Few types of indoor air quality have benefitted as important research but aircraft cabin air quality, as served by important attention by crew and passengers as well as by aviation industry and their governmental and intergovernmental agencies, due to potential flight safety and health concerns.

As described in official texts, concerns go to the air contamination by different dedicated compounds, especially fluids such as engine oil, hydraulic and de-icing products. Worldwide estimates suggest cabin air quality events in one flight out of 2000 –when 36,8 million flights in 2017 alone,

Sampling and analysis results range essentially from 1975 to today, but based on different methods and protocols. The evidence has been released since 1975 in a large panel of documents, but with such diverse approaches in methodology that data can hardly be compared over the years and the tests. Sought pollutant are in aerosol form, liquid or solid, from nano to pm sizes, and gaseous phase, at concentrations ranging from below ng/m3 to mg/m3, including organic and inorganic products, thus deserving different sampling and analytical methods, target and non-target, which resolution also significantly progressed over the past 45 years, at last by 1000 time fold .

In flight offline sampling methods included canisters, pumps of different flows (typically 2 to 800 l/min) and with different capture media such as membranes, PU foam, cartridge sorbents from activated carbon to different specialty resins, when all such samples failed to document even one in-flight contamination episode with odors and crew/pax symptoms. Online measurement ranged from particle counter (number and sizes) for aerosols, on board GC/MS for volatiles and SVOCs, other specific analyzers 'O3, C0, C02, No and NOx, RH, T°, P, Wipe samples did reflect the presence of most of the non or semi-volatile compounds. The number of tested flights is by several thousands, but only a few hundreds of them published in a few key articles. Additionally, dozens of laboratory tests have been conducted on the acft products, for over 70 years, with consideration to initial and used fluids, their potential thermo degradation by-products (basically from 20 to 1000 °C), but also by simulating fluid engine ingestion on dedicated test acft. Many different airlines and aircraft manufacturers worldwide have contributed to such investigations, based on different acft types.

So is there a considerable number of data worldwide, of which only a small fraction is published. As environmental forensic experts, the authors, started over 20 years ago an excel spreadsheet to bring together usable chemical data (usable meaning to be in the public domain, and sufficiently well-described sampling and analytical protocols).

Furthermore, the sampling time being critical as to the detection and quantification limits, all such parameters having been so variable over the years, or not indicative of a possible short term air quality event, or distinct flight cycles (tarmac, take off and ascent, cruise, descent). So how to compare measured concentrations when methods and test conditions so different, It is a duty to forensic expert to accept such honest and factual discrepancies, so did we elect to not release the concentration data and ranges, instead, to focus on the list of acceptable list of compounds found above DL… Over 340 different chemicals have been brought together in the xls spreadsheet attached to the hereby publication as supplemental information.

- But how to use such a list of chemical names, many of them also having synonyms or brand names, without adding the specific CAS # for each of them for exact reference.
- Why not also search the toxicity of these individual compounds, their exposure thresholds and toxicity mechanisms / target organs: This is central to the issue, the parties opposing reasoning such as: :
    - No measured concentrations in excess of TLVs for any of the evidenced individual chemicals, and "thus" no possible symptoms,
    - Can one relay on the toxicity of individual chemical species, when the blend is rich of at least 330 chemicals, some possibly having synergistic vs antagonistic effects in the blend? To get enhanced reliability, the authors have consulted multiple sources over the toxicity mechanisms and target organs or TLVs ((EU, NIOSH /OSHA, , Chemspider…). In fact, over the 20 years it took to synthetize such scientific evidence, one need to realize that such values or opinions do get updated/upgrades every year, thus turning the "mise à jour" of this database to a considerable work effort, when authors do anticipate annual updates of the spreadsheet.

- How to account for individual susceptibility, of genetic or epigenetic nature, different individual co-morbidity factors or from multiples exposures, even at low dose.
- As shown in database, same compounds are found between 6 and 13% only when comparing campaigns: so, can the analytical evidences be considered as reliable?
- Why is it that the sum of individually irritant compounds present in list are classified as irritants (68% for skin, 67 for eye, and 51% for respiratory system) or neurotoxic (CNS) for 24%), does match with the preponderance of symptoms as reported by aircrew.

There is or has been over 100 legal cases filed worldwide over such contamination events by exposed crew. The time correlation between reported CAQ events and symptoms has turned more accepted by aviation accident/incident investigation boards as well as by courtrooms. In total, aircraft system failure remains rarely demonstrated after inspection by official aviation investigation boards (estimate goes to 25%).

There has been hundreds of official documents released by aviation authorities and aircraft manufacturers, several governmental enquiries into the issue, and some advanced national and international research projects. We have elected to relay on these official research efforts, to avoid being reproached some form of bias, even if aviation industry is logically part of these investigations

As forensic scientists, the authors are not to present here their personal opinions, instead to respect the judicial expertise ethical and deontological principles of objectivity, exhaustively, respect of contradictory principle, integrity, And thus elected to release the attached database, with only a very scientifically objective facts and questions, for the benefit of the worldwide scientific community and all parties.
Please realize that aircraft air quality issues is part of a worldwide issue and effort, The data shared is unique in its way
: it is apparent that the cost of grounding or flying commercial aircraft for testing purposes is at very high cost, the database presented here as supplemental information being worth several million $.

Rostowski P. & al: 2019: The strength in numbers: comprehensive characterization of house dust using complementary mass spectrometric technique. Analytical and bioanalytical chemistry. 22 pp.
EASA 2015: AVOIL Characterization of the toxicity of turbine engine oils. Final report EASA-REP_RSEA_2015-2, 158 pp.
Guan J & al.: 2013 Measurement of volatile organic compounds in aircraft cabins Methodology and detected VOC species in 107 commercial flights. Building and environment, 72, 154-161
EASA 2014: CAQ Preliminary cabin air quality measurement campaign, final report EASA_REP-RSEA_2014-4, 128 pp

The structure of the database

The **source page** refers to in aircraft VOC data that has been available through different sources, and dated 1998 through 2016. Such data acquisition has also not met the contradictory principles, nor technical basis as needed / essential to judicial or rule making uses. It is further limited to non-complaint flights, for such flights have not been measured, nor were sampling, analytical methods meeting common and certifiable grounds. Thus the concentration values to be used with proper forensic discernment. It may however indicate some concentration ranges, which are high enough to suggest that all flights or sampling / analytical campaigns do not compare. All data has been acquired by aviation industry (the compounds found by Guan et al, 2014 are included at bottom of page.

The **Tox TLV VOCs** refers to in aircraft VOC as available from source page, by CAS #, as for target organs land toxicity mechanisms as can be found under Chemspider (http://www.chemspider.com/ as largest and publicly available database). NC is acronym for Not Classified for Thresholds under Chemspider. When Thresholds under NOSH or OSHA, please refer to M to Q columns. Note that many of these CAS # are not documented for their toxicities. The compounds have been sorted for being (or not) classified for TLVs and per CAS #. The last lines of this page represent sums of compounds per criteria. The acronym AI or ED stands for Autoimmune / endocrine disruptor (perturbateur endocrinien). All data to be used with discernment for all toxicity evidence not comparable upon investigations nor with time.

The **SVOCs** page refers to some of aircraft used SVOCs . The **elemental MEB** (Electronic microscopy) refers to some of the elementals found in acft particulate matter. A concern goes to toxic metals and suspected vapour/particle partitioning…

On lines AJ, AK & AL, the data from avoil,, CAQ and Guan are summarized : It is important to note that Avoil is focused on oil whilst CAQ & Guan are focused on CAQ : 19 out of 317 (6%) compounds are found in all 3 investigations; 32 are found by Guan and CAQ (9,8%), 43 compounds are found in both avoil and CAQ (13,6%) . In absence of individual data set for each of the measured tests, it is not possible to use advanced statistical tools (multivariate analysis and correlation factors) to better interpret the existing relationship between the observed compounds.

By Jean-Christophe BALOUET