Aircraft cabin air contamination and oil seals

Dr. Susan Michaelis

MICHAELIS AVIATION CONSULTING
PhD, ATPL

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Disclaimer

- I am an independent PhD researcher in the area of bleed air contamination.

- I undertake some research on behalf of the Global Cabin Air Quality Executive (GCAQE).

- I declare no conflicts of interest.
Who am I?

PhD - http://handle.unsw.edu.au/1959.4/50342
Bleed air = Cabin air

UNFILTERED
Move to bleed air to supply cabin air

Non Bleed air

B 707 - 1954

Dreamliner

Bleed air

• Bleed air – SUD- E Caravelle, 1955

B727: 737: DC9…
The problem

✈ Synthetic engine oils –
✈ Leakage past seals into super heated compressor/bleed air
✈ Compromising flight safety
✈ Adverse health effects
✈ Other substances can leak into bleed air – hydraulic/deicing fluids…
Pressurised air/seals

- Compressor pressurised air used to:
  - Supply cabin ventilation air supply &
  - Seal oil bearing chamber

- Seals leak oil at low levels in normal operations and will enter air supply (not just during failure condition)

- Toxicity of super heated oils recognised in 1954-USAFL

- Reports of adverse effects commenced after introduction of bleed air
Substances - Oils

- Synthetic ester base stock ~95%
- Antiwear additive - Triaryl phosphate (OP) ~3%
  - TCP - includes orthos isomers/TOCP... & TXP...
- Amine antioxidant – (1%)
- Proprietary substances
- Wide variety of pyrolysis substances
- Endocrine disruptors (TCP; TBP; TPP)
## EU/UN Hazard Classifications (CLP /REACH)

### Oil, hydraulic, deicing fluids: HAZARDS

<table>
<thead>
<tr>
<th>Harmful if swallowed/dermal:</th>
<th>Eye/skin irritant &amp; ? Respiratory irritant</th>
</tr>
</thead>
<tbody>
<tr>
<td>May (suspected) cause damage fertility or harm the unborn child</td>
<td>Skin sensitizer</td>
</tr>
<tr>
<td>Single exposure &amp; repeated target organ toxicity - nervous system</td>
<td>Very toxic by inhalation</td>
</tr>
<tr>
<td>May cause genetic defects</td>
<td>May cause allergy/asthma or breathing difficulties if inhaled</td>
</tr>
<tr>
<td>May (Suspected) of causing cancer</td>
<td>May cause drowsiness or dizziness</td>
</tr>
</tbody>
</table>

### TXP – Substance of Very High Concern (SVHC) – REACH

- May cause harm to the unborn/Impair fertility
ICSC/HSDB- adverse effects

- Oils, Hydraulic & de-icing fluids associated with a wide range of acute and long-term effects: e.g:

<table>
<thead>
<tr>
<th>Irritant of skin, eyes, mucous membranes, respiratory tract</th>
<th>Gastrointestinal upset</th>
<th>Decrease in strength of arms/legs</th>
<th>Tingling of hands, feet (limbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertigo</td>
<td>Headache</td>
<td>Numbness</td>
<td>Cramps</td>
</tr>
<tr>
<td>Abdominal Pain, diarrhea.</td>
<td>Formation of Methemoglobin in blood</td>
<td>Low blood pressure</td>
<td>Attack on Peripheral nerves/pyramidal tract</td>
</tr>
<tr>
<td>Irritability</td>
<td>Nausea/vomiting</td>
<td>Dizziness</td>
<td>Visual disturbances</td>
</tr>
<tr>
<td>Muscular weakness</td>
<td>Blue lips/fingernails/skin</td>
<td>Confusion</td>
<td>Skin redness</td>
</tr>
<tr>
<td>Excessive sweating</td>
<td>Convulsions/Unconsciousness</td>
<td>Cough/sore throat</td>
<td>Pain/redness in eyes</td>
</tr>
</tbody>
</table>
PhD research objective 1

- Review health problems reported by aircrew when exposed to contaminated bleed air whilst flying;
- Undertake a health survey of BAe 146 pilots exposed to contaminated air in aircraft.
Upper airway and breathing problems

Performance decrement

Memory impairment

Headache

Vision problems

Nausea/GI

Exhaustion/fatigue

Dizziness

Confusion

Tingling - extremities/nerve problems

Cardiovascular

Chronic fatigue

BAe 146/RJ - Health effects  n=219

BAe 146 pilot health survey

Medium/longterm

Immediate/short term
Aircrew/passengers are reporting: Chronic neurological, respiratory disease consistent with exposure to jet engine oils including OPs.

Cancers: Higher than population averages

**Aerotoxic Syndrome** is a valid term
- Causative relationship exists
- Published literature - ✔

### Table 2 Aerotoxic syndrome: short- and long-term symptoms

<table>
<thead>
<tr>
<th>Short term exposure</th>
<th>Long term exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Neurotoxic symptoms</em>: blurred or tunnel vision, nystagmus, disorientation, shaking and tremors, loss of balance and vertigo, seizures, loss of consciousness, parathesias;</td>
<td><em>Neurotoxic symptoms</em>: numbness (fingers, lips, limbs), parathesias;</td>
</tr>
<tr>
<td><em>Neuropsychological or Psychotoxic symptoms</em>: memory impairment, headache, light-headedness, dizziness, confusion and feeling intoxicated;</td>
<td><em>Neuropsychological or Psychotoxic symptoms</em>: memory impairment, forgetfulness, lack of coordination, severe headaches, dizziness balance, sleep disorders;</td>
</tr>
<tr>
<td><em>Gastro-intestinal symptoms</em>: nausea, vomiting;</td>
<td><em>Gastro-intestinal symptoms</em>: salivation, nausea, vomiting, diarrhoea;</td>
</tr>
<tr>
<td><em>Respiratory symptoms</em>: cough, breathing difficulties (shortness of breath), tightness in chest, respiratory failure requiring oxygen;</td>
<td><em>Respiratory symptoms</em>: breathing difficulties (shortness of breath), tightness in chest, respiratory failure, susceptibility to upper respiratory tract infections;</td>
</tr>
<tr>
<td><em>Cardiovascular symptoms</em>: increased heart rate and palpitations;</td>
<td><em>Cardiovascular symptoms</em>: chest pain, increased heart rate and palpitations;</td>
</tr>
<tr>
<td><em>Irritation of eyes, nose and upper airways</em>;</td>
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<td><em>Sensitivity</em>: signs of immunosuppression, chemical sensitivity leading to acquired or multiple chemical sensitivity</td>
<td><em>General</em>: weakness and fatigue (leading to chronic fatigue), exhaustion, hot flashes, joint pain, muscle weakness and pain.</td>
</tr>
</tbody>
</table>

Bradford Hill

- Strength – ✔ Extensive history & recognition of exposure
- Consistency – ✔ effects repeatedly observed globally
- Specificity – ✔ Onset of symptoms specific to flight
- Temporality – ✔ Close relationship: exposure & effects
- Dose response ✗ Many reports after repeat low-level exposure
- Plausibility – ✔ Both biologically & in terms of engineering
- Coherence – ✔ Cause & effect between flying & illness
- Experiment – ✔ Each crew member – onset, recovery, recurrence
- Analogy – ✔ F111 workers; veterans; agricultural workers…
Various published studies

Treon: (USAF) 1954 – Oil pyrolysis
Aldridge: 1954 – TCP neurotoxicity
Montgomer: 1977 – Case study
Winder: 2002 – Aerotoxic Syndrome
Michaelis: 2002; 2003; 2005 – Crew health
Harper: 2005 – Occupational
Mackenzie Ross: 2008; 2016 – Cognitive
Abou-Donia: 2005: 2013, 2014 – Chronic neurotoxicity
OHRCA: 2009 – Medical protocol
Michaelis: 2010 - PhD
Burdon: 2011; 2012/2014 – Respiratory
Baker: 2012 – TAP biomarkers
Furlong: 2011 – TAP biomarkers
Hausherr: 2014 – Glutamate Signaling
Kojima: 2014 – EDs TCP, TBP….
Reneman: 2015 – TOCP P450s
Reinen: 2015 – P450s & TCP
Megson: 2016 – Oil pyrolysis

& Many more…
Toxic cabin air - 5th biggest engine problem - manufacturer

High Court of Australia – Oil injures the lungs/ causes harm

High rates of crew impairment: ~32%

Temporal relationship between “perceived” fume events and acute ill health (COT 2013)

TCP studies: 25-100% of flights/ samples-positive

TLVs/OELs - DO NOT apply

Low-level exposure to heated complex mixture V high dose individual substance exposure

Under-reporting; health evaluation not undertaken; low awareness

General acceptance of oil leakage- AAIB 2013

Frequency – varies from infrequent to 1% of flights (COT 2007) to all flights as a feature of design (Michaelis 2011; 2016)

Strong industry under-recognition

Cabin fumes - can be low-levels of oil and difficult to investigate & eliminate - manufacturer
Industry/Government positions

- No evidence

- No epidemiological studies with monitoring
  - Case studies & no detection systems despite requirement by regulation
  - Symptoms due hyperventilation/ nocebo

- Symptoms not consistent with TOCP toxicity

- 10% of population get such symptoms daily?

- Too few effected
  - Data not collated/ low awareness/ passengers not advised

- Substances cause irritation only/not toxicity

- Aviation medical community show corporate conflict of interest

- Aviation regulators do not have OHS/hazardous substances expertise & OHS regulators not given access with OHS directives…. Ignored

Airbus COO (Farnborough 2014) contaminated air is absurd/does not happen
Solutions

✈ Bleed free aircraft
✈ Filter/clean bleed air
✈ Detection systems
✈ Better engine design & sealing systems
✈ Health studies – independent – We need your help!!

Director General for DG employment, Mr Koos Richelle: “Cabin air quality can be a genuine workplace health issue & there may be a need to start looking at such areas.”
Thank you

Further information:
www.susanmichaelis.com
susan@susanmichaelis.com
44(0) 7880554551

www.gcaqe.org