

# Aerotoxic Syndrome: A New Occupational Disease?

S. Michaelis PhD, ATPL<sup>1</sup>; J. Burdon MBBS, MD, FRACP<sup>2</sup>; CV Howard MB. ChB. PhD. FRCPath.<sup>3</sup>

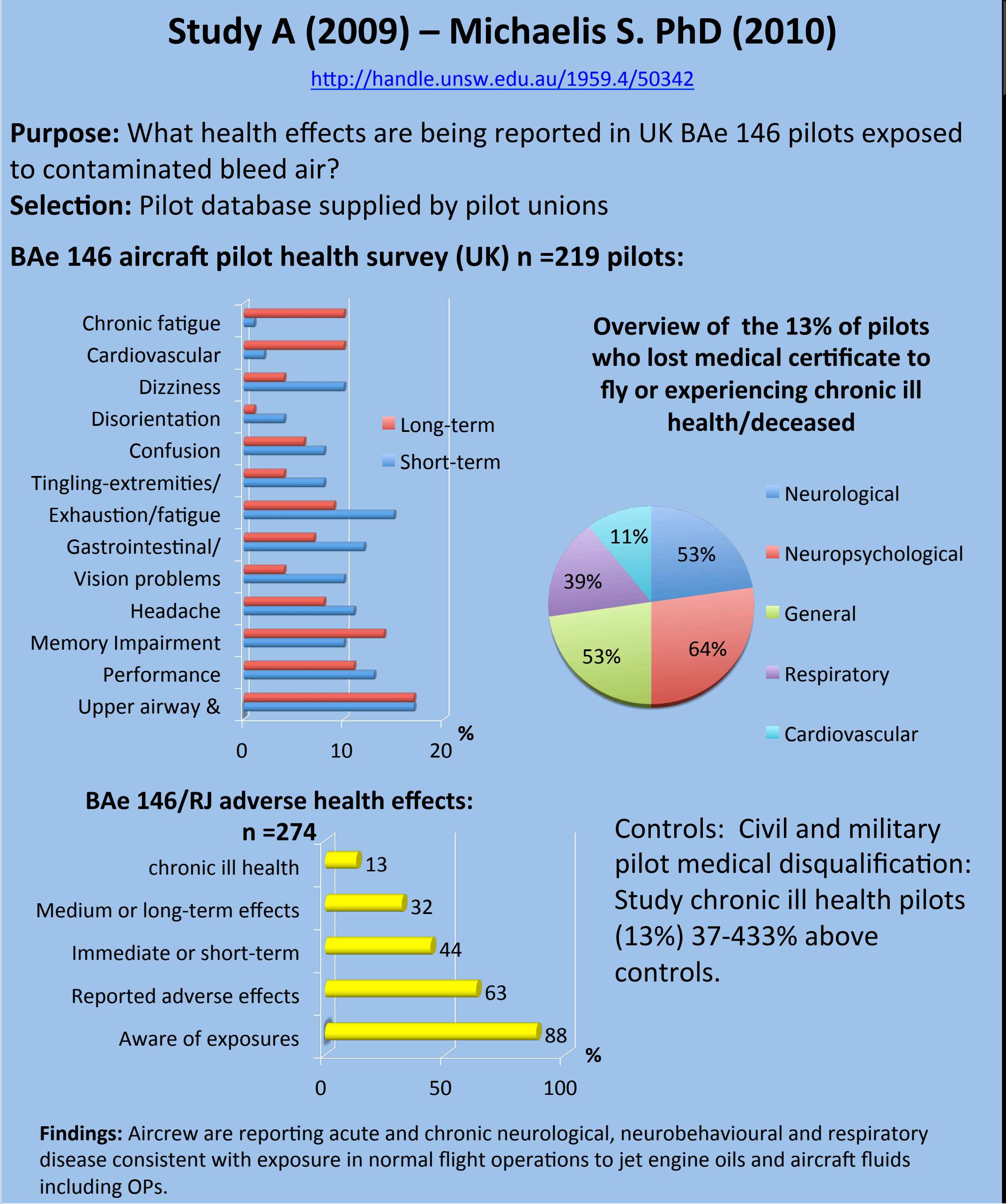
1. Michaelis Aviation Consulting, Sussex 2. Mercy Hospital, Melbourne, 3. University of Ulster.   Contact: susan@susanmichaelis.com



**Aim:** An ecological study has been undertaken reviewing a cohort of aircrew involved in suspected aircraft contaminated air events to determine if the reported symptoms and diagnosis are consistent with exposure to jet engine oil and engine/aircraft fluids or other factors.

**Method:** Two independent studies were utilized to review the circumstances and symptoms of a cohort of aircrew involved in a variety of reported cabin air supply related incidents. A table of symptoms has been utilized to review the reported symptoms for the health studies against the published literature, chemical hazards and other potential factors. The symptoms were then referenced to the Bradford Hill criteria.

**Background:** Aircraft breathing/ventilation air (“bleed air”) has been supplied since the 1950s to the aircraft cabin unfiltered from the engine compressor. The use of compressor pressurised air to seal the bearing chamber as well as supplying bleed air for the cabin provides a design mechanism for low-level engine oil leakage into the cabin air in normal aircraft operations. In addition to low-level oil leakage over the bearing chamber oil seals, higher level exposures can occur less frequently under operational factors such as seal wear or mechanical failure conditions. Hydraulic and deicing fluids may also enter the aircraft breathing air supply. The fluids are exposed to very high compressor air temperatures. The synthetic jet engine oils contain an ester base stock, Triaryl phosphates (TAP) antiwear additives including Tricresyl phosphate (TCP), amine anti-oxidants, a wide range of pyrolysed breakdown products, corrosion inhibitors and proprietary substances. The substances in the oils and the fluids contain a wide range of globally harmonized CLP hazard classifications. These substances are being found in ad-hoc studies between 25-100% of sampling/flights undertaken. There are no detection systems fitted to aircraft to detect when the fluids enter the breathing air. A wide range of adverse effects have been reported by aircrew and passengers, yet there are differing views on the effects of such exposures.



### Study B (2015) – Case study: Analysis of 15 suspected cabin air contamination events

**Purpose:** Review undertaken of well documented incidents, to determine if the pattern and effects are consistent with aircraft cockpit and cabin air contaminated with engine oils, hydraulic or deicing fluids and their pyrolysed products or other factors.

**Selection:** Incidents selected based upon extensive data being publicly available and reference made to some of these events in various publications.

**Key findings: (Based on 15 incidents in 3 continents, 4 countries)**

- Type of event: fumes:12; fumes and haze or smoke: 3
- Location: flight deck: 8; cabin: 3; both: 4
- Phase of flight: climb and/or descent: 12
- Non steady state engine operation: 15
- Aircraft types: BAe 146 (5); B757 (3); A319 & A330 (2); B737; B747 (1); B767 (1)
- Previous reports of fumes on aircraft: 10 (3 ?)
- Following reports of fumes on aircraft: 10 (5 ?)
- Maintenance findings: oil: 11; oil and hydraulic fluid: 2 2: unknown (1 possible oil overflow)
- Level of effect: (at time of event)
  - Incapacitation and/or partial incapacitation: 7
  - Incapacitation and impairment: 2
  - Impairment: 5
- Time of effect: immediate (in flight): 14; short-medium-term: 12; long-term: 8
- Number of acute symptoms reported/incident: 1-9: 8; 10-23: 7
- More than 1 crewmember affected: 11
- Passengers effected: 4
- Medical tests undertaken at time of event: 11
- Medical findings at time of event: 7
- Medical findings/diagnosis later on: 10; ?;5
- Loss of pilot medical certificate/ability to fly: 9
- Loss of cabin crew long-term fitness to fly: 5
- Use of oxygen (both pilots): 6; 1 pilot: 3; all crew: 0; Delayed usage by pilots: 5
- Oxygen helped: 8
- Emergency checklist used by pilots: 2
- Air Accident Investigation Bureau report: 10

### Short-term medical Diagnoses/findings

- None
- Hydrocarbon fume inhalation/chemical injury on aircraft
- Adverse effect on the vocal chords and bronchial tubes
- TCP in blood
- Raised levels of VOCs, nickel, cell degradation
- Double hernia due vomiting
- Poisoning by non-medical agent
- SPO2 70% / 80%
- Abnormal blood results: CK; CK-MB; LDH; GOT (AST); GPT (ALT)
- Traumatic muscle damage and ischemia
- Toxic effect of gas, fumes or smoke
- Possible inhibition of the enzyme AChE or other neurospecific esterase caused by organophosphate,
- Muscle trauma due excessive athletic sports or contamination
- Toxicopy
- carboxyhemoglobin at or above the high normal range - exposure to burned organic chemicals
- TOCP adduct on Bche
- Inhalation injury
- OP type poisoning/internal bleeding

### Long-term medical diagnoses

- RADS/occupational asthma x6
- PTSD x3
- Neurotoxic injury x1
- Toxic encephalopathy x1
- Neuropathy on vocal chords/limbs x3
- MCS x1
- CFS x1
- Anxiety/depression x1
- Cognitive dysfunction x4
- Dementia x1
- ADHD x1
- Seizure disorder x1
- Depression x1
- Aerotoxic Syndrome x1
- Chemical injury at work x1
- Neurological chemical injury x1
- CNS injury x1
- G4 GBM x1 (deceased)
- Wallerin degeneration x1
- Vocal polyps x1
- Heart attack + phosphate exposure x1 (deceased)
- Frontal lobe damage x1
- Optic nerve damage x1
- Migraines x1

**Findings:** A consistent pattern of acute and long-term adverse effects and medical findings are occurring in temporal association to aircraft fume events, occurring primarily during periods of changing engine operating conditions, that are consistent with exposure to jet engine oil and hydraulic fluid leakage into the aircraft air supply.

SYMPTOM	STUDY A N=142 Number reporting symptoms		STUDY B 15 incidents No. of incidents/symptom		REACH/CLP HAZARD CLASSIFICATIONS (harmonized & notified) - oil, hydraulic, deicing fluids*	HAZARDOUS SUBSTANCES DATABASES -ICSC, HSDB, NIOSH.....*		LITER- ATURE	HYPOXIA	HYPERVENTIL- ATION
	Acute	Chronic	Acute	Chronic		Acute	Chronic			
NEUROLOGICAL						X	X	X		
CENTRAL (CNS)						X	X	X		
Incapacity/paralysis; Impaired/loss of consciousness	6%	1%	100%			X	X	X	Loss of consc.	Semi consc.
Headache/pressure in head/trouble speaking	33%	15%	73%	33%		X	X	X	Headache	Headache
Balance problems/erratic movement/ataxia	8%	5%	13%	7%		X	X	X		
Vision problems/tunnel or double vision/dilated pupils/nystagmus	8%	7%	53%	7%		X		X	Vis disturb.	Vis disturb.
PERIPHERAL (PNS) - Motor; Sensory; Autonomic						X	X	X		
Shaking/tremors; Inco-ordination/motor response	9%	12%	77%	40%		X	X	X		Shakes/twitch
Paraesthesia/numbness in limbs/other; Peripheral neuropathy	9%	18%	33%	46%	Neurotoxicity, (single/rpt)	X	X	X		Tingling/numb.
Sweaty/temperature control/pallor/flushing/taste	5%	4%	21%	60%		X	X	X	Sweats	Sweats/temp
NEUROBEHAVIOURAL						X	X	X		
NEUROLOGICAL						X		X		
Discomfort/intoxication/disorientation/confusion	11%	2%	66%	7%		X		X	Confus/disor.	Confus/disor.
Behavioural/personality changes; Unreality/anxiety/depression	1%	14%		46%		X	X	X	Unreality	Unreality/anx.
Dizziness/light-headedness / lethargy/drowsiness	15%	6%	73%	20%	Drowsiness/dizziness, CNS	X	X	X	Light headed	Light headed
COGNITIVE						X		X		Dizziness
Cognitive problems: problem solving/concentration/memory/writing	32%	41%	86%	60%		X	X	X	Cognitive Imp.	Cognitive imp.
Giggling/euphoric			13%			X		X	Euphoria	
GASTROINTESTINAL						X	X	X		
Nausea/vomiting/diarrhea	18%	10%	93%	33%	Harmful if swallowed	X	X	X	Nausea/vom.	
Cramps/bloating/pain/digestive problems		1%	27%	13%	Harmful/fatal if inhaled	X	X	X		Bloating/belch.
RESPIRATORY					Respiratory tract irritant			X		
Breathing problems/cough/chest discomfort/wheezing/lung irritation	11%	23%	73%	27%	Resp sens/breathing diff	X	X	X	Resp problem	Resp problem
CARDIOVASCULAR					Allergy/asthma	X		X		Chest pain
Chest pain/tightness/variable heart rate/palpitations/BP	4%	14%	33%			X		X	Var hr/palpit.	Var hr/palpit.
GENERAL: rheumatological; miscellaneous; soft tissue					Target organ tox-single/rpt					
Joint/muscle pain/aches/twitches/weakness	6%	16%	27%	13%	Liver; urinary tract; heart;	X	X	X		Weakness
Feeling unwell/performance decrement	23%	38%	100%	20%	Respiratory; systemic; CNS			X		
Fatigue/chronic fatigue/exhaustion	19%	46%	20%	40%	Blood; kidneys	X	X	X	Fatigue	Exhaustion
Chemical sensitivity	2%	9%		33%				X		
Vocal/nasal/throat polyps/swelling			7%	7%				X		
IRRITATION										
Eye, nose, throat and voice irritation/burning/redness/hoarseness	29%	11%	100%	21%	Eye irritation	X	X	X		Dry mouth
SKIN					Harmful-skin exposure					
Skin reaction/blisters/rash (uncovered areas);Burning scalp/alopecia	5%	8%	27%	34%	Skin irritant/skin sens	X	X	X	Blue/red skin	
IMMUNE SYSTEM					Genetic defects	other	other	other		
Recurrent respiratory tract infections/altered immune system	8%	8%		7%	Damage: fertility/unborn			X		
CANCERS		6%		7%	Carc 1B/2 - bladder; liver		X	X		

**Findings:** A pattern of acute, chronic and acute-on-chronic symptoms, signs, medical findings and diagnoses are reported in temporal relationship to aircraft cabin air supplies contaminated by engine oils and fluids. The adverse effects are consistent with recognized hazard classifications and published literature. While some acute symptoms are consistent with hypoxia or hyperventilation, the totality of effects recorded is more consistent with exposure to a mixture of bleed air contaminants.

**Notable factors:** The findings of this study ought to be addressed in light of the following factors:  
1) UK Committee of Toxicity (COT) reports bleed air contamination occurs and does cause acute effects with chronic effects reported; 2) TOCP/TCP unlikely to be the only toxic mechanism; 3) Nocebo mechanism unsupported; 4) Exposure standards do not apply to the aircraft cabin environment.

BRADFORD HILL CRITERIA	
Strength	+++
Consistency	+++
Specificity	+++
Temporality	+++
Dose/response	x
Plausibility	+++
Coherence	+++
Experiment	+++
Analogy	+++

## CONCLUSIONS:

Aircraft air supplies contaminated by engine oil and other aircraft fluids are reasonably linked to acute and chronic symptoms and findings/diagnoses creating a cause and effect outcome. Other potential causes are sometimes suggested, however these fail to recognize the following:  
1) The design mechanism allowing chronic low-level exposure to a complex mixture in normal flight along with specific incident events with confirmed leakage;  
2) Effects seen are consistent with recognized hazards;  
3) Acute effects affect safety;  
4) Chronic effects are common.