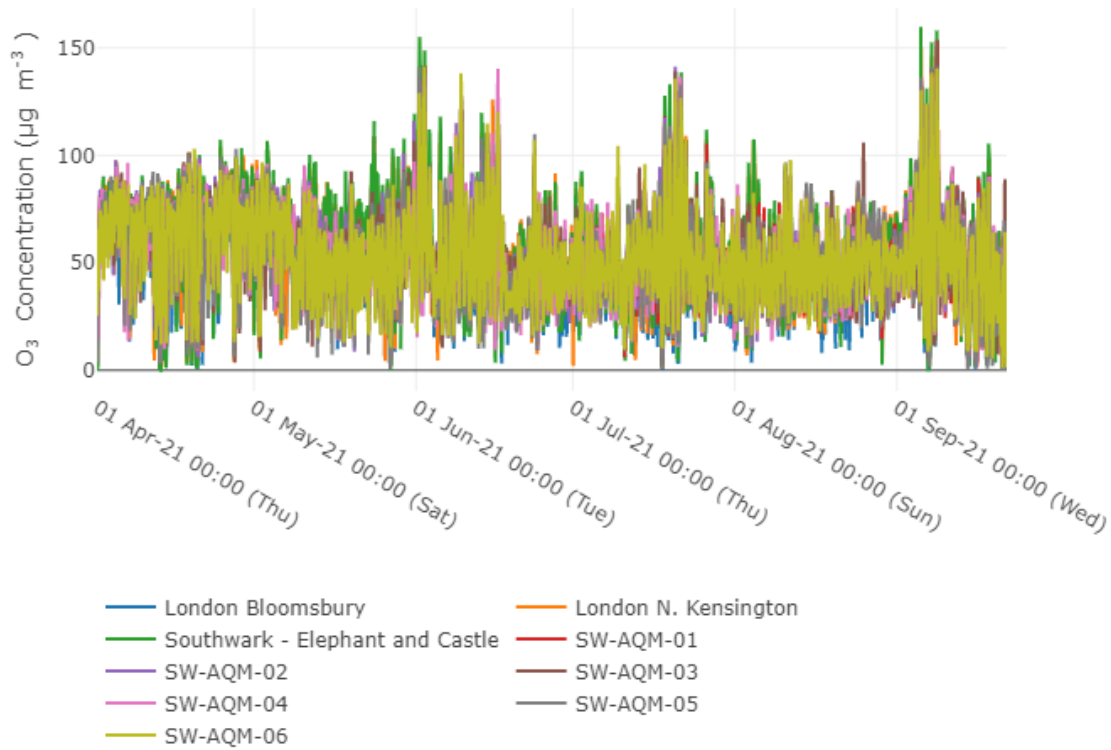


Figure 6: Time series plot of hourly O₃ concentrations

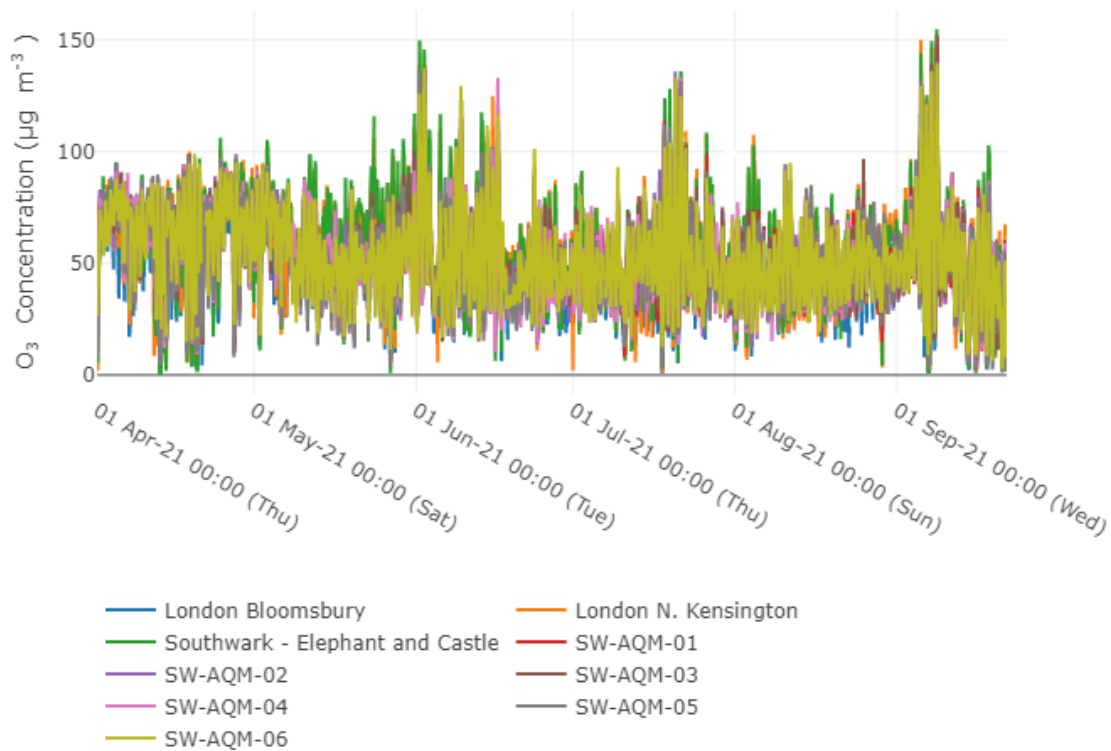
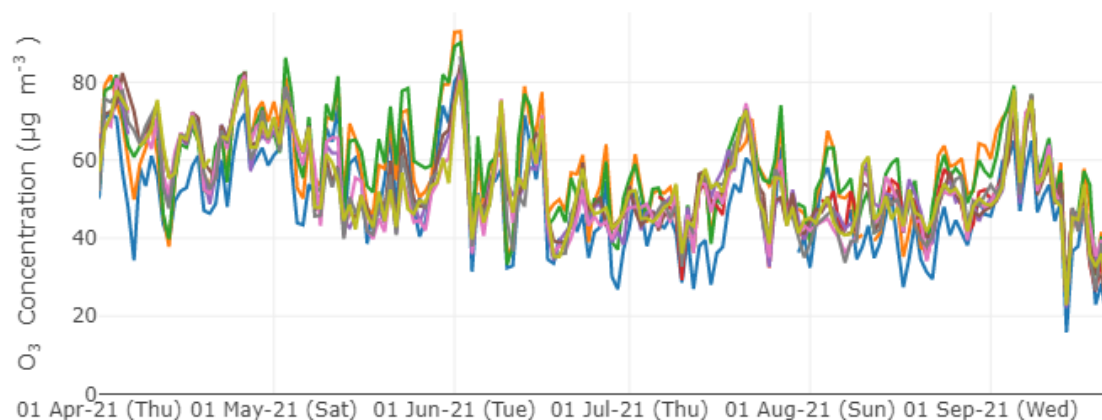


Figure 7: Time series plot of daily O₃ concentrations



3.3 Correlation

The plots shown in Figures 8 to 13 are correlation plots of the relationships between the Vortex sensors and nearby Southwark Borough Council or AURN reference sites for NO₂ and O₃. These plots quickly highlight patterns in the relationships between the sensor and reference sites.

Specifically, for NO₂ there is a stronger correlation between the sensor sites and Southwark - Lower Road reference site (strongest in the hourly concentrations) indicating that the sensors are accurately capturing the diurnal variations in NO₂ concentrations and that the inter-comparability with reference measurements is good. There is an underlying trend that is consistent across the Southwark reference monitoring network with moderate correlations with the remaining reference sites.

The correlation in O₃ measurements between London N. Kensington, London Bloomsbury, Southwark Elephant and Castle reference sites and the sensor sites is strong across all time averages ($R > 75$ or greater). The correlation weakens slightly when comparing the sensors to the reference sites versus sensor to sensor, however, the data indicate that the sensors are accurately capturing the diurnal variations in O₃ concentrations and that the inter-comparability with reference measurements is good.

3.4 Concentration Distributions

Figures 14 and 15 show the concentration distributions of 15-minute averages as measured by the Vortex sensor network and the nearby reference sites. The NO₂ plot shows again that the sensor data have a similar distribution as the closest reference site - Southwark Lower Road. Similarly, for O₃ the sensors are measuring the same range of concentrations as the reference sites.

Figure 14: NO₂ concentration distributions

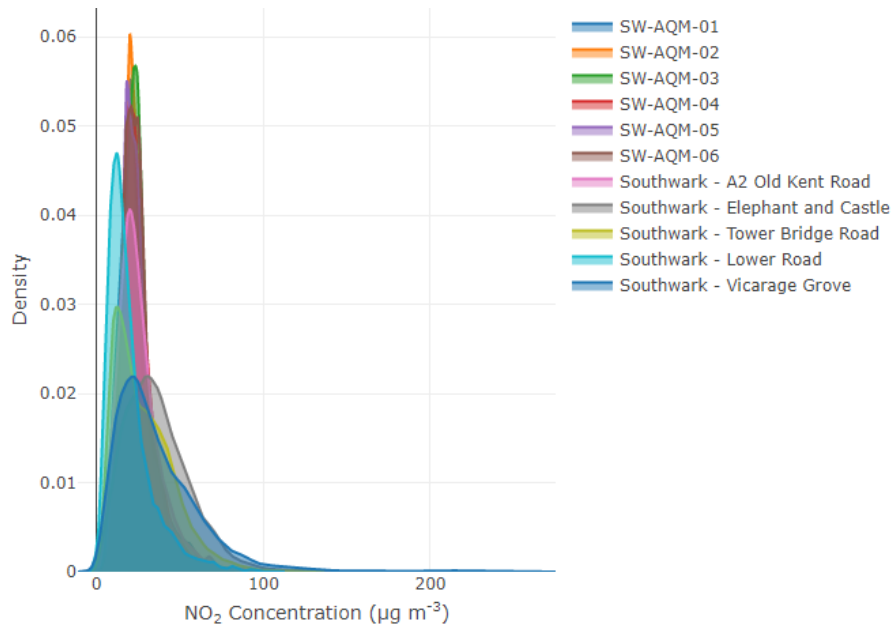
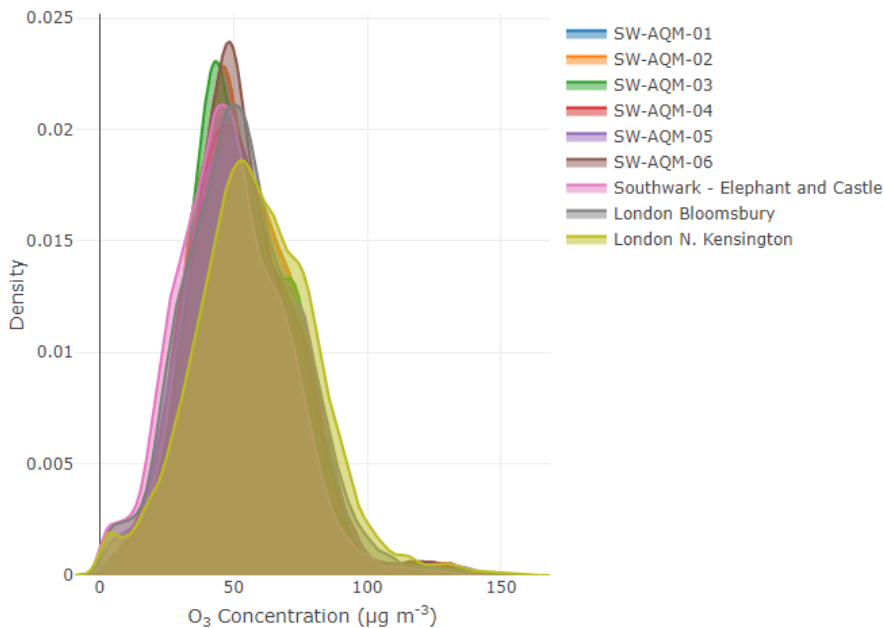


Figure 15: O₃ concentration distributions



4 Summary

Sensor site-specific issues:

- SW-AQM-01 has a low data capture rate of 42.9% for both NO₂ and O₃.

NO₂ sensors:

- The intra-comparability between sensor sites and precision is excellent.
- The inter-comparability between sensor sites and reference sites is excellent.

O₃ sensors:

- The intra-comparability between sensor sites and precision is excellent.
- The inter-comparability between sensor sites and reference sites is excellent.