Published in: *Journal of Occupational Health and Safety – Australia and New Zealand* 17: 471-483, 2001

Aircrew Exposure to Chemicals in Aircraft: Symptoms of Irritation and Toxicity[1]

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Keywords: Aerotoxic syndrome, irritation, toxicity, airborne chemicals, neurotoxicity, chemical safety, phosphate esters, case studies

Summary

Materials used in the operation of aircraft may contain hazardous ingredients, some with significant toxicities, and need care in handling and use. Some maintenance or operational activities, such as leaks or poorly controlled maintenance procedures, can, through contamination of aircraft cabin air, produce unwanted exposures to crew and passengers. Occasionally, such exposures (either short term intense or long term low level) may be of a magnitude to induce symptoms of toxicity.

These symptoms are associated with air crew exposure at altitude to atmospheric contaminants from engine oil or other aircraft fluids, temporally juxtaposed by the development of a consistent symptomology of short-term skin, gastro-intestinal, respiratory and nervous system effects, and long-term central nervous and immunological effects. Symptoms from seven case studies, from flight crew and flight attendants in four airlines operating in four countries and in three airplane models are listed. These symptoms may be reversible following brief exposures, but features are emerging of longer term problems following significant exposures. This has significant implications for safety in the aviation industry and occupational health.

Introduction

Chemical exposures in aircraft are not unheard of. Aircraft materials such as jet-fuel, de-icing fluids, engine oil, hydraulic fluids, and so on, contain a range of ingredients, some of which are toxic.[1,2,3,4] In 1953, The Aeromedical Association first expressed their concerns about the toxicity risks of cabin air contamination by hydraulics and lubricants.[5] Other risks have been identified more recently, either as part of the chemicals routinely used in maintaining airplanes,[6] or as toxicological factors in aviation accidents[7] There are a range of possible situations that can arise whereby airplane cabin air can be contaminated.[8]

The aviation industry has used engine oil, hydraulic fluids and other materials that can contain a range of toxic ingredients, for example:

- organophosphate compounds, including Tricresyl phosphates (TCP), Tributyl phosphates (TBP), Triphenyl phosphates (TPP) and their derivatives, from 3 to 25% in content;
- other toxic inorganic molecules, such as naphthylamines, amines and esters;

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- organometallic additives (zinc dialkyl dithiophosphates, calcium alkyl phenates, magnesium sulphonates, molybdenum and barium containing additives).

Some of these contamination problems can persist for decades. For example, a problem of oil contamination of the air conditioning system of the BAe 146 was first noted by the aircraft manufacturer in 1984,[9] but was the subject of a specific term of reference to an Australian Senate Aviation Inquiry held 1999-2000, over fifteen years later.[10] While changes in product formulations have attempted to make less toxic products,[11] concern still exists as to the potential toxicity that exposure to these materials may cause.[12]

Although these chemicals are usually retained in the engines and equipment into which they have been added (such as auxiliary pack units or APUs), they can sometimes find their way into cabin air where crew and passengers are located, through incidents such as engine oil leaks, seal failures and fluid ingestion by APU/engines.

Dozens of in-cabin leak/smoke events are documented annually (for example, through the NASA self reporting system, BASI, NTSB), often correlated to aircraft fluid leak events. Fume events are much more frequent, correlated to less important aircraft fluid leaks (hundreds per year), or to other independent sources (not statistically studied in this paper). In total, aircraft fluid leak/fume/smoke events are estimated to impact over 300 flights per year world-wide (statistically above 1 complaint flight out of 25,000 flights), resulting in exposures to an annually estimated 40,000 or more crew and passengers worldwide (a billion passengers in 1999).[13] However, a figure of over one complaint flight out of 2500 flights is documented in at last three major airline companies.

Symptoms following Irritating and Toxic Exposures

Symptoms may be possible from single/short term or longer-term exposures.

The earliest case found in the literature was reported in 1977. A previously healthy member of an aircraft flight crew was acutely incapacitated during flight with neurological impairment and gastrointestinal distress. His clinical status returned to normal within a day. The etiology of his symptoms was related to an inhalation exposure to aerosolised or vaporised synthetic lubricating oil arising from a jet engine of his aircraft.[14]

Other studies of exposures in airplanes exist in the literature, including a 1983 study of eighty nine cases of smoke/fumes in the cockpit in the US Air Force,[15] a study of 1983 study of Boeing 747 flight attendants in the USA,[16] and a 1998 study of BAe 146 flight crews in Canada over a four-month period.[17] There are common themes in symptom clusters in these studies, as shown in the table below.

Table 1: Studies reporting symptoms of irritancy and toxicity in aircrew

	Reference	15	16	17
	Number of cases/reports	89	248	112
❍	watery eyes			6
❍	eye irritation	31	74%	
❍	burning eyes			27
❍	blurred vision			1
❍	loss of visual acuity	10	13%	
❍	runny nose		43%	
❍	sinus congestion	31	54%	6
❍	dry painful nose		57%	
❍	nose bleed		17%	

	Reference	15	16	17
	Number of cases/reports	89	248	112
❍	burning throat			48
❍	throat irritation		64%	
❍	gagging and coughing	2		3
❍	cough dry		69	
❍	cough wet		6%	
❍	cough blood		2%	
❍	shortness of breath		73%	
❍	difficulty in breathing		68%	
❍	pain on deep breathing	6	81%	
❍	chest pains	6		7
❍	increased heart rate		2%	
❍	breathing problems requiring oxygen			2
❍	loss of voice		35%	
❍	headache	22	52%	29
❍	dizziness/loss of balance	42		7
❍	light-headedness	42		6
❍	feeling faint		54%	
❍	actually faint/loss of consciousness	4	4%	
❍	trouble thinking or counting	23	39%	
❍	disorientation	23		17
❍	behaviour modified	23	20%	
❍	feeling “spaced out”		36%	
❍	tingling of nose and lips	8		3
❍	numbness			2
❍	muscle cramp		29%	
❍	nausea	23	23%	9
❍	abdominal spasms/vomiting	23		
❍	change in urine		3%	

The range of symptoms in these studies is quite broad, affecting many body systems. In some cases, it is quite likely that symptoms in one study are similar to those in the others (for example, trouble in thinking and counting and cognitive problems).

A preponderance of the symptoms reported above are related to exposure to an irritant, (indeed, the earlier Tashkin study suggests ozone as a cause, even though a battery of pulmonary function tests failed to reveal abnormalities). However, the presence on symptoms related to central nervous system dysfunction, hair loss, muscular and gastrointestinal problems, suggests the possibility of a component of systemic toxicity.

The Case Studies

To study some of the problems of exposure to flight crew and flight attendants exposed to in cabin contamination while flying, seven cases of symptom development from such exposure events were investigated. These case studies were taken from flight crew and flight attendants in four airlines operating in four countries and in three airplane models. A wide range of symptoms is reported in these seven case studies. A summary of the effects seen in these seven case studies is shown in the table below.

Table 2: Symptom Summary: Seven Case Studies

Symptom/Symptom cluster	Case Study No							Tot
	1	2	3	4	5	6	7	
Loss of consciousness, “grey out”		✓		✓	✓			3
Ataxia, seizures				✓				1

Symptom/Symptom cluster	Case Study No							Tot
	1	2	3	4	5	6	7	
Narcosis, somnolence		✓	✓					2
Vertigo	✓	✓						2
Loss of balance	✓	✓			✓	✓		4
Disorientation	✓	✓	✓	✓				4
Shaking/tremors/tingling				✓	✓	✓		3
Numbness (fingers, lips, limbs), loss of sensation		✓			✓	✓	✓	4
Light-headed, dizziness, feeling of intoxication	✓	✓	✓	✓	✓	✓	✓	7
Severe headache, head pressure	✓	✓	✓	✓	✓	✓	✓	7
Memory loss, memory impairment, forgetfulness, confusion	✓	✓	✓	✓	✓	✓	✓	7
Coordination problems	✓	✓	✓	✓	✓	✓		6
Word blindness			✓					1
Sleep problems			✓		✓	✓		3
Irritability		✓	✓			✓	✓	4
Depression	✓	✓	✓					3
Nystagmus					✓			1
Irritation of eyes, nose and throat	✓	✓	✓	✓	✓	✓	✓	7
Eye pain, problems			✓	✓	✓	✓		4
Vision problems				✓	✓	✓	✓	4
Sinus problems			✓			✓		2
Respiratory distress, difficulty in breathing	✓			✓		✓	✓	4
Chest tightness	✓	✓		✓				3
Chest pain		✓		✓				2
Increased heart rate, palpitations	✓	✓		✓				3
Nausea, vomiting	✓	✓	✓		✓	✓	✓	6
Abdominal pain, cramps, diarrhoea	✓			✓	✓			3
Sweating				✓				1
Rashes, blisters (uncovered body parts)			✓	✓		✓	✓	4
Hair loss	✓			✓		✓		3
Joint pain, muscle weakness					✓		✓	2
Fatigue, exhaustion	✓	✓	✓	✓	✓	✓	✓	7
Chronic fatigue	✓		✓	✓		✓	✓	5
Metabolic difficulties			✓					1
Weight loss					✓			1
Swollen glands, glandular problems			✓		✓	✓		3
Dysmenorrhoea				✓				1
Thyroid problems	✓							1
Immunodepression			✓				✓	2
Food/alcohol intolerances			✓		✓	✓	✓	4
Multiple Chemical Sensitivity			✓		✓	✓	✓	4

The consistency between the symptoms between these individuals is, in many cases, quite remarkable. The comparison of symptoms between Tables 1 and 2 are also noteworthy. The term aerotoxic syndrome was proposed in 1999 to describe the association of symptoms observed amongst crew exposed to hydraulic or engine oil smoke/fumes.[18,19]

An additional case which supports the problem of neurotoxicity in flight crew occurred in July 1997, when a pilot experienced difficulties (difficulty in concentration and loss of situational awareness) following the presence of strong oily odours and fumes in the cockpit while landing a plane, whereby the pilot had to hand over the plane to the first officer. This incident was subject of a report to the Australian Bureau of Air Safety.[20] One extract of this report is:

> *At 3,000 ft on approach to Melbourne Airport, the pilot suffered vertigo and handed control of the aircraft to the co-pilot. At the same time a check pilot suffered from*

nausea. The incapacitation occurred after the crew smelt oil fumes in the cockpit air supply.

The onboard maintenance record noted that an oil smell had been reported 23 days prior to this incident, and that the repair had been noted for repair at company convenience, indicating even in 1997, the lack of priority that the airlines gave to oil fume problems. The consequences of what might have occurred if oil fumes had affected two of two pilots, rather than two of three pilots are unthinkable.

Further, it is possible to separate out short term and long term symptoms.

Symptoms from short term exposure

Symptoms from single or short-term exposures include:

- neurotoxic symptoms: blurred or tunnel vision, nystagmus, disorientation, shaking and tremors, loss of balance and vertigo, seizures, loss of consciousness, parathesias;
- neuropsychological symptoms: memory impairment, headache, light-headedness, dizziness, confusion and feeling intoxicated;
- gastro-intestinal symptoms: nausea, vomiting;
- respiratory symptoms: cough, breathing difficulties (shortness of breath), tightness in chest, respiratory failure requiring oxygen;
- cardiovascular symptoms: increased heart rate and palpitations;
- irritation of eyes, nose and upper airways.

Neurotoxicity is a major flight safety concern, especially where exposures are intense.

Symptoms from long term exposure

Symptoms from long term low-level exposure or residual symptoms from exposure events include:

- neurotoxic symptoms: numbness (fingers, lips, limbs), parathesias;
- neuropsychological symptoms: memory impairment, forgetfulness, lack of co-ordination, severe headaches, dizziness, sleep disorders;
- gastro-intestinal symptoms: salivation, nausea, vomiting, diarrhoea;
- respiratory symptoms: breathing difficulties (shortness of breath), tightness in chest, respiratory failure, susceptibility to upper respiratory tract infections;
- cardiovascular symptoms: chest pain, increased heart rate and palpitations;
- skin symptoms: skin itching and rashes, skin blisters (on uncovered body parts), hair loss;
- irritation of eyes, nose and upper airways;
- sensitivity: signs of immunosupression, chemical sensitivity leading to acquired or multiple chemical sensitivity

- general: weakness and fatigue (leading to chronic fatigue), exhaustion, hot flashes, joint pain, muscle weakness and pain.

One last point should be noted. In a US NTSB 1983 study of problems of turbine oil by-product contamination, a statement appears which says:[21]

> "*there are certain instances in which chronic or repeated exposure may sensitize a person to certain chemicals so that later concentrations in the ppb range may later elicit an acute hypersensitivity type reaction*."

The number of cases now following exposure to irritating and toxic exposures in airline personnel suggest that a hypersensitivity reaction of this type may be occurring in an estimated 2 to 3% of the exposed. However, the intensity of the hypersensitivity reaction now occurring would suggest that it is not of a life threatening form.

Symptom duration

It is also apparent that some symptoms occur immediately or soon after exposure, for example, many of the irritant, gastric, nervous and respiratory effects. However, others, such as nervous system impairment, immunosupression and chemical sensitivity, develop later, perhaps months after exposures may have ceased. Further, while some of these symptoms are fully reversible, others appear to persist for longer (in some of the longer cases, for at least five years). Debate is also continuing about the links between exposure and some of longer-term symptoms (such as chemical sensitivity).

Symptom severity

Symptom severity depends on a number of factors, including the range of contaminants present, the intensity, duration and frequency of exposure, toxicity of compounds (expectedly influenced by cabin environment factors such as humidity, decreased oxygen concentration and contaminants such as carbon monoxide), and individual susceptibility.

While single/long term exposure to aircraft engine lubricants and hydraulics (basically due to their chemical content and possible thermal decomposition products) is diagnosed as responsible for the reported symptoms, air crew or passengers exposed to same events or similar doses do not necessarily develop same symptom severity. Variation in symptom severity is attributed to individual sensitivity, and may also depend on other susceptibility factors, including prior exposure events.

In terms of toxicity, a large number of crew are developing symptoms[16,17,22,23] following both short-term and long term repeated exposures. Neurotoxicity is a major flight safety concern,[24] especially where exposures can be intense.

Attempts by airlines to address this problem through design, maintenance and operational improvements and through staff support and medical care have not been successful, and in the main, continue to be reactive. Obviously, improving options such as engine design, using less toxic fluids, improved reporting systems, and better maintenance procedures are not within the sole sphere of activity of the operators. However, the manner in which some airlines have pursued workers compensation cases brought by staff with some of the longer term symptoms indicates a confrontational approach which is unlikely to be beneficial to all parties in the long-term.

Conclusions

Direct exposure to smoke/fumes from hydraulic fluids and lubricants are known to be toxic, causing effects such as blurred vision, disorientation, memory loss, lack of coordination, nausea, that if they occurred in flight crew, are direct threats to flight safety. Further, through documentation such as reports of cabin air contamination by engine oil and hydraulic fluids in engine logs and pilot reports, factual evidence is available that flight deck, cabin crew and passengers can be directly exposed to airborne chemicals on aircraft in sufficient concentrations to cause acute, immediate to long-term symptoms.

These exposures can and do produce symptoms of toxicity. Symptoms associated with cabin contamination clearly include irritancy, neurotoxicity and neuropsychological effects, as well as other symptoms typically correlated to chemical intoxication. Links between neurotoxic effects and certain contaminants known to be neurotoxic (such as the phosphate esters) are suspected.

These exposures, and the symptomology they produce, present significant issues with regard to the health of pilots, cabin crew and passengers, but most notably with regard to air safety if pilots are incapacitated and cabin crew cannot supervise cabin evacuations during emergencies. Health effects include short-term irritant, skin, gastro-intestinal, respiratory and nervous system effects, and long-term central nervous and immunological effects. Some of these effects are transient, others appear more permanent. The exacerbation of pre-existing health problems by toxic exposures is also highly probable.

Aviation has been a pioneering industry for decades. However, the industry is coming under increasing pressure to improve its standards. Public confidence in a traditionally safe, high technology industry, is eroding to the perception of a standpoint of “fly at any cost”. Minimalist approaches to regulatory compliance, an almost total focus on profit making at the expense of other commercial priorities (such as safety or staff health), and strident denials that problems exist are not hidden do little to build confidence.[25,26]

Human factors need to be considered too. Staff of the airlines are worried about job security and what might happen to them if they complain about working conditions and make their symptoms public. At present, with only a few dozen cases proceeding in the courts, little compensation has been awarded to airline workers affected by toxic fumes and several have already lost their jobs (for example: the pilot fired two months after incident in case study no 2; pilot in early retirement within one year after incident, early retirement by five years, in-flight engineer fired a few months after incident for “insubordination” in case study no 3; flying licence lost in case studies nos 5 and 7). Therefore, staff are reluctant to come forward until their health is jeopardised sufficiently that they can no longer fly without compromising their health and safety.

In one workers’ compensation court proceedings in Australia, one airline has admitted that exposure events are significant enough to produce symptoms of irritation.[27] Debate about other effects, and about the significance of long term sequelae continues. The case was concluded as the exposures exacerbating a pre-existing medical condition.

The issue has generated considerable interest in the international community and various international programs are being started in the USA and Europe. This international dimension is of major importance since exposed and symptomatic crews have been identified in at least three continents, and all aircraft types have had leak problems.

APPENDIX 1: THE CASE STUDIES

CASE STUDY NO 1				
Demographic/occupational	Country:	France		
	Aircraft type:	B-747	Date of incident:	1985
	Occupation:	Cabin crew	Years of experience:	15-20
	Age at incident:	35-40	Gender:	Female
	Medical:	Asthma, non-smoker, no alcohol, no recent illness. One first in-cabin smoke exposure eight years previously (no fire on board), with all crew reporting headache, nausea, vertigo, blurred vision.		
Incident:	Residual leak:	Symptoms occurred on three flights where complaints were reported.		
Symptoms:	Onset:	Symptoms including tight chest, difficulty in breathing, nausea and abdominal spasms, palpitations, disorientation, feeling intoxicated		
	In-flight treatment:	None		
	Longer term symptoms:	Alopecia, memory impairment, chronic fatigue, altered coordination, loss of balance, hypothyroidy (not existing prior to exposure), depression.		
	Company actions:	Incapacitation acknowledged by social security three years after exposure. Compensation for loss of licence (private insurance).		

CASE STUDY NO 2				
Demographic/occupational	Country:	Canada		
	Aircraft type:	Fokker 100	Date of incident:	May 19, 1989
	Occupation:	Cabin crew	Years of experience:	more than10
	Age at incident:	35-40	Gender:	Female
	Medical:	No relevant medical precedent, non-smoker, no alcohol, no recent illness.		
Incident:	Fumes in cabin	One-hour flight. Odours detected and recorded on flight log. Evidence also available of mechanical problems on this flight and ongoing aircraft repairs. Two other cabin crew had similar symptoms, though headaches less severe. Pilot without symptoms, co-pilot reported feeling "intoxicated" and legs very weak, generalised fatigue, inability to stand up and talk.		
Symptoms:	Onset:	Initiated during flight, worse during descent. Severe headache, vertigo, loss of balance, nausea, loss of sensation in leg, difficulties in keeping eyes open (probably narcosis).		
	In-flight treatment:	Oxygen supply, producing a slight improvement after some time, although difficulties with opening eyes persisted for a few days.		
	Post-flight:	A visit to emergency room, four hours after incident - same symptoms as in flight, plus: chest pain, tight chest, heart palpitations, exhaustion, problems in concentration, irritability, feeling intoxicated. Symptoms diagnosed as possible carbon monoxide intoxication, although clinical and biochemical examination normal (concluded that the O_2 intake during flight corrected the CO exposure)		
	Longer term symptoms:	Irritability, somnolence, generalised weakness, "grey out" (incapacity to stand up and talk), weakness, confusion, memory problems, nausea, concentration difficulties, paralysis events (whole body versus left hemiplegia, positively treated by Serax), depression.		
	Diagnostic tests:	Neuropsychological tests concluded in reduced visuo-spatial analysis and organisation, reduced visual information retention, altered verbal fluidity for phonologic tests while semantic within normal, reduced analytical reasoning, limited capacity for information evocation, cognitive disorders, depression. No structural anomaly evidenced.		
	Symptom persistence:	Symptoms (mainly neuropsychological) have been almost stable over a four year period post-exposure. She has not been able to work for over 4 years after incident.		

Company actions:	Occupational exposure acknowledged and compensation for deficit granted 3½ years after the incident.

CASE STUDY NO 3

Demographic/occupational		Country:	Australia	
	Aircraft type:	BAe 146	Date of incident:	September 30 October 1993
	Occupation:	Cabin crew	Years of experience: 2-4	
	Age at incident:	25-30	Gender: Female	
	Medical:	Non-smoker, low alcohol. Deteriorating health over previous two years while continuing to work. The following complaints commenced in January 1992: headaches, watery eyes, sinus problems, nausea, swollen glands, dizziness, sleep difficulties, brain fogginess and skin rashes. Oxygen was requested on a flight in June 1992. Blood was coughed up post-flight. Diagnosed for EBV (Epstein Barr Virus) nine months before major incident.		
Incident:	Smoke in cabin	1-2 hour flight. Black smoke emitted into the cabin from the air-conditioning ducts, sufficient for passengers to believe a fire had started. Captain vented the cabin but a haze remained sufficient to obscure the back of the plane for the flight. Event logged. Other cabin crew had symptoms of irritation.		
Symptoms:	Onset:	Pre-existing symptoms from previous flights exacerbated: Fatigue, headaches, inability to concentrate, skin rash.		
	In-flight treatment:	None.		
	Post-flight:	Same symptoms as in flight, plus: headaches and head spasms, sinus problems, nausea, eye soreness and pain, exhaustion, problems in concentration, irritability, swollen glands, neuropsychological symptoms, such as giddiness, “brain fogginess”, memory lapses, irritability, sleep difficulties, dyslexia.		
	Longer term symptoms:	Chronic fatigue, headaches, weakness, confusion, memory problems, nausea, concentration difficulties, depression, multiple chemical sensitivity.		
	Diagnostic tests:	Chemically sensitised. Neurological dysfunction in (AERP) auditory evoked response potential test. Metabolic imbalances.		
	Symptom persistence:	Some symptoms abated, some declined but flared on chemical exposure, some remained. Symptom-free on holiday in 1997, but symptoms recur on return to city. Now working part time in an unrelated field.		
Company actions:		Formed an expert panel that acknowledged irritant effects but repudiated long term effects. Defended a workers compensation case, which was decided against the company in 1999 for exacerbation of pre-existing illness.		

CASE STUDY NO 4

Demographic/occupational		Country:	USA	
	Aircraft type:	B-727	Date of incident:	1992
	Occupation:	Cabin crew	Years of experience:	3-5 years
	Age at incident:	40-45	Gender:	Female
	Medical:	No relevant medical precedent, non-smoker, no alcohol, no recent illness.		
Incident:	Fumes in cabin:	One-hour flight. Blue haze and “sweet smell” in cabin ten minutes after take-off. Loss of hydraulic pressure detected before take-off and “repaired on tarmac”. Aircraft grounded after landing at destination for hydraulic repair. All cabin crew intoxicated, although less severe symptomatology as compared to the present case study. Flight deck crew used oxygen masks and reported no symptoms.		
Symptoms:	Onset:	Initiated during flight, ten minutes after take off. Severe headache, dizziness, nausea, sweating, shaking, laboured painful breathing - tight chest and chest pain, incoherence, weakness, stumbling, disorientation, memory impairment, palpitations, tunnel vision, eye burns, loss of consciousness.		
	In-flight treatment:	None		

Post-flight:	At emergency room on same day and visit the next day: further symptoms to those reported to the in-flight reported symptoms: abdominal pain and cramps, blurred vision and disorientation, altered coordination, blurred speech. Diagnosed as toxic encephalopathy.
Longer term symptoms:	Skin rash and blisters on uncovered body parts, tunnel vision, diarrhoea (for a week), loss of balance, neck/eye pain, alopecia (for 2 months), no menses for 6 months, impairment in cognitive and reasoning problems, altered memory, unstable body temperature, ataxia, muscle weakness, chronic fatigue, seizures.
Company actions:	Compensation for medical bills and partial compensation for loss of income (five years after).

CASE STUDY NO 5				
Demographic/occupational	Country:	Australia		
Aircraft type:	BAe 146	Date of incident	30 October 1997 (major exposure event hereunder described, further incapacitated on a flight three weeks later).	
Occupation:	Flight crew	Years of experience	15-20	
Age at incident:	30-35	Gender:	Female	
Medical:	non-smoker, almost no alcohol. No recent illness, against a background of deteriorating health over previous six months. Six years flying BAe 146 with chronic exposure and numerous exposures under pack burnout procedures.			
Incident: Residual leak:	One to two hour flight. Flying in plane with smell of engine contamination of air. Event logged. Eventually subject to (BASI) Bureau of Air Safety and Investigation report. Eye redness and lacrimation in flight crew. Cabin crew and passengers complaining of smell.			
Symptoms: Onset:	Nausea, vestibular problems, tunnel vision, “grey out”, headaches, sore eyes.			
In-flight treatment:	None. Was not able to think clearly enough to use oxygen or hand over to first officer.			
Post-flight:	Visit to general medical clinic immediately after landing. Same symptoms as in flight, plus: scalp numbness, perception displacement, feeling of intoxication, fatigue. Diagnosed as nystagmus / labyrinthitis.			
Longer term symptoms:	Headaches, and head pressure, weakness, chronic fatigue, concentration and memory difficulties, loss of clarity of thoughts, slurred speech, eye problems including severe nystagmus, accommodation and vision (fluorescent, bright lights, bright background lights) problems, sleep problems, weight loss, nausea and diarrhoea, reactive hypoglycemia, tremors, food and alcohol intolerance, multiple chemical sensitivity, lack of coordination, loss of muscle control in face, head movement sideways or up or down, motion sickness.			
Diagnostic tests:	CT scan normal. Chemically sensitised. Neurological dysfunction in auditory evoked response potential AERP test. Metabolic imbalances.			
Symptom persistence:	Some symptoms abated, some declined but flared on chemical exposure, some remained. Unable to pass aviation medical test for flying licence. Not working since incident.			
Company actions:	Suspended flying licence. formed expert panel that acknowledged irritant effects but repudiated long term effects			

CASE STUDY NO 6			
Demographic/occupational	Country:	Australia	
Aircraft type:	BAe 146	Date of incident:	November 1997
Occupation:	Cabin crew	Years of experience:	10-15
Age at incident:	30-35	Gender: Female	

	Medical:	non-smoker, low alcohol. No relevant medical precedent, but deteriorating health over previous twelve months, including headaches, nasal congestion, sinus problems, hypoosmia.
Incident:	Residual leak:	Three days of short and long haul flights up to eight hours/day with reported air quality problems and complaints. The situation of oil leaks/inoperative filters detailed in Engineers and Flight reports. All three cabin crew taken to hospital post-flight.
Symptoms:	Onset:	Overcome by fumes. Exacerbation of fatigue, inability to concentrate, coordination and speech impairment, body paralysis lasting few minutes, swelling, nausea, pain in left temple, breathing difficulties, dilated pupils, bloodshot eyes.
	In-flight treatment:	None.
	Post-flight:	Same symptoms as in flight, plus: intense headaches, nausea, eye soreness and pain, exhaustion, problems in concentration, irritability, neuropsychological symptoms, skin rash, skin colour grey, impaired vision, bruising of legs.
	Longer term symptoms:	disorientation, reactive hypoglycemia, confusion, poor concentration, impaired memory, short term memory loss, grey in colour for 7 months, dilated pupils, constricted breathing (sometimes), chronic fatigue, nausea, gastrointestinal problems, food and alcohol intolerance, irritability, alopecia, dermatitis, conjunctivitis, pressure and sharp head pains, chemically sensitive, motion sickness.
	Diagnostic tests:	Neurological dysfunction in AERP, metabolic imbalances.
	Symptom persistence:	Many symptoms remain, two years after incident.
Company actions:		Established odour committee and collected samples. Formed expert panel that acknowledged irritant effects but repudiated long term effects. One cabin crew was granted workers compensation for 1 day. This crew member denied workers compensation but was granted leave to proceed for negligence/damages against airline/employer.

CASE STUDY NO 7

Demographic/occupational		Country:	Australia	
	Aircraft type:	BAe 146	Date of incident:	Ongoing exposures 1994-97
	Occupation:	Flight crew	Years of experience:	10-15
	Age at incident:	30-35	Gender: Female	
	Medical:	non-smoker, low alcohol. No relevant medical precedent, but deteriorating health 1994-97, including headaches, nasal and throat problems, stridor, nausea, fatigue/lethargy, loss of concentration.		
Incident:	Residual leak:	Planes generally contained odours regularly throughout final three years of flying (worse on ground, takeoff, climb, descent). Exposures on occasion were intense enough to cause temporary incapacitation.		
Symptoms:	On exposure:	Upper airway irritation, hoarseness leading to loss of voice (eventually requiring surgery), headaches and head pressure, fatigue becoming worse over time, inability to concentrate, (all these symptoms would begin soon after switching on the air conditioning and abate quickly when leaving the plane). Later symptoms include nausea and development of sensitivity to chemicals in and around the airport environment.		
	In-flight treatment:	None. Hand over to other flight officer on occasion.		
	Last two days:	All symptoms as above, abating on the first day, and increasing on the second day. Symptoms continued, followed by massive increase in head pressure (sufficient to presuppose a stroke had occurred), fatigue, weakness, loss of voice within 24-48 hours.		
	Longer term symptoms:	Headache and head pressure, numbness, tingling, dizziness, reactive hypoglycemia, confusion, poor concentration and information processing, impaired memory, short term memory loss, feeling as though not enough oxygen is getting to the body, chronic fatigue, nausea and vomiting, food and alcohol intolerance, skin rashes, chemically sensitive.		
	Diagnostic tests:	Neurological dysfunction in AERP, evidence of injury to CNS in neuropsychological tests, abnormality in lung diffusion test.		

Symptom persistence:	Many symptoms remain, over three years after last exposure. Unable to pass aviation medical test for flying licence. Not working since last exposure.

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