

Aerotoxic syndrome & environmental forensics



US Airways flight



Videos courtesy of
Tim Van Beveren



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Conference Atmosfair Juin 2015 ;

Aviation industry...

Is a major component of modern economy with 3,2 billion passengers in 2014, doubling every 10 years.

Facing different environmental challenges, including the Kyoto Protocol, as well as sustainable development issues (airports, recycling, toxic compounds).

but also a major health issue related to its use of neurotoxic compounds in its aircraft hydraulics and lubricants, contaminating aircraft cabin air at an estimated rate of one incident every 200 flights, and thus exposing an estimated 16 million passengers and crews a year.

Organophosphates were first mass produced during second World War as chemical warfare, also known as nerve gases.

A brief history...

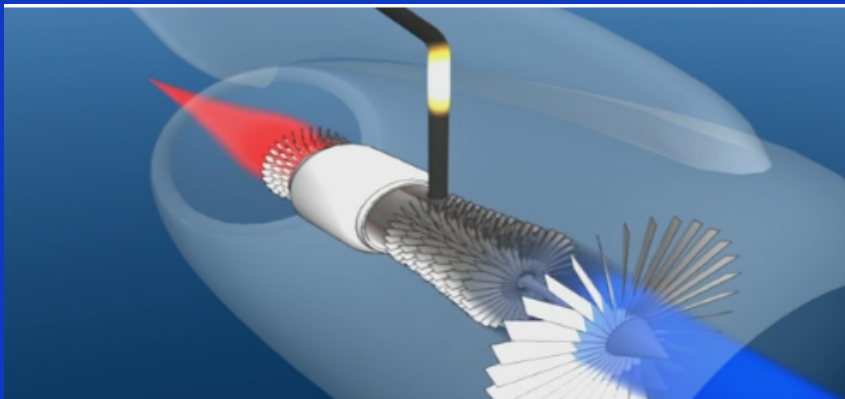


By 1949, Organophosphates were used as flame retardants additives in aircraft fluids (Messerschmidt).

By 1953, bleed air systems were designed and fitted in jet aircraft and Aerospace Medical Association expressed their concerns about the toxicity risks of cabin air contamination by hydraulics and lubricants

By 1955 International Society of Automotive Engineers referred to bleed air contamination « because of internal oil leakage into compressor air ».

Jet Blue flight



How to get fresh air ...

A brief history... Continued

1974 : Garrett Corp establishes least favourable location of exhaust inlet, as for cabin air contamination:

1977 : first documented and published case of toxicity following jet oil exposure and adverse health problems. On an acutely incapacitated flight crew . Asma publishing same concerns.

1984: Problems of oil contamination with air conditioning system on Bae 146.

1989 : Allied Signal notes that « the current compressor seal has shown an unacceptable rate of failure which can result in smoke in the cabin.

1992 : Industry's substantial information is circulated

1999-2000 : Australian Senate Enquiry ...

BY 2015, AVIATION INDUSTRY KEEPS DENYING THAT THERE IS A PROBLEM

When thousands of other evidences available throughout the planet.

See also www.aerotoxic.org and

<https://www.youtube.com/watch?v=fOLQRNnWYH4>

Aerotoxic syndrome...

First presented in 1998 by Balouet & Winder at ASHRAE / ASTM meeting.
Published in 1999 by Winder, Fonteyn, Balouet



Chris Winder
15-8.1951 † 21.5.2014



Harry Pitts Hoffman, M.D., M.P.H.
1942 – 2004



Chris Balouet

Named after Air (and aircraft : aero) and the neurotoxic compounds used in aircraft fluids (hydraulics & lubricants) as well as flame retardants and pesticides.

Describing short and long term symptoms, from smoke events and long term/low dose repeated exposures.

(also name of early international egroup started 1995)

Aerotoxic issues and environmental forensics :

- The exposure events and their worldwide incidence,
- The causes and mechanisms of contamination events
- the symptoms, health and safety hazards,
- The reporting of these events (crew to airline, to state officials)
- Propose procedures
- Establish which tests and methods to document the chemical contamination and the health effects (including genetics, bioassays, medical...).
- Identify the long term compliant solutions (by design i.e. RAM air rather than bleed, less toxic additives ...
- Answer scientific community, attorneys, Courts and governmental enquiries

Acknowledgements (naming only a few...)

Prof. ABOU DONIA	Duke University	USA	Countess of MAR	House of Lords UK	UK
Dr Judith ANDERSON	AFA Seattle	USA	Dr Susan MICHAELIS	GCAQE	Australia
Frank CANNON	Attorney Glasgow	UK	Dr Michel MULDER	Aeromed	Netherlands
Deanne DEWITT	AFA Seattle	USA	Jean-Luc PAILLET	SNPNC	France
Prof. Clem FURLONG	University of Washington	USA	Dr Jeremy RAMSDEN	Cranfield University	UK
Capt. Niels GOMER	Malmoe Aviation	Sweden	Tim VAN BEVEREN	TVB Media	Germany
Randy GORDON	Attorney Washington	USA	Prof. Chris VAN NETTEN	University British Columbia	Canada
Prof. Robert HALEY († 2003)	University of Texas	USA	Prof. Chris WINDER († 2014)	University of New South Wales	Australia
Dr Harry HOFFMAN († 2004)	Occupational Clinic Sacramento	USA	Sen. Revd WOODLEY	Australian Senate	Australia
Capt. John HOYTE	Aerotoxic.org	UK			
Alankar GUPTA	SAE	USA			
Capt. Tristan LORRAINNE	GCAQE	UK			

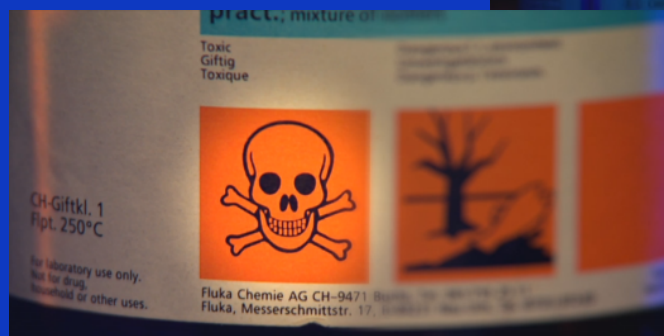
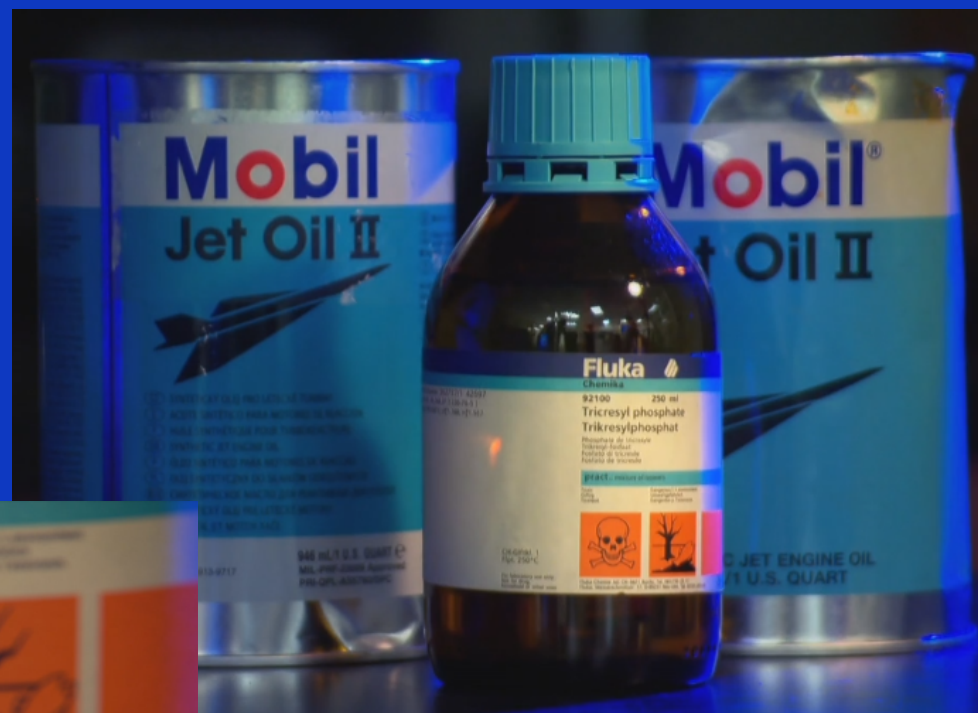
when tousands more to be thanked...

So... what are Organophosphates



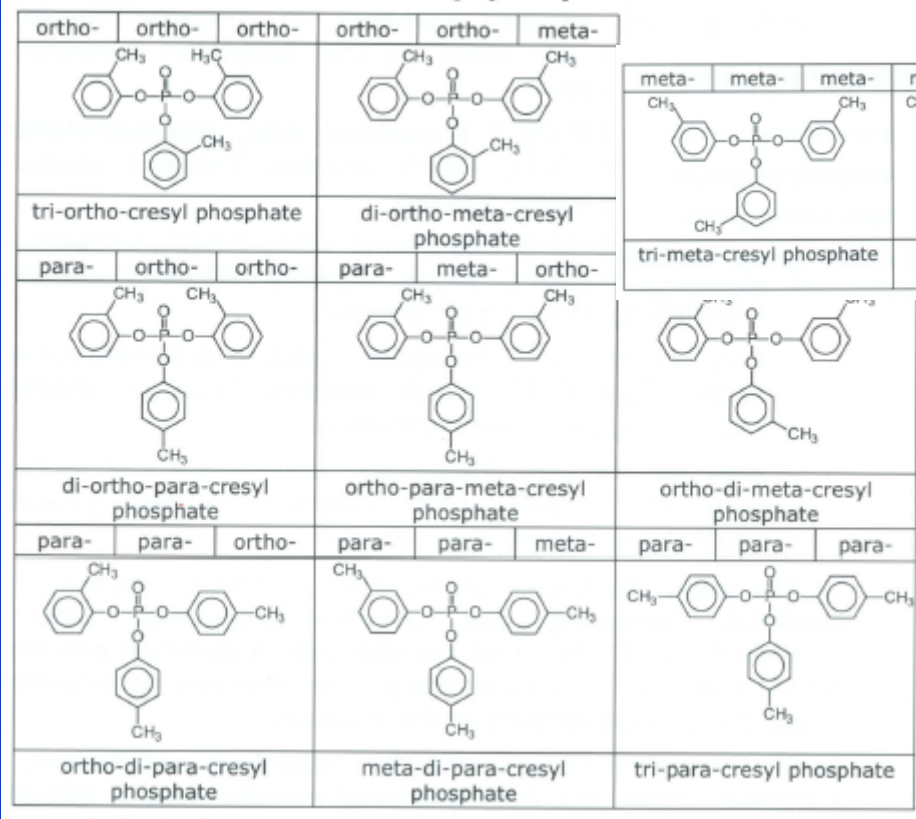
3 OPs of occupational interest all act by blocking the normal function of the enzyme acetylcholinesterase at neuronal, autonomic effector organ or neuromuscular junctions and thus interfere with the normal transmission of nerve impulses.

They are used in aircraft hydraulic and lubricating fluids, as flame retardant , and as pesticides.



Tri Cresyl Phosphate, fresh & used oils

Figure 4-7: Possible Tricresyl phosphate Structures



Winder & Balouet, 2006



Eckels et al, 2014

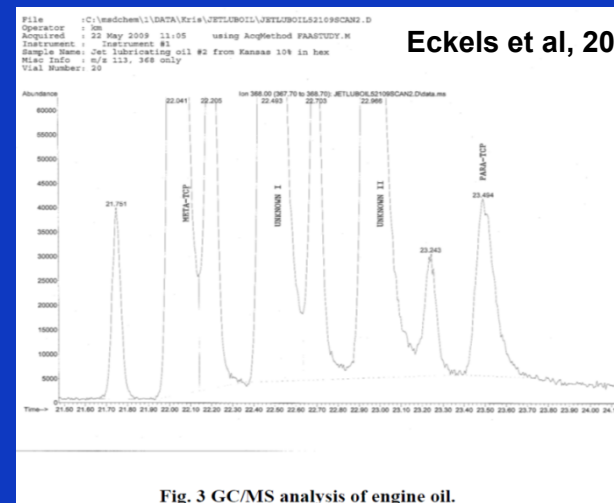


Fig. 3 GC/MS analysis of engine oil.

TCP has 10 isomers, at various concentrations. 3 found by conventional GC. 150 compounds isolated in used oil (400°C), over 100 of which are not yet identified : GC x GC MS pending on fresh and used oils.

A long history of OP massive poisonings

USA 1929-30 : Ginger Jake Paralysis 20000 people in wheel chair, during prohibition times. Another 50 000 to 100 000 affected.,

South Africa , Durban 1937 : 60 victims

Germany, 1940 : dozens

Switzerland 1952 : 92 victims

Morocco 1959-1960 : 10 000 victims

Bombay 1960, 58 victims.

Fidji 1967 : dozens

India 1988 : 1000 victims.

1/3 world : 2013: 200 000 annual fatalities (15%) with OP pesticides.



Some rules

...

FAR / JAR 25.831

Only CO and CO₂, airflow & cabin altitude regulated by FAA/JAA.

Only mandatory contamination measuring device is smoke detector.

EXTRACT FROM FEDERAL AVIATION REGULATIONS (FARs)

PART 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

Sec. 25.831 Ventilation.

- (a) Under normal operating conditions and in the event of any probable failure conditions of any system which would adversely affect the ventilating air, the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute.
- (b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapors. In meeting this requirement, the following apply:
 - (1) Carbon monoxide concentrations in excess of 1 part in 20,000 parts of air are considered hazardous. For test purposes, any acceptable carbon monoxide detection method may be used.
 - (2) Carbon dioxide concentration during flight must be shown not to exceed 0.5 percent by volume (sea level equivalent) in compartments normally occupied by passengers or crewmembers.
 - (c) There must be provisions made to ensure that the conditions prescribed in paragraph (b) of this section are met after reasonably probable failures or malfunctioning of the ventilating, heating, pressurization, or other systems and equipment.
- (d) If accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation must be readily accomplished, starting with full pressurization and without depressurizing beyond safe limits.

Commonly accepted threshold limit values do not apply to cabin environment, because of synergistic effects of contaminants' mix, because of cabin altitude (8000'), because of exposed population including infants, elderly, or some passengers can suffer chronic condition (COPD...), or there is no way to open the window or escape the acft when at 30 000', or in absence of breathing protective device.

Some rules

...

CAR 1988

How can an exposed crew safely fly an aircraft?
Some flight crew left flight deck because nauseous, others forgot to slow down the acft before landing, or contact control, or prepare landing gear...

EXTRACT FROM CIVIL AVIATION REGULATIONS 1988 (CARs)

256 Intoxicated persons not to act as pilots etc. or be carried on aircraft

- (1) A person shall not, while in a state of intoxication, enter any aircraft.

Penalty: 5 penalty units.

- (2) A person acting as a member of the operating crew of an aircraft, or carried in the aircraft for the purpose of so acting, shall not, while so acting or carried, be in a state in which, by reason of his or her having consumed, used, or absorbed any alcoholic liquor, drug, pharmaceutical or medicinal preparation or other substance, his or her capacity so to act is impaired.

Penalty: 50 penalty units.

- (3) A person shall not act as, or perform any duties or functions preparatory to acting as, a member of the operating crew of an aircraft if the person has, during the period of 8 hours immediately preceding the departure of the aircraft consumed any alcoholic liquor.

Penalty: 50 penalty units..372 *Civil Aviation Regulations 1988*

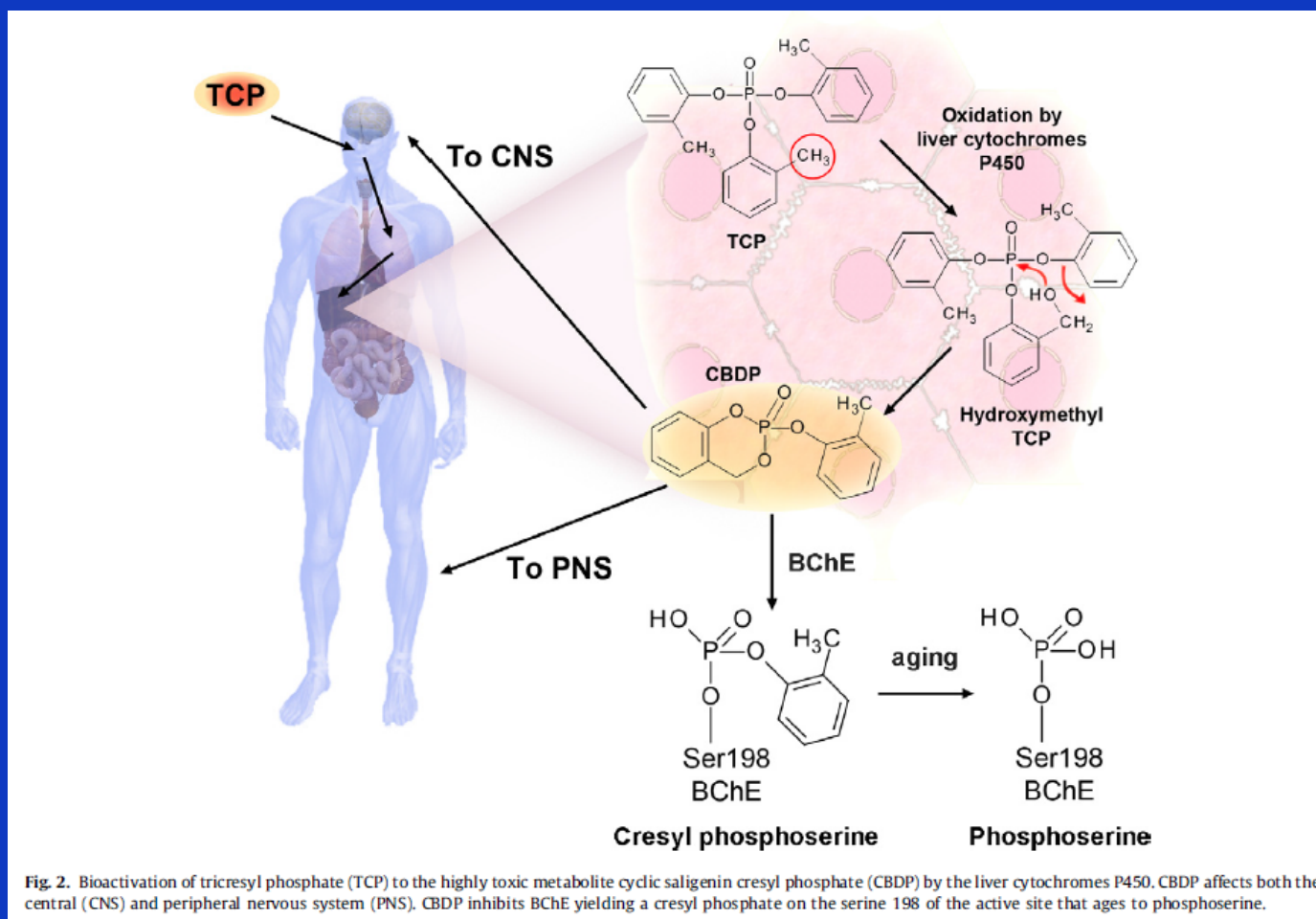
- (4) A person who is on board an aircraft as a member of the operating crew, or as a person carried in the aircraft for the purpose of acting as a member of the operating crew, shall not consume any alcoholic liquor.

Penalty: 50 penalty units.

- (5) A person shall not, while acting in any capacity in either Air Traffic Control or Flight Service, be in a state in which, by reason of his or her having consumed, used, or absorbed any alcoholic liquor, drug, pharmaceutical or medicinal preparation or other substance, his or her capacity so to act is impaired.

Penalty: 50 penalty units.

Metabolic / Toxicity of TCP



Reproduced from Clem Furlong

Toxicity of organophosphates

Neurotoxicity known at last since 1899 when reported for phosphorene –used then in the treatment of tuberculosis-.

Organophosphate poisoning : cholinesterase inhibitors / cholinergic oversimulation : early symptoms : salivation, lacrimation, conjunctivitis, visual impairment, nausea and vomiting, abdominal pain and cramps, diarrhoea, parasympathomimetic effects, fasciculation and muscle twitches.

Low level intoxication : headache, vertigo, drowsiness, lethargy, difficulty in concentration, slurred speech, confusion, emotional lability and hypothermia.

Organophosphate Induced delayed neuropathy (OPIDN)

With progressive neuronal damage

Toxicity of organophosphates

Intermediate syndrome (neuromuscular synapses): proximal limb paralysis, weakness of neck muscles, inhibition of respiratory muscles and cranial nerve involvement.

Organophosphate Induced delayed neuropathy (OPIDN)

With progressive neuronal damage

Chronic Organophosphate Neuropsychological Disorder
(COPIDN):

Gulf war syndrome

Worrisome for flight safety and health

OP Toxicity acknowledged ... and describing same symptoms



Guidance Note MS 17

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Medical aspects of work-related exposures to organophosphates

Guidance Notes are published under five subject headings:

Medical
Environmental Hygiene
Chemical Safety
Plant and Machinery
General



CHEMICAL EMERGENCIES

TOXIC SYNDROME DESCRIPTION

Nerve Agents and Organophosphate Pesticides

The purpose of this document is to enable health care workers and public health officials to recognize an unknown or suspected exposure to a nerve agent or an organophosphate (OP) pesticide. Nerve agents are chemical warfare agents that have the same mechanism of action as OP pesticides. They are potent inhibitors of acetylcholinesterase. Inhibition of acetylcholinesterase leads to an accumulation of acetylcholine in the central and peripheral nervous system. Excess acetylcholine produces a predictable cholinergic syndrome consisting of copious respiratory and oral secretions, diarrhea and vomiting, sweating, altered mental status, autonomic instability, and generalized weakness that can progress to paralysis and respiratory arrest.

Management of acute organophosphorus pesticide poisoning

Michael Eddleston, Nick A Buckley, Peter Eyer, Andrew H Dawson

Organophosphorus pesticide self-poisoning is an important clinical problem in rural regions of the developing world, and kills an estimated 200 000 people every year. Unintentional poisoning kills far fewer people but is a problem in places where highly toxic organophosphorus pesticides are available. Medical management is difficult, with case fatality generally more than 15%. We describe the limited evidence that can guide therapy and the factors that should be



CHEMICAL EMERGENCIES

TOXIC SYNDROME DESCRIPTION

Nerve Agents and Organophosphate Pesticides

Signs and symptoms

The following is a more comprehensive list of signs and symptoms that may be encountered in a person exposed to a nerve agent or OP pesticide. Signs and symptoms are not listed in order of presentation or specificity. Also, partial presentations (an absence of some of the following signs/symptoms) do not necessarily imply less severe disease.

Central nervous system signs and symptoms

- Miosis (unilateral or bilateral)
- Headache
- Restlessness
- Convulsions
- Loss of consciousness
- Coma

Respiratory signs and symptoms

- Rhinorrhea (profuse watery runny nose)
- Bronchorrhea (excessive bronchial secretions)
- Wheezing
- Dyspnea (shortness of breath)
- Chest tightness
- Hyperpnea (increased respiratory rate/depth)—early
- Bradypnea (decreased respiratory rate)—late

Cardiovascular signs

- Tachycardia (increased heart rate)—early
- Hypertension (high blood pressure)—early
- Bradycardia (decreased heart rate)—late
- Hypotension (low blood pressure)—late
- Dysrhythmias (prolonged QT on EKG, ventricular tachycardia)

Gastrointestinal signs and symptoms

- Abdominal pain
- Nausea and vomiting
- Diarrhea
- Urinary incontinence, frequency

Musculoskeletal signs and symptoms

- Weakness (may progress to paralysis)
- Fasciculations (local or generalized)

Skin and mucous membrane signs and symptoms

- Profuse sweating (local or generalized)
- Lacrimation (tear formation)
- Conjunctival injection

Laboratory finding suggestive of nerve agent poisoning

- Decreased plasma or red blood cell (RBC) cholinesterase activity

Some victims of Aerotoxic syndrome



Freya Von der Ropp Karen Burns
Annie Estes

Coroner's Enquiry

Capt Richard Westgate † 12/12/2012



BA pilot Richard Westgate, 43, died after complaining he was being poisoned by toxic fumes in the cockpit

But several more deceased crews ...



Sheriff Stanhope Payne,
Senior Coroner for The County of Dorset

REGULATION 28: REPORT TO PREVENT FUTURE DEATHS (2)

REGULATION 28 REPORT TO PREVENT FUTURE DEATHS

THIS REPORT IS BEING SENT TO:

1. Chief Executive – British Airways
2. Chief Operating Officer – Civil Aviation Authority

1 CORONER

I am Sheriff Stanhope Payne, senior coroner, for the coroner area of Dorset

2 CORONER'S LEGAL POWERS

I make this report under paragraph 7, Schedule 5, of the Coroners and Justice Act 2009 and regulations 28 and 29 of the Coroners (Investigations) Regulations 2013.

3 INVESTIGATION

On 27th December 2012 I commenced an investigation into the death of RICHARD MARK WESTGATE, aged 43. The investigation has not yet concluded and the inquest has not yet been heard.

4 CIRCUMSTANCES OF THE DEATH

On 12th December 2012 Richard Mark Westgate was found deceased in his room at the Bastion Hotel in Bussum, Netherlands. His body was repatriated to Dorset. He was a British Airways pilot who had been on medical leave since September 2011 suffering cognitive dysfunction, ataxia & other deficits. Post mortem examinations gave causes of death of either Pentobarbital toxicity or lymphocytic myocarditis, individually or in combination. Testing of samples taken both prior to and after death disclosed symptoms consistent with exposure to organo-phosphate compounds in aircraft cabin air. Such exposure can cause lymphocytic myocarditis.

Post-mortem



BA pilot Richard Westgate, 43, died after complaining he was being poisoned by toxic fumes in the cockpit

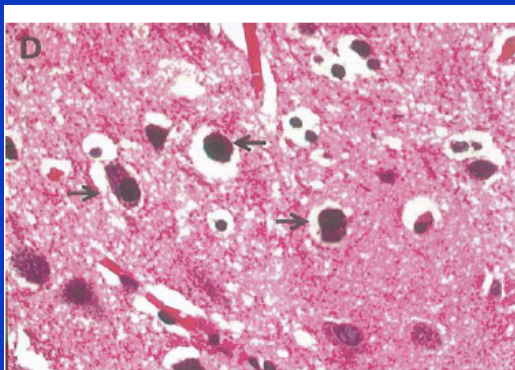


Figure 7. Highly magnified section through the prefrontal cortex showing shrunk and dying neuronal cell indicated by arrows. Note the dense chromatin in the dying cells.

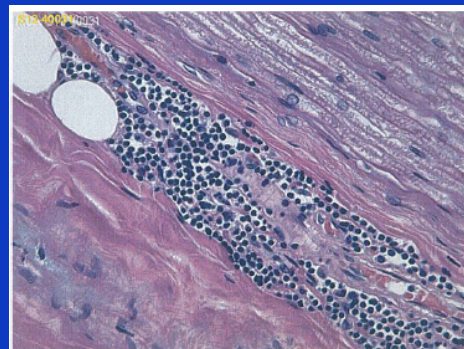


Figure 2. Demyelination (absence of more white material) and lymphocytic invasion (black dots) of peripheral nerve.

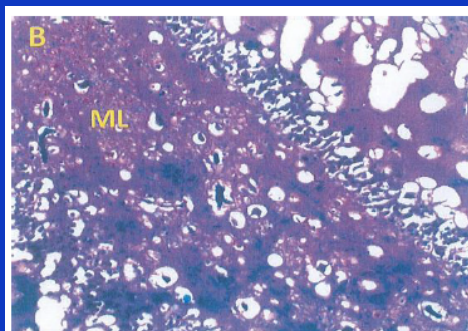


Figure 13. Section of hippocampus dentate gyrus showing areas of demyelination. The blue staining (colour online) gives way to pink, where the myelin is missing.

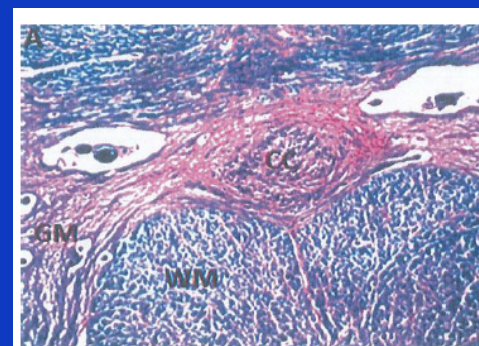


Figure 22. $\times 4$ section of spinal cord shows demyelination of white matter (WM), grey matter (GM) and central canal (CC).

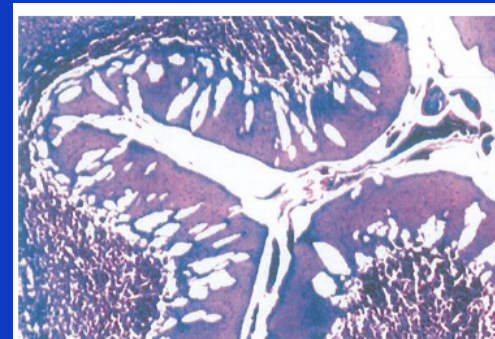


Figure 17. A low magnification showing demyelinated cells where blue gives way to pink (colour online).



05AB14A

Autoantibody markers of neural degeneration are associated with post-mortem histopathological alterations of a neurologically-injured pilot

Mohamed B. Abou-Donia,^{1,*} F.R.W. van de Goot² and M.F.A. Mulder³

¹ Duke University Medical Center, Durham, North Carolina 27710, USA

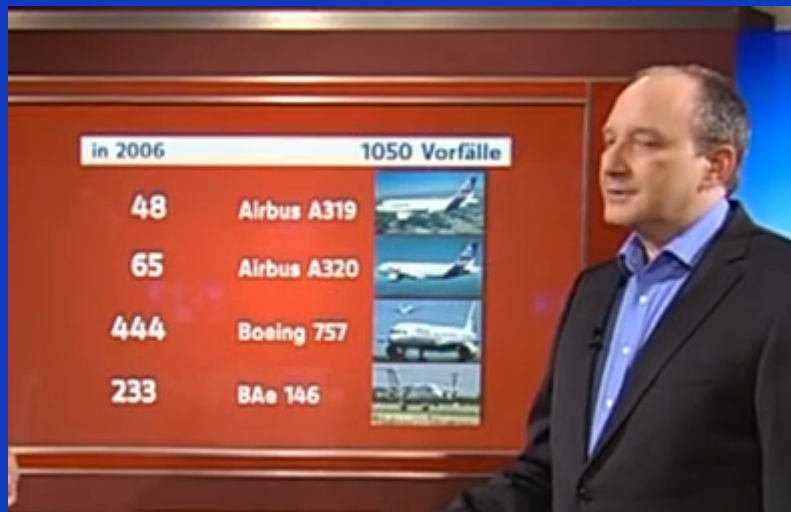
² Symbiant BV, Wilhelminalaan 12, 1815 JD Alkmaar, The Netherlands

³ Aviation Medical Consult, Karbounvstraat 14, 1402 VC Bussum, The Netherlands

Reporting?

Thousands reports...
& several tens of thousand
incidental flights

From dirty sock smell to
short term / long term,
mild symptoms ...
... and post-mortem



790 incidental flights in Germany (2006) and 300
German complains filed, not one accounted.

IN-FLIGHT HEALTH SURVEY


DATE: 19-7-92
TIME: 0610

AIRCRAFT REGO: I J K L M R S EWM

FLIGHT NO: 352-353 SYD-BNE-HTI-BNE

PURSER: [REDACTED]

NAMES OF FLIGHT ATTENDANTS: [REDACTED]



1. Odour Detected

Yes ☒ No ☐ If Yes by how many 2 F/As + pilots (1 F/A has no sense of Pungent smell)
2. Duration of Odour during Flight

Foul ☐ Stale ☐ Oil ☒ Pungent ☒

Please describe: Oil fumes detected on initial boarding of a/c at SYD. Pilots had been burning off airconditioning packs - strong oil fumes at row 1 at all times (on ground, ascent, cruise, descent) - especially noticed throughout a/c when landing & on the ground at all ports - oil odour around engine area during cruise. Pilots could smell oil fumes in cockpit - they found oil to be leaking from an engine.
3. F/A Reactions to Odour Symptoms

None ☐ Nausea ☐ Lightheaded ☒ Dizzy ☐

Sore Throat ☒ Dry throat from first sector onwards
Shortness of Breath ☒ Requiring Oxygen ☒ Other very dry, stinging, red eyes
4. Number of F/A's with Symptoms 2
5. Passenger Reaction

Yes ☐ No ☒ If Yes, how many? ☐

Comments: After noticing oil fumes on initial boarding of a/c at SYD, F/S Ferguson started to have a very dry throat & slight breathlessness during the first & 2nd sectors to BNE & HTI. Noticed at all times throughout duty, oil fumes were strong around row 1, close to my own area.

Upon closing a/c doors at HTI, I found it difficult to breathe. F/A Paire noticed I was having a problem breathing, which continued throughout the entire flight & the next few hours after signing off at BNE. I found it necessary to use supplementary oxygen throughout the entire flight, except when I tried to do the cabin service & still could not breathe properly. I felt lightheaded as well. Please note that I did not have any breathing problems before boarding the a/c today.

Reporting smoke / fume events (Australia)

Incident reporting by crew (Ansett non-mandatory reporting). 53 in 6 weeks for 7 aircraft only. But 3828 aircraft discrepancy reports in 4 years

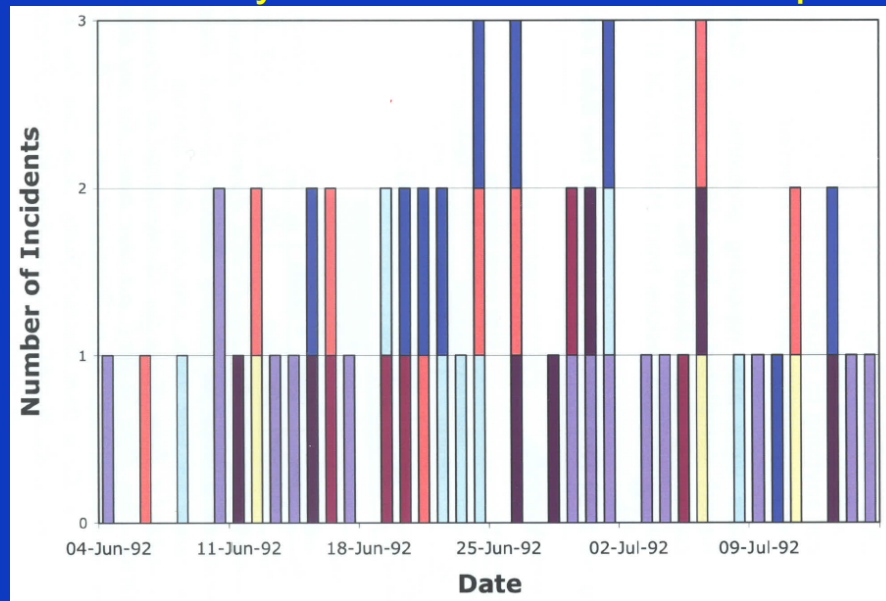
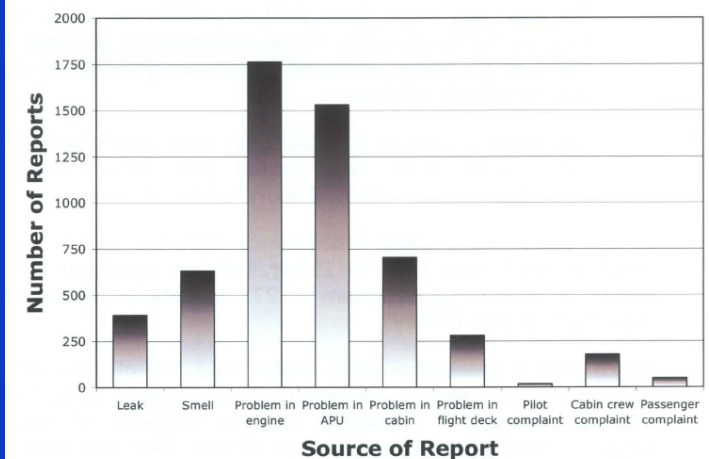


Figure 1-8: 1992-94 Discrepancy Reports, by Source of Problem (Reported by Crew)



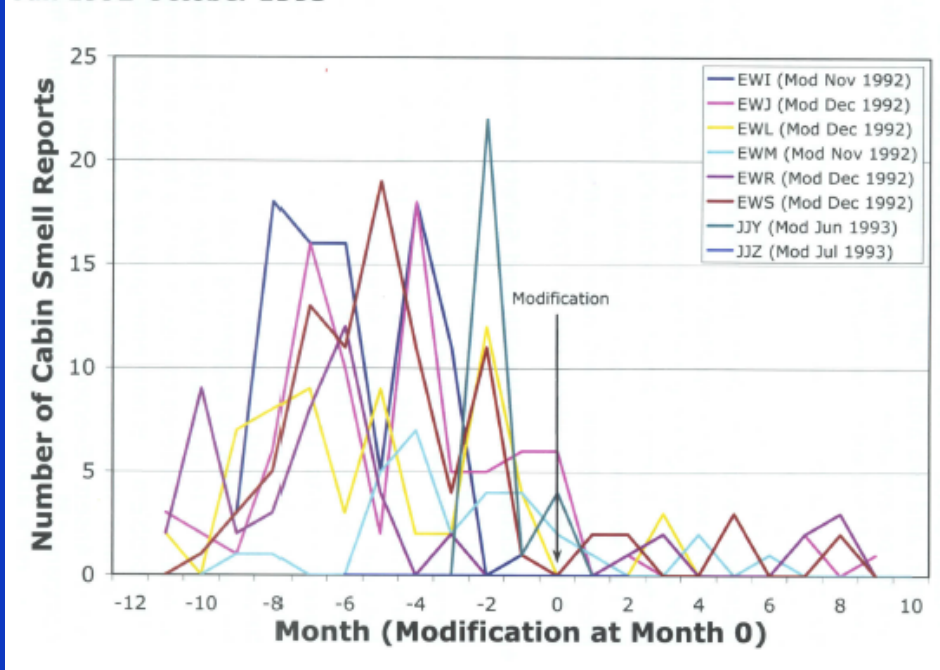
Commonly acknowledged at one in 200 flights.

Under-reporting? UK CAA suggests 1 smoke, gas or leak incident in 22,265 flights, but many incident reports not forwarded by British Airways to UK CAA.

Confidentiality

Agreement between Ansett and Est West Airlines, British Aerospace, Allied Signal and Avco Lycoming for 1 M \$. Released in August 2007 by the Tasmanian Senator Kerry O'Brien.

Figure 1-10: Impact of Engine Modifications on Cabin Odour Reports Jan 1992-October 1993



« Installation of new filtration system had been successful and has had a significant effect on reducing the number of reports of this problem ». Bryan Girdwood, Engineering fleet manager. However, the sources of the leaks had not been addressed.



Parliament of the Commonwealth of Australia

Air Safety and Cabin Air Quality in the BAe 146 Aircraft

Report by the
Senate Rural and Regional Affairs
and Transport References Committee

OCTOBER 2000



Engineering Solutions

Use RAM air, not bleed...

install CO detectors (compliance) ...

Use less toxic fluids ...

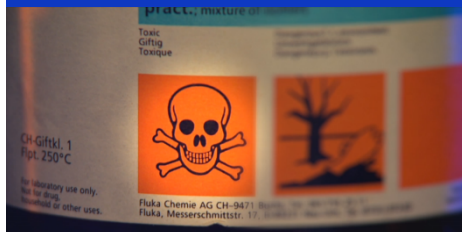


Procedures :

- Ground leaking acft
- Fix leaking seals;
- Report smoke / fume events;
- Don oxygen masks (pilots) and invite PAX to breath through fabrics (pillow, blanket...).
- Tell the exposed what they have been exposed to (Human Rights);
- Have the symptomatic crew and PAX for medical examination.

Main Ongoing Debates

- **Sampling on selected flights:** no smoke/fume flight sampled nor leaking acft, nor experimental tests.
- **Chemical analysis:** limitation in equipment air sampling (selective duration + detection limits,); Selecting the less toxic and abundant compounds (i.e. ToCP)
- **Symptoms:** Pretending symptoms are of another cause (i.e. hyperventilation or jetlag). When independent medical examination expected.
- **Toxicity mechanisms :** Parties not acknowledging OP toxicity in debate and legal cases (whatever acknowledged by International Community.)
- **Low dose / repeated** exposure to be accounted for
- Genetic condition and Low dose / no threshold (Calabrese).
- **Reporting** : crew to airline and airline to Aviation authorities vs environmental & health authorities.
- **Corporate bias & Confidentiality agreements** to cover up the issues
- **Authorities (Aviation)** : safety not health.
- **Legal cases** : settled confidentially to avoid legal precedents.
- **Information** : A duty and a Human Right to know ...



Thank you



*“The Truth, The Whole Truth, and
Nothing But The Truth.”*

See also www.aerotoxic.org and
<https://www.youtube.com/watch?v=fOLQRNnWYH4>

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Fidji Airways, Jan. 2015

