



Air quality and public health impacts of UK airports. Part II: Impacts and policy assessment

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H I G H L I G H T S

- UK airport emissions are estimated for the present-day and 2030 scenarios.
- 2030 Scenarios considered include expanding Heathrow and a new Thames Hub airport.
- A multi-scale approach to assessing air quality impacts of airports is used.
- The air quality and public health impacts of UK airports are estimated.
- A Thames Hub airport results in lower health impacts than Heathrow expansion.

A R T I C L E I N F O

Article history:

Received 6 September 2012

Received in revised form

11 October 2012

Accepted 12 October 2012

Keywords:

Aviation
Airports
Aircraft
Emissions
Air quality
Particulate matter
Dispersion

A B S T R A C T

The potential adverse human health impacts of emissions from UK airports have become a significant issue of public concern. We produce an inventory of UK airport emissions – including emissions from aircraft landing and takeoff operations, aircraft auxiliary power units (APUs) and ground support equipment (GSE) – with quantified uncertainty. Emissions due to more than 95% of UK passenger enplanements are accounted for. We apply a multi-scale air quality modelling approach to assess the air quality impacts of UK airports. Using a concentration–response function we estimate that 110 (90% CI: 72–160) early deaths occur in the UK each year (based on 2005 data) due to UK airport emissions. We estimate that up to 65% of the health impacts of UK airports could be mitigated by desulphurising jet fuel, electrifying GSE, avoiding use of APUs and use of single engine taxiing. Two plans for the expansion of UK airport capacity are examined – expansion of London Heathrow and new hub airport in the Thames Estuary. Even if capacity is constrained, we find that the health impacts of UK airports still increases by 170% in 2030 due to an increasing and aging population, increasing emissions, and a changing atmosphere. We estimate that if Heathrow were to be expanded as per previous UK Government plans, UK-wide health impacts in 2030 would increase by 4% relative to the 2030 constrained case, but this increase could become a 48% reduction if emissions mitigation measures were employed. We calculate that 24% of UK-wide aviation-attributable early deaths could be avoided in 2030 if Heathrow were replaced by a new airport in Thames Estuary because the location is downwind of London, where this reduction occurs notwithstanding the increase in aircraft emissions. A Thames hub airport would (isolated from knock-on effects at other airports) cause 60–70% fewer early deaths than an expanded Heathrow, or 55–63% fewer early deaths than an unexpanded Heathrow. Finally, replacing Heathrow by a Thames Estuary airport combined with emissions mitigation measures would reduce UK-wide aviation-attributable early deaths by 56% in 2030 while increasing aircraft movements, which would represent aviation causing about the same level of adverse health impacts as today in absolute terms. We note that because aviation emissions are included in the EU Emissions Trading Scheme, all options are CO₂-neutral in terms of direct emissions (but not climate-neutral).

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1. Introduction

1.1. Context

The UK Department for Transport (DfT, 2011) recently forecast that the number of air passengers using UK airports will increase from 211 million passengers per annum (mppa) in 2010 to 335 mppa in 2030 and to 470 mppa in 2050 if current airport runway capacity is maintained. Without runway capacity constraints, the passenger forecasts for 2030 and 2050 are 3% and 11% greater, respectively. Airports in London currently account for 60% of the UK-wide aviation demand. The Greater London Authority (2011) argues that the capacity of London's five primary airports is insufficient to fulfil long-term UK aviation needs. The British government is currently considering various aviation policies to address the airport capacity issue under environmental constraints.

Ambient pollutant concentrations in the proximity of airports are positively correlated with aircraft landing and takeoff (LTO) activities (Hsu et al., 2012). Various studies have investigated the air quality impacts of airport emissions. For example, Carslaw et al. (2006) applied both bivariate polar plots and data filtering techniques to quantify the contribution of aircraft emissions to NO_x concentrations for a network of seven measurement sites close to the Heathrow airport. The results showed that aircraft emissions account for approximately 23% of annual mean NO_x and NO_2 near the airports and <15% 2–3 km downwind of the airport. Carslaw et al. (2012) and CERC (2007) also estimated that emissions of NO_x from Heathrow airport contributed 12–16 $\mu\text{g m}^{-3}$ at Oaks Road, which is a measurement site located at the south boundary of Heathrow airport. Hsu et al. (2012) monitored ultrafine particulate matter and other pollutants in order to correlate airport operations at T.F. Green Airport with airport-vicinity pollutant concentrations. Similarly, Westerdahla et al. (2008) found a positive correlation between aircraft operations and increases in ultrafine particle concentrations at Los Angeles International Airport.

It is known that poor air quality adversely impacts human health (USEPA, 2011). Epidemiological studies have found that long-term exposure to fine particulate matter ($\text{PM}_{2.5}$) is associated with increased risk of early death, and such exposure accounts for the majority (>80%) of the health costs of air pollution (USEPA, 2011). Specifically, each $\mu\text{g m}^{-3}$ of long-term exposure results in an increase in all-cause mortality of 1%, with a range of 0.4–1.8% (USEPA, 2011).

Ratliff et al. (2009) employed CMAQ to study the impact of aircraft LTO emissions (i.e. emissions below 3000 ft above ground level) on regional air quality in the United States. The study estimated that aircraft LTO emissions at 325 airports account for ~160 (range: 64–270) annual incidences of PM-related premature mortality in US. Beyond LTO emissions, Barrett et al. (2010) found that aircraft cruise emissions also impact surface air quality and human health. However, the impacts of cruise emissions are hemispheric in nature and are not sensitive to the specific location of emission because emissions occur in high speed westerly winds at ~10 km altitude, where impacts mix zonally.

1.2. Purpose of paper

In this paper, we quantify the regional and local air quality and health impacts due to emissions of current and future UK airport operations, including emissions from aircraft LTO operations, ground support equipment (GSE), and aircraft auxiliary power units (APUs). We assess options for mitigating both present-day and future impacts: (i) desulphurising jet fuel; (ii) electrifying GSE; (iii) widespread use of single engine taxiing; and (iv) use of fixed ground electrical power so as to avoid use of aircraft APUs. We

assess future aviation impacts on UK air quality and public health under three scenarios: (i) no capacity increase; (ii) unconstrained growth with a third runway at Heathrow Airport; and (iii) unconstrained growth with Heathrow replaced by a new Thames Estuary hub airport.

2. Methods

Here we provide an overview of the methods employed, which will be described in greater detail in the following subsections. UK aviation emissions are estimated based on Stettler et al. (2011) [Part I] for 2005 to be representative of the present-day, while the future year modelled is 2030. The top 20 UK airports by passenger numbers are accounted for, capturing >95% of passengers. We use a regional chemistry-transport model with multiple nested domains, where a domain encompassing the UK and a higher resolution nested domain capturing 88% of UK aviation-attributable health impacts [defined as “Southern Great Britain” (SGB)] are used to assess aviation's air quality impacts in the UK. Dispersion modelling is used to capture the impact of sub-grid near airport peaks in $\text{PM}_{2.5}$ concentrations. Local dispersion and regional scale results are combined with population density data (for the present-day and a future forecast) to produce estimates of aviation-attributable $\text{PM}_{2.5}$ exposure. We apply a concentration-response function to estimate early deaths attributable to aviation in each scenario considered, and to estimate the health benefits (expressed as averted early deaths) of emissions mitigation measures. Uncertainties in emissions are estimated and propagated through to uncertainties in health impacts, and an estimate for uncertainties in atmospheric modelling and the concentration-response function is captured. Where mitigation measures are considered, a paired Monte Carlo approach is used so that the resulting uncertainty distribution for averted early deaths does not “double count” uncertainty common to both the baseline and the mitigation scenarios.

2.1. Airport emissions

We use the methods described by Stettler et al. (2011) [Part I] to calculate emissions from aircraft LTO activity, aircraft APUs and GSE at the top 20 UK major airports, ranked by passenger numbers. The location and name of the 20 UK existing airports are shown in Fig. 1 and Table 1, respectively. Emissions totals for each of the scenarios considered are given in the Supporting Information (SI), available in the online version of this paper. Emissions of CO_2 , CO, hydrocarbons (HC), NO, NO_2 , HONO, SO_2 , sulphate, black carbon (BC) and organic carbon (OC) are estimated. For BC and OC – the emissions of which are particularly uncertain – the method proposed in Part I is used for our analysis, but the sensitivity to an alternative method [FOA3 (Wayson et al., 2009)] is also considered.

Aircraft emissions are spatially distributed according to the corresponding phase of the LTO cycle. Specifically, emissions arising from takeoff are assigned to the runways, emissions from taxiing are assigned to the taxiways and terminal areas, emissions from holding are assigned to taxiways near to the end of runways, and emissions from APUs and GSE are assigned to terminal areas. Emissions from the approach phase are distributed assuming a straight 3° (5.5° at London City Airport) glide slope while emissions from takeoff and climb phases up to 3000 ft above field elevation (AFE) are resolved using Standard Departure Charts available through the NATS (NATS, 2012), assuming high, medium and low climb angles of 9.6°, 6.9° and 4.2° for the initial climb phase and 6.9°, 5.5° and 4° for the climb out phase, respectively.

Other airport or airport-attributable emissions are not considered in this study.

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