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Source apportionment of wide range particle size spectra and black carbon collected at the airport of Venice (Italy)

Mauro Masiol [2], Tuan V. Vu, David C.S. Beddows, Roy M. Harrison*, [1]

Division of Environmental Health and Risk Management, School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom

HIGHLIGHTS

- Particle number, size and black carbon were measured at the airport of Venice.
- Data were analysed along with gases, weather parameters and flight traffic.
- Six potential sources were identified and apportioned by PMF analysis on PNSD.
- Airport emissions contributed ~20% to the total PNC.
- No specific local sources of BC can be identified as dominant.

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ABSTRACT

Atmospheric particles are of high concern due to their toxic properties and effects on climate, and large airports are known as significant sources of particles. This study investigates the contribution of the Airport of Venice (Italy) to black carbon (BC), total particle number concentrations (PNC) and particle number size distributions (PNSD) over a large range (14 nm–20 μm). Continuous measurements were conducted between April and June 2014 at a site located 110 m from the main taxiway and 300 m from the runway. Results revealed no significantly elevated levels of BC and PNC, but exhibited characteristic diurnal profiles. PNSD were then analysed using both *k*-means cluster analysis and positive matrix factorization. Five clusters were extracted and identified as midday nucleation events, road traffic, aircraft, airport and nighttime pollution. Six factors were apportioned and identified as probable sources according to the size profiles, directional association, diurnal variation, road and airport traffic volumes and their relationships to micrometeorology and common air pollutants. Photochemical nucleation accounted for ~44% of total number, followed by road + shipping traffic (26%). Airport-related emissions accounted for ~20% of total PNC and showed a main mode at 80 nm and a second mode beyond the lower limit of the SMPS (<14 nm). The remaining factors accounted for less than 10% of number counts, but were relevant for total volume concentrations: nighttime nitrate, regional pollution and local resuspension. An analysis of BC levels over different wind sectors revealed no especially significant contributions from specific directions associated with the main local sources, but a potentially significant role of diurnal dynamics of the mixing layer on BC levels. The approaches adopted in this study have identified and apportioned the main sources of particles and BC at an international airport located in area affected by a complex emission scenario. The results may underpin measures for improving local and regional air quality, and health impact assessment studies.

1. Introduction

Ambient air pollution, particularly airborne particulate matter (PM), exerts a large influence on public opinion and with policymakers and the scientific community because of its known adverse effects on human health (Heal et al., 2012; Beelen et al.,

* Division of Environmental Health and Risk Management, School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom.
E-mail address: r.m.harrison@bham.ac.uk (R.M. Harrison).
[1] Also at: Department of Environmental Sciences/Center of Excellence in Environmental Studies, King Abdulaziz University, PO Box 80203, Jeddah, 21589, Saudi Arabia.
[2] Now at: Center for Air Resources Engineering and Science, Clarkson University, Potsdam, NY, 13699, USA.

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2014) and its complex implications for climate (Kulmala et al., 2011; Fiore et al., 2012). The transformation and combustion of fossil fuels are amongst the main sources worldwide impacting upon PM and are studied widely because of the increasing demand for energy driven by industrialised countries and the economic growth of emerging regions. Besides the well-recognised sources which combust fossil fuels (e.g., road traffic, shipping, industries, domestic heating), aviation deserves particular attention because of the rapid growth of civil aviation. Despite the occurrence of events of global impact, such as the terrorist attack of 11th September 2011, the outbreak of severe acute respiratory syndrome in 2002–2003 and the recent global economic crisis (2008–2009), civil aviation has experienced an almost constant growth from the 1930s to present day. This trend (about +5% every year) is expected to continue over the next decades (Lee et al., 2009).

The global-scale impacts of civil aviation are heavily debated and are principally attributed to the climate forcing of exhausts emitted at cruising altitudes. In the lower troposphere, civil aviation has more local effects, which are mainly attributed to the noise and the deterioration of air quality at ground-level due to airport operations. Up to today, many studies have been reported on aircraft engine exhaust emissions (Masiol and Harrison, 2014 and references therein), and emission standards for new types of aircraft engine have been implemented since the late 1970s for carbon monoxide (CO), nitrogen oxides ($NO_x = NO + NO_2$), unburned hydrocarbons and smoke number (ICAO, 2008).

However, beside aircraft engine exhausts, other sources may affect air quality around airports, e.g. non-exhaust emissions from aircraft, emissions from the units providing power to the aircraft on the ground, the traffic due to the airport ground service, maintenance work, heating facilities, fugitive vapours from refuelling, transportation systems and road traffic for moving people and goods in and out of the airport. Beyond this complex emission scenario, most large airports are also located near heavily populated urban areas and are responsible for the build-up of some pollutants and exceedance of some air quality standards.

The Marie Skłodowska-Curie project CHEERS (Chemical and Physical Properties and Source Apportionment of Airport Emissions in the context of European Air Quality Directives) was motivated by the lack of information regarding the impacts of airports located near large cities. In particular, the role of airport emissions on the black carbon (BC), particle number concentration (PNC) and particle number size distributions (PNSD) are still debated, although some previous studies have provided evidence that aircraft are major sources of such pollutants. For example, Dodson et al. (2009) found that aircraft activity in close proximity to a small regional airport contributed 24–28% of the total BC measured at five sites 0.16–3.7 km from the airfield; Hudda et al. (2014) concluded that emissions from the Los Angeles international airport increase PNC 4-fold at 10 km downwind; Keuken et al. (2015) reported that the PNSD in an area affected by emissions from Schiphol airport (The Netherlands) was dominated by ultrafine (10–20 nm) particles.

This study aims to investigate the impacts of on-airport emissions on the levels of BC, PNC and PNSD over a very wide range (14 nm–20 μm) at a runway/taxiway-side site of the Marco Polo international airport (VCE). The airport is located ~5.5 km N to the historic city centre of Venice and ~6 km NE to the large urban area of Mestre (~270,000 inhabitants). This is an area characterised by many strong local anthropogenic pressures and a Mediterranean climate.

Among the well-established source apportionment methods, cluster analysis and receptor modelling techniques have been widely applied for characterising the PNSD and the most probable sources of airborne particles (e.g., Dall'Osto et al., 2012). Among the cluster analyses, *k*-means is the most widely used technique. Salimi et al. (2014) tested various clustering methods on PNSD data and reported that *k*-means resulted in a highest performance among others. Many studies have successfully applied *k*-means clustering for purposes similar to this study and under weather conditions comparable to N Italy: for example, Wegner et al. (2012) studied the characteristic size distributions in urban background environments; Brines et al. (2014, 2015) categorised PNSD measured in high-insolation cities (Barcelona, Madrid, Rome, Brisbane and Los Angeles), i.e. under weather conditions comparable to Venice; Beddows et al. (2014) explored the variations in tropospheric submicron particle size distributions all across Europe.

Among the receptor modelling techniques, positive matrix factorization (PMF) has been applied to PNSD data: Friend et al. (2013) compared the application of PMF and absolute principal component scores (PCA–APCS) for resolving sources of PNSD along a traffic corridor and concluded that PMF results were more reliable; Ogulei et al. (2007) modelled the source contributions to submicron PNSD measured in Rochester, NY, USA; Harrison et al. (2011) used PMF to quantify the sources of wide size spectra PNSD in the vicinity of a highway.

In this study, particle spectra were used as input for a *k*-means cluster analysis and a PMF receptor model aiming to characterise the PNSD and identify and quantify the main potential sources of particles, respectively. Data were also analysed jointly with common air pollutants, weather parameters and traffic profiles of airport and road traffic to investigate potential sources and formation mechanisms. Furthermore, an analysis of BC levels associated with different wind sectors allowed extraction of information on sources of soot particles and pointed out the effects of mixing layer dynamics on driving the levels of some pollutants in the study area.

2. Materials and methods

2.1. Site description

Amongst other regions, the Po Valley (Northern Italy) represents one of the few remaining hotspots in Europe, where the levels of air pollutants (mainly NO_2, PM_{10} and $PM_{2.5}$) are currently breaching the *target* or *limit* values imposed by European Directives. For this reason, the study of the main PM sources in the Po Valley is fundamental and VCE (Fig. 1) represents an interesting case study for a number of reasons:

- it is the third airport of Italy for flight traffic with more than 100,000 annual aircraft movements. The major type of aircraft flying at VCE are short-to medium-range, narrow-body, twin-engine airliners: A320 > A319 > A321 > B737-800 > B717;
- it is located close to a densely populated urban area (Mestre), where the levels of particulate matter pollution do not fully comply with the EC limit and target values (Masiol et al., 2014a);
- it is located in a coastal area and is therefore affected by the atmospheric circulation associated with sea/land breezes during the warm season. This circulation may potentially advect the pollutants emitted at the airport toward the mainland during the daytime;
- being located on the eastern edge of the Po Valley, it is potentially affected by the transport of pollutants at regional or even transboundary scales (e.g., Squizzato and Masiol, 2015);
- the air quality scenario of the area is extremely complex because of the high range of differing potential sources, including: (1) high density residential areas mostly using methane for domestic heating, even though the burning of wood (i.e. logs, briquettes, chips and pellets) is nowadays becoming an increasing alternative; (2) heavily trafficked roads which are