Ricardo
Energy & Environment

Air Quality Monitoring Annual Report 2015

Birmingham Airport

Report for Birmingham Airport Ltd
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Executive summary

This report provides details of air quality monitoring conducted at Birmingham Airport during 2015. The work, carried out by Ricardo Energy & Environment on behalf of Birmingham Airport Ltd, is a continuation of monitoring undertaken at Birmingham Airport since 1995. The aims of the programme are to monitor air pollution around the airport, to assess compliance with relevant national air quality objectives, and to investigate changes in air pollutant concentrations over time.

Automatic continuous monitoring was carried out at one location, referred to as Birmingham Airport 2. The site monitored oxides of nitrogen (nitric oxide and nitrogen dioxide), ozone, carbon monoxide, sulphur dioxide and PM_{10}. The PM_{10} data were measured using a Tapered Element Oscillating Microbalance (TEOM), therefore there was the need to adjust data using the King's College London Volatile Correction Model to correct for potential losses of volatile and semi-volatile components.

The data capture target of 90% (from the European Commission Air Quality Directive[1]) was achieved for the station's NO_x, CO, and O_3 instruments. PM_{10} and SO_2 data captures were slightly below the target (89.7% and 88.7%) in 2015.

The UK AQS hourly mean objective for NO_2 is 200 µg m^{-3}, with no more than 18 exceedances allowed each year. The monitoring site has registered no exceedances of this value during the year, and therefore met this objective for 2015.

The annual mean AQS objective for NO_2 is 40 µg m^{-3}. This objective was also met in 2015; an annual mean of 21 µg m^{-3} was measured in 2015. This value is slightly lower to the one measured in 2014 (25 µg m^{-3}), showing a small decrease in concentration for this pollutant.

PM_{10} may exceed the 24-hour mean limit of 50 µg m^{-3} no more than 35 times per year to meet the AQS objective. During 2015, three exceedances of the limit value were registered at the site. This AQS objective was therefore met in 2015. The annual mean AQS for PM_{10} is 40 µg m^{-3}. This objective was met at Birmingham Airport 2.

The UK AQS objectives for ozone state that the limit value for this pollutant is of 100 µg m^{-3}, not to be exceeded more than 10 days a year. The ozone levels measured at Birmingham Airport monitoring station show that this pollutant had 67 exceedances of the limit value in 11 days during 2015. The AQS objective for ozone was therefore not met in 2015. However, ozone is a transboundary pollutant which is difficult to control by local measures: it is therefore not currently included in the Local Air Quality Management regime.

The AQS objectives for CO and SO_2 were met by Birmingham Airport 2 monitoring station in 2015.

Table ES-1 shows an overall summary of the AQS objective and data capture statistics recorded in 2015 at Birmingham Airport 2. Green shaded cells demonstrate the objective or requirement has been met whilst red shaded cells show failure to meet requirements.

Table ES-1- Summary of AQS Objective Compliance and Data Capture

Pollutant	Data Capture (%)	Annual Mean (µg m^{-3})	Hourly mean[NO_2], Running 8 Hour [O_3], Daily mean [PM_{10}], Daily max 8 Hour [CO], and SO_2 Objective Exceedances
NO_2	98.53	21	0
PM_{10}	89.73	15	3
O_3	94.81	50	67(11)
CO	98.92	0	0
SO_2	88.68	2	0

The investigation of potential pollutant sources identified the airport grounds as a key source of the NO, and NO_2 measured at the monitoring site. Highest concentrations of particulate matter (PM_{10}) tended

to occur at higher wind speeds and with a south easterly wind direction. CO concentrations seem to follow both profiles, showing that its origin is both local and long range.

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Appendices

1 Introduction

Birmingham Airport Ltd (referred to here as "Birmingham Airport") has undertaken continuous ambient air quality monitoring at a monitoring station on the airport premises since April 1995. This forms part of the Airport's commitment to monitor air quality through the requirements of the Section 106 Planning Agreement between Solihull Metropolitan Borough Council (SMBC) and Birmingham Airport. The monitoring is intended to provide information on current air quality in the area and the levels of pollution to which the neighbouring community is exposed. The data from the air monitoring station are managed and collated by Ricardo Energy & Environment. This report has been prepared by Ricardo Energy & Environment, on behalf of Birmingham Airport, to provide analysis and commentary on the 2015 dataset.

Data in the annual report have been processed according to the rigorous quality assurance and quality control procedures used by Ricardo Energy & Environment. These ensure the data are reliable, accurate and traceable to UK national measurement standards.

1.1 Aims and Objectives

The aim of this monitoring programme is to monitor concentrations of several important air pollutants at the airport. The results of the monitoring are used to assess whether applicable national air quality objectives have been met, and how pollutant concentrations in the area have changed over time. Additionally, meteorological data were used to investigate the importance of various sources of pollution.

It is important to note that the pollutants measured in this study could have been originated from a wide variety of sources, both local and long range. Not all of these sources will be directly connected with the airport.

Monitoring data collected at Birmingham Airport are compared in this report with:

• Relevant UK air quality limit values and objectives.

• Relevant periods of regional/national elevated pollutant concentrations.

• Corresponding results from a selection of national air pollution monitoring sites.

1.2 UK Air Quality Strategy

Within the European Union, controls on ambient air quality are covered by Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe[1], known as the Air Quality Directive. This consolidated three previously existing Directives, which set limit values for a range of air pollutants with known health impacts. The original Directives were transposed into UK law through The Environment Act 1995 which 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 Environment Act 1995 also introduced the system of local air quality management (LAQM). This requires local authorities to review and assess air quality in their areas against the national air quality objectives. Where any objective is unlikely to be met by the relevant deadline, the local authority must designate an air quality management area (AQMA). Local authorities then have a duty to carry out further assessments within any AQMAs and draw up an action plan specifying the measures to be carried out, and the timescales, to achieve the air quality objectives. The legal framework given in the Environment Act has been adopted in the UK through the UK AQS. The most recent version of the AQS was published by Defra in 2007[2], and the currently applicable air quality objectives are summarised in Appendix 1 of this report.

1.3 Emissions from Airports

Airports are potentially significant sources of many air pollutants. Aircraft jet engines emit pollutants including oxides of nitrogen (NO_x), carbon monoxide (CO), oxides of sulphur (SO_x), particulate matter, hydrocarbons from partially combusted fuel, and other trace compounds. There are also pollutant

emissions from the airside vehicles, and from the large number of road vehicles travelling to and from the airport each day.

1.3.1 The Air Quality Strategy and Birmingham Airport

The UK Air Quality Strategy Objectives apply anywhere that public exposure may occur, for example at residential properties, at a bus stop etc. As the airport monitoring site is located by the runway, where members of the public do not have access, strictly these limits do not apply. However, this report compares the data from the site with the Air Quality Strategy (AQS) Objectives. If the site is showing compliance with the objectives for the primary pollutants that are likely to be emitted directly from the airport - namely NO_2, PM_{10}, CO and SO_2 - then it is reasonable to assume that, in the absence of any other significant sources, the objectives are likely to be met at the nearby residential properties.

For the purposes of LAQM, the airport falls under the jurisdiction of Solihull MBC. The Council has reviewed air quality across their area and found that pollutant levels do not exceed the AQS Objectives. Therefore, at the time of writing (April 2016), no air quality management areas have been declared in Solihull.

2 Air Quality Monitoring

2.1 Pollutants Monitored

2.1.1 Nitrogen Oxides (NO_x)

Combustion processes emit a mixture of oxides of nitrogen – NO and NO_2 - collectively termed NO_x.

i) 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.

ii) NO_2 has a primary (directly emitted) component and a secondary component, formed by oxidation of NO. NO_2 is a respiratory irritant and is toxic at high concentrations. It is also involved in the formation of photochemical smog and acid rain and may cause damage to crops and vegetation.

Of the NO_x emissions (including NO_2) considered to be airport-related, over 50 % arise from aircraft during take-off and landing, with around two-thirds of all emissions occurring at some distance from airport ground-level. The Air Quality Expert Group (AQEG) [3] has stated that: "*Around a third of all NO_x emissions from the aircraft (including ground-level emissions from auxiliary power units, engine testing etc., as well as take-off and landing) occur below 100 m in height. The remaining two-thirds occur between 100 m and 1000 m and contribute little to ground-level concentrations. Receptor modelling studies show the impact of airport activities on ground-level NO_2 concentrations. Studies have shown that although emissions associated with road traffic are smaller than those associated with aircraft, their impact on population exposure at locations around the airport are larger*". Previous rounds of review and assessment within the LAQM process have not highlighted any cases where airports appear to have caused exceedances of air quality objectives for particulate matter measured as PM_{10}. Therefore, in the context of LAQM, the key pollutant of concern from airports is NO_2. Local authorities whose areas contain airports with over 10 million passengers per annum must take these into account in their annual review and assessment of air quality.

2.1.2 Particulate Matter (PM_{10})

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The terms PM_{10} is used to describe particles with an effective size less than 10 µm. 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.

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. Based on 2013 NAEI data, less than 0.1% of UK total PM_{10} emissions are believed to originate from civil aircraft taking off and landing[4].

Previous rounds of review and assessment within the LAQM process have not highlighted any cases where airports appear to have caused exceedances of air quality objectives for particulate matter measured as PM_{10}.

2.1.3 Ozone (O_3)

Ozone is not emitted directly into the atmosphere in significant quantities, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2) and hydrocarbons, in the presence of sunlight. Whereas nitrogen dioxide (NO_2) contributes to ozone formation, nitrogen oxide (NO) destroys ozone and therefore acts as a local sink. For this reason, ozone levels are not as high in urban areas (where NO is emitted from vehicles) as in rural areas. Ozone levels are usually highest in rural areas, particularly in hot, still, sunny weather conditions giving rise to "summer smog".

2.1.4 Carbon Monoxide (CO)

Carbon monoxide is a gas that results as a product of the incomplete combustion of fuels. On the presence of the adequate O_2 supply, CO gets oxidized, and turns into CO_2. The highest levels of CO occur generally in areas with intense traffic released by the exhaust pipe of motor engines. Other CO emission sources may include some industrial processes, biomass burning for heating or natural sources like forest fires. CO causes can cause harmful health effects, as it reduces the oxygen delivery to the body's organs and tissues.

2.1.5 Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas mainly originated by activities related to burning of fossil fuels (diesel burning of heavy vehicles), and burning of coal and petrol in power plants. In nature, SO_2 can also be released to the atmosphere from a volcanic eruption. The sulphur reacts with oxygen, forming SO_2, which in contact with the moisture in the air, can cause sulfuric acid, causing – the so called acid rains.

2.2 Automatic Monitoring

The following techniques were used for the automatic monitoring of NO_x (i.e. NO and NO_2), PM_{10}, O_3, CO and SO_2:

•PM_{10} - Tapered Element Oscillating Microbalance (TEOM);

•NO, NO_2 – Chemiluminescence;

•O_3 – UV absorption analyser;

•CO – Non dispersive infrared absorption (NDIR).

•SO_2 – Ultraviolet Fluorescence (UVF).

Further information on these techniques is provided in Appendix 2 of this report. These analysers provide a continuous output, proportional to the pollutant concentration. This output is recorded and stored every 10 seconds, and averaged to 15-minute mean values by internal data loggers. The analysers are connected to a modem and interrogated through a GPRS internet device to download the data to Ricardo Energy & Environment. Data are downloaded hourly. The data are converted to concentration units at Ricardo Energy & Environment then averaged to hourly mean concentrations.

Fortnightly calibrations are performed by Local Site Operators (LSOs) based at Birmingham Airport, to monitor the performance of the analysers. Data from these fortnightly checks, and from two six-monthly independent QA/QC audits carried out by Ricardo Energy & Environment, are used to scale and ratify the data. This data scaling and ratification is carried out by Ricardo Energy & Environment. The analysers are also serviced on a six-monthly basis to ensure their continued operation.

All ambient concentration measurements in the report are quoted in micrograms per cubic metre (µg m^{-3}) or in the case of carbon monoxide milligrams per cubic metre (mg m^{-3}) at reference conditions of 20 °C, 1013 mbar.

2.3 Volatile Correction Model

The TEOM particulate monitor uses a 50 °C heated sample inlet to prevent condensation on the filter. Although necessary, this elevated temperature can result in the loss of volatile and semi-volatile components of PM_{10} such as ammonium nitrate[5].

It is not possible to address this problem by applying a simple correction factor. However, King's College London (KCL) has developed a Volatile Correction Model[6] (VCM), which allows TEOM PM_{10} data to be corrected for the volatile components lost as a result of the TEOM's heated inlet. It uses data from nearby TEOM-FDMS (Filter Dynamics Measurement System) particulate analysers in the national air quality monitoring network, which measure the volatile and non-volatile components of PM_{10}. The volatile component (which typically does not vary much over a large region), can be added to the TEOM measurement. KCL states that the resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent.

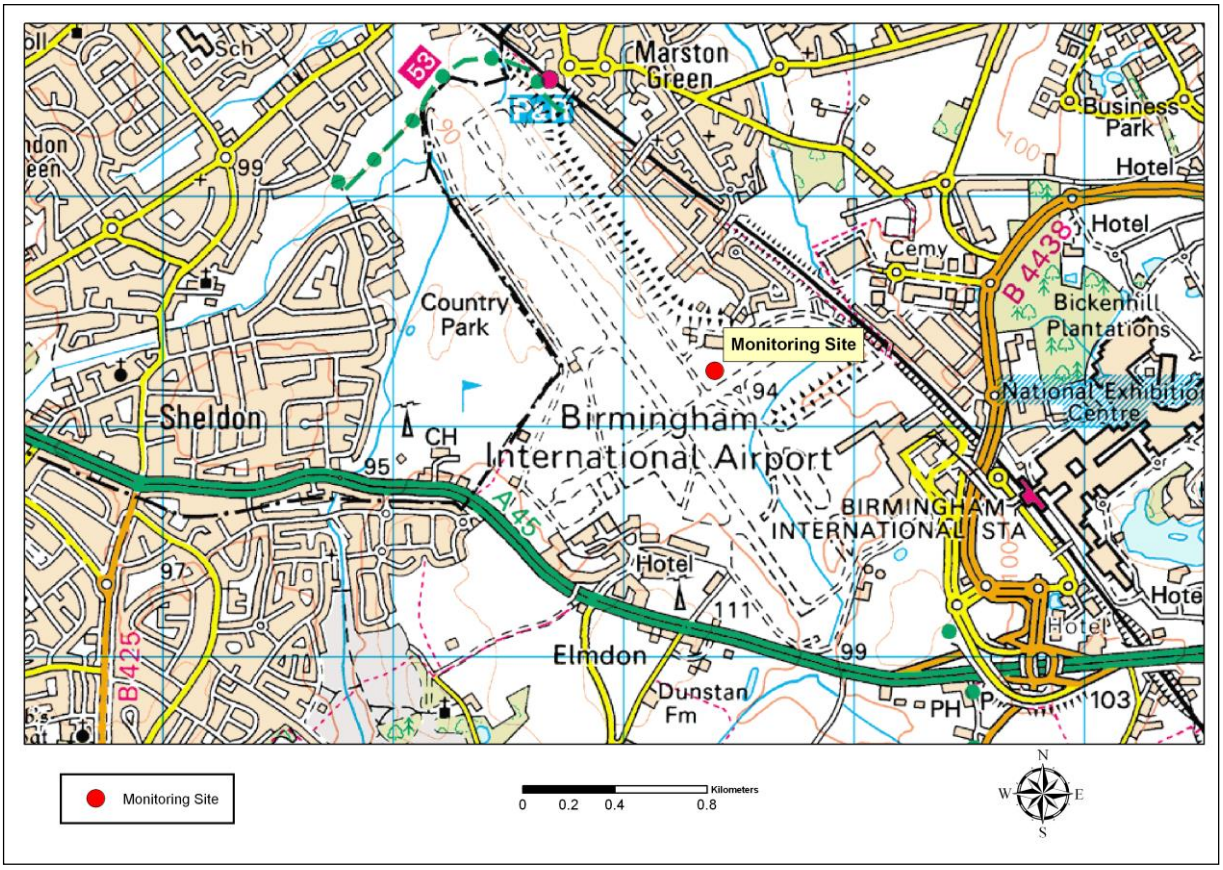
Correction using the VCM is now the preferred approach when comparing TEOM data with air quality limit values and objectives. In this report, it is clearly indicated when the VCM has been used to correct PM_{10} data.

More information about the VCM correction of PM_{10} data is presented in Appendix 2 of this report.

2.4 Monitoring station

The monitoring site is located on the airfield near airport buildings to the east of the runway and north-west of the Main Terminal (OS grid ref. 417395, 284240), having previously been located to the west of the apron area, approximately 300 m due west of the Main Terminal. The site relocation occurred in January 2006. The current location of the monitoring site is shown in Figure 2-1. A map showing the old and new locations is included in Appendix 3.

Figure 2-1 Location of monitoring site. © Crown Copyright Ordnance Survey Reproduced from Landranger 1:50000 map series, Licence number 100040905



3 Results and Discussion

This section provides a summary of Birmingham Airport 2 data for 2015, and a comparison with the AQS Objectives. It also provides analyses of pollutants seasonal, weekly and daily trends, identifies potential emission sources based upon pollution measurements and meteorological data from the site, and explains periods of elevated pollutant concentration. The results from the Birmingham Airport site are also compared with those from other monitoring sites in the area.

3.1 Automatic Monitoring data

The summary statistics for 2015 are presented in Table 3-1. All gaseous pollutant mass units are at 20°C and 1013mb. Particulate matter concentrations are reported at ambient temperature and pressure. NO_X mass units are NO_X as NO_2 µg m^{-3}. A statistical summary of results from 2006-2015 is provided in Appendix 4.

Table 3-1 Air pollution statistics for Birmingham Airport 2, from 1st January to 31st December 2015

Birmingham Airport 2	O_3 (ug m^{-3})	NO (µg m^{-3})	NO_2 (µg m^{-3})	NO_x (µg m^{-3})	PM_{10} * (µg m^{-3})	CO (mg m^{-3})	SO_2 (µg m^{-3})
Maximum 15 minute mean (SO_2)	-	-	-	-	-	-	19
Maximum 8 hour (CO, O_3)	178	-	-	-	-	1	-
Annual Max	190	248	109	486	118	1	16
Maximum daily mean	140	69	61	167	54	0	8
Annual mean	50	6	21	31	15	0	2
Data capture	94.8	98.5	98.5	98.5	89.7	98.9	88.7

* VCM corrected using FDMS data from AURN sites

The Defra Technical Guidance document for LAQM (LAQM.TG(09))[7], requires the use of the Volatile Correction Model (VCM)[6] to correct TEOM data to gravimetric equivalent, as explained in section 2.3. The hourly average concentrations of PM_{10} in this section are therefore corrected using the VCM to enable direct comparison with the Air Quality Strategy (AQS) objectives. The FDMS data used for this purpose are from the Automatic Urban and Rural Network (AURN) sites.

Data capture for all monitored pollutants except PM_{10} and SO_2 was above the Defra target of 90%[2] for ratified datasets. This data capture target does not include losses due to regular calibration or maintenance of the instrument. Any data capture rate above 75% is deemed representative of the full annual period.

Table 3-2 shows the most significant gaps in the data set, and the reasons for them.

Table 3-2 Significant data gaps (Periods ≥ 24h) occurred at Birmingham Airport 2 during 2015

Pollutant	Date started	Date ended	Duration (days)	Reason	Observations
All pollutants	11/10/2015	13/10/2015	1.2	Communications fault	No data
All pollutants	14/12/2015	15/12/2015	1	Modem Issue	Flat data
O_3, PM_{10}, SO_2 and NO_x	07/01/2015	08/01/2015	1	Communications fault	Flat data
O_3	01/03/2015	11/03/2015	10.4	Instrument fault	Callout 11/03
PM_{10}	18/02/2015	11/03/2015	21.1	Power cut + Instrument Fault	Motherboard replacement
PM_{10}	17/05/2015	27/05/2015	10	Instrument Fault	Flat data, flow and filter loading
PM_{10}	22/07/2015	24/07/2015	2.2	Instrument Fault	Unstable, poor data
SO_2	22/07/2015	27/08/2015	36	Instrument Fault	Awaiting delivery parts

The time series of data for the full year, as measured by the automatic monitoring sites, are shown in Figure 3-1.

Figure 3-1 Time series of hourly averaged concentrations of NOx, PM10, O_3, CO and SO_2 for Birmingham Airport 2 site, 2015

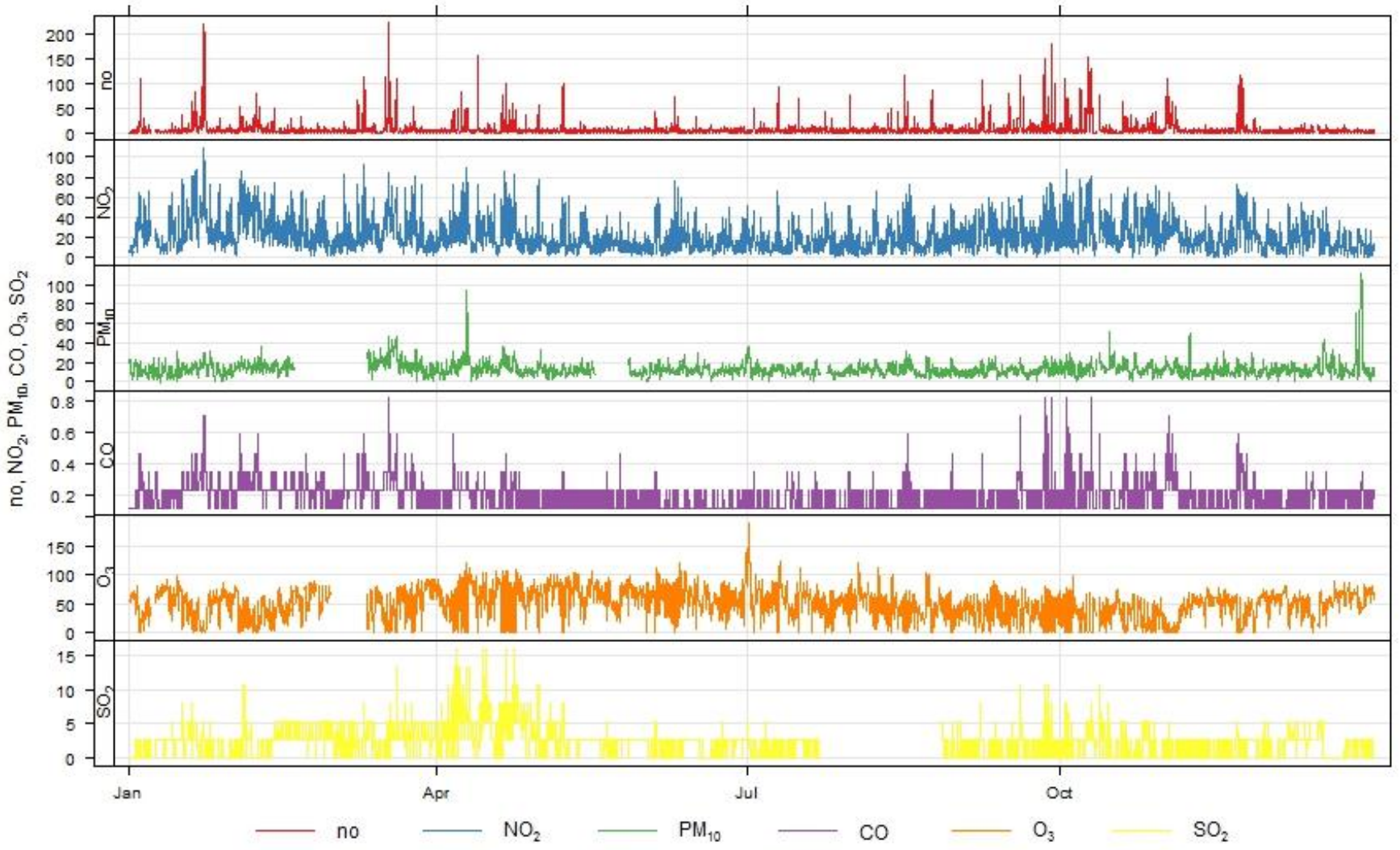


Figure 3-1 shows that peak concentrations of NO and NO_2 appeared to coincide with peak concentrations of CO and to some extent SO_2. O_3 levels are in general slightly lower during the periods when concentrations of the other pollutants are high, as the NO emitted from local emission sources tends to react fast with ozone, to form NO_2. For PM_{10}, there were two peaks in 2015: one in mid-April, and another one in late December. The origin of such elevated concentrations of PM_{10} are investigated later in the report.

3.2 Comparison with Air Quality Objectives

None of the annual, hourly or daily mean limits specified by Defra for CO, SO_2, NO_x and PM_{10} were exceeded at Birmingham Airport 2 monitoring location in 2015. Details of UK air quality standards and objectives specified by Defra are provided in Appendix 1.

The AQS objective for hourly mean NO_2 concentration is 200 µg m^{-3} which may be exceeded up to 18 times per calendar year. During 2015 there were no hourly mean NO_2 measurements exceeding 200 µg m^{-3}. The lower threshold of the Defra "Moderate" air quality band is 201 µg m^{-3} as an hourly mean. Therefore NO_2 levels at stayed within the Defra "Low" band for the whole year. The AQS objective was accomplished for 2015.

The annual mean AQS objective for NO_2 is 40 µg m^{-3}. This objective was also met at Birmingham Airport 2, where the calculated annual mean was 21 µg m^{-3}.

The AQS objective for PM_{10} is 50 µg m^{-3} for 24h mean periods, not to be exceeded more than 35 times a year. Results show that three exceedances of this objective were registered, with a maximum 24h mean of 54 µg m^{-3}. The site was therefore well within the yearly maximum permitted number of exceedances (35), meeting the AQS objective for 24-hour mean PM_{10}.

The annual mean AQS objective for PM_{10} is 40 µg m^{-3}. The site measured an annual mean of 15 µg m^{-3}; this objective was therefore met.

The AQS objective for daily maximum 8-hour running mean O_3 is of 100 µg m^{-3} (not to be exceeded more than 10 days a year). Birmingham Airport 2 exceeded the AQS objective for ozone on 11 days during 2015, therefore the site did not meet the AQS objective for this pollutant in 2015. The maximum concentration of ozone was registered on the 1st of July recorded at 178 µg m^{-3}.

Ozone is a secondary pollutant; it is formed by chemical reactions in the air, involving precursor pollutants, rather than emitted directly from source. It is therefore trans-boundary in nature. As a result, Local Authorities have little control over ozone concentrations in their areas. The Government has recognised the problems associated with achieving the air quality objective for ozone, and this is not included in the LAQM regime.

CO and SO_2 measured at Birmingham Airport 2 met all the AQS objectives for 2015, both with zero exceedances during the year.

3.3 Temporal variation in pollutant concentrations

Figure 3-2 and Figure 3-3 show the variation of monthly and daily averaged NO_x PM_{10}, O_3, CO and SO_2 concentrations during 2015 at Birmingham Airport 2. The pollutants concentrations were normalized (the measured values were adjusted to a notionally common scale) for better visualization purposes.

Figure 3-2 seasonal and diurnal variations of NO, NO_2 and PM_{10} for Birmingham Airport 2, 2015

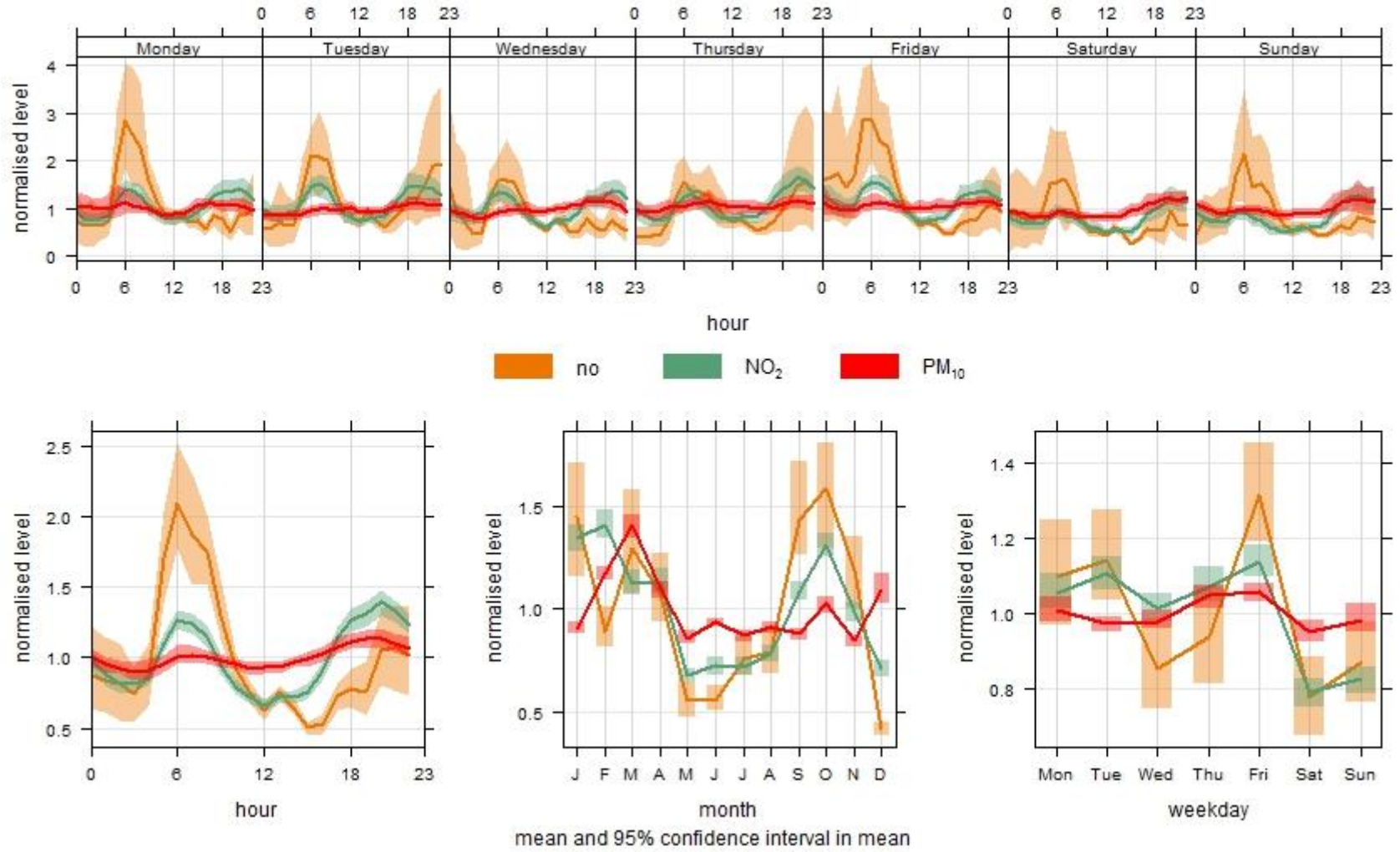
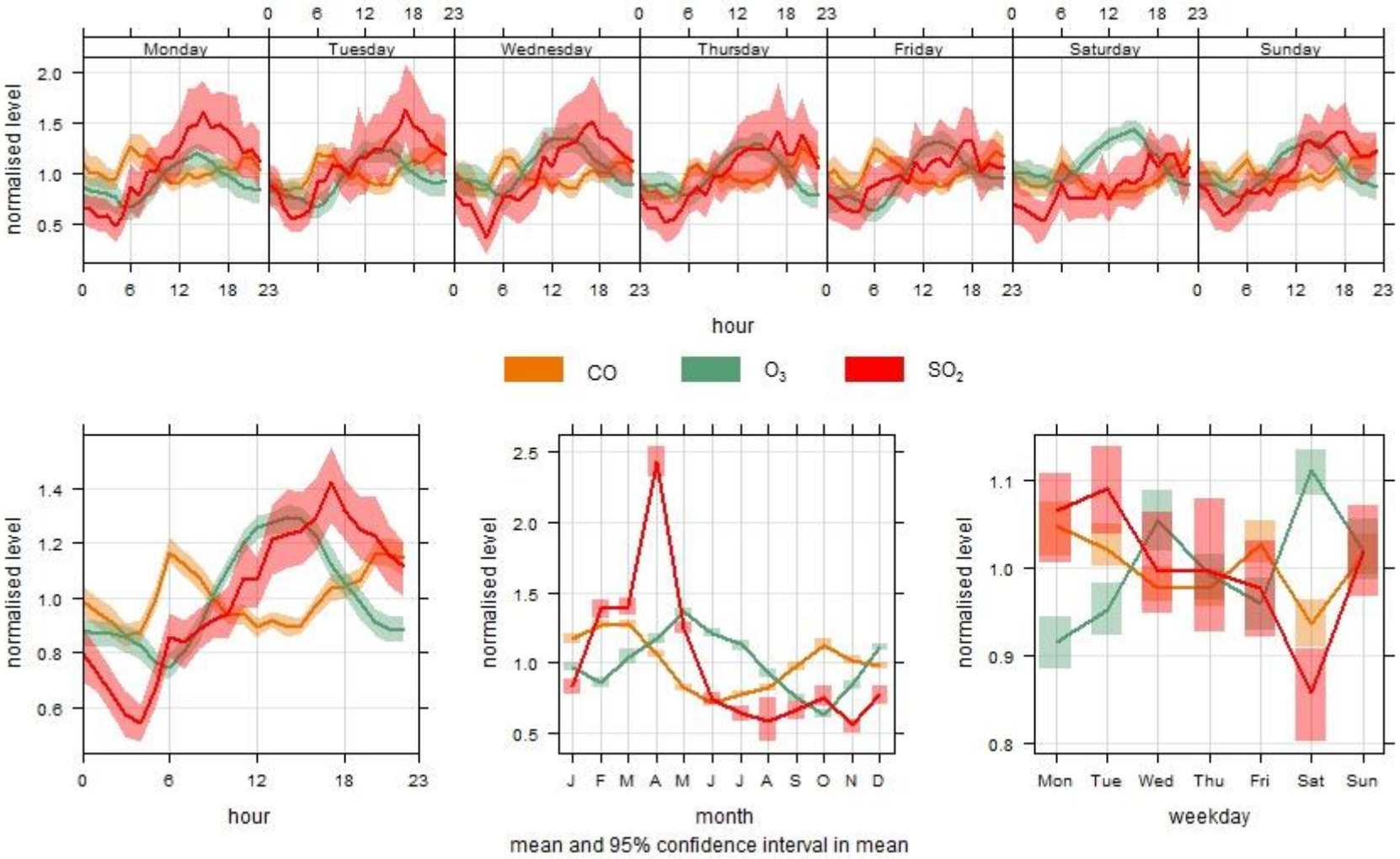


Figure 3-3 Seasonal and diurnal variations of O_3, CO and SO_2 for Birmingham Airport 2, 2015



3.3.1 Seasonal Variations

Seasonal variations seem to follow similar patterns for NO_x, PM_{10} and CO at Birmingham Airport 2 during 2015, as can be observed in the 'month' plots of Figure 3-2 to Figure 3-3. Two major concentration peaks were registered for these pollutants. For PM_{10}, those occur in March and October. For NOx they occur in Feb and October. This peaks are not representative of a typical seasonal variation, and are the result of specific pollution episodes, that are to be explained further on this report (section 3.5).

PM_{10} concentrations showed much less seasonal variation than oxides of nitrogen. Excluding the February and October peaks, NO and NO_2 concentrations seem to follow a typical seasonal variation for urban areas. The highest concentrations of this pollutants occurred during the winter months. This pattern was also observed in previous years and is typical of urban monitoring sites. 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.

O_3 concentrations registered at Birmingham Airport 2 continue to follow a typical seasonal variation for this pollutant, with higher concentrations being registered in April, May, and June. At low/mid latitudes, high O_3 concentrations are generally observed during late spring and/or summer months, where anti cyclonic conditions (characterized by warm and dry weather systems) help increasing the number of photochemical reactions in the atmosphere, responsible for the increasing of ground level ozone production. In addition, the convective fluxes created during hot summer days can also be responsible for an increase of O_3 (stratospheric intrusion). The hot air generated at ground level due to high temperatures is lighter and tends to ascend, being replaced by colder stratospheric air masses coming from above, dragging stratospheric O_3 down into the troposphere (the lowest part of the atmosphere).

SO_2 seasonal variation should follow a typical winter trend, as the major source of this pollutant is the combustion of coal and oil; this increases during winter, mainly because of domestic and industrial heating requirements. The SO_2 measurements are all very low during 2015. However, some elevated periods of concentrations were observed for this pollutant in April. Those concentrations are probably related to periods of cold weather, and reduced pollutant dispersion.

3.3.2 Diurnal Variations

The diurnal variation analyses viewed in the 'hour' plots in figures between 3.2 and 3.3 showed typical urban area daily patterns for NO, NO_2, CO, and PM_{10}. Pronounced peaks can be seen for these pollutants during the mornings, corresponding to rush hour traffic at around 07:00. Concentrations tend to decrease during the middle of the day, with a much broader evening road traffic rush-hour peak in building up from early afternoon. NO also showed a much smaller peak than NO_2 in the afternoons. This is likely to be because concentrations of oxidising agents in the atmosphere (particularly ozone) tend to increase in the afternoon, leading to enhanced oxidation of NO to NO_2. A good example of this atmospheric reaction can be seen at the site. The NO concentration suffers a huge decrease in the early afternoon, while the concentration of O_3 increases on the same proportion. The diurnal concentration of O_3 at Birmingham Airport 2 follows a typical diurnal pattern.

O_3 concentrations always increase during daylight hours due to the photochemical reactions of NO_2 and photo oxidation of VOC's, CO, hydrocarbons, (O_3 precursors). In the afternoon/ night O_3 gets consumed by a fast reaction with NO (titration of O_3 by NO). The absence of sunlight prevents the photolysis of the O_3 precursors.

The diurnal patterns for PM_{10} are determined by two main factors. The first is emissions of primary particulate matter, from sources such as vehicles. The second factor is the reaction that occurs between sulphur dioxide, NO_x and other chemical species, forming secondary sulphate and nitrate particles. Morning and afternoon road traffic rush-hour peaks for PM_{10} can be seen at the site, but these were less pronounced than those for oxides of nitrogen.

The SO_2 diurnal pattern appears to follow the ozone profile, building up on the early morning, with a major peak in the late afternoon, which can indicate that the pattern of this pollutant is not majorly dependent on the same type of anthropogenic activities that influence the other pollutants (mainly traffic), and more dependent of atmospheric dispersion processes.

3.3.3 Weekly variations

The analyses of each pollutants weekly variation showed that the same type of diurnal patterns occur for all the days of the week. NO, NO_2 and CO early morning and late afternoon rush hour peaks are in general much more pronounced on the early days of the week (Monday, Tuesday), and in the end of the week (Friday), and much less pronounced during the middle of the week and weekends. PM_{10} concentrations don't seem to vary much along the week.

Saturday registers the lowest concentrations of CO, PM_{10}, SO_2, and NOx (NO/NO_2), and the highest readings of O_3.

The SO_2 weekly pattern seems to show that the highest concentrations occur on a Monday, starting to decrease up until Friday, and starting to build up again during the weekend.

3.4 Source Investigation

In order to investigate the possible sources of air pollution being monitored around Birmingham Airport, real meteorological data measured at the Airport was used to add a directional component to the air pollutant concentrations.

Figure 3-4 shows the wind speed and direction data, measured at Birmingham Airport 2. The lengths of the "spokes" against the concentric circles indicate the percentage of time during the year that the wind was measured from each direction. The wind direction was 180 ° to 240 °, showing that the prevailing wind was clearly from the south west. Each "spoke" is divided into coloured sections representing wind speed intervals of 2 m s^{-1} as shown by the scale bar in the plot. The mean wind speed was 3.97 m s^{-1}. The maximum measured wind speed was 13.90 m s^{-1}. Some of the highest wind speeds occurred during the months of November and December 2015.

Figure 3-4 Wind rose showing the wind speeds and directions at Birmingham Airport 2 in 2015.

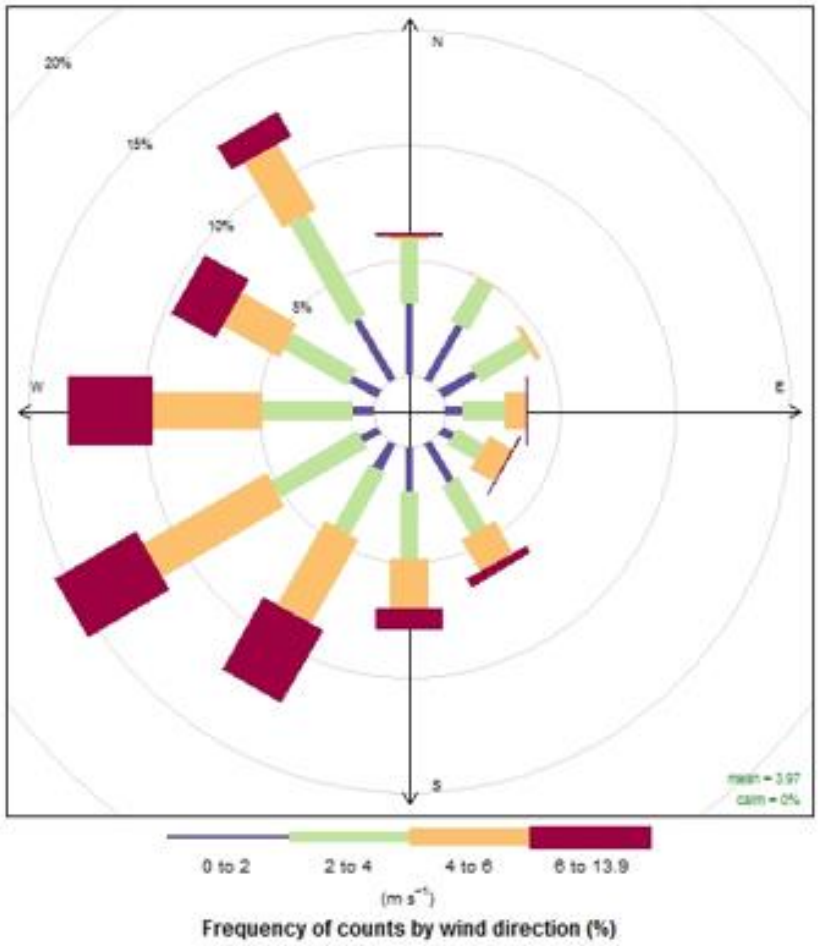


Figure 3-5 to 3.7 show bivariate plots of hourly mean concentrations of NO, NO_2, PM_{10}, CO, SO_2 and O_3 at Birmingham Airport 2 against wind speed and wind direction. These plots should be interpreted as follows:

- The wind speed is indicated by the distance from the centre of the plot; the grey circles indicate wind speeds in 2 m s^{-1} intervals.
- The pollutant concentration is indicated by the colour (as indicated by the scale).

These plots therefore show how pollutant concentrations varied with wind direction and wind speed.

The plots do not show distance of pollutant emission sources from the monitoring site. However, in the case of primary pollutants such as NO, the concentrations at very low wind speeds are dominated by emission sources close by, while at higher wind speeds, effects are seen from sources further away.

Figure 3-5 Pollution rose for NO (left) and NO_2 (right) at Birmingham Airport, 2015

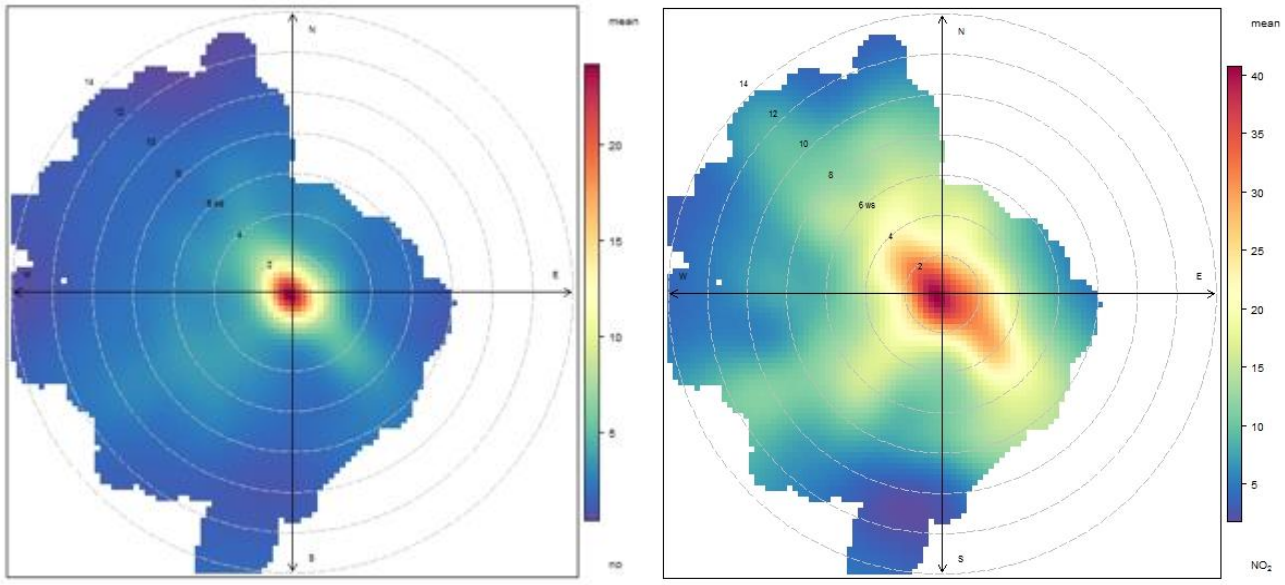
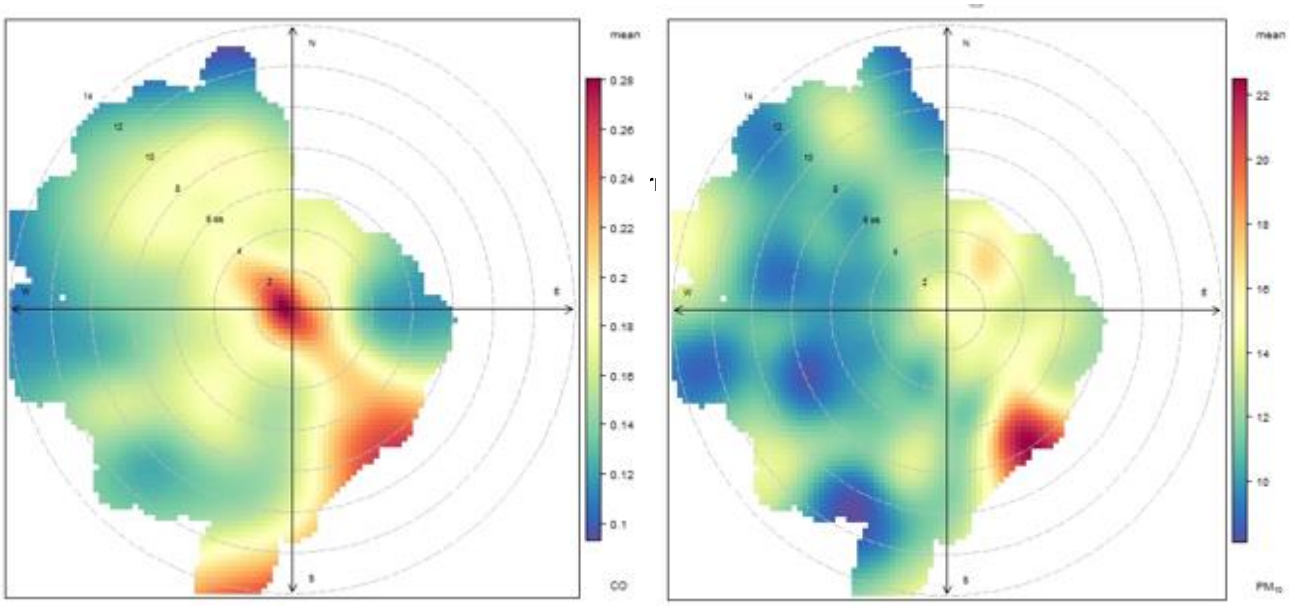
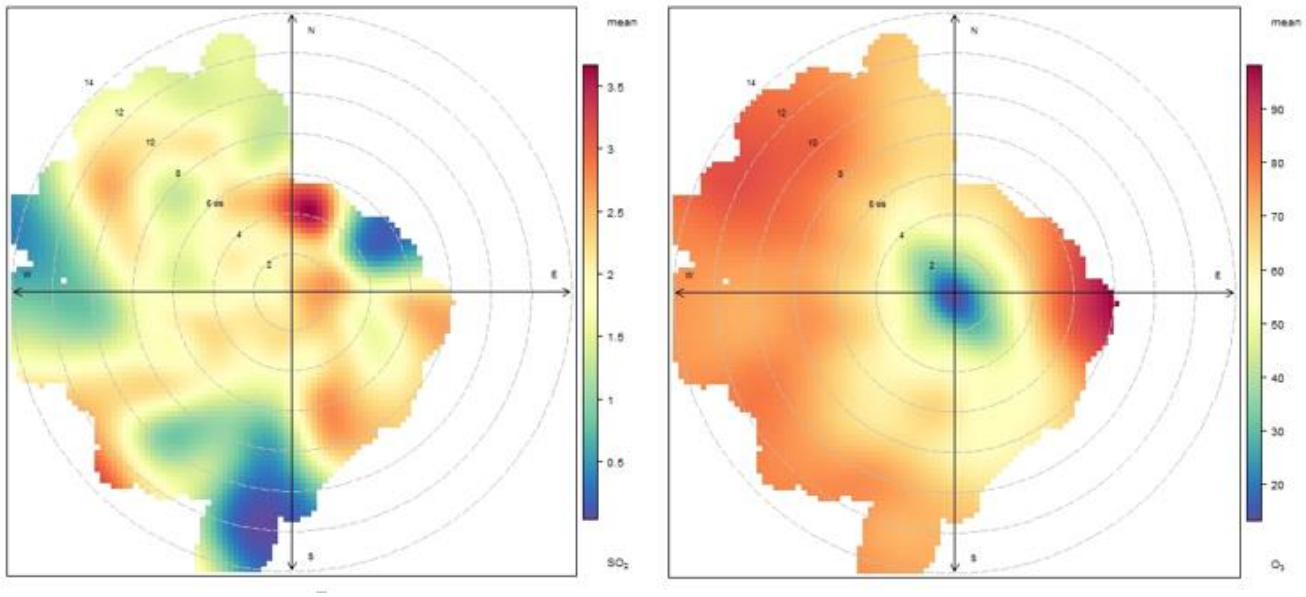


Figure 3-6 Pollution rose for CO (left) and PM_{10} (right) at Birmingham Airport, 2015





NO (which, like CO and SO_2, is a "primary" pollutant i.e. one emitted directly from source rather than formed from chemical reactions in the air) shows a clear pattern of highest concentrations in the centre of the plot, i.e. associated with low wind speeds. Such calm conditions will have allowed NO emitted from nearby sources - probably aircraft and airside vehicles to build up, reaching relatively high concentrations.

For NO_2, which has both a primary and secondary component, there is some trace evidence of sources to the North West and South West, the direction of the Birmingham residential areas and the A45 – Coventry Road. However, the highest concentrations registered in 2015 seem to be originated at low wind speeds, which clearly indicates that most of the NO_2 measured has its origin from local emission sources, and mainly by the fast reaction of NO with O_3 in the presence of UV light.

The pollution rose for VCM-corrected PM_{10} shows a major contribution from the southeast of the site. In 2015, highest concentrations appeared to occur at highest wind speeds – this could perhaps have included some wind-blown dust, coming from the car park, or some construction work that occurred off-site.

As with previous years the plot of CO shows that the highest concentrations are in the centre of the plot (i.e. when wind speeds are low) with lower concentrations as wind speeds increase to the north. Other major concentrations seem to appear from the south east, in line with what is observed for PM_{10}. These pollutants seem to be moved by the same emission source.

The pollution rose for SO_2 shows a very different pattern. SO_2 emissions seem to be originated from multiple sources. The highest concentrations seem to come from the north, for wind speeds between 4-6 ms^{-1}. Several other "moderate" sources seem to be visible coming from the south west and south east – direction of the runways. However, there is no clear directional pattern and SO_2 concentrations remain low.

The final bivariate plot shows concentrations of ozone. This shows a contrasting pattern to that of CO and NO, in that lowest ozone concentrations are associated with calm conditions. Being a secondary pollutant ozone is formed from chemical reactions in the ambient air. The plot demonstrates that higher concentrations of ozone are measured at the site when wind speeds are sufficient to bring in ozone-rich air from other areas of the region. At very low wind speeds, when NO concentrations are highest, any ozone present reacts with the NO emitted by the sources in the immediate vicinity.

3.5 Periods of elevated pollutant concentration

This section reviews the most significant periods of high air pollution concentrations for the whole year. It is important to stress that, despite there being some periods when pollutant concentrations exceeded the applicable air quality objectives at Birmingham Airport 2, these were all attributable to specific external sources.

The historic Air Quality Index data presented at the Department of Environment, Food & Rural Affairs (Defra) UK-AIR website[8] shows that the air quality index band ranged from 4 (Moderate) to 10 (Very High) for most of the UK regions during two days in March (17th and 18th), and two days in April (9th and 10th). These pollution episodes are consistent with the period of elevated PM and NO_x concentrations measured in Birmingham Airport 2, and explanations for this pollution events follow below:

- Information provided by King's College London (KCL) Environmental Research Group at their website LondonAir[9] states that: "*Between Tuesday 17th and Friday 20th March, a high pressure system centred over Scandinavia resulted in settled conditions in south-east England and light easterly to south-easterly winds. Consequently, air arriving from the north of continental Europe mixed with local emissions to produce a widespread particulate episode across the whole region".* Further analysis by King's show that the particulate was mainly composed of nitrate with a strong ammonium signal - consequence of springtime application of slurry and fertiliser in agricultural regions on the near-continent. The episode was dominated by $PM_{2.5}$ particulate with, at times, almost 90% of the measured PM_{10} particulate being made up of this smaller size fraction.
- Several newspaper articles (ex: BBC[10] and Airqualitynews[11]), and information provided by King's College at their website seem to agree that on the 9th and 10th April: "(…) *warm, still conditions motivated by a high pressure system over southern England and the northern part of continental Europe, have resulted in low wind speeds and accumulation of pollutants"*. The meteorological conditions, combined with traffic fumes, pollution from Europe and some Saharan dust from the south were the main drivers of this air pollution episode.

Other regional pollution episode was also identified in 2015 by KCL, that help explain the elevated measurements of PM_{10} registered at the Birmingham Airport 2 site between the 26th and 28th of December 2015. The KCL study states: "*Coupling the size and chemical information along with wind patterns suggests that this episode was most likely due to an influx of Saharan dust (…)"*.

3.6 Comparison with other local monitoring sites

Table 3-3 compares the annual mean concentrations at Birmingham Airport with other air quality monitoring sites in Birmingham. The sites selected are all part of the UK's national Automatic Urban and Rural Network (AURN) and are as follows:

- Birmingham Tyburn: An urban background site, located within the car park of council owned offices.
- Birmingham Tyburn Roadside: An urban traffic site located on the south side of the A38 in Tyburn outside council owned offices, and approximately 700 metres to the north of the M6 motorway.
- Birmingham Acocks Green: Another urban background site, located within the grounds of an annex to a large school near Shirley road.

Table 3-3 Annual means for Birmingham Airport 2 and three local AURN monitoring sites, 2015.

Pollutant	Birmingham Airport 2	Birmingham Tyburn	Birmingham Tyburn Roadside	Birmingham Acocks Green
PM_{10}*	15	19	17	-
NO_2	21	30	45	19
O_3	50	45	35	47
SO_2	2	1	-	-
CO	0	-	-	-

* VCM corrected using FDMS data from AURN sites

The annual mean concentration of PM_{10} measured at the Birmingham Airport site in 2015 was comparable with those measured at the other Birmingham sites. As in previous years, the annual mean concentration of SO_2 at Birmingham Airport was low, though slightly higher than that measured at Birmingham Tyburn. The annual mean concentration of NO_2 and O_3 measured at Birmingham Airport 2 were comparable with the ones measured in Acocks Green, an urban background site located far away from busy roads.

Elevated annual means of O_3 are typical from rural areas, far away from strong local emission sources (responsible for ozone scavenging processes). The ozone exceedances seen at Birmingham Airport 2 are still comparable to the wider air quality and therefore, the failure of meeting the AQ targets is not a direct result of Birmingham Airport Activities.

These statistics together indicate that the pollution levels registered at Birmingham Airport 2 were low in 2015.

4 Conclusions

The following conclusions have been drawn from the results of air quality monitoring at Birmingham Airport during 2015.

Oxides of nitrogen, particulate matter (as PM_{10}), carbon monoxide (CO), sulphur dioxide (SO_2) and ozone (O_3) were monitored throughout 2015 at one monitoring site in Birmingham Airport (Birmingham Airport 2. The conclusions of the 2015 monitoring programme are summarised below.

1. Data capture of at least 90% was achieved for oxides of nitrogen, ozone and CO at Birmingham Airport 2 in 2015. This target was not achieved for PM_{10} and SO_2, for which the data capture was 89.7 and 88.7%.
2. The site did not exceed the AQS objective of 200 µg m^{-3} for hourly mean NO_2 more than the 18 permitted times per year, neither did it exceed the AQS annual mean objective of 40 µg m^{-3} for NO_2 in 2015.
3. One pollutant (O_3) exceeded the air quality standard of 100 ug m^{-3} as (maximum daily 8 hour mean) on 11 days in 2015. This is more than the permitted 10 days per calendar year. The AQS objective for O_3 was therefore not met in 2015.
4. The site met the AQS objective for 24-hour mean of 50 µg m^{-3} (not to be exceeded more than 35 times a year) and annual mean of 40 µgm^{-3} for PM_{10}. The particulate matter was measured using a TEOM instrument with VCM correction required.
5. Seasonal variations in pollutant concentrations at Birmingham Airport 2 show both NO, NO_2 and CO exhibited higher concentrations during the winter months. PM_{10}, which have primary and secondary components, showed a much less pronounced seasonal pattern. Ozone levels were highest during the spring and summer, as is typical. SO_2 seems to show a pronounced peak in April (when compared with the values registered at the other months), but the concentrations are still low.
6. The diurnal patterns of concentrations of all pollutants were similar to those observed at other urban monitoring sites. Peak concentrations of NO, NO_2, particulate matter and CO coincided with the morning and evening rush hour periods, and levels of ozone peaked in the afternoons. SO_2 daily patterns seems to follow ozone, with a unique peak value in the late afternoon, which can indicate that this pollutant is influenced by other anthropogenic emissions, different from the ones influencing NOx and CO.
7. Some periods of elevated PM_{10} concentration occurred at regional and national level during 2015. This periods are consistent with some of the higher concentrations measured at Birmingham Airport 2, and therefore reflect regional variations in PM_{10} concentration, rather than any emission sources specific to the airport.
8. Meteorological data was used at Birmingham Airport 2, allowing the effect of wind direction and speed to be investigated. Bivariate plots of NO, NO_2 concentration and wind data showed that concentrations of these pollutants at the monitoring site were typically highest in calm conditions, indicating that the main sources of these pollutants were nearby. The pattern was slightly different for PM_{10}, with a strong signal also appearing from the south east and at higher wind speeds. CO concentrations seem to follow both profiles, showing that its origin is both local and long range. SO_2 emissions seem to originate from multiple sources, with some coming from the north, at moderate wind speeds, and several other contributions from the south west and south east – the direction of the runways.
9. Mean concentrations of pollutants at the three Birmingham AURN sites in 2015 were comparable with those measured at Birmingham Airport 2, especially the urban background monitoring station at Acocks Green.

5 References

1. Directive 2008/50/EC of the European Parliament and of the Council of 21st May 2008 on ambient air quality and cleaner air for Europe [online]. Official Journal of the European CommunitiesL152/1.Available at: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm [Accessed 22nd April 2016].
2. Department for Environment, Food and Rural Affairs (2007). The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1) [online]. London, UK: Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf [Accessed 22nd April 2016]. Also original Air Quality Strategy published 2000 and addendum 2003.
3. Air Quality Expert Group (2004) Nitrogen dioxide in the United Kingdom [online]. London, UK: Department for Environment, Food and Rural Affairs. Available at: http://uk-air.defra.gov.uk/library/aqeg/publications [Accessed 22nd April 2016].
4. National Atmospheric Emissions Inventory (2013). NAEI UK National Atmospheric Emissions Inventory [online]. Available at http://naei.defra.gov.uk/ [Accessed 22nd April 2016].
5. Department for Environment, Food and Rural Affairs (2009). QA/QC procedures for the UK Automatic and Urban Rural Air Quality Monitoring Network (AURN) [online]. London, UK: Department for Environment, Food and Rural Affairs and the Devolved Administrations. Available:http://ukair.defra.gov.uk/reports/cat13/0910081142_AURN_QA_QC_Manual_Sep_09_FINAL.pdf [Accessed 22nd April 2016].
6. King's College London Volatile Correction Model available at http://www.volatile-correction-model.info/Default.aspx . July 2008. (Accessed 22nd April 2016).
7. Department for Environment, Food and Rural Affairs (2009). Part IV of the Environment Act 1995. Local air quality management – Technical Guidance LAQM.TG (09) [online]. London, UK: Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland. Available: http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/quality/air/airquality/local/guidance/documents/tech-guidance-laqm-tg-09.pdf [Accessed 22nd April 2016].
8. Air Quality Index. UK-air Website [online]. Available at: http://uk-air.defra.gov.uk/latest/index?date=01%2F04%2F2014#summary [Accessed 22nd April 2016].
9. Environmental Research Group, King's College (London). London Air website [online]: http://www.londonair.org.uk/london/asp/PublicEpisodes.asp?species=All&region=0&site=&postcode=&la_id=&level=All&bulletindate=31%2F10%2F2015&MapType=Google&zoom=9&lat=51.4750&lon=0.119824&VenueCode=&bulletin=explanation&episodeID=PM10PM25endOctober2015 [Accessed 22nd April 2016].
10. BBC news website [online]. Available at: http://www.bbc.co.uk/news/uk-32233922 [Accessed 22nd April 2016].
11. Air Quality news website [online]. Available at: http://www.airqualitynews.com/2015/04/09/england-braced-for-high-air-pollution-episode/ [Accessed 22nd April 2016].

Appendices

Appendix 1 - Air Quality objectives and Index bands

Table A1.1: UK air quality objectives for protection of human health, July 2007.

Pollutant	Air Quality objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 µg m^{-3}	Running annual mean	31/12/2003
England and Wales only	5.00 µg m^{-3}	Annual mean	31/12/2010
Scotland and Northern Ireland	3.25 µg m^{-3}	Running annual mean	31/12/2010
1,3-Butadiene	2.25 µg m^{-3}	Running annual mean	31/12/2003
Carbon monoxide England, Wales and Northern Ireland	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31/12/2003
Scotland	10.0 mg m^{-3}	Running 8-hour mean	31/12/2003
Lead	0.5 µg m^{-3}	Annual mean	31/12/2004
	0.25 µg m^{-3}	Annual mean	31/12/2008
Nitrogen dioxide	200 µg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31/12/2005
	40 µg m^{-3}	Annual mean	31/12/2005
Particles (PM_{10}) (gravimetric) All authorities	50 µg m^{-3}, not to be exceeded more than 35 times a year	24-hour mean	31/12/2004
	40 µg m^{-3}	Annual mean	31/12/2004
Scotland	50 µg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31/12/2010
	18 µg m^{-3}	Annual mean	31/12/2010
Particles ($PM_{2.5}$) (gravimetric)* All authorities	25 µg m^{-3} (target)	Annual mean	2020
	15% cut in urban background exposure	Annual mean	2010-2020
Scotland only	12 µg m^{-3} (limit)	Annual mean	2020

Sulphur dioxide	350 µg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31/12/2004
	125 µg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31/12/2004
	266 µg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31/12/2005
PAH*	0.25 ng m^{-3}	Annual mean	31/12/2010
Ozone*	100 µg m^{-3} not to be exceeded over 10 days a year	8-hour mean	31/12/2005

** Not included in regulations.*

Table A1.2: UK air quality objectives for protection of vegetation and ecosystems, July 2007

Pollutant	Air Quality objective		Date to be achieved by
	Concentration	Measured as	
Nitrogen oxides measured as NO_2	30 µg m^{-3}	Annual mean	31st December 2000
Sulphur dioxide	20 µg m^{-3}	Annual mean	31st December 2000
	20 µg m^{-3}	Winter average (October to March)	31st December 2000
Ozone	18 µg m^{-3}	AOT40+, calculated from 1-hour values May to July. Mean of 5 years, starting 2010	1st January 2010

+ AOT40 is the sum of the differences between hourly concentrations greater than 80 µg m^{-3} (= 40 ppb) and 80 µg m^{-3} over a given period using only 1-hour averages measured between 08:00 and 20:00.

Defra Air Pollution bands and index values

Table A1.3: Air pollution bandings and descriptions.

Banding	*Index*	*Accompanying health messages for at-risk individuals**	*Accompanying health messages for the general population*
Low	1	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
	2		
	3		
Moderate	4	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
	5		
	6		
High	7	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
	8		
	9		
Very high	10	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Appendix 2 - Monitoring apparatus and techniques

Monitoring Equipment

The following continuous monitoring methods were used at the Birmingham Airport 2 air quality monitoring station:

- NO, NO_2: chemiluminescence with ozone.
- PM_{10}: Tapered Element Oscillating Microbalance (TEOM).
- O_3: UV absorption analyser.
- CO: Non dispersive infrared absorption (NDIR)
- SO_2: Ultraviolet Fluorescence (UVF)

These methods were selected in order to provide real-time data. The chemiluminescence and the UV absorption analysers are the European reference method for ambient NO_2 and O_3 monitoring.

The chemiluminescence with ozone analyser is based on the principle that nitric oxide (NO) and ozone react to produce excited NO_2 molecules, which emit infrared photons when going back to lower energy states:

$NO + O_3 \rightarrow [NO_2]^* + O_2 \rightarrow NO_2 + O_2 + hv$

A stream of purified air (dried with a Nafion Dryer) passing through a silent discharge ozonator generates the ozone concentration needed for the chemiluminescent reaction. The specific luminescence signal intensity is therefore proportional to the NO concentration. A photomultiplier tube amplifies this signal. NO_2 is detected as NO after reduction in a molybdenum (Mo) converter heated at about 325 °C. The ambient air sample is drawn into the analyser, flows through a capillary, and then to a valve, which routes the sample either straight to the reaction chamber (NO detection), or through the converter and then to the reaction chamber (NO_X detection). The calculated NO and NO_X concentrations are stored and used to calculate NO_2 concentrations ($NO_2 = NO_x - NO$), assuming that only NO_2 is reduced in the Mo converter.

The UV absorption analyser determines ozone concentrations by measuring the absorption of O_3 molecules at a wavelength of 254 nm (UV light) in the absorption cell, followed by the use of the Beer-Lambert law. The concentration of ozone is related to the magnitude of the absorption. The reference gas, generated by scrubbing ambient air, passes into one of the two absorption cells to establish a zero light intensity reading, I_0. Then the sample passes through the other absorption cell to establish a sample light intensity reading, I. This cycle is reproduced with inverted cells. The average ratio $R=I/I_0$ between 4 consecutive readings is directly related to the ozone concentration in the air sample through the Beer-Lambert law.

The Non-Dispersive Infra-Red (NDIR) detectors are the industry standard method of measuring the concentration of carbon monoxide (CO). Each constituent gas in a sample will absorb some infra-red at a particular frequency. By shining an infra-red beam through a sample cell (containing CO), and measuring the amount of infra-red absorbed by the sample at the necessary wavelength, a NDIR detector is able to measure the volumetric concentration of CO in the sample.

The Ultraviolet Fluorescence analyser determines SO_2 by, at first, scrubbing the air flow to eliminate aromatic hydrocarbons. The air sample is then directed to a chamber where it is irradiated at 214 nm (UV), a wavelength where SO_2 molecules absorb. The fluorescence signal emitted by the excited SO_2 molecules going back to the ground state is filtered between 300 and 400 nm (specific of SO_2) and amplified by a photomultiplier tube. A microprocessor receives the electrical zero and fluorescence reaction intensity signals and calculates SO_2 based on a linear calibration curve.

The analysers for NO_x, O_3, CO and SO_2 are equipped with an automatic calibration system, which is triggered daily under the control of the data logger. Fully certificated calibration gas cylinders are also used at each site for manual calibration.

The PM_{10} TEOM analyser cannot be calibrated in the same way as the gas analysers and these data are scaled using the results of 6-monthly checks. In these checks, the flow rate through the analyser is measured and the mass determination checked with pre-weighed filters.

The TEOM measures the mass collected on an exchangeable filter cartridge by monitoring the frequency changes of a tapered element. The sample flow passes through the filter, where particulate matter is collected, and then continues through the hollow tapered element on its way to an electronic flow control system and vacuum pump. As more mass collects on the exchangeable filter, the tube's natural frequency of oscillation decreases. A direct relationship exists between the tube's change in frequency and mass on the filter. The TEOM mass transducer does not require recalibration because it is designed and constructed from non-fatiguing materials. However, calibration is yearly verified using a filter of known mass.

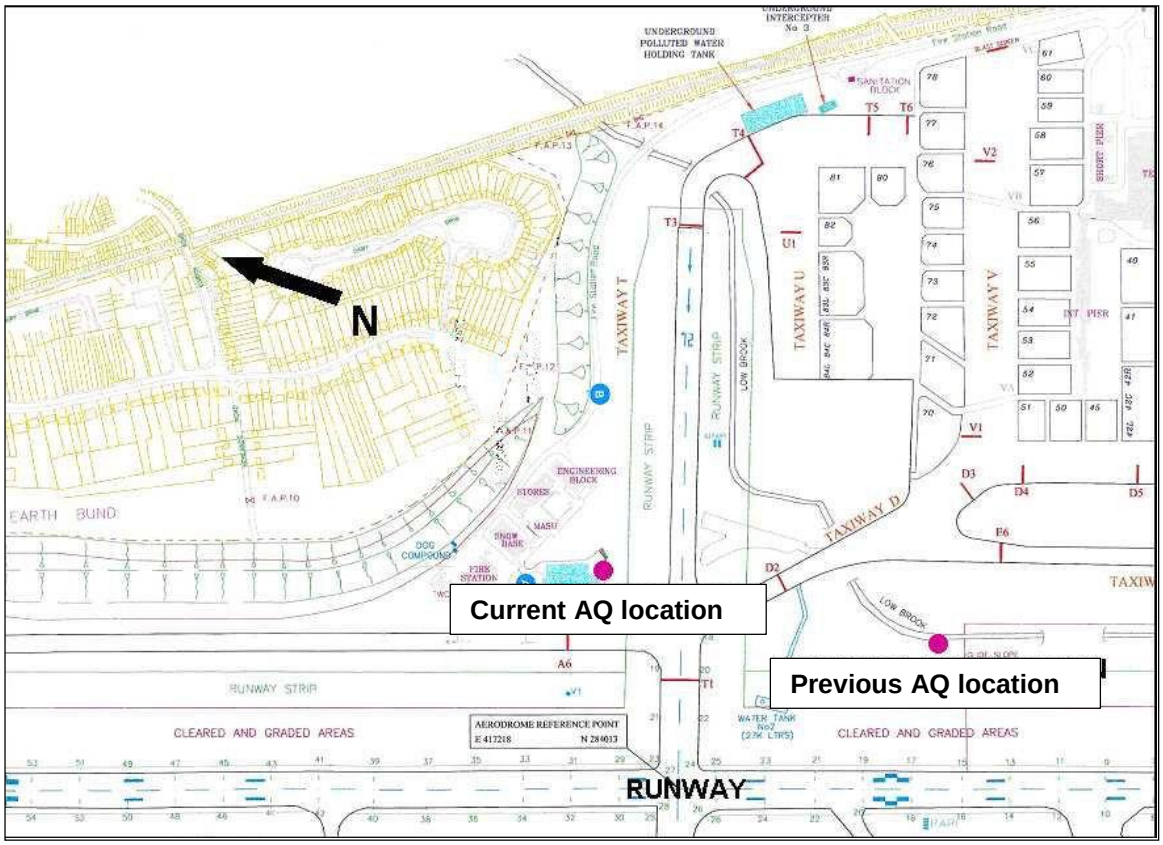
The PM_{10} monitoring data recorded by TEOM monitors were corrected with the King's College Volatile Correction Model (VCM) [6]. This online tool allows TEOM measurements to be corrected for the loss of volatile components of particulate matter that occur due to the high sampling temperatures employed by this instrument. The resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent.

The VCM works by using the volatile particulate matter measurements provided by nearby FDMS (Filter Dynamic Measurement System) instruments (within 130 km) to assess the loss of PM_{10} from the TEOM; this value is then added back onto the TEOM measurements.

Each analyser provides a continuous output, proportional to the pollutant concentration. This output is recorded and stored every 10 seconds, and averaged to 15 minute average values by the on-site data logger. This logger is connected to a modem and interrogated twice daily, by telephone, to download the data to Ricardo Energy & Environment. The data are then converted to concentration units and averaged to hourly mean concentrations.

Appendix 3 – Location of the AQ monitoring site

Figure A3.1 – Location (current and pre-2006) of Birmingham Airport monitoring station



Appendix 4 – Statistical summary 2006 - 2015

Figure A4.1 – Statistical summary of pollution data for Birmingham Airport monitoring site (2006-2015)

Statistic	PM_{10} (μgm^{-3})†	NO_x (as NO_2) (μgm^{-3})	NO (μgm^{-3})	NO_2 (μgm^{-3})	O_3 (μgm^{-3})	SO_2 (μgm^{-3})	CO (mgm^{-3})	Benzene (μgm^{-3})
2015								
Max. hourly mean	146	485	-	109	190	16	1	nm
Annual mean	15	31	6	21	50	2	0	nm
Max. daily mean	54	167	69	61	140	8	0	nm
Max. running 8-hr mean	-	-	-	-	178	-	1	nm
Max. 15-min mean	-	-	-	-	-	19	-	nm
Data capture (%)	89.7	98.5	98.5	98.5	94.8	88.7	98.9	nm
2014								
Max. hourly mean	349	1031	579	143	132	32	1.6	nm
Annual mean	18	39	9	25	45	2	0.2	nm
Max. daily mean	71.1	439	237	76	84	12	1	nm
Max. running 8-hr mean	-	-	-	-	116	-	1	nm
Max. 15-min mean	-	-	-	-	-	37	-	nm
Data capture (%)	91.3	96.9	96.9	96.9	93.3	88.3	96.7	nm
2013								
Max. hourly mean	106	551	286	115	158	29	0.8	-
Annual mean	19	35	8	24	47	1	0.2	0.49**
Max. daily mean	62	224	101	69	96	8	0.4	-
Max. running 8-hr mean	-	339	175	91	138	16	0.7	-
Max. 15-min mean	-	657	351	128	160	37	1.4	-
Data capture (%)	95.8%	98.8%	98.8%	98.8%	99.1%	98.9%	98.9%	**100%**
2012								
Max. hourly mean	157	605	321	115	158	56	1.6	-
Annual mean	18	40	10	24	41	2	0.2	0.41**
Max. daily mean	51	-	-	-	-	11	-	-
Max. running 8-hr mean	-	-	-	-	144	-	1.2	-
Max. 15-min mean	-	-	-	-	-	61	-	-
Data capture (%)	97	98	98	98	99	98	99	100

2011								
Max. hourly mean	135	460	241	117	158	35	0.9	-
Annual mean	21	36	8	24	49	2	0.2	0.51**
Max. daily mean	71	-	-	-	-	8	-	-
Max. running 8-hr mean	-	-	-	-	136	-	0.8	-
Max. 15-min mean	-	-	-	-	-	40	-	-
Data capture (%)	91	96	96	96	96	96	96	92
2010								
Max. hourly mean	200	682	371	159	168	32	1.5	-
Annual mean	19	46	12	28	41	2	0.2	0.8**
Max. daily mean	48	-	-	-	-	7	-	-
Max. running 8-hr mean	-	-	-	-	144	-	0.8	-
Max. 15-min mean	-	-	-	-	-	32	-	-
Data capture (%)	93	99	99	99	99	97	97	100
2009								
Max. hourly mean	85	640	356	180	126	35	2.0	-
Annual mean	18	34	9	21	42	2	0.2	*1.0**
Max. daily mean	55	-	-	-	-	10	-	-
Max. running 8-hr mean	-	-	-	-	108	-	1.6	-
Max. 15-min mean	-	-	-	-	-	37	-	-
Data capture (%)	92	94	94	94	94	94	94	100
2008								
Max. hourly mean	305	1289	720	220	158	29	3.1	
Annual mean	16	41	11	25	47	2	0.2	0.9**
Max. daily mean	61	-	-	-	-	9	-	-
Max. running 8-hr mean	-	-	-	-	152	-	2.4	-
Max. 15-min mean	-	-	-	-	-	29	-	-
Data capture (%)	91.3	95.6	95.6	95.6	91.5	95.6	95.6	100.0
2007								
Max. hourly mean	244	932	521	145	148	*43**	2.6	
Annual mean	21	49	14	28	40	*5**	0.2	1.0**
Max. daily mean	116	-	-	-	-	*13**	-	
Max. running 8-hr mean	-	-	-	-	135	-	1.6	
Max. 15-min mean	-	-	-	-	-	*90**	-	
Data capture (%)	89.7	86.5	86.5	86.5	99.2	40.2	97.5	100.0
2006								
Max. hourly mean	466	686	349	189	202	32	2.1	
Annual mean	22	47	13	27	47	5	0.2	1.1**
Max. daily mean	92	-	-	-	-	16	-	
Max. running 8-hr mean	-	-	-	-	195	-	1.7	
Max. 15-min mean	-	-	-	-	-	43	-	
Data capture (%)	90.4	79.8	79.8	79.8	93.8	91.6	93.3	100.0

† - VCM corrected 2009 onwards; * Results indicative only due to the low data capture.; ** Results based on monthly exposure periods. nm - Benzene monitoring discontinued at end of 2013.

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