Impact of green screens on concentrations of particulate matter and oxides of nitrogen in near road environments

Prepared for the Royal Borough of Kensington and Chelsea

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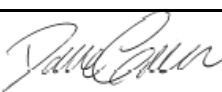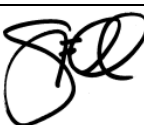| Title	Impact of green screens on concentrations of particulate matter and oxides of nitrogen in near road environments

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Summary

Research on urban vegetation suggests that it can help reduce the impact of pollution on people and buildings by acting as a pollution sink, especially for particles. Furthermore, the transport of pollutants from nearby traffic sources in urban areas can be effectively reduced by using green barriers. Thus, green infrastructure might be a cost effective and easy way to reduce the impact of pollution in near road environments. This is especially important for vulnerable members of the population, such as children, whose lung growth is slowed in areas with high pollutant concentrations. Therefore, a measure to reduce pollution levels at schools situated at roadsides will be of particular benefit.

To assess the efficacy of a green screen to prevent the transport of vehicle emissions from the nearby road into the playground, an ivy screen was installed at St. Cuthbert with St. Matthias Primary School in the Royal Borough of Kensington and Chelsea. NO_X and PM_{10} were then measured immediately either side of the screen using two standard chemiluminescence NO_X analysers and two Turnkey Osiris light scattering PM analysers, respectively. The difference in concentration between the roadside side and playground side of the screen was assessed as it matured.

To quantify the measurement uncertainty, the instruments were co-located at the start and the end of the programme. This data was used to correct for systemic biases and to calculate a daily between sampler uncertainty, which was 7.2% for NO_2 and 15.2% for PM_{10}.

Highest concentration could be observed during September for NO_2 and in March and September/October for PM_{10}. Annual mean air quality objective would not have been met on either side of the screen for NO_2 assuming that the analysis period is representative of the entire year. The average PM_{10} concentration was below the annual mean objective; this is with the significant caveat that the PM_{10} measurement methodology is not equivalent. NO_2 and PM_{10} concentrations rise during morning rush hour and remain elevated throughout the day. The concentration difference between the sites also remains highest throughout the daytime period.

NO_2 and PM_{10} source directions are aligned with the road axes suggesting that pollution levels were generally highest when emissions were either recirculated from the A3220 (northbound) or blown along the road from sources on northbound A3220, old Brompton Road and southbound A3220.

The screen was found to be an effective pollution barrier once the ivy had started growing and a significant impact could be seen once the screen had matured. The ivy screen led to a decrease in the pollution concentrations on the playground side of the screen by 24% for NO_2 and 38% for PM_{10}; both were higher than the measurement uncertainty and thus significant. Comparing school hours independently a reduction in concentrations of up to 36% and 41% were found for NO_2 and PM_{10}, respectively. This demonstrates that the screen is very effective during daytime hours, when both emissions and exposure are highest.

Although it is clear that the screen has a significant effect in preventing the transport of pollution from the roadside into the playground, further work would be required to assess the impact of the screen at greater distances from the road.

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Contents

1   Introduction

The concentration of toxic air pollutants such as nitrogen dioxide and particulate matter are elevated close to roads in London, these have been shown to have detrimental health effects including increased cardio-pulmonary and lung cancer mortality and increased risk of respiratory symptoms (WHO, 2003). Many of these effects are more enhanced in sensitive populations, such as children. Indeed, exposure to PM has been shown to negatively affect the development of the lung function in elementary schoolchildren (Horak Jr. et al. 2002). Many schools in London and in the Royal Borough of Kensington and Chelsea (RBKC) are located close to roads, with classrooms and playgrounds only a few meters from heavy traffic.

Despite many years of investment in exhaust emission abatement technology, moving from Euro 4 to 5 etc. (EC Regulation 715/2007/EC), and policy interventions such as the London Low Emission Zone, the concentrations of pollutants, especially nitrogen dioxide, remain high close to roads. Alternative methods to reduce human exposure, in particular for the sensitive populations such as children, are therefore being sought.

One such method is the installation of green screens to act as a barrier to the transfer of polluted air. Research on urban vegetation suggests that it can help reduce the impact of pollution on people and buildings by acting as a pollution sink, especially for particles. Furthermore, the transport of pollutants from nearby traffic sources in urban areas can be effectively reduced by using green barriers (Sternberg et al, 2010; Hill, 1971). Thus, green infrastructure might be a cost effective and easy way to reduce the impact of pollution in near road environments. As mentioned above this is especially important for vulnerable members of the population, such as children, whose lung growth is slowed in areas with high pollutant concentrations (Kelly and Fussel, 2011). Therefore, a measure to reduce pollution levels at schools situated at roadsides will be of particular benefit.

Figure 1: Playground area with and without ivy screen

The hypothesis was that a green screen will have a beneficial effect on the PM and NO_X concentrations inside the school grounds. To assess the efficacy of a green screen to prevent the transport of vehicle emissions from the nearby road into the playground, 51m of ivy screen were installed at St. Cuthbert with St. Matthias Primary School in the London Borough of Kensington and Chelsea (Figure 1). This had the effect of increasing the existing roadside barrier from around 2m to 2.7m high. The primary school was chosen due to its location close to a busy road (A3220), with the main playground area adjacent to that road (Figure 3). PM_{10} and NO_X were then measured

immediately either side of the screen. Data was collected as the screen was growing and thus the impact of the screen could be monitored during the maturing of the ivy screen.

2   Methods

2.1   Measurement configuration

The primary data source for this study were the temporary monitoring stations at St. Cuthbert with St. Matthias primary school (Figure 2, Figure 3). The stations were installed for the duration of one year (November 2013-November2014) and were situated along Warwick Road (A3220), either side of an ivy screen. One set of analysers was inside the school grounds in order to measure the concentrations on the playground side of the screen and the other set of analysers was situated on the outside of the green screen to measure the roadside concentrations.
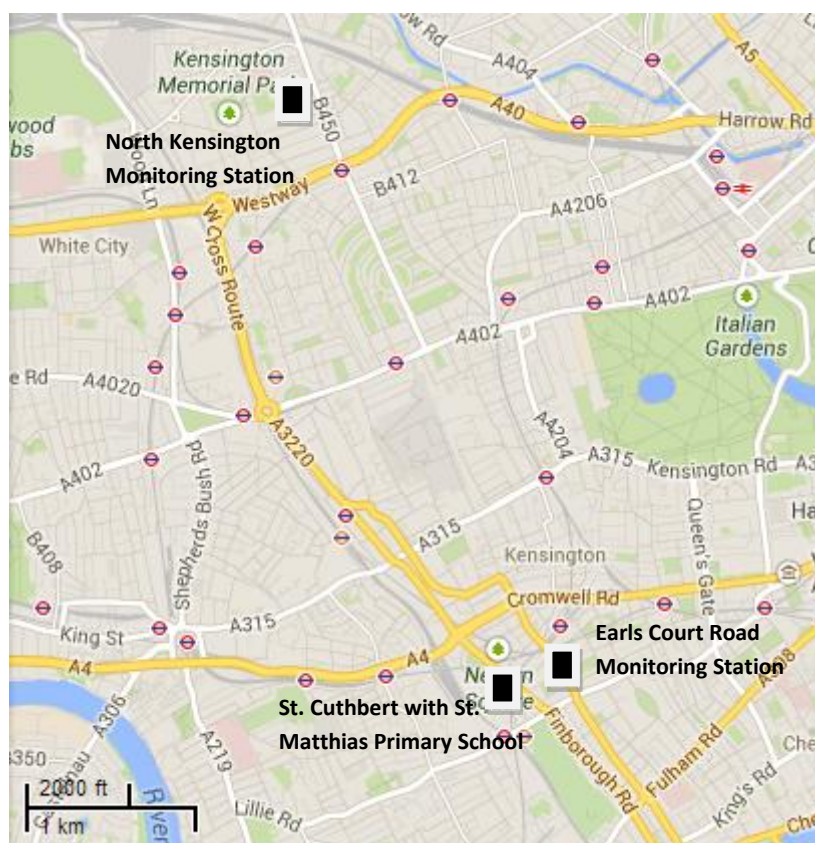

Figure 2: Locations of the Earl's Court Road kerbside monitoring station and the North Kensington background monitoring site.

Additionally, in order to provide a comparison, North Kensington and Earl's Court Road monitoring site data were used as comparison sites .The North Kensington monitoring station, a background site, is situated in a school yard in the north of the borough. The Earl's Court Road monitoring station, a kerbside site, is situated on the southern end of Earl's Court Road, between the Braham Gardens and Bolton Gardens (Figure 2).
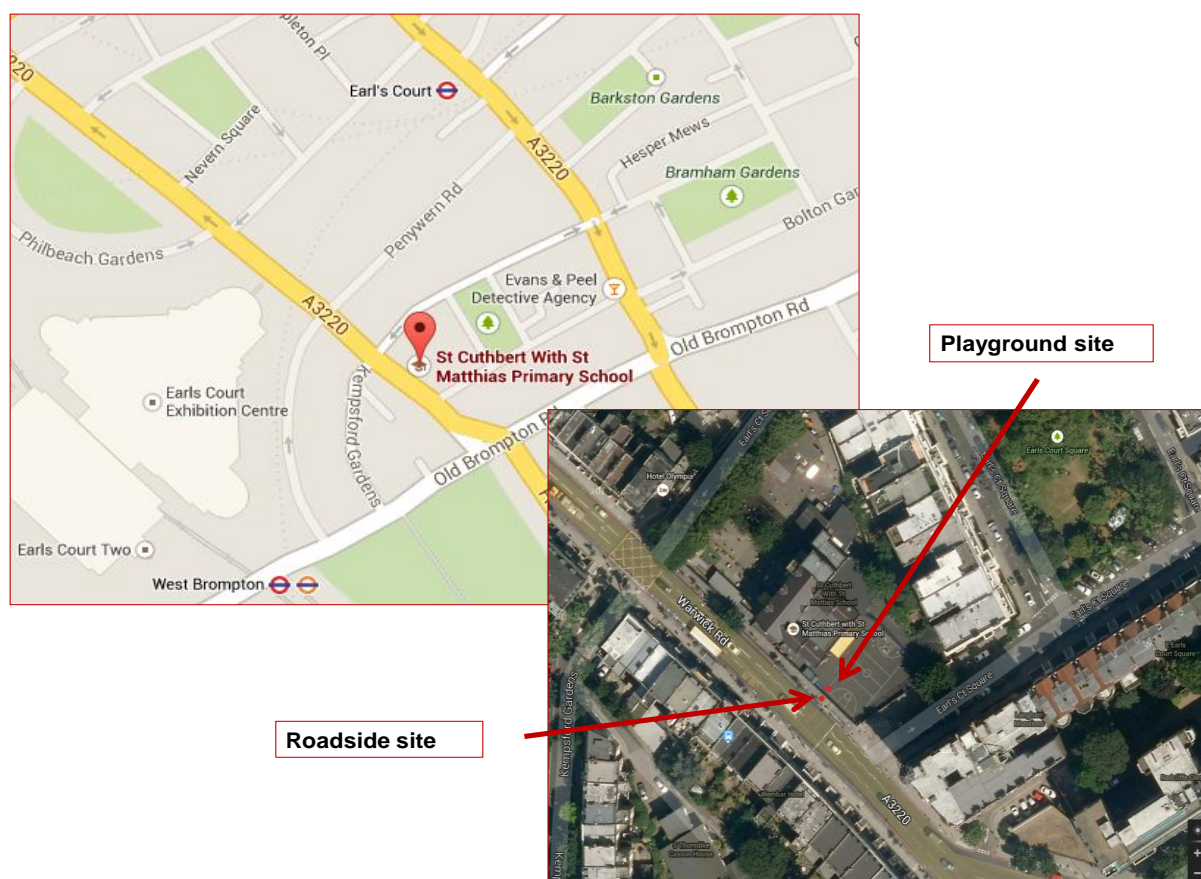
Figure 3: Location of St. Cuthbert with St. Matthias primary school and the location of the monitoring sites in the school

Two standard chemiluminescence NO_X analysers (ML9841) and two Turnkey Osiris light scattering PM analysers were used to assess the difference in concentration between the roadside side and playground side of the screen as it matured. The Osiris instrument was chosen as space was limited and the experimental design dictated that the inlets were placed either side of the screen; however this instrument is indicative and is not equivalent to the EU reference measurement for either PM_{10} or $PM_{2.5}$. Nevertheless, as percentage differences are used to analyse the impact of the green screen, this does not detract from the final conclusions. NO_X data were ratified to LAQN and AURN QA/QC standards and PM data were ratified using instrument calibration and regular flow checks. The North Kensington and Earl's Court Road data were preliminary and not yet fully ratified.

All data analysis was undertaken on hourly mean concentrations containing at least 3 valid fifteen-minute means. "London Mean" meteorological data was used in the analysis; this is a "typical" meteorological data set representing London, which is a composite of data from several instruments co-located with air pollution monitoring sites (Carslaw, 2013). At the start (NO_X only) and end of the measurement programme the analysers were co-located so that a between instrument uncertainty could be calculated. Orthogonal regression analysis was undertaken and graphed using MS-Excel 2010. Other analyses utilised R statistical software and the Openair function package within it (Carslaw et al, 2013).

Figure 4: Osiris analyser and NO$_X$ inlet situated on the playground side of the green screen

3   Results and Discussion

The instruments were installed in November 2013, however, it took some time to undertake a co-location exercise and ensure that both pairs of instruments were working correctly. The main time periods considered for the data analysis were between the 1st Feb 14 to 22nd Sep 14 for the NO_2 and between 1st Jan 14 to 30th Oct 14 for PM_{10}. The first three months of the year were considered as a "pre-growth" period, during which the impact of the ivy screen was considered to be low.

3.1   Co-location and analyser comparison

As stated in the methods section the instruments were co-located for a short period of time in order to quantify the measurement uncertainty. Figure 5 shows the results of orthogonal regression analysis on the daily mean measurements from the two analysers for NO_2 and PM_{10}. The NO_X analyser co-location analysis contained measurements from co-locations undertaken both before and after the trial; the consistency between the pre and post periods offers a great deal of confidence in this result. PM_{10} co-location data was only available for a period after the study.

The co-location exercise and orthogonal regression of the data revealed that there was a systematic over-read of the roadside NO_X analyser in comparison with the background. The analysis for NO_2 results in a slope of 0.83 (±0.02), and an intercept of +0.75 (±0.4) ppb. The regression analysis for PM_{10} results in a slope of 1.08 (±0.06), and an intercept of -1.15 (±1.52) μgm^{-3}. Hence, in the case of the Osiris analysers there was a small systematic under-read of the roadside instrument compared to the background instrument.
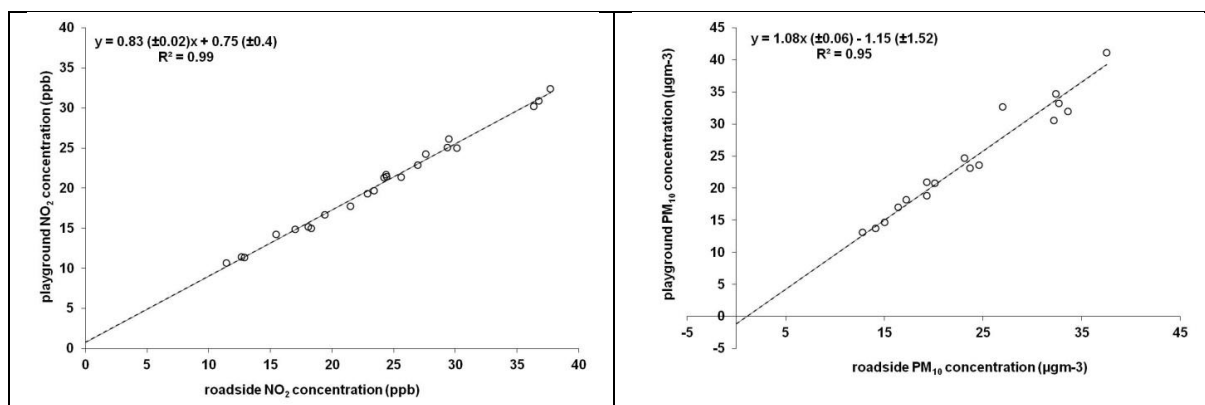

Figure 5: Scatter plot for NO_2 (left) and PM_{10} (right) concentration from the two analysers

The coefficient of determination (R^2) is very high for both (0.99 for NO_2 and 0.95 for PM_{10}) and ensures a great deal of confidence in correcting for these systematic biases. To do this, the concentrations of the instruments were corrected using factors derived from orthogonal regression of the instrument measurements in comparison to the mean of the two co-located measurements. All further analysis was carried out on these corrected concentrations.

The calculated between sampler uncertainties are given in Table 1 and are a measure of the sensitivity / detection limit of the experiment. Therefore, when comparing measurements between the analysers, any change induced by the ivy screen would need to be greater than the relevant expanded between analyser uncertainty to be considered significant.

	NO_2 (%)	PM_{10} (%)
Hourly Between Sampler Expanded Uncertainty	8.1	16.4
Daily Between Sampler Expanded Uncertainty	7.2	15.2

Table 1: Between sampler uncertainties for hourly and daily mean concentration from the paired analysers at St. Cuthbert with St. Matthias primary School

3.2   Overview of monitoring data

When comparing between instruments of the same type, the data were analysed only for periods where both of the paired instruments were producing valid data. Therefore NO_2 data were analysed between the 1st Feb and 22nd Sep 14 and PM_{10} data were analysed between 1st Jan and 31st Oct 14. The mean and median concentrations of NO_2 and PM_{10} are given in Table 2 and show that the mean, as well as the median roadside concentrations were higher for both pollutants. Means provide the information necessary to assess regulatory targets (e.g. the 40 µg m^{-3} annual mean limit value) but can be heavily influenced by a small number of high concentrations. However, medians provide a better descriptor of the data populations that are log normally distributed; like air pollution concentrations.

Pollutant	Site	Concentration	
		Median	**Mean**
NO_2	**Roadside**	34.2 (65.2)	34.7 (66.3)
in ppb (µgm^{-3})	**Playground**	28.2 (53.9)	29.2 (55.8)
PM_{10}	**Roadside**	28.8	32.1
in µgm^{-3}	**Playground**	20.5	22.3

Table 2: Summary of pollution concentrations at St. Cuthbert with St. Matthias primary school

Assuming that the analysis period is representative of the entire year, the annual mean air quality objective would not have been met on either side of the screen for NO2 but was consistently below the annual mean objective for PM10. A significant caveat is that the PM10 measurement methodology is not equivalent and should therefore not be compared to the regulatory limit value.
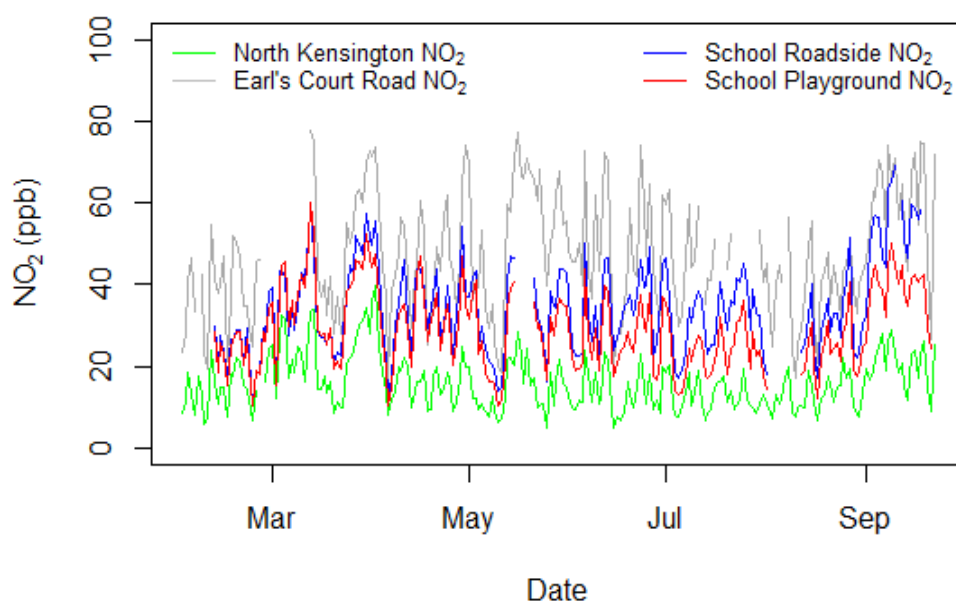
Figure 6: Time series plot of NO$_2$ (ppb) concentrations at the roadside and playground side of the green screen in comparison to the North Kensington background site and Earl's Court Road roadside site

The timeseries of the NO$_2$ and PM$_{10}$ data are shown in Figure 6 and Figure 7, respectively. The highest NO$_2$ concentrations could be observed at the roadside site in September and the lowest concentrations were seen at the start of the monitoring period. Comparing the concentrations measured at the school to the North Kensington background site and Earl's Court Road roadside site, it was found that the concentrations at the school were between those measured at the background station and that measured at the roadside station.
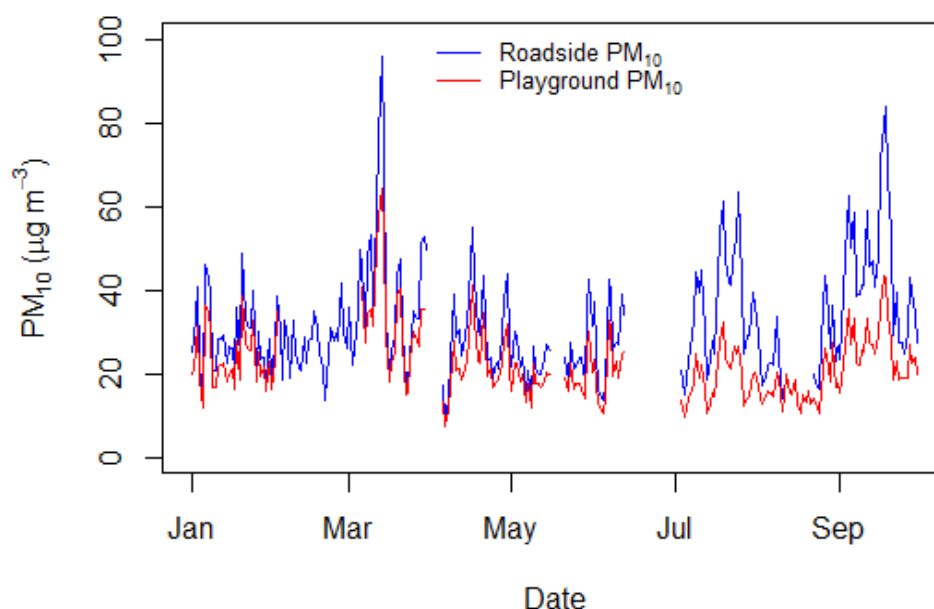

Figure 7: Timeseries plot of PM$_{10}$ (µgm^{-3}) concentrations at the roadside and playground side of the green screen

For the PM$_{10}$ there were clear episodes in March and September/ October and as with NO$_2$ the roadside concentrations were generally higher than the background concentrations. These data

were not compared to other borough PM_{10} measurements as the data measured by Osiris is used for indicative purposes and it not equivalent to the EU reference measurement.

3.3   Influence of wind speed and wind direction

Bivariate polar plots were produced using the openair analysis package in R (http://www.openair-project.org/). They show a smoothed concentration surface in relation to wind speed (radial axis) and wind direction (polar axis) and were used to highlight the relative influence of local sources to pollution. Their use in characterising ambient air pollution sources is described in Carslaw *et al.* (2006).

Polar plots for both sites were produced for the NO_2 and PM_{10}. When interpreting such plots it is important to consider that the predominant wind direction for this site is south-westerly (Barratt et al., 2012), thus sources from this direction will have a much greater impact than other sources.
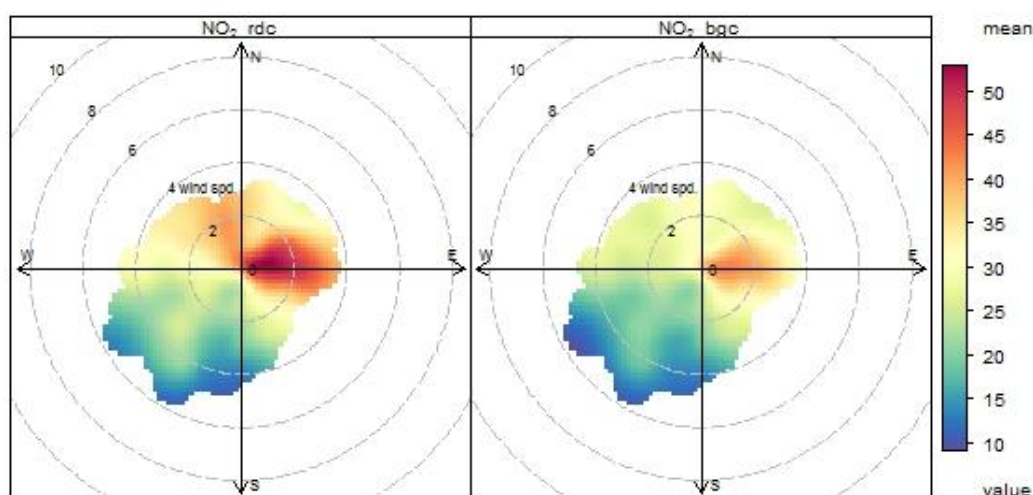

Figure 8 shows that NO_2 concentrations were highest during north-easterly and easterly winds at both sites. A secondary source could be observed for the roadside NO_2 in north-north-westerly wind direction. These directions are aligned with the road axes suggesting that pollution levels were generally highest when emissions were either recirculated from the A3220 (northbound) or blown along the road from sources on northbound A3220, old Brompton Road and southbound A3220.

There were initial concerns that the boiler within the school grounds might be a substantial source of NO_2 and, with increasing growth of the ivy screen, led to an increase in concentrations within the playground area. There is no evidence of this as the concentrations on the playground side of the screen are consistently lower than the roadside concentrations.