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Discussion forum

An emerging concern: Toxic fumes in airplane cabins

Virginia Harrison [a,*] *and Sarah J. Mackenzie Ross* [b]

[a] *Department of Psychology, Open University, Walton Hall, Milton Keynes, UK*
[b] *Research Department of Clinical, Educational & Health Psychology, University College London, London, UK*

Toxicology is a new science, the complexities of which have been highlighted in the papers contained within this special section. Our understanding of the mechanisms through which various chemicals interfere with nervous system function is constantly evolving and research is unable to keep up with the speed with which new chemicals are produced and put onto the market. Thus there are often controversies surrounding the health-effects of commercially available compounds and disagreement around what constitutes safe exposure limits. This article will introduce readers to an emerging concern in this field, *the potential risk to health of toxic fumes in airplane cabins*. We explore the challenges and methodological issues encountered by researchers who have tried to investigate this issue and highlight the need for further research on this topic. We hope this article will promote discussion amongst academics and clinicians, and lead to the identification of creative solutions to the methodological issues encountered to date.

1. How does the air become contaminated?

Over the last two decades, aircrew and some passengers around the world have been complaining of ill health following exposure to toxic fumes in airplane cabins (Mackenzie Ross, 2008; Mackenzie Ross et al., 2011; Montgomery, Weir, Zieve, & Anders, 1977; Murawski, 2011; Somers, 2005), but it is only recently that this issue has received attention in the UK (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment [COT], 2007). The process by which cabin air can become contaminated is as follows: outside air is drawn into the aircraft and circulated around the engine where it is heated and pressurised to a safely breathable level. On most commercial aircraft types this air is then 'bled off' and pumped into the aircraft, unfiltered (Hunt, Reid, Space, & Tilton, 1995). Occasionally this bleed air becomes contaminated by hydraulic fluids, synthetic jet engine oils and combusted or pyrolised materials. Contamination can occur through mechanical failures, the overfilling of oil or hydraulic reservoirs and faulty seals which allow engine oil fumes to escape into the airflow (Shehadi, Jones, & Hosni, 2015). This is commonly referred to by aircrew as a 'fume event'. Exposure to engine oil fumes is potentially hazardous as jet engine oil contains a large number of chemicals some of which are irritating and sensitising (e.g., phenyl-naphthylamine, tri-butyl phosphate) and some of which are neurotoxic (e.g., toluene, xylenes and the organophosphate – OP, tricresyl phosphate – TCP; Winder & Balouet, 2002).

2. Incidence of contaminated air events

The incidence of contaminated air events is difficult to determine as cabin air is not routinely monitored for the presence of chemical contaminants and airlines are reluctant to share engineering records which document these incidents. Furthermore, the frequency of fumes events is difficult to quantify as underreporting is common among aircrew, possibly due to fears about job security (Winder & Michaelis, 2005). Nevertheless, the aviation industry accepts that occasional fume events occur on commercial aircraft, with certain aircraft types recording more events than others (e.g., the BAe 146 and Boeing 757 aircraft types). And on some occasions, aircrew and pilots have felt so overwhelmed/incapacitated by

* *Corresponding author*. Department of Psychology, Open University, Walton Hall, Milton Keynes MK7 6AA, UK.
E-mail address: gini.harrison@open.ac.uk (V. Harrison).

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fumes they have had to make an emergency landing (Newman, 2007).

Estimates of how often fume events occur vary widely depending upon whether the information is sourced from regulatory authorities such as the UK Civil Aviation Authority (CAA), from airlines or from trade unions who represent aircrew. For example, between 2004 and 2005, 109 fume events were reported to the CAA, but almost double that figure (204) were reported to the British Airline Pilots Association (personal communication). Figures from the CAA show that since 2010 they have received more than 1300 reports of smoke or fumes on a British airline and there were 251 incidents of fumes or smoke in the cabin reported between April 2014 and May 2015. In 2007 a Government Scientific Advisory Committee reviewed the evidence on contaminated air and estimated that fume events occur on approximately .05% of flights (COT, 2007). And a recent, comprehensive review of officially documented fume events in the USA places this estimate at .02% (Shehadi et al., 2015). Whatever, the actual frequency, it is important to note that although discreet fume events do occur, some aircrew report continuous exposure to noxious fumes throughout flight, particularly those who work on the BAe 146 aircraft type (Michaelis, 2010). Thus the estimated frequency of exposure to chemical contaminants in cabin air may be grossly underestimated as aircrew may be exposed to contaminated air on a continual basis as well as being exposed to contaminated air during discreet fume events. Without constant monitoring of on-board air quality, however, it is difficult to reliably assess such a claim.

3. Health complaints amongst aircrew

Pilots and cabin crew work in unique physical conditions where they are exposed to jet fuels, changes in temperature, pressure, gravitational forces, radiation and hypoxia. They also experience unusual routines, shift work, long hours of duty and time zone changes. The long-term impact of these factors on the health of aircrew remains unclear, but many aircrew report health complaints such as fatigue, dizzy spells, insomnia, stress, anxiety and marital conflict and evidence suggests they have increased rates of certain diseases and neurological conditions such as melanoma, cataracts and motor neuron disease (Nicholas et al., 2001). Despite this, specific data on incidence, prevalence and potential causes of ill health among aircrew is lacking. In the last two decades, an increasing number of aircrew have reported symptoms of ill health to regulatory authorities, which they attribute to exposure to neurotoxins in engine oil fumes. However, very little research has been undertaken on this issue, making it impossible to draw firm conclusions. According to de Boer, Antelo, van der Veen, Brandsma, and Lammertse (2015) between 2 and 3 pilots out of every 1000 retire from work on ill health grounds every year suffering from neurological symptoms such as tunnel vision, memory impairment and headaches; a figure which has doubled over the last two decades. However, the cause of these symptoms remains unclear.

4. Causation

Some researchers have suggested chronic exposure to OP compounds (particularly TCP) in engine oil may be to blame (Winder & Balouet, 2002). To reflect this, in 2000 Winder and Balouet proposed the term 'Aerotoxic Syndrome' to describe the common symptoms reported by aircrew following exposure to toxic fumes in aircraft cabins, and encompasses both short- and long-term effects such as ear/nose/throat irritation, skin conditions, nausea and vomiting, respiratory problems, headaches, dizziness, weakness and fatigue, sensory changes and nerve pain, tremors, chemical sensitivity and cognitive impairment (e.g., Abou-Donia, 2003; Cox & Michaelis, 2002; Coxon, 2002; Mackenzie Ross, Harper, & Burdon, 2006; Mackenzie Ross et al., 2011; Michaelis, 2010; Montgomery et al., 1977). In addition, recent studies have reported evidence of neuropsychological impairment (Heuser, Aguilera, Heuser, & Gordon, 2005; Mackenzie Ross, 2008; Mackenzie Ross et al., 2006; Mackenzie Ross et al., 2011; Reneman et al., 2015) and neurological damage (Heuser et al., 2005); evidence of nervous system degeneration (Abou-Donia, Abou-Donia, El Masry, Monro, & Mulder, 2013; Abou-Donia, van de Goot, & Mulder, 2014); and altered white matter microstructure, cerebral perfusion and activation (Reneman et al., 2015) in aircrew and pilots.

Although these studies have shown those working in the airline industry complain of an array of symptoms and/or show evidence of neurological damage, none of these studies have been able to determine cause. Indeed, without any objective measurement of exposure, it is very difficult to claim that contaminated air is to blame.

The only studies published to date that have attempted to explicitly measure and link ill-health with exposure to cabin fumes have relied solely on self-report questionnaires. In these studies, pilots and air crew were asked to report whether (and how often) they had experienced fume events or noxious smells whilst flying, as well as being given a health survey where they could report any symptoms that they believed they had experienced as a consequence (Cox & Michaelis, 2002; Harper, 2005; Michaelis, 2003). These studies found that an array of symptoms were typically reported immediately following exposure, including headache, cognitive impairment, fatigue, eye, nose, throat irritation, respiratory problems, nausea and skin irritation. They showed a temporal relationship with exposure and usually resolved within a few hours following cessation of contact, although a number of individuals reported persistent chronic ill health lasting months or years following exposure, particularly following repeated exposures over time.

However, it is important to note that these studies relied on subjective measures of self-reported exposure. Given the variation in human sensory sensitivity, the fallibility of memory and the fact that these self-reported levels generally appear to be much higher than those officially reported to industry (and therefore cannot be objectively confirmed), it is difficult to determine the reliability/validity of this data. Secondly, none of these studies utilised control groups to determine whether the rate or type of health complaints differs from that seen in the general population or in pilots who have not experienced fume events. Therefore, it remains difficult to