ICAO Airport Air Quality Manual Update (Doc 9889)

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Background

Interest in aircraft and airport air pollutant emissions has been on the rise ever since the substantial increase in commercial turbojet traffic in the 1970s. Aircraft emissions as well as emissions from any other combustion or evaporation source produce air contaminants such as nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbon (HC), sulfur oxides (SOx) and fine particulate matter (PM), which in turn can involve broader environmental issues related to ground level ozone (O_3) and climate change, and present potential risks relating to public health and the environment. Unlike most transportation modes, aircraft travel great distances at a variety of altitudes, generating emissions that have the potential to have an impact on air quality in the local, regional and global environments.

States have historically adopted local air quality regulations to protect public health and the natural environment. Usually, air quality is regulated by a combination of national, regional and/or local regulations that establish standards on emissions sources and/or ambient (i.e. outdoor) levels of various pollutants and define the procedures for achieving compliance with these standards. However, emissions standards for aircraft engines are agreed internationally through the ICAO and subsequently adopted into domestic regulations by each ICAO Member State.

Assessing the local air quality industry-specific in a broader local context is complex and comprises several aspects (Figure 1). Airport related emissions together with other local or regional emissions sources lead to specific concentration levels in the vicinity of airports.

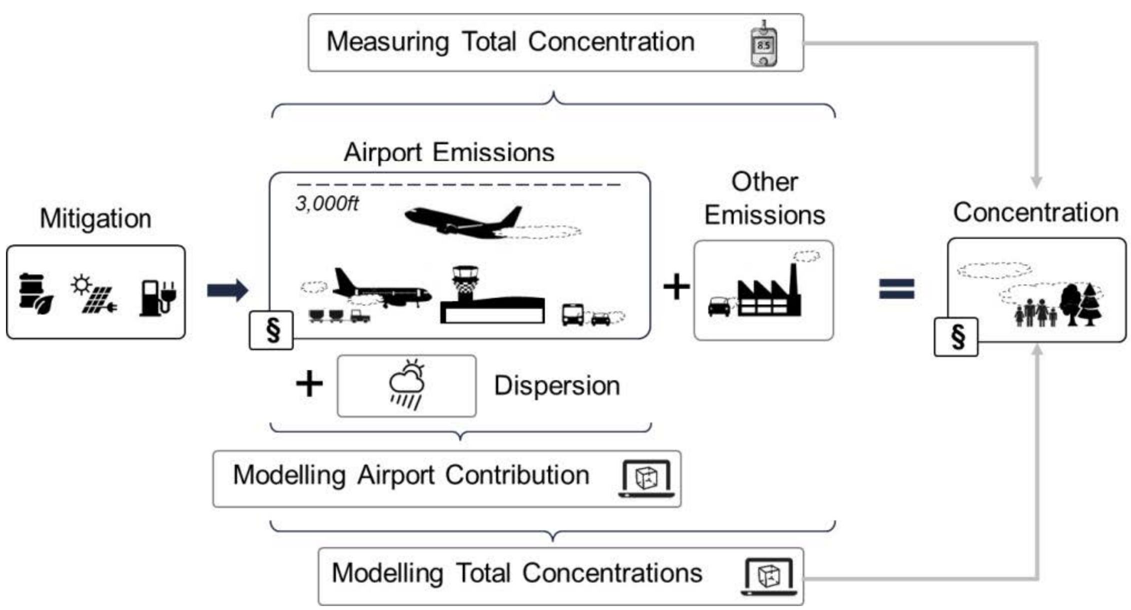

FIGURE 1: Airport air quality framework

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They can be measured, but only as an ambient total. In order to determine the contribution of the airport system, concentration modelling is required – sometimes not only for airport sources, but also for the whole region with multiple sources. The assessment of the situation gives room for designing mitigation measures that will directly influence the emissions of the specifically addressed sources.

While many States, authorities, or industry practitioners have developed their methods and approaches to assess air quality, the need for state-of-the-art, internationally harmonized and recommended guidance for the global aviation industry remains unchallenged.

Airport Air Quality Manual (ICAO Doc 9889)

The International Civil Aviation Organization (ICAO) had started to develop guidance on airport air quality as early as 2006 with a first edition of the Airport Air Quality Manual (ICAO Doc 9889) being published in 2011. This guidance material was developed to assist ICAO Member States and their aviation industries in applying best practices in relation to airport-related local air quality. Doc 9889 focuses on the core of the assessment - the emission inventory. Guidance is provided on a number of key subjects including, but not limited to: emission inventory construction, emissions parameters and species, airport-related sources, local and regional sources, forecasting, and quality assurance procedures. An emissions inventory can be conducted at various levels of complexity, depending on the required fidelity of the results as well as the availability of the supporting knowledge, data, and other resources. The guidance provided in Chapter 3 is intended to be a framework for conducting studies at various levels of complexity and the guidance is given for three different levels of complexity (e.g. simple, advanced, and sophisticated).

A pre-requisite for concentration modelling is the spatial and temporal resolution of the emissions (Chapter 4). The spatial and temporal allocation of emissions provides information on locations and times with high emissions and the relevance of different emission groups. As the pollutant concentration is (neglecting other parameters) proportional to the emission, such an allocation provides a first estimate of pollutant hot spots and source apportionment with respect to pollutant concentration. It is only a first estimate because transport effects due to exhaust dynamics, wind flow, atmospheric diffusion, deposition and physical or chemical conversion processes are not considered.

Such additional effects are considered in the discussion on atmospheric dispersion models (Chapter 5), whereby the input of emission inventories alongside meteorological information is processed. The result of these processes is a time-dependent, three-dimensional concentration distribution of the pollutant and/or a specific emission source, where the concentration is the quantity of the pollutant per unit volume. Atmospheric dispersion models are an important complement to pollutant measurements. They provide comprehensive three-dimensional concentration distributions, insight into relevant transport mechanisms and a clear source apportionment. In addition, they allow study of future or other scenarios for which measurements are not available or not possible. Measurements are often conducted in order to meet legal obligations, as part of voluntary programs or for model verification (Chapter 6). Very characteristic to measurements is that they are not source discriminating and provide no option to predict future concentrations. This constitutes the need to introduce concentration modelling at the same time.

Finally, the guidance offers insights into the development of mitigation plans – outlining that any measures taken only address emissions and benefits could be seen in decreasing concentrations – and potential interrelationships associated with methods for mitigating environmental aspects (Chapters 7 and 8).

ICAO Doc 9889 Update

The Airport Air Quality manual is a document that follows the development of the scientific and technical understanding of the expert community. As new knowledge evolves, the guidance for its proper interpretation and application has to be developed as well. To this end, almost each CAEP cycle has seen an update of the manual, thus providing the practitioners with the latest available information. In the CAEP/13 cycle, a focus has been set on the modelling of particulate matter (PM) emissions, addressing not only non-volatile particle emissions, but newly the volatile particle emissions from aircraft main engines.

As a new topic, the consideration of the use of sustainable aviation fuels (SAF) in the context of local air quality has been addressed. SAF will play an important role in the decarbonization of aviation with local air quality benefits alongside. Acknowledging that SAF in the more global context is assessed for their carbon benefits, particularly over their full lifetime, Doc 9889 just looks at direct emissions from the engines. The combustion of SAF can have significant effects on the emissions of local air quality substances like SOx and PM (mass and number) in the LTO cycle and during the cruise phase. However, these effects depend on the fuel composition, the flight phase and the combustion technology of certified subsonic engines and can vary from engine model to engine model. Whereas for SOx and nvPM, the effects are significant, no outstanding emission effects for NO_X, HC and CO have been identified to date.

Enhancement in Particle Matter Estimations

Particle Matter (PM) can generally be divided into two components: non-volatile PM (nvPM) and volatile PM (vPM). So far, ICAO Doc 9889 contained information on calculating nvPM (both mass and number) and vPM (mass), but no guidance to address vPM droplet numbers. In the CAEP/13 cycle, work was done on improving nvPM emission estimation and introducing vPM number calculations (Figure 2).

The ICAO Engine Emission Database (EEDB) contains a data sheet with information on engine nvPM mass and number emissions. However, in certain cases (such as

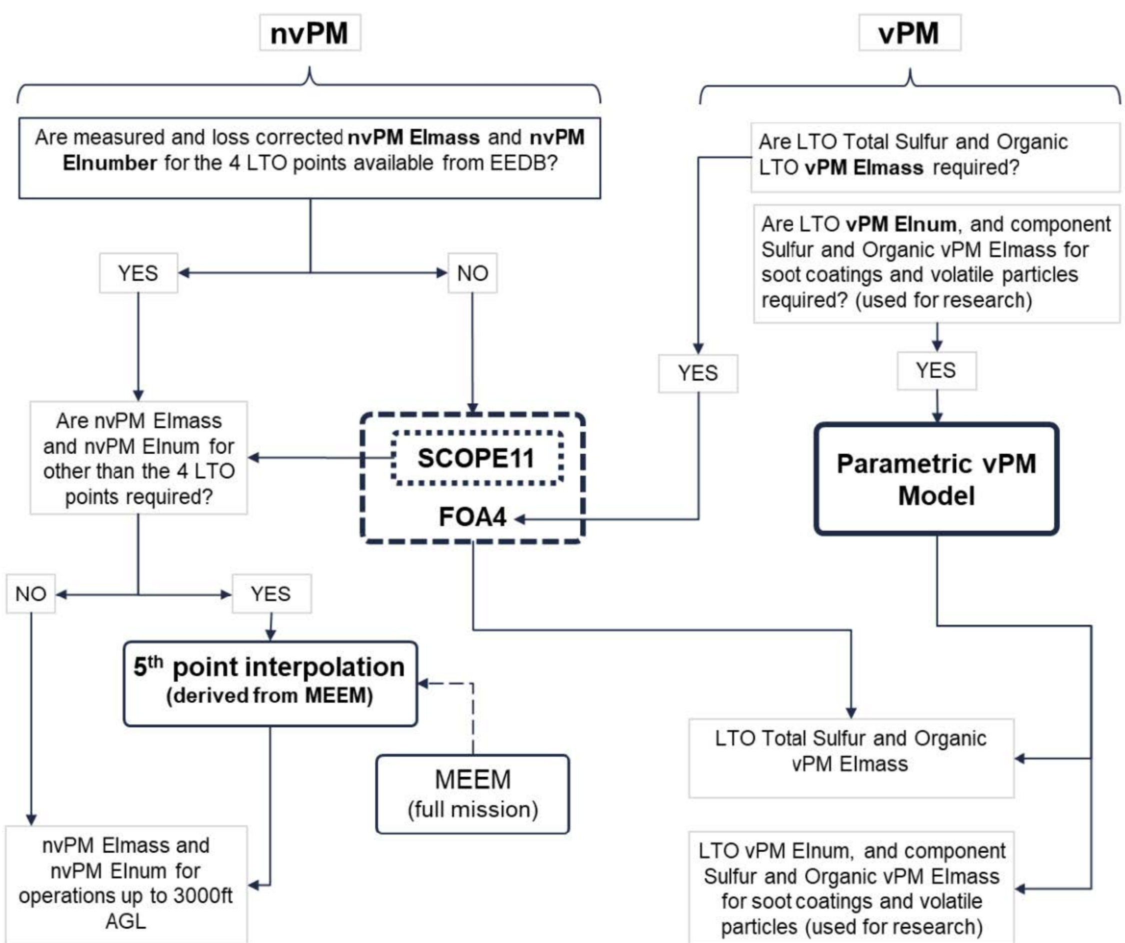

FIGURE 2: Particulate Matter Estimation Scheme

out of production engines) this information may not be available. A method to determine the nvPM (mass and number) other than with the EEDB data is using the First Order Approximation, version 4 (FOA4) using measured smoke number (SN) data. FOA4 is a method for estimating the engine exhaust particulate emissions. For non-volatile and volatile particle mass, the results for each mode of engine operation are given in the form of emission indices (EIs), as mass emitted per kilogram of fuel. For non-volatile particle number emissions, the EIs for each mode of engine operation are given as number of emitted particles per kilogram of fuel.

A new calculation methodology for estimating vPM properties in more detail has been developed by Aerodyne Research.[2] This methodology is a parameterized model based on microphysical modeling of exhaust plumes over a wide range of emissions levels. This methodology provides the vPM contributions in a more detailed breakdown than the FOA4 methodology. In addition to providing a breakdown of sulfates and condensable HC by how much of each reside in volatile droplets or as soot coatings, the methodology also allows for the estimation of vPM droplet number. That parameterized vPM methodology is a supplement to the FOA4 methodology.

There are continued efforts underway to improve vPM estimation methodologies, and those presented here provide the best available guidance at this time. The vPM guidance will be updated as needed, consistent with new developments in vPM estimation.

Summary

The latest development of Doc 9889 will provide practitioners with new guidance to address nvPM and vPM, both for mass and number. This considerably helps to not only better understand local air quality at and around airports, but also to bridge the gap between measured PM concentration which usually contain both total particle mass and numbers with modelled values.

ICAO Doc 9889 will be continually updated as civil aviation technology evolves and modelling methodologies improve.

2 Jones, S. H., & Miake-Lye, R. C. (2024). Parameterization of H_2SO_4 and organic contributions to volatile PM in aircraft plumes at ground idle. *Journal of the Air & Waste Management Association*. https://doi.org/10.1080/10962247.2024.2354820