Update of ICAO's Airport Air Quality Manual (Doc 9889)

By Bethan Owen and Ralph Iovinelli

INTRODUCTION

ICAO's Airport Air Quality Manual (Doc 9889)[1], provides guidance for the determination of aviation-related local air quality emissions and pollutant concentrations within the vicinity of an airport (including aircraft, up to approximately 3,000ft above ground).

The document is published free of charge on the ICAO website and provides technical guidance and practical information to assist ICAO Member States in implementing best practices with respect to quantifying the incremental contribution of aviation-related emissions to ambient air quality. The document contains information related to: State requirements, emissions from airport sources, emission inventories, and emission allocations.

During the CAEP/11 cycle, Doc 9889 was updated to reflect recent advances in industry best practices, specifically with respect to emissions of particulate matter (PM) and especially emissions of non-volatile PM (nvPM) discharged by aircraft engines.

The update was done using new information on aircraft particulate matter emissions (mass and number) with recommended calculation methodologies that use new engine measurement data. Information has been updated on aircraft main engines and on auxiliary power units (APU) when the information was available.

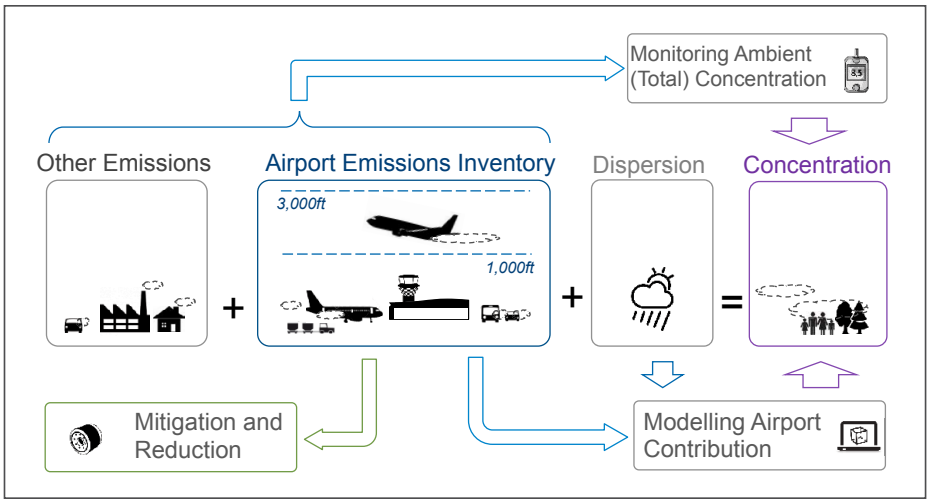
DOC 9889

As shown in Figure 1, the two main areas of an airport air quality assessment are:

- emissions inventories
- dispersion modelling of pollution concentrations

The opening chapters of Doc 9889 provide introductory material and information on the local air quality and emissions regulatory framework. Guidance is provided in Chapter 3 on a number of key subjects including: emission inventory construction, emissions parameters and species, airport-related sources, local and regional sources, forecasting, and quality assurance procedures. The Document then provides information on the temporal and spatial distribution of emissions, and guidance on dispersion modelling, including application and interpretation of results. Guidance and advice on ambient air quality measurements for airports is also provided on: designing a measurement

FIGURE 1: Local air quality elements and their interactions (figure courtesy of E. Fleuti, Zurich Airport)



1 ICAO's Airport Air Quality Manual (Doc 9889). https://www.icao.int/publications/Documents/9889_cons_en.pdf

plan, analysis of data, measurement quality assurance, and quality control. Finally, the concluding chapters of Doc 9889 provide guidance on mitigation options and the interrelationships associated with methods for mitigating environmental impacts.

Chapter 3 on constructing emission inventories and the associated appendices are thus the focus of this update article regarding PM emissions.

WHY UNDERTAKE THE UPDATES?

The technical emissions work undertaken by ICAO CAEP in support of the standard setting process involves state-of-the-art data analyses and the development of emissions quantification methodologies. This technical work enables ICAO CAEP to conduct global assessments of the incremental effects of aviation-related emissions. In addition, ICAO CAEP recognizes that Member States would also benefit from the use of already developed emissions methodologies to quantify aviation-related emissions for their domestic regulatory and planning purposes. ICAO Doc 9889 is the guidance document that allows ICAO CAEP to provide Member States with state-of-the-art emissions quantification methodologies to assess air quality in the vicinity of airports. To this end, it makes sense for ICAO CAEP to continue to update Doc 9889 periodically to reflect the evolutionary nature of technology in the civil aviation industry.

Driven by potential adverse health effects of ultrafine particulate matter concentrations in the ambient air, there is increasing environmental pressure to estimate the incremental particle mass and number emissions from aviation activities, as part of the broader set of PM emissions sources. In general, airports have a reasonable understanding of NOx emissions from airport related sources and their impacts on local and regional concentrations, and based on this understanding, they have developed and implemented mitigation plans that have successfully yielded benefits to local air quality. A developing consensus of understanding about the possible health effects of aircraft emitted pollutants, other than NOx, is driving airport operators' needs for a better quantitative and qualitative understanding of aircraft engine emissions of the mass and number of ultrafine particles (nvPM).

Improved quantification of the emissions of nvPM number and mass from aircraft sources will aid the better understanding of how pollutants evolve and disperse in the local and regional environment and will help put aviation emissions into context with other emission sources. Improving the quantification of the relative contribution of engine emissions and other airport sources in the context of wider transport sources will help to understand the potential reductions necessary. Ultimately, these methodologies may also be used to quantify the impacts of policy measures aimed at reducing PM emissions.

This latest update of Doc 9889 will bridge the gap until certified particle emissions data are publicly available. The methods covered in Doc 9889 also provide a way to estimate PM emissions contributions from older engine designs, where certified particle emissions data will not be available in the future.

Doc 9889 provides worldwide harmonization of methods which allows proper comparison between airport inventories and other sources.

WHAT UPDATES ARE INCLUDED?

While it is understood that local air quality and ambient pollutant concentrations in the vicinity of an airport include other non-airport sources of emissions, Doc 9889 focuses on the estimation of emissions from airport operations, concentrating specifically on aircraft combustion engines, including both propulsion engines and auxiliary power units (APUs). Airport emissions are also affected by emissions from other sources such as ground service vehicles, airside ground transportation and evaporative emissions of non-volatile organic compounds from de-icing and re-fueling operations, which are covered in Doc 9889 under the term aircraft handling emissions. These various emissions interact with each other, and thus each contribution to the total regional inventory of pollutants must be quantified and evaluated as accurately as possible. This update to Doc 9889 includes nvPM emission estimation improvements for aircraft engines, APUs and aircraft handling operations. The volatile PM emissions remain unchanged at this point, but work is planned in this area in the coming years.

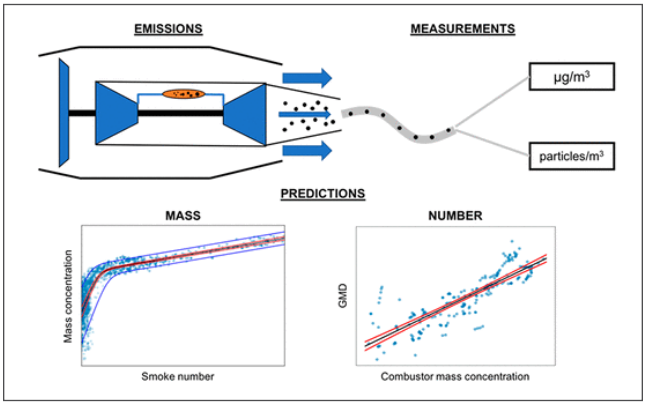
Aircraft engines with turbofans > 26.7 kN rated thrust are regulated for their emissions, which include: oxides of nitrogen (NOx), unburned hydrocarbons (HC), carbon monoxide (CO), and smoke. Smoke emissions are mainly carbonaceous particles emitted as a product of incomplete combustion, and these particles are now the subject of new standards that regulate the number and mass of non-volatile particles (nvPM).

The implementation of new regulatory standards means that emissions from new aircraft engines certified over the next few years will be specifically included in a publicly available database of nvPM mass and number measurements. This will allow airport operators to more accurately represent the nvPM emissions, using comparable methods as for NOx emission estimations, for example. However, in the meantime the data collected as part of the standard-setting process has been used to develop improved methods of nvPM mass emission estimation based on the certified smoke number (SN) measure and a new method has been developed to estimate the nvPM number for the first time. These methods can also be used in the longer term for engines where nvPM measurement data will not be available through certification, such as engines that are no longer in production but still in operation.

As work to develop the new nvPM standards has progressed in ICAO over the past six years, the data collected has lead to a better understanding of nvPM emissions from aircraft engines. As part of the standard-setting work, an engine nvPM values database, consisting of confidential proprietary measurement data for 24 current aircraft engine models, was built up using standardized measurement techniques (SAE, 2013) for both nvPM mass and nvPM number emissions, as well as the traditional SN measurements.

The database allowed a correlation to be derived between the traditional SN measurements and the new nvPM measurements, as illustrated in Figure 2. The correlation methods can then be used to estimate nvPM mass and number emissions from the SN measure and this method forms the nvPM part of the newly formulated 4th version of the First Order Approximation methodology (FOA4), as detailed in Doc 9889.

FIGURE 2: Illustration of the relationship between a visibility-based Smoke Number with both mass and number of non-volatile particulate matter. (Speth et al, 2019)[2]



In summary, the updated version of Doc9889 includes the following updates:

- Particulate matter emissions estimation method for aircraft main engines, auxiliary power units (APU), and for aircraft handling.
- Improvement of existing estimation method for non-volatile PM mass, using more robust measured data obtained during the development of the CAEP/11 nvPM standards.
- First time inclusion of an estimation method for non-volatile PM number.
- Total PM mass and non-volatile PM number methodology summarized as the First Order Approximation FOA 4.0 (Speth et al, 2019).
- Several new aircraft types have been added with their emissions from the LTO-cycle.

THE NEXT THREE YEARS

Doc 9889 will be continually updated as civil aviation technology evolves. As certification data for the CAEP/11 nvPM mass and number standards starts to become available in the coming years, the nvPM engine emissions database will be populated and the data will become publically available. The engine emissions certification data will then be used for the majority of the modern

2 Speth et al., "SCOPE11 Method for Estimating Aircraft Black Carbon Mass and Particle Number Emissions," Environmental Science and Technology, January 2019.

engines in the global commercial fleet to determine nvPM emissions from airport operations.

Further work planned on the Doc 9889 includes a review and assessment of the current volatile PM (vPM) estimation method (part of the FOA4), and a review of the dispersion modelling aspects of the document.

ICAO

CHAPTER FOUR

Climate Change Mitigation: Technology and Operations