FACTS

FRESH AIRCRAFT

2017- 2020

Consortium included Airbus, Honeywell, Fraunhofer, RIVM, VITO, TNO

Service Contract MOVE/B3/SER/2016-363/SI2.748114

Over-arching objectives from tender

- Characterization of composition and concentration of contaminants of bleed air and their impact on cabin/cockpit air quality.

- Identification of short- and/or long-term health effects (toxicological and physiological), that might evolve from exposure to cabin air.

- Strategy for simulating CAC-events.

- Toxicological risk assessment methodology for decision-support relating to cabin air quality

- Risk mitigation strategy aimed at reducing likelihood of CAQ-risk.

FACTS
FRESHAIRCRAFT

Set up Bleed Air Contamination Simulator BACS

FACTS
FRESH AIRCRAFT

Exposure variable monitored

- Pressure, temperature, relative humidity continuously
- Following compounds continuously:
  - Carbon monoxide
  - Carbon dioxide
  - Nitrogen oxides
  - Sulphur dioxide
  - Ozone
  - Formaldehyde
  - Total Volatile Organic Compounds
  - Selected Volatile Organic Compounds
  - Particulate matter 0.005 – 40 µm (UFP, PM1, PM2.5, PM10 and larger)
  - Black carbon

Compounds
Volatile Organic Compounds (VOC, C6-C16, incl. BTXE, halogenated)
Volatile Organic Compounds (VOC, C6-C16, incl. BTXE, Acrolein)
Very Volatile Organic Compounds (VVOC, C2-C6)
SVOC in suspension (phthalates, PAHs, PCBs, flame retardants, organo phosphates)
Aldehydes/Ketones
Carboxylic acids
Organo-phosphates (28 incl. 10 TCP isomers)
Dioxins and furans
PAHs
Odour active compounds
Characterisation of particles

FACTS
FRESH AIRCRAFT

Risk assessment methodology

- Objective (tender): **Toxicological risk assessment methodology for decision-support relating to cabin air quality**

- Three main areas of interest identified
  - Suitability of available reference values in cabin air quality

  - Development of risk assessment framework
    - For incidental fume events and normal flight conditions.
    - Flight crew as well as passengers.
    - Focus on exposure and effects via inhalation

  - Flowcharts and Excel files as basis for a **CAQ III**

FACTS
FRESH AIRCRAFT

Toxicity testing - objectives

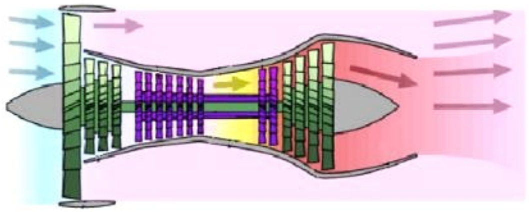
- **Main goal**:
  assess whether exposure to fume events contributes to neuronal effects as observed in cases of ‘aerotoxic syndrome’

- **Specific objectives**
  - **Hazard identification**: rank fume mixtures in terms of general toxicity and specific neurotoxic potency
  - **Screening for biomarkers** in test animals used in controlled exposure to characterized fumes/extracts → not performed, CAQ III will do this in vivo/mice

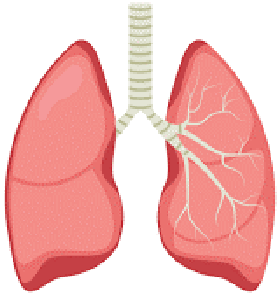
FACTS
FRESHAIRCRAFT

Toxicity testing

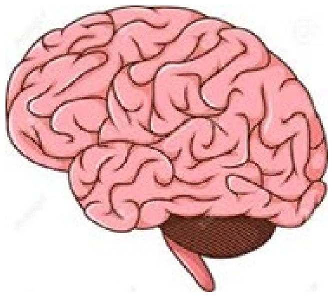
An air-liquid interface (ALI) exposure system for realistic inhalation exposure to fumes generated with miniBACS to assess pulmonary and neurotoxicity of simulated fume events in the aircraft cabin



Fume generation under laboratory conditions



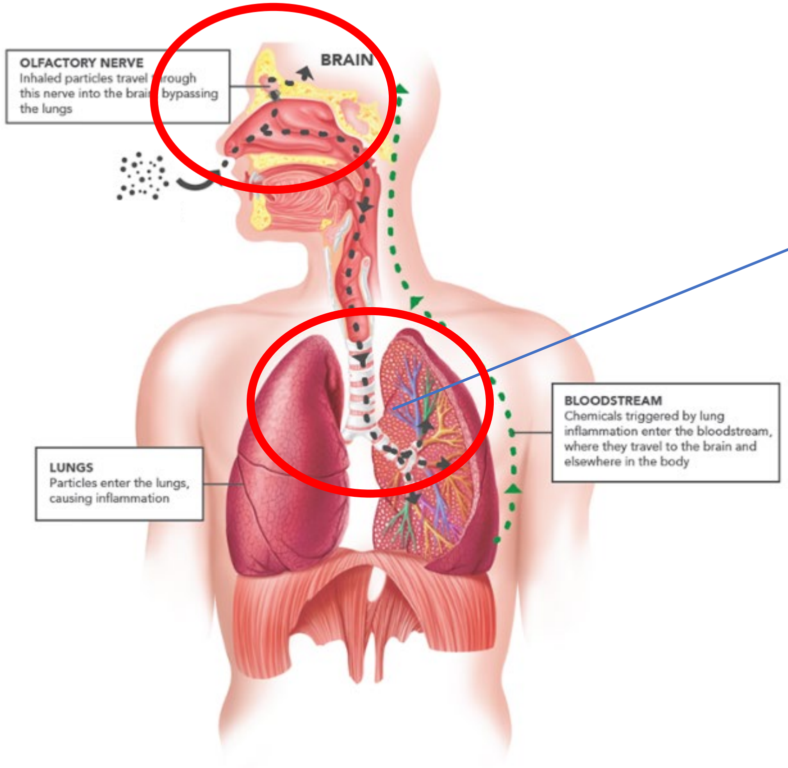
Air liquid interface exposure of epithelial lung cells

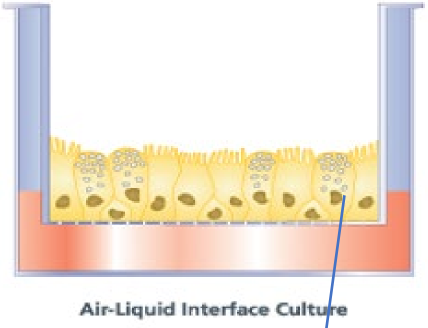


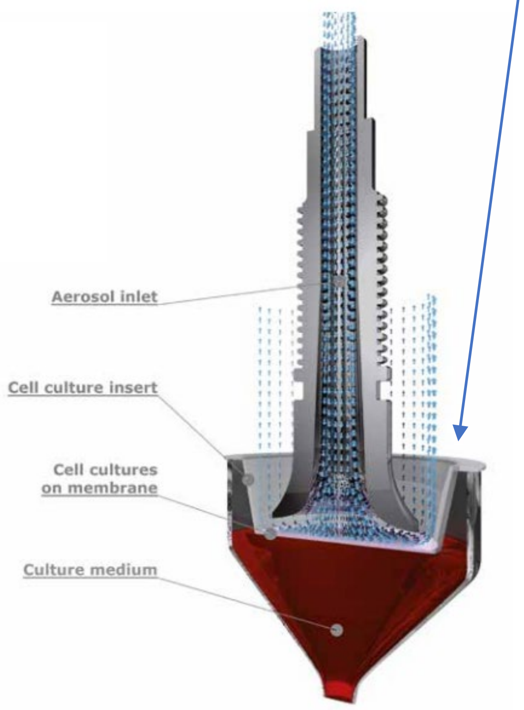
Exposure of primary cortical cultures to conditioned media from ALI experiment

FACTS FRESH AIRCRAFT

Inhalation exposure in vitro

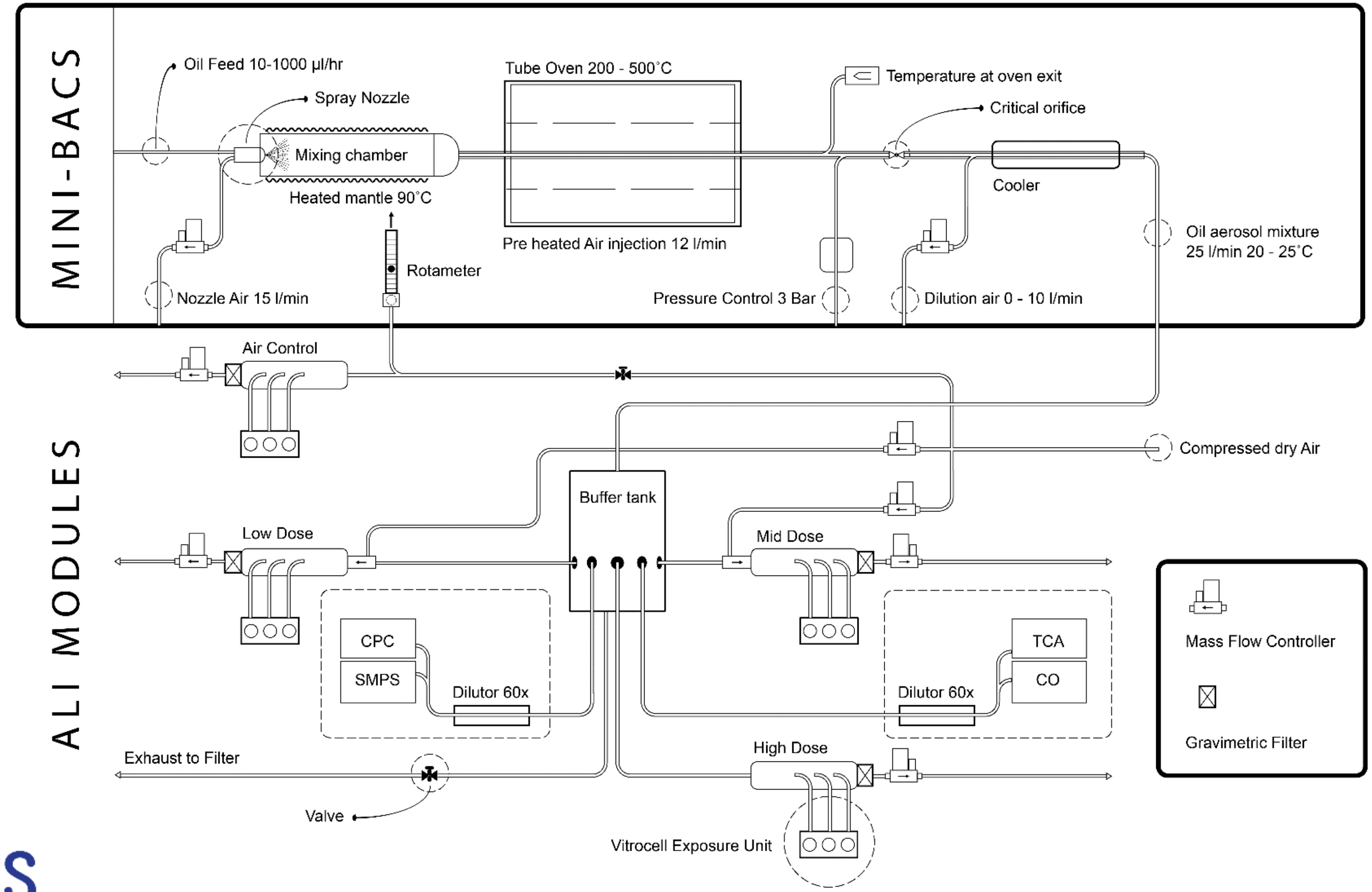






FACTS
FRESHAIRCRAFT

Diagram of mini-BACs and ALI exposure system



FUME GENERATION

Mini-BACs
and
ALI exposure system

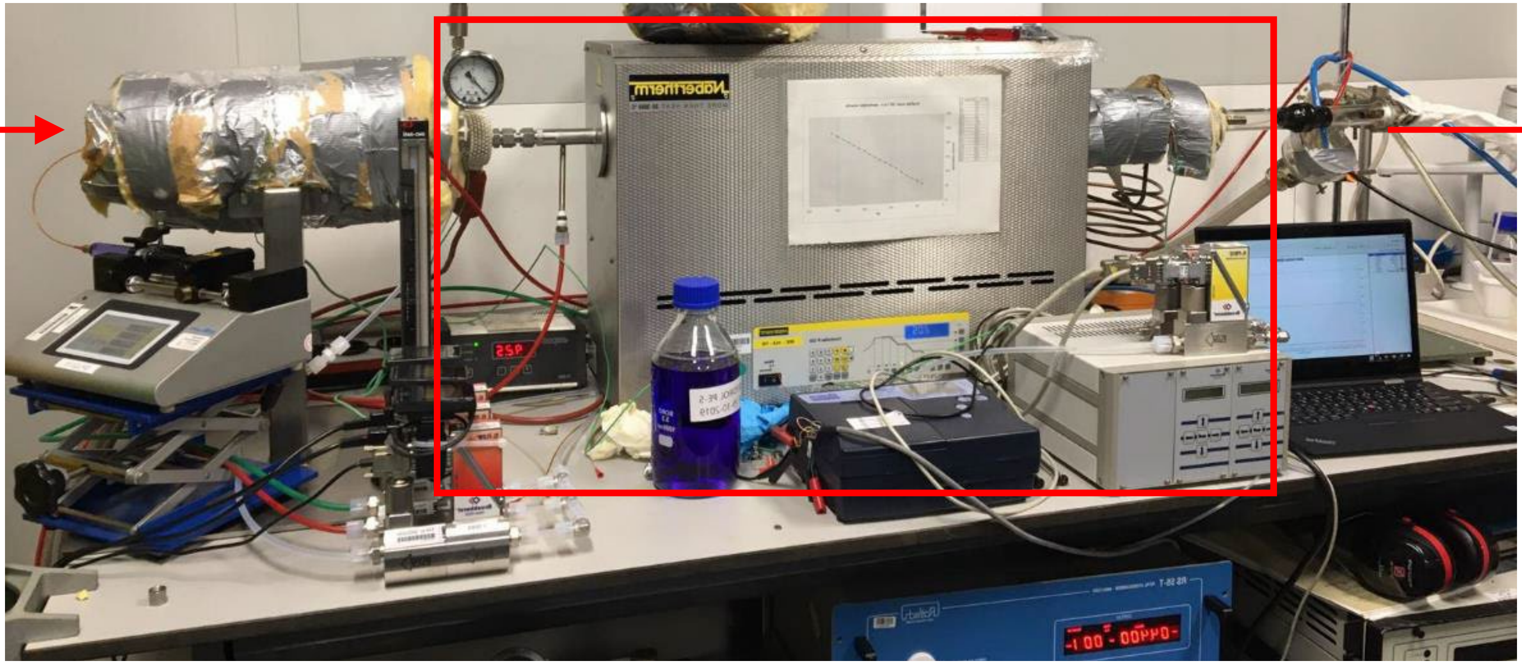
Lung cell exposure and
fume characterzation

Bleed Air Contamination Simulator (mini-BACS)

Generation of oil fume samples

Heating to 350°C or 200°C

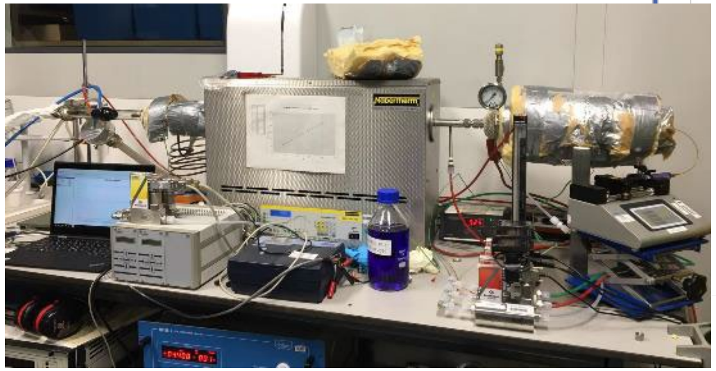
Oil injection

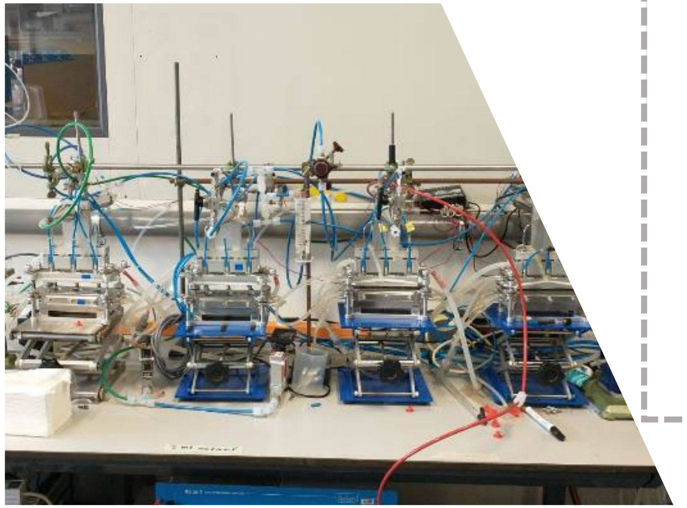


Direct exposure lung cells or sampling on filters

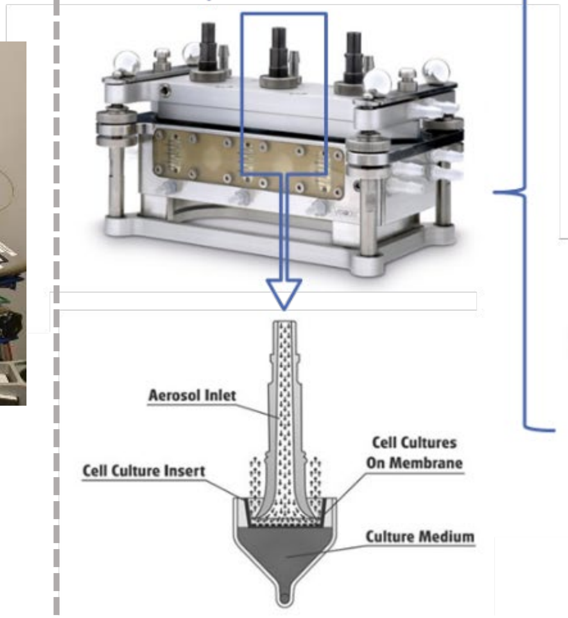
Extraction for neurtoxicity

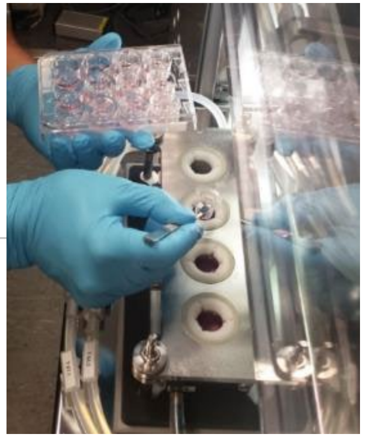
Ai-liquid interface lung connected to mini-BACs





connect to ALI modules





Lung cell modules

One for air control and several for aerosol samples. Cells are transferred into each wells for exposure

Can be connected with analytical instruments: particle number concentration, size, and; VOCs, etc.

Conclusions – Lung model

- 4 commonly engine oils and 2 hydraulic oils
- Almost oil samples can induce **cytotoxicity** at applied doses (0 - 100 mg/cm^3)
- **Hydraulic oil** samples are **more toxic** than engine oil samples

ELSEVIER

Environment International

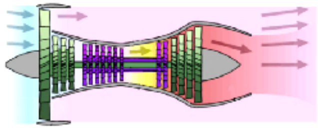
Volume 156, November 2021, 106718

In vitro hazard characterization of simulated aircraft cabin bleed-air contamination in lung models using an air-liquid interface (ALI) exposure system

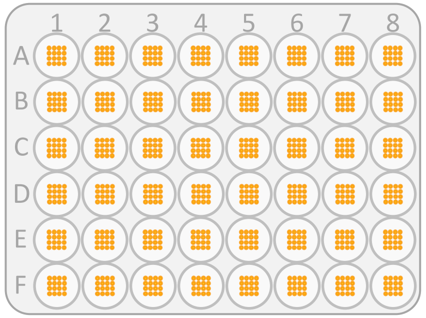
Rui-Wen He [a, b], Marc M.G. Houtzager [c], W.P. Jongeneel [a], Remco H.S. Westerink [b], Flemming R. Cassee [a, b]

Direct neurotoxicity testing

mini-BACS

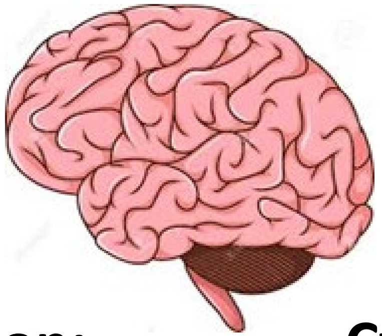


Oil fume extracts

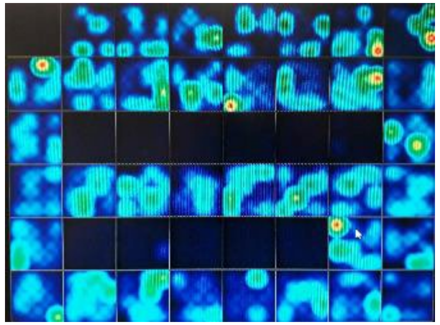


primary cortical culture

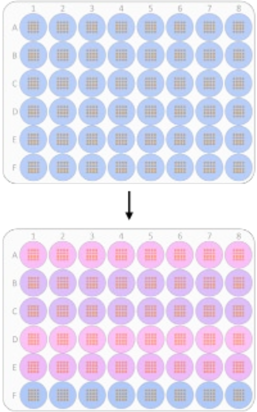
0.5 – 48 h



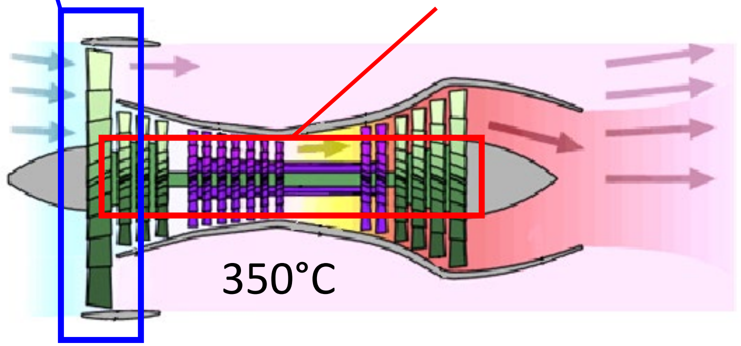
Neuronal function:
Multi-Electrode Array Assay



Cyotoxicity:
Alamer Blue Assay



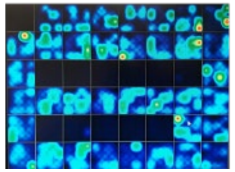
Hydraulic oil-derived fumes exhibit higher neurotoxic potential than engine oil-derived fumes



Mean Spike Rate

Oil type	ID	Temp.	IC_{50} values [µg/mL] + CI 95%: 0.5 h exposure	24 h exposure	48 h exposure
Engine Oil	Engine 1	350°C	121 [85 - 233]	86	98
	Engine 2	350°C	39 [33 – 47]	45 [? – 57]	62 [46 - ?]
	Engine 3	350°C	57 [41 – 81]	47 [40- 56]	37 [24 – 56]
	Engine 4	350°C	84 [57 – 140]	37 [? – 43]	52 [43 – 64]
Hydraulic Oil	Hydraulic 1	200°C	2.3 [1.7 – 2.9]	15 [? – 19]	17 [13 – 23]
	Hydraulic 2	200°C	5.8 [5.0 – 6.7]	17 [14 – 21]	16 [13 – 19]

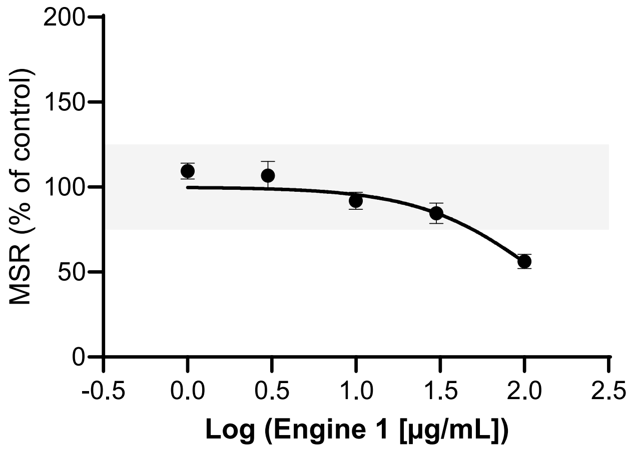
Neuronal function:
Multi-Electrode Array Assay



Utrecht University

Neurotoxicity testing

- Fumes deriving from engine and hydraulic oils reduce neuronal activity
- Engine oil fumes-induced neurotoxicity mainly occurs after prolonged exposure whereas for hydraulic oils already acute exposure affects neuronal activity
- Fumes generated from hydraulic oils more potent in inhibition neuronal activity compared to engine oil-derived fumes



FACTS
FRESH AIRCRAFT

Remarks

- Simulated fume events
- Relative long and high concentration exposure
- Simplified (in vitro) models, outcome need to be interpreted with a lot of caution
- Guidance for understanding chemical component related effects and ranking potencies but not for risk assessment