Title of Project:

**"Cabin Air Contamination Calculation Theory"**

Inspiration:

EASA: **CAQ - Preliminary cabin air quality measurement campaign**, 2017. -
URL: https://www.easa.europa.eu/document-library/research-projects/easarepresea20144.

Abbreviations:
CAC cabin air contamination
CAQ cabin air quality
TCAC technical cabin air contamination

Theory roughly explained, but mathematics and examples not fully given:

Chapter 7
**General discussion on cabin air contamination release and detection**
(page 83)

High air exchange rates (>20 1/h) being maintained in the aircraft. The high air exchange has important consequences on the measurable VOC concentrations in the aircraft cabin.

**Figure 53**
The arrow labelled Si quantifies the source strength [mass/time] of various internal (i) volatile compounds (VOC) while the arrows labelled Q indicate the mass flow [mass/time] related to the defined air exchange. High air exchange rates (>20 1/h) are maintained in aircraft cabins. An equilibrium concentration is soon established for each volatile substance (VOC) with a constant source strength. For the considerations introduced here the outside air is initially regarded as free of pollutants (pure). In the box model, most of the VOC dilutes within a few minutes below detectable limits due to the applied high air exchange rates.

**Figure 54**
Calculated carbon dioxide ($CO_2$) concentrations (Equation 1) in a fully occupied aircraft with consideration of typical flight parameters. The green curves give the concentration course of $CO_2$ for a hypothetical aircraft with 470 $m^3$ ventilated cabin volume (well mixed box) and an air exchange rate of 20 1/h. The hypothetical aircraft is occupied by 345 passengers who start breathing at $t_0$. Each passenger releases 0.44 g $CO_2$ per minute and the ambient air contains 388 ppm $CO_2$. These conditions are very similar to an A340-6 aircraft. In less than 10 min a dynamic equilibrium is established which is close to 1060 ppm, a commonly accepted value for appropriate air quality in indoor environments. Without passengers the $CO_2$ concentration would remain at 388 ppm according to the box model, since the outdoor air is, as the cabin air

"contaminated" with CO2. This example shows that the simple box model can provide good predictions regarding the concentration profile of contaminants which are continuously fed into cabin air by external sources such as bleed air oil leakage. Again, the importance of the high air exchange rate in aircraft is pointed out here. Without air exchange, toxic CO2 concentrations (8000 ppm) would be reached within 25 minutes. The use of typical indoor air exchange rates (lambda=3) would also lead to undesired CO2 concentrations above 5000 ppm within 25 minutes.

Consider additionally:

a) outside air is not free of volatile pollutants (VOC) at the airport.
b) the thinning of VOC is delayed or hindered by sinks within the cabin (delayed "thinning effect").

**Figure 57**

The differentiation between external (e.g., engine oil leakage, contaminated airport air, etc.) and internal (e.g., interior, passengers, food, etc.) emission sources is hardly possible by indoor (cabin) measurements alone.

**Reverse calculation:**

The box model also allows a more detailed examination of possible CAC-events. It is possible to estimate the oil quantity which causes such an event. Calculation is possible with Eq. 2 (page 99).

**Figure 63**

Calculate TCP concentration curves with a box model. Simplified release is modeled for an instantaneous 100 g engine oil release (or alternatively: 10 g/min). A 100% oil transfer from the engine into the cabin is assumed.

**Figure 64**

Possible primary and secondary sources of TCP contamination in affected aircraft compartments causing TCAC-events.

A. Event free situation with creeping oil component deposits in the bleed air/ECS/ducts compartment (Depot).
B. Sealing failure in engines may cause primary TCAC-events with high contamination loads which cannot be deposited due to capacity.
C. Event triggered oil component release at the descent/landing phase from contaminant (deposit). Triggering events can be any physico-chemical influences on the deposit in the associated compartments.

**Note:**

Cabin air measurements cannot distinguish between primary and secondary TCAC-events.