Cabin Air Quality in Commercial Aircraft

Is there any cause for concern?
A review of the current evidence

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Chairman AsMA Air Transport Medicine Committee
 Disclosure Information 

82\textsuperscript{nd} Annual Scientific Meeting 
Dr Martin Hudson

I have the following financial relationships to disclose:

Medical Adviser to Thomas Cook Airlines (UK)

I will not discuss off-label use or investigational use in my presentation
Cabin Air Quality; the controversy

• Two hypotheses:-

Cabin Air is harmless to Pilots, Cabin Crew and Passengers

V

Cabin Air is potentially a threat to the health of Pilots, Cabin Crew and Passengers
Cabin Air Quality – the History

- 1998 Canadian study BAe 146 and USA study Boeing aircraft no TCPs detectable
- 1999 Ansett Airlines; BAe146 reports odours and fumes from crew members
- Australian Senate investigation; possible health issue but no compensation awards
- Boeing 757 in USA overfilling of oil leading to some fume events
- UK reports from Boeing 757 and BAe 146 of fume events
- Small number of crews report long term ill-health problems
- 2000 UK House of Lords report on air travel and health
- 2006 Global Cabin Air Quality Executive (GCAQE) formed
- 2007 Aerotoxic Association founded
Cabin Air Quality History

- 2004 UK Aviation Health Working Group monitored 50 flights in BAe 146 and Boeing; no air pollutant exceeded safety limits
- 2007 UK Committee on Toxicity (COT) independent review of data suggesting health risk from cabin air; no conclusive evidence but an association was plausible
- 2008 COT study no evidence of TCPs in BAe 146 or Boeing 757
- 2009; ICE project; no evidence of any deleterious health effects in flights up to 8 hours, but bleed air not measured
- 2010-2011; Cranfield Study on behalf of the UK Government Department of Transport; to be reported in this panel
Cabin Air Quality History

- 2007 UK Mandatory Occurrence Reports 116 fume events out of 1.3 million flights i.e. 1:2000 flights (0.05%)
- 2008 20,000 UK pilots of whom 21 reported symptoms associated with exposure to cabin fumes, 10 long term unfit (0.10%)
- 2010 Award of compensation to a member of cabin crew in Australia for lung damage resulting from dust exposure
The Aerotoxic Association

- Founded in 2007 by Captain John Hoyte
- Run by a group of airline pilots who believe they were made ill by contaminated bleed air
- Use the term ‘Aerotoxic Syndrome’
- Aims to inform aircrew and passengers about possible effects of contaminated cabin air
- Acts as a lobby to influence regulators and airlines to improve the quality of cabin air
Cabin Air Quality; the deniers

- Reports are based on anecdotes
- No study has yet discovered any significant harmful contaminants in cabin air
- Extremely small number of cases compared to numbers who could be at risk
- Airlines cannot ‘cover up’ incidence because of the mandatory occurrence report system
- Lack of peer reviewed scientific evidence
- Symptoms are non specific and can be explained by conditions such as hyperventilation
- Similar acute and chronic illness occurs in non aviation personnel i.e. Chronic fatigue syndrome (ME)
Cabin Air Quality possible explanations

- Chronic ill health of unknown aetiology occurs in all populations and work groups
- Many of the acute symptoms can be explained by hyperventilation
- Hyperventilation associated with anxiety is a normal well-recognised response
- Symptoms of ‘Aerotoxic syndrome’ may be similar to those in placebo groups in drug trials or in surveys of the general population
Cabin Air Quality – the protagonists

- Continued reports from a small number of pilots and cabin crews of acute and chronic health problems
- There is serious under-reporting of incidents and cases
- Protagonists suggest airlines and governments are covering up the problem
- Union and press pressure
Cabin Air Quality – the controversy

Since the debate is ongoing this Panel has been convened :-

• to review current scientific evidence from both sides of the argument
• To see what conclusions can be drawn based on the existing science
• to answer the question:-Do we need more scientific studies and if so what should these be?
• To consider whether AsMA should publish a position paper?
Cabin Air Quality
Science versus Prejudice

• Pepys (17th century politician and diarist) in his hour of peril collecting evidence in his defence: “Pray learn of me this one lesson: to be slow to believe what we most hope to be true”

• From a letter of T.H. Huxley (19th century English Biologist) ; “Sit down before fact as a little child; be prepared to give up every preconceived notion; follow humbly wherever Nature leads or you shall learn nothing”
Health And Flight Safety Implications From Exposure To Contaminated Air In Aircraft.

Aerospace Medical Association Meeting – Anchorage May 2011
Airline Transport Medical Committee Cabin Air Quality

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I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation.

I am here today as the Head of Research for the Global Cabin Air Quality Executive – ( GCAQE )
Research Questions

✈ What health effects are being reported in crew exposed to contaminated bleed air?

✈ What monitoring has been undertaken, can such data be used to assess exposure impact on human health?

✈ How often do contaminated bleed air events occur and what are the flight safety implications?

✈ Have the aviation industry and Governments dealt with the contaminated bleed air issue appropriately?
## Air Quality Monitoring

<table>
<thead>
<tr>
<th>General air studies</th>
<th>‘n’</th>
<th>Contaminated air studies</th>
<th>‘n’</th>
</tr>
</thead>
<tbody>
<tr>
<td>General air studies - no fume events (38%)</td>
<td>20</td>
<td>Contaminated air studies - (62%)</td>
<td>33</td>
</tr>
<tr>
<td>Epidemiological studies – during monitoring (no fume event)</td>
<td>06</td>
<td>Fume event *short duration/minor</td>
<td>01</td>
</tr>
<tr>
<td>Epidemiological studies – Not during monitoring (no fume event)</td>
<td>2</td>
<td>Epidemiological studies – not during monitoring (no fume event)</td>
<td>05</td>
</tr>
<tr>
<td>Cabin air deemed acceptable (60%)</td>
<td>12</td>
<td>TCP found (48%)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil constituents identified as source (60%)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cabin air deemed acceptable (27%)</td>
<td>09</td>
</tr>
</tbody>
</table>

- Epidemiological studies of very limited benefit
- Air deemed acceptable: strong industry affiliation
Monitoring

- Oil studies – Extensive;
- 1954: USAF – Toxicity of heated synthetic oils identified;
- Study techniques – generally inadequate;
- Analysis of results – inappropriate;
- General air quality monitoring studies have been inappropriately widely used to suggest acceptability of cabin air;
- Specific contaminated air studies were of mixed value; with oil identified in 60% and TCP identified in 48% of the studies;
- Epidemiological studies are of very limited value and cannot be used to suggest air is safe.

- Studies undertaken cannot be used to suggest air quality is acceptable and not able to cause adverse effects.
Frequency of Events

UK

✈ CAA records incomplete;
✈ 32% of contaminated air events involved crew impairment;
✈ 21% of events involved at least 1 pilot impairment;
✈ 10% of events involved impairment of both pilots;
✈ Oxygen used by 1 (both) pilots in 4% (9%) of events (transient)
✈ Significant flight safety events identified;
✈ Boeing 757: Oil fumes reported in 1% of flights at one airline.

Global


Frequency of Events

✈ Significant under-reporting and contaminated air events not rare;
✈ Regulatory / airline / manufacturer databases are unreliable;
✈ Less than 4% of events are reported;
✈ It is not possible to determine a reliable rate of contaminated air events – (EASA 2009);
✈ **Seal design fails to prevent oil leakage over the full engine operating range and seal wear provide the basis for oil leakage at lower levels. This is an inadequate design and operational feature of using bleed air;**
✈ Industry focus has incorrectly been placed on maintenance failures;
✈ Lower level synthetic oil leakage is an expected / accepted occurrence of the bleed air system.
Awareness

**Extensive awareness in 1950s and 1960s**

- Exposure to synthetic lubricants: Hazardous / Toxic
- Critical temp: (> 600°F): Degradation of base stock/TCP
- Contamination of air was key concern: Design/performance
- Concern of rising engine temperatures & toxicity – forgotten by 1970
- Adverse effects in crews

**General**

- Industry awareness – Extensive: To the – present day
- Engines temps routinely used above critical oil temps
- Engine compressor bleed air fails to meet certification and safety analysis requirements as occurrence > 10^-5 (remote)
- Wide variety of regulations (oil leakage) fail to be met
Health Effects

BAe 146/RJ Adverse health effects. n=274

- Lost medical/health: 13%
- Medium or long term effects: 32%
- Immediate or short term effects: 44%
- Reported adverse effects: 63%
- Aware of exposure: 88%

- Chronic ill health:
  - Cardiovascular: 25%
  - Respiratory: 39%
  - General: 53%
  - Neurological: 53%
  - Neuropsychological: 64%
# Health Effects

**BAe 146/RJ - Health effects  n=219**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Immediate/short term</th>
<th>Medium/longterm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic fatigue</td>
<td></td>
<td></td>
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<tr>
<td>Cardiovascular</td>
<td></td>
<td></td>
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<tr>
<td>Dizziness</td>
<td></td>
<td></td>
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<tr>
<td>Confusion</td>
<td></td>
<td></td>
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<tr>
<td>Tingling - extremities/nerve problems</td>
<td></td>
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<tr>
<td>Exhaustion/fatigue</td>
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<td></td>
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<tr>
<td>Nausea/GI</td>
<td></td>
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<tr>
<td>Vision problems</td>
<td></td>
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<tr>
<td>Headache</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory impairment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance decrement</td>
<td></td>
<td></td>
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<tr>
<td>Upper airway and breathing problems</td>
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</tr>
</tbody>
</table>

0% 2% 4% 6% 8% 10% 12% 14% 16% 18%
Identifiable / consistent ST and LT pattern of adverse effects with emerging chronic neurological condition

- Oil leaks as design feature
- Extensive documentation supports oil leaking
- Pilot medical disqualification from 37% to 433% higher than all disqualifications
- Misdiagnosis common
- Similar pattern globally: crew and passengers
- Consistent exposure to synthetic jet oils including OPs
- Published literature available

Health
Aerotoxic Syndrome (2000)

Studies show consistent pattern of acute and chronic symptoms/dysfunction.

Causative relationship exists.

Illness from a complex set of symptoms resulting from unique occupational environment.

Specific symptoms can vary between people but general types of symptoms remarkably consistent.

Term Aerotoxic Syndrome is valid.
Conclusions

✈ Adverse effects with temporal association are evident;
✈ Monitoring cannot be used to say cabin air is satisfactory;
✈ Contaminated air is a function of design and operation of bleed air systems and therefore explains frequency;
✈ Awareness of issue dates back to 1950s;
✈ The problem remains unresolved and flight safety continues to be compromised;
✈ Lubricant manufacturer raises toxicity concerns with EASA;
✈ Solutions exist: Bleed free technology is now flying on the Boeing 787 and bleed air filtration solutions could be used.

The data from this presentation was extracted from the PhD Thesis by Susan Michaelis (2011) entitled: "Health and Flight Safety Implications from Exposure to Contaminated Air in Aircraft".
ISBN: 978-0-95-554377-7 susanmichaelis.com
Exposure to aircraft bleed air contaminants
A guide for health care providers

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• University of British Columbia - Christian van Netten, PhD
• Association of Flight Attendants | CWA, AFL-CIO - Judith Murawski, MSc., CIH, Christopher Witkowsk, JD and John Cornelius
• Harvard School of Public Health - John Spengler, PhD, Eileen McNeely, PhD, Donald Milton, MD, Dr.PH, and Julie Bradley

• University of California, Berkeley - Ira Tager, MD, MPH
http://www.ohrca.org/

- Funded by FAA Office of Aviation Medicine
- Written for health care providers and their “patients”
- Tool to improve health care for airline workers after exposure to bleed air
Take-home points

• What is bleed air?
• What are the health problems from exposure?
• What are recommendations for diagnosis and treatment?
What is bleed air?

Pyrolyzed engine oils and hydraulic fluids that leak into aircraft cabin and flight deck air supply systems

<table>
<thead>
<tr>
<th>Type of fault</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical failures</td>
<td>Oil seals leak or fail in APU</td>
</tr>
<tr>
<td>Maintenance irregularities</td>
<td>Overfill or spill from oil/hydraulic reservoirs</td>
</tr>
<tr>
<td>Faulty designs</td>
<td>Oil seals ineffective during high-temperature engine operations; hydraulic fluid flow through air supply inlet</td>
</tr>
</tbody>
</table>
Tricresylphosphates (TCPs)

- Added to most synthetic engine oils for anti-wear properties (1 to 5%)
- Three cresyl groups attach to phosphate molecule to form 10 isomers (including one tri-ortho isomer)
- Aviation engine oil is a mixture of isomers
Tricresylphosphates (TCPs)

- 1920’s - Ginger Jake
- organophosphate-induced delayed neuropathy (OPIDN) from inhibition of neuropathic target esterase (NTE)
- damage to long nerves (neuropathy), balance problems (ataxia), paralysis
Bleed Air and TCP Exposure

- Detectable TCP residual on air filters, cabin and flight deck walls; and in airborne samples
- No exposure limits (PELs) except for TOCP (0.1 mg/m$^3$)
- Crewmembers report most bleed air events during taxi/take off or upon descent
- Estimated 2-3 bleed air events/day in U.S.
### Documentation of bleed air exposure

<table>
<thead>
<tr>
<th>Source</th>
<th>Data</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline</td>
<td>Pilot log book entries, maintenance records</td>
<td>Not covered under OSHA records access</td>
</tr>
<tr>
<td>FAA SDR</td>
<td>Service Difficulty Reporting System</td>
<td>Poor compliance</td>
</tr>
<tr>
<td>Employee</td>
<td>Material Safety Data Sheets</td>
<td>May be incomplete</td>
</tr>
</tbody>
</table>
What are the health problems from bleed air exposure?

Acute and/or chronic symptoms

<table>
<thead>
<tr>
<th>Respiratory</th>
<th>Neurological</th>
<th>Systemic</th>
<th>Psychiatric</th>
<th>Dermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>Headache</td>
<td>Nausea</td>
<td>Anxiety</td>
<td>Rash</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>Dizziness</td>
<td>Fatigue</td>
<td>Sleep problems</td>
<td></td>
</tr>
<tr>
<td>Chest tightness</td>
<td>Lightheadedness</td>
<td>Muscle weakness</td>
<td>Depression</td>
<td></td>
</tr>
<tr>
<td>Wheezing</td>
<td>Memory</td>
<td>Palpitations</td>
<td>PTSD</td>
<td></td>
</tr>
<tr>
<td>ENT irritation</td>
<td>Concentration</td>
<td>Diarrhea</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Tremor</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Gait/balance</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Cognitive</td>
<td></td>
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</tbody>
</table>

Other exposures: reduced oxygen, ozone, insecticides, deicing fluids, exhaust fumes, disinfectants, deodorizers
Case definition

Documented exposure to bleed air contaminants or history of flying on aircraft known to have increased risk of air supply contamination events

and

Initial symptoms within 48 hours of exposure

and

Objective documentation of acute or persistent symptoms
Irritant-induced asthma

- Acute, single episode of chemical inhalation
- Asthma symptoms persist for > 3 months

**Diagnosis**
Pulmonary function studies/methacholine challenge

**Treatment**
Remove from exposure
Bronchodilators
Inhaled corticosteroids
Neurotoxic injury

- Cognitive dysfunction
- Headaches
- Movement disorder
- Peripheral neuropathy

Diagnosis
- Neuropsychological testing
- Evoked potentials
- Brain MRI
- NCVs/EMGs
- SPECT/PET scans

Treatment
- Migraine medications
- Cognitive rehabilitation
Recent cases (9)

- January 16, 2010
- US Airways B757 from Charlotte
- “dirty sock” odor on ascent and descent
- Acute symptoms: burning eyes, sore throat, headaches
- Persistent symptoms: headaches, balance problems, problems concentrating, shortness of breath
Future research

• Biological assay for TCPs
• Exposure monitoring
• Improved engineering systems

Thanks to…
Mohamed Abou-Donia PhD, John Balmes MD, Jonathan Burdon, James Cone MD, Andrew Harper MD, Steven Hecker MSPH, Laurel Kincl PhD, Captain Susan Michaelis, Goran Jamal MD, Captain Tristan Loraine, Sarah MacKenzie-Ross MA, Karen Mulloy MD, Bhupi Singh MD, Dennis Shusterman MD, Ira Tager MD, Cris Van Etten PhD
Expert Panel on Aircraft Air Quality (EPAAQ)

Assoc Prof Pooshan Navāthē
MBBS, MD, Dip Aviation safety Regulation, FAFOEM (RACP), FRAeS, PhD
Principal Medical Officer
Disclaimer

I receive a salary from the Commonwealth of Australia.

I have no financial relationships to disclose.

I will not be discussing drugs and off label use.

I will try to fairly represent the Policy and Practice of the Civil Aviation Safety Authority (Australia), and to clearly indicate where I am straying into personal/professional opinion for which I and I alone am responsible.
EPAAQ

- Created 2008
- Independent of CASA
- External Chair
- High levels of expertise
Expertise

- Epidemiology
- Toxicology research
- Toxicology practice
- Occupational Medicine
- Aviation Medicine
- Aero Engineering (flyer)
- Aero Engineering (ground)
- Immunologist
- External Chair
- Ethicist
Terms of reference

- Establishing the current state of knowledge
- Current research sufficient? More needed?
- Further actions
Methodology

- Preliminary discussions
- Basic understanding
- All elephants on show
- Search criteria
  - Published
  - Grey
- What are the questions
- Research team
Methodology

- Research team
  - Invited submissions
  - Carried out search
  - Collected and collated evidence
  - Created Reviews on questions
  - Circulated to panel
  - Panel wrote their integrated opinion based on review
Methodology

- Panel wrote up chapters
  - Dissent & Debate & Discussion
  - Dissent & Debate & Discussion
  - Debate & Discussion & less dissent
  - Debate
  - Consensus!
- Executive Summary
- Recommendations
Completed

- 2011
- 247 pages
- 37 recommendations
- Awaiting release
Disclaimer

- 247 page report
- 10 minutes
- Some things in/out
How?

- Through seal failure
- Transients
How Often?

- Low rate
- ? Unlinked databases
- More in Mil than Civil  ?Culture
What?

- CO
- Organophosphates
- Problems with current tests
Biological monitoring?

- What to monitor for?
- Some tests for OP for acute
- Genetic work ??
- Specific testing development
Sub-detectable exposure?

- No evidence
- Not impossible
Acute effects

- Well reported
  - Irritant
  - CNS
- No toxdrome
Link symptoms with causes

- Potential to cause symptoms
- No investigations
- No consistent features
Effect on flying

- Nothing attributable
- Low numbers
Chronic illness?

- No epidemiological evidence
Case definition?

- Need to have one
- None at present
Plausible

- Some symptoms can be due to exposure
- Same symptoms due to anxiety and hyperventilation
Not plausible

- Malingering
- Primary Psych illness
- Autonomic dysfunction
- Mitochondrial disorder
- Immune dysfunction
- DNA damage
- Metabolic abnormality
- Autoimmune reaction
- Allergic reaction
Epidemiology shows....

- Aircrew experience variety of acute and chronic conditions
  - Sufficient Evidence of an association
- ‘Aerotoxic Syndrome’
  - Inadequate or Insufficient Evidence to determine whether an association exists
- Difficult to confirm using standard epidemiological methods
Aircraft Related Illness

…Unfortunately, the label aerospace syndrome … may only perpetuate illness and reinforce disability

(Sparks, et al., 1990)
A circumstance where there is suggestive evidence of the potential for serious harm resulting from an occupational exposure will always generate debate about whether, how and when to intervene. In the case of cabin air smoke/fume incidents there is the added imperative of the safety of passenger aircraft where pilots and other cockpit crew may be impaired.
The products of thermal degradation of engine oils and hydraulic and de-icing fluids such as CO and VOCs that are known to be generated when bleed air is contaminated are sufficient to cause concern. Assertions about “low toxicity” TCP in jet engine oils are not reassuring. An extensive environmental monitoring programme conducted during smoke/fume events would be necessary to clarify whether the exposures of concern exist before making recommendations for change.
Even in the absence of definitive data on the exposures that occur during smoke/fume incidents, the Panel considered that the prudent approach would be to take whatever action is necessary to prevent these incidents through engineering means.