



Quantification of air quality impacts of London Heathrow Airport (UK) from 2005 to 2012



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HIGHLIGHTS

- Eight years of hourly air pollution data from 8 sites around Heathrow are analysed.
- Temporal analysis reveals diurnal, weekly and seasonal patterns and annual trends.
- Statistical tools are applied to depict the inter-site relationships.
- The relationships with weather parameters and atmospheric circulation are studied.
- The contributions of airport and motorway traffic are quantified.

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ABSTRACT

Among other emission sources in the Greater London area, the international airport of Heathrow is recognised to be a major source of air pollution and is one of the UK locations where European air quality Limit Values are currently breached. However it is very difficult to differentiate between pollutants arising from airport operations and those from the large volumes of road traffic generated by the airport, as well as the nearby M4 and M25 motorways, A4 and A30 major roads, the conurbation of London and other external sources. In this study, eight years (January 2005–December 2012) of measurements of various air pollutants (NO , NO_2 , NO_x , O_3 , CO , PM_{10} and $\text{PM}_{2.5}$) were investigated from 10 sites: eight sites are located within a distance of 2.5 km from the airport, while two sites representative of the regional background and of background air quality in London (Harwell (60 km WNW) and North Kensington (17 km ENE), respectively) were included. A series of statistical tools was thus applied to: (1) investigate the time series by analysing hourly data as diurnal, weekly, seasonal and annual patterns; (2) reveal the effects of the atmospheric circulation upon air pollution by analysing background-corrected polar plots and (3) quantify the impact of the airport upon air quality in the local area using the inter-site differences of measured concentrations. The results show different diurnal patterns in emissions of NO_x from the airport and from the motorways. The concentration increment arising from passage of air across the airport during airport activity (6 am–10 pm) and with wind speed $> 3 \text{ m s}^{-1}$ is ca. $1\text{--}9 \mu\text{g m}^{-3}$ of NO_2 and $2\text{--}20 \mu\text{g m}^{-3}$ of NO_x at background stations. Such results are slightly lower than in a previous study analysing the 2001–2004 period. Air quality impacts of the M25 and M4 motorways are substantial only at the Hillingdon site (30 m from M4). Concentration increments of particulate matter can take either small positive or negative values.

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1. Introduction

During the last decades, an increasing number of epidemiological studies have established a direct association between the exposure to some ambient air pollutants and adverse effects on human health due to respiratory and cardiovascular diseases (e.g., Dockery, 2009; Katsouyanni et al., 2009; Raaschou-Nielsen et al.,

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2013). Recently, outdoor air pollution has been classified as known carcinogenic to humans (Group 1) by the IARC. However, in the last decades, most European countries have experienced a general drop of ambient levels for many air pollutants. Generally, this air quality improvement has followed the implementation of legislation, technological advances, the application of successful abatement technologies and other mitigation measures. However, air pollution in Europe remains an actual and serious concern. Under this scenario, the identification, characterisation and quantification of the most relevant sources is amongst the main objectives addressed in research by policy-makers and stakeholders.

In Europe, air quality is monitored by local and national authorities through an extended monitoring network and data are managed to meet EC Directive requirements. In case of the exceeding of Limit Values or even lower assessment thresholds, such data can be used to inform the population about air quality and potential impacts upon health. Moreover, such data represent a valuable resource to develop and implement possible mitigation measures.

Among the EU-27 countries, UK has fewer critical issues in relation to air pollution than some other regions, such as Benelux, Northern Italy and some Eastern European countries (EEA, 2014). However, high levels of air pollutants exceeding the European air quality Limit Values are still recorded in the Greater London urban area (GL), where an extensive and densely populated conurbation hosts more than 9 million inhabitants, with the related high traffic and energy demand for domestic heating. In particular, those pollutants which currently do not fulfil the EU and UK air quality standards and objectives (DEFRA, 2013a) are nitrogen dioxide (>Limit Value) and ozone (>target value).

Among other emission sources in the Greater London area, the airport of Heathrow (LHR) is recognised to be a major source of nitrogen oxides (e.g., Carslaw et al., 2006, 2008; Stettler et al., 2011; Yim et al., 2013) and NO₂ concentrations have breached the EU and UK annual mean Limit Value (40 µg m⁻³) at some locations around the terminals in the last decade (UK Department of Transport, 2006; HAL, 2011). The Airports Council International (ACI, 2014) reported that LHR is amongst the busiest airports for arriving and departing passengers (~72 million passengers y⁻¹ in 2013), and consequently has congested flight traffic with near capacity utilisation during many hours of the day (e.g., Gelhausen et al., 2011; Bernhart et al., 2012). In the past decade some studies have attempted to estimate the contribution of LHR to local air quality, especially for nitrogen oxides (NO + NO₂ = NO_x). For example, Carslaw et al. (2006) estimated that airport operations accounted for ~27% of the annual mean NO_x and NO₂ at the airfield boundary and less than 15% (<10 µg m⁻³) at background locations 2–3 km downwind of the airport. Carslaw et al. (2008) investigated the nitrogen oxides levels in individual plumes from aircraft departing on the LHR northern runway and found that aircraft operational factors such as take-off weight and aircraft thrust setting have effects on concentrations of NO_x. Results of a model evaluation for the 2008/9 period by AEA (2010) indicated that the source attribution from airport operations at surrounding monitoring sites was similar to that calculated by Carslaw et al. (2006). Stettler et al. (2011) estimated that emissions due to the landing and take-off (LTO) cycles accounted for ~8.19 × 10⁶ kg NO_x in 2005, of which more than 80% are in form of NO. HAL (2011) reported that 46% of the total ground level NO_x from aircraft in 2010 was emitted during take-off roll, 21% in taxi-in and taxi-out phases, 19% by the auxiliary power units (APUs), while the remaining 14% is attributed to hold, landing roll and engine testing. Carslaw et al. (2012) quantified the impact of the flight-ban due to the eruption of the Icelandic volcano Eyjafjallajökull on concentrations of NO_x in April 2010 and stated that airport closure resulted in an unambiguous effect on NO_x and

NO₂ concentrations. Yim et al. (2013) applied a multi-scale air quality modelling approach to assess the air quality impacts of UK airports and calculated that 24% of UK-wide aviation-attributable early deaths could be avoided in 2030 if Heathrow were replaced by a new airport in the Thames Estuary, because the location is generally downwind of London, and at greater distance.

This study analyses an eight year hourly time series (January 2005–December 2012) of air pollutants measured at 10 monitoring sites. Eight sites are located in the surroundings of LHR, while two stations were selected to be representative of regional background and GL pollution, respectively. The main aims are to investigate the time series for patterns and trends, and study the potential location and strength of the main sources and their impact upon air quality.

2. Materials and methods

Data were measured at 10 sites managed by the UK Department for Environment, Food and Rural Affairs (DEFRA; <http://uk-air.defra.gov.uk/>) and London Heathrow authorities (<http://www.heathrowairwatch.org.uk/>). A map of the sites is shown in Fig. 1, with greater detail of the sites local to Heathrow in Figure S11, while the site names, acronyms, some characteristics, the monitored pollutant and the periods of available data are summarized in Table 1. One site (LHR2) is situated 180 m north to the northern runway centreline and a few metres inside the airport boundary. Four sites (GRG, OAK, HAT, HOA) are positioned close (<330 m) to the outer perimeter of the airport, while three sites (HRL, HIL, SLC) are located farther from the airport (>1 km). The maximum distance between any pair of sites is 6 km (SLC–HOA). A very similar set of monitoring stations was used in a previous study (Carslaw et al., 2006) which investigated data up to 2004. Because of their relative proximity, the eight sites are affected to differing degrees by the same set of sources, which include airport activities (aircraft, ground support equipment, auxiliary power units), road traffic (mainly due to the M4 and M25 motorways, A4, A30 and minor local roads) and urban emissions (domestic heating). However, due to the high density of potential emission sources in the study area, sites are categorized differently (Table 1). Two supplementary sites were selected to provide comparative data for regional (HAR) and urban London (LNK) background pollution. Despite being classified as “urban background” the Hillingdon site is only 30 m from the busy M4 motorway, and hence heavily influenced by it.

Analysed pollutants were measured hourly using automatic instruments according to European protocols. Quality assurance and quality control procedures follow the standards for the Automatic Urban and Rural Network (AURN) and the London Air Quality Network (LAQN): all instruments are routinely calibrated, and every six months are fully serviced and undergo an intercalibration audit. Weather data measured at Met Office Heathrow (station ID no. 708) including wind direction and speed, atmospheric pressure, air temperature and relative humidity (RH) were provided by the Met Office (<http://www.metoffice.gov.uk>) and BADC (<http://badc.nerc.ac.uk/data/>).

Data were analysed using R version 3.0.1 (R Core Team, 2013) and a series of supplementary packages, including ‘Openair’ (Carslaw and Ropkins, 2012; Carslaw, 2013). Preliminary data handling and clean-up were carried out to check the datasets for outliers and anomalous records. Particulate matter (PM₁₀ and PM_{2.5}) was measured automatically using TEOM or TEOM-FDMS (Table 1). However, the main concern with the use of the TEOM technique is the loss of the more volatile component (principally some semi-volatile hydrocarbons and nitrates) because the inlet is held at a temperature of about 50 °C. A simple adjustment applied to the UK data is to apply a factor of 1.3 to TEOM-measured concentrations to give approximate comparability with the European

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