HyBRid adsorption-photocatalytic air filtEr for rEmoving pollutants from aircraft cabin ZonE

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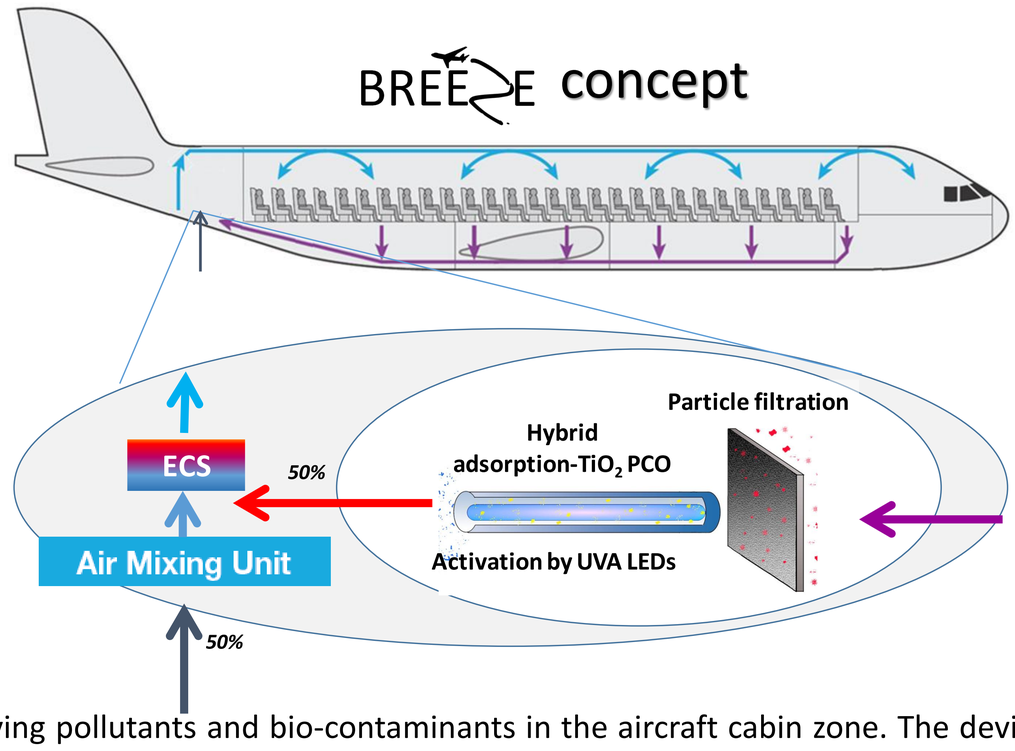
CONTEXT AND OBJECTIVES

In the majority of aircraft approximately half of the cabin air is exhausted while the other half is recirculated, passing through a High Efficiency Particulate Air (HEPA) filter to extract contaminants (particles, bio-contaminants) [1], after which it is mixed with outside air to be returned to the cabin. The mixing ratio is controlled by the Environmental Control System (ECS) which provides air supply, thermal control and pressurization of the cabin.

This configuration, along with a high occupation density, leads to the dispersion of germs and viruses and the accumulation of pollutants:

- Ozone from outside air
- Volatile organic compounds (VOC)
  - Bioeffluents (acetone and ethanol)
  - VOC representative of indoor atmosphere
- Polybrominated diphenyl ethers (PBDEs) used as flame retardants
- Bio-contaminants (bacteria and viruses)

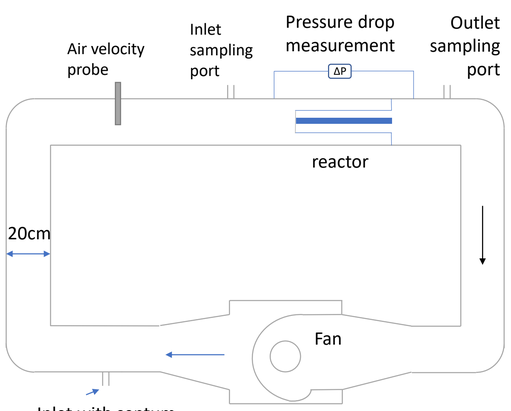
This poor quality of cabin air has been related with symptoms such as headaches, blurred vision, dizziness, nausea and other health problems.



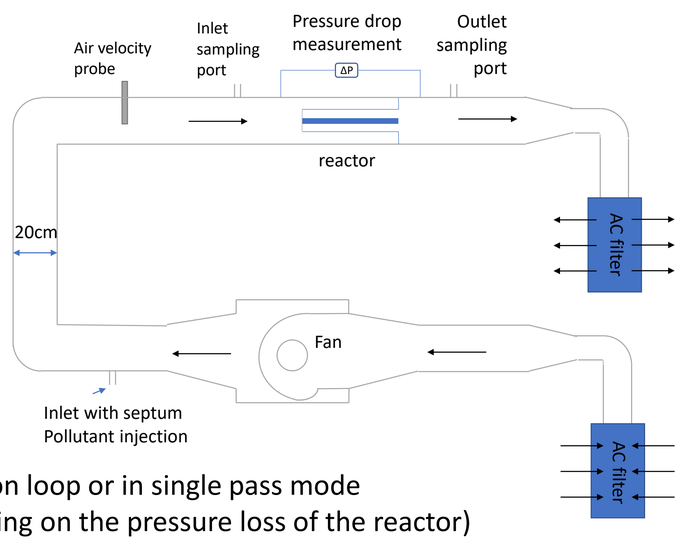
The objective of the Breeze project is the development of a novel air purifier capable of removing pollutants and bio-contaminants in the aircraft cabin zone. The device will be installed after the HEPA filtration stage of the recirculated air and will provide efficient and durable degradation of ozone, VOCs, PBDEs and bio-contaminants.

MATERIALS & METHODS

Tests in recirculation mode

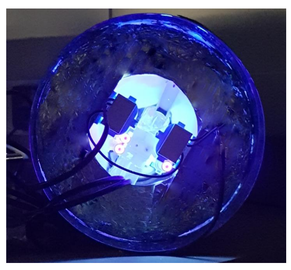


Tests in single-pass mode



- The test set-up can work in recirculation loop or in single pass mode
- High air velocity (up to 10 m/s depending on the pressure loss of the reactor)
- Pollutant injection by microfluidic syringe pump
- Analytical method:
  - TVOC measurement by PID
  - Tenax sampling + GC-MS
  - DNPH reactant + HPLC-MS

Reactor configuration



Air is filtered in 2 stages

1. Photocatalysis

- Degradation of VOC and microorganisms
- Improve the span life of the activated carbon

2. Adsorption

- Adsorption of first stage unreacted compounds
- Adsorption of photocatalytic by-products

Constraints for air filter subassembly integration in the ECS

Weight (kg)	9 kg clean
Length and width (mm)	550 mm x 550 mm
Life span of filter (h)	>3,000 h
Treated air flow (L/s)	300 L/s up to 6,000 ft 420 L/s up to 8,000 ft
Air velocity (m/s)	1,1 m/s
Pressure drop (mbar)	6 mbar clean to 10 mbar end of life
Relative humidity	15%
Temperature	23ºC

Pollutant tested

VOC:

- Toluene
- Limonene
- aldehydes

Ozone

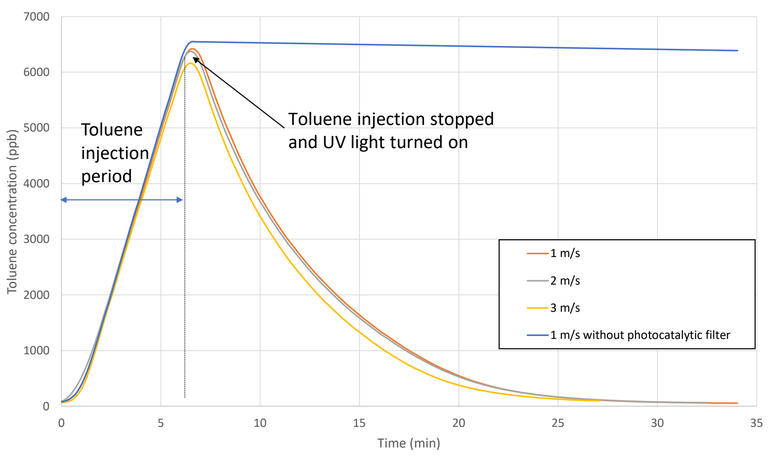
BIO-contaminants in aerosol

Bang jet nebullizer for bioaerosol generation

RESULTS

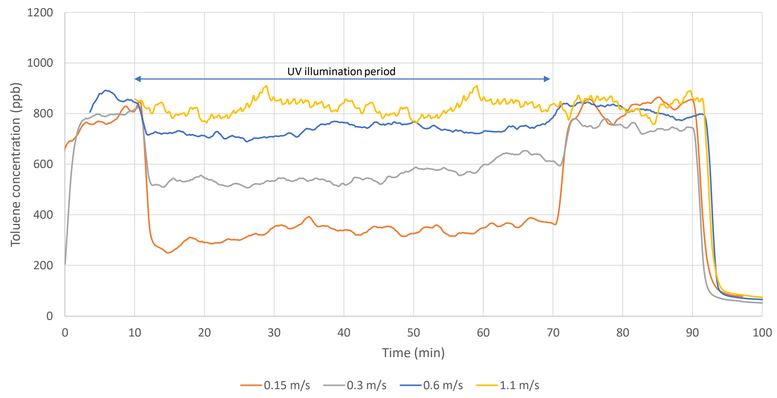
PHOTOCATALYTIC FILTER

Toluene degradation in recirculation mode



Air velocity (ranging from 1 to 3 m/s) in recirculation mode had no influence on the kinetic of the toluene photocatalytic degradation. The effect of mass transfer on the photocatalysis process was not significant and the only influence factor seems to be the total residence time of the pollutant into the reactor

Toluene degradation in single-pass mode



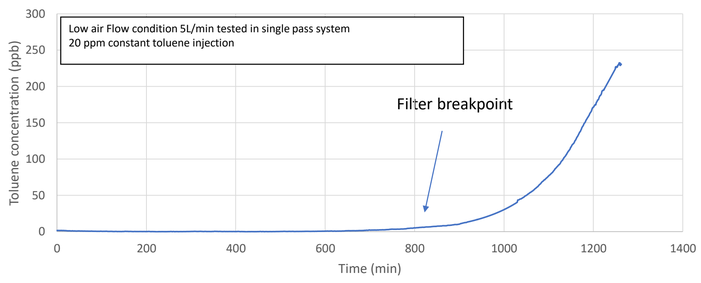
Toluene and limonene degradation ratio after 1h UV

Air velocity (m/s)	TOLUENE Degradation (%)	LIMONENE Degradation (%)
0,15	54	/
0,3	26	/
0,6	7	/
1,1	0	40

When air treatment was conducted in a single pass mode, the degradation rate decreased with increasing flow rates (tested range 0,15-1,1 m/s). Limonene is more reactive than toluene by photocatalysis.

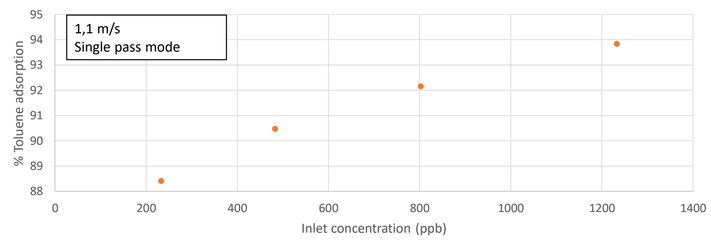
ACTIVATED CARBON FILTER

Breakthrough curve of activated carbon foam filter



Activated carbon filter get saturated with time. The purpose of the photocatalytic filter is to delay the breakpoint appearance by reducing inlet concentration, thus extending the span life of the filter

Short-term performance at aircraft conditions



Toluene adsorption is above 88% for a new filter at aircraft conditions

CONCLUSION

Evaluation of the toluene degradation by photocatalysis is dependent on the test method. Air velocity doesn't impact the kinetics in recirculation mode but has a large impact when tests are performed in single passage. At representative air velocity (1,1 m/s) in single passage, degradation of toluene was not measurable but was significant on Limonene (40% degradation). This is an interesting result as high boiling point compounds (like limonene) have the tendency to replace adsorbed lower boiling point compounds already adsorbed on activated carbon. Scale-up of the reactor will be done by increasing the size of the filter and the UV irradiance.

PERSPECTIVE

- Scale-up of the reactor to obtain toluene degradation by photocatalysis
- Identification and quantification of by-products generated by photocatalysis
- Study of the influence of photocatalysis on the breakthrought of the AC filter
- Study of others compounds (VOC, O_3, microorganisms)
- The optimized BREEZE device will be integrated in an Environmental Control System (ECS) demonstrator in Liebherr Aerospace's facilities for its final validation (TRL6)

REFERENCES

[1] DR. Space, RA. Johnson, WL Rankin, NL Nagda, in *Air quality and comfort in airliner cabins*, NL. Nagda, (Ed), West Conshohocken, ASTM International, 2000, p. 189.
[2] CleanSky2 Joint Technical Programme. Brussels, 23 March 2015.

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