POSITION PAPER ON CABIN AIR

1.   For some years, there have been concerns about possible adverse health effects, both short- and long-term, in the crew of commercial aircraft, as a consequence of episodes in which cabin air becomes contaminated by components and/or combustion products of engine oils (fume events).

2.   At its meetings on 17 September and 29 October 2013, the Committee on Toxicity (COT) discussed reports of four research projects (Cranfield University 2008, 2009; Institute of Environment and Health 2011a/b; Institute of Occupational Medicine 2012) that had been commissioned by the Department for Transport (DfT) in response to recommendations that had been made by the Committee in 2007 (COT, 2007). These projects aimed to assess airborne concentrations and surface deposition of chemical pollutants in the cabins of commercial aircraft, and to investigate operational parameters associated with fume events. The Committee also considered papers that had been published in the peer-reviewed scientific literature since 2007, concerning exposures to chemical pollutants in aircraft cabins.

3.   This position paper summarises the Committee's evaluation of the four reports, the conclusions that can be drawn from the evidence that it has considered to date, the scientific uncertainties that remain, and options for further research to address these continuing uncertainties.

4.   The first of the four projects was a preliminary study to test air-sampling devices that might be used to monitor cabin air (Cranfield University, 2008). It highlighted several problems that would need to be overcome in an air-monitoring study. These included a need for correct orientation of sampling tubes, better standardisation of methods (inter-laboratory agreement on quantitative measurements was poor), further validation of the analytical methods, and adaptation of the methods to measure compounds up to C17. It also indicated that one method – diffusive SPME fibres – was unsuitable. Measurements during a perceived fume event revealed a transient increase in ultra-fine particle concentration, lasting only a few seconds. With the technology that is available, peak concentrations of such short duration would be difficult to detect for many pollutants, unless the increases above background were extremely large.

5.   These findings were taken into account in the design of a subsequent air-sampling study (Institute of Environment and Health, 2011a/b), although quality assurance was still less than desirable. The specific flights that were monitored

were determined by practical considerations, but the study design ensured that various types of aircraft and engine were covered, including some about which (based on anecdotal reports) there had been a priori concern. No major fume events occurred during the sampling. Only a limited range of analytes were measured, although retained gas chromatography traces would allow assessment of others if required. Visual inspection suggested that in the absence of a major fume event, there was little correlation between pollutants in the temporal fluctuation of airborne concentrations (i.e. they did not all tend to go up or down at the same time). However, this was not examined by formal statistical methods.

6. Conclusions that can be drawn from the study are:

  i. Prospective monitoring of cabin air by the methods that were employed in this investigation is difficult because of the limited space in the flight deck and the need to accommodate both equipment and an operator. Given the rarity of major fume events, it would be extremely expensive to conduct such monitoring on sufficient flights to be confident of obtaining useful information about the patterns and levels of pollution during such incidents.

  ii. For the types of aircraft studied, and in the absence of a major fume event, airborne concentrations of the pollutants that were measured in the study are likely to be very low (well below the levels that might cause symptoms) during most flights. The data do not rule out the possibility of higher concentrations on some flights (only a limited sample of aircraft could be tested), or of higher concentrations of other pollutants that were not measured.

7. The study also provided data which had been useful in interpretation of the surface residues study (see below).

8. COT members did not identify any scientific questions of high priority that could be addressed by further analysis of data from the study.

9. A study on surface residues (Institute of Occupational Medicine, 2012) looked at an even smaller number of chemicals – four organophosphate compounds selected because they were common additives in aircraft lubricants and fluids, and had been a source of concern because of their potential neurotoxicity. However, the methods used could be extended to other non-volatile pollutants. The 17 aircraft studied had not been subject to any major fume events, and the levels of chemicals that were measured were all low. The authors of the report concluded that the levels appeared consistent with those from the cabin air-sampling study. However, this assumed a single value for deposition velocity applicable to all particles, and that that all of the contaminant was present as particles and not vapour, which may not be justified.

10.	A statistical analysis of reported incidents (Cranfield University, 2009) was limited by lack of information about the timing of fume events during the flights that were analysed. Thus parameters that were statistically associated with flights in which incidents occurred may have reflected the pilot's response to the incident rather than aspects of function that predict the occurrence of a fume event. The study did, however, demonstrate the feasibility of this type of statistical analysis, which with some refinement and simplification might usefully be applied in further research (see below).

11.	The review of recently published literature on chemical pollutants in aircraft cabin air was consistent with the results of the studies commissioned by DfT in showing only low levels of pollutants in the absence of any major fume event. Of particular note was a biomonitoring study by Schindler et al (2013) in which urine samples had been collected from pilots and cabin crew members who reported fume/odour during their last flight. None of the samples contained *ortho* tricresyl phosphate (*o*-TCP) above the limit of detection (0.5 µg/l), and while the fume incidents may only have been minor, the study demonstrated the feasibility of collecting meaningful data in this way. A study by Liyasova et al. (2011) who monitored adducts of a TCP metabolite with butyrlycholinesterase in blood, illustrated another biomarker of exposure that might be used. Adducts were detected in six out of 12 jet plane passengers, but only at very low levels.

12.	Taking into account information that it had considered previously (COT, 2007), along with the results from the new research that had now been reviewed, the Committee agreed several conclusions:

i.	Contamination of cabin air by components and/or combustion products of engine oils, including triaryl phosphates, does occur, and peaks of higher exposure have been recorded during episodes that lasted for seconds.

ii.	Episodes of acute illness, sometimes severely incapacitating, have occurred in temporal relation to perceived episodes of such contamination.

iii.	There are a number of air crew with long-term disabling illness, which they attribute to contamination of cabin air by engine oils or their combustion products.

iv.	The acute illness which has occurred in relation to perceived episodes of contamination might reflect a toxic effect of one or more chemicals, but it could also have occurred through nocebo effects.

v.	While there is strong scientific evidence that nocebo effects can lead to (sometimes severely disabling) illness from environmental exposures that are perceived as hazardous, there is no simple and reliable way of establishing

that nocebo responses are responsible for individual cases of illness. However, they are a plausible alternative explanation if toxicity seems unlikely. Distinguishing whether acute illness from fume events is likely to arise from toxicity or nocebo responses depends on: assessment of the patterns of symptoms and clinical abnormalities in affected individuals; the levels of relevant chemicals to which they might have been exposed; and what is known about the toxic effects of those chemicals and the levels of exposure at which such toxic effects occur (including the possibility that some individuals might be unusually sensitive).

vi.   The patterns of illness that have been reported following fume events do not conform with that which would be expected from exposure to triaryl phosphates such as o-TCP (which differs from the pattern of illness that occurs with over-exposure to organophosphate insecticides and nerve agents). Over-exposure to tricresyl phosphates would be expected to cause delayed peripheral neuropathy. Given the short duration of reported fume incidents, in order to cause such toxicity, peak exposures would have to be much higher than those which have been indicated by monitoring to date. For example, the current short-term exposure limit averaged over a 15 minute period) for o-TCP is 300 $\mu g/m^3$, whereas the maximum concentration of the compound that was recorded in the cabin air-sampling study was 22.8 $\mu g/m^3$. Assuming that a peak of exposure was sustained for a minute, it would need to exceed 4000 $\mu g/m^3$ to breech the short-term limit.

vii.   More generally, the Committee considers that a toxic mechanism for the illness that has been reported in temporal relation to fume incidents is unlikely. Many different chemicals have been identified in the bleed air from aircraft engines, but to cause serious acute toxicity, they would have to occur at very much higher concentrations than have been found to date (although lower concentrations of some might cause an odour or minor irritation of the eyes or airways). Furthermore, the symptoms that have been reported following fume incidents have been wide-ranging (including headache, hot flushes, nausea, vomiting, chest pain, respiratory problems, dizziness and light-headedness), whereas toxic effects of chemicals tend to be more specific. However, uncertainties remain, and a toxic mechanism for symptoms cannot confidently be ruled out.

viii.   Decisions to undertake further research will need to balance the likelihood that it will usefully inform further management of the problem against the costs of undertaking the work.

ix.   One possibility would be to collect better information about the incidence and nature of fume incidents, and the circumstances in which they occur. This would require airlines to record and retain a limited set of information on all

flights that they operate, including the place, date and time of departure and arrival; the type and age of aircraft and engines; the relevant service history of the engines; and whether a fume incident was reported during the flight. In addition, for the small minority of flights on which fume incidents were reported, information would be collected on the stage of the flight at which the incident occurred; its nature and duration; and any consequences (e.g. health effects in crew). This information could then be used to determine the incidence of contamination episodes by type and severity, and to assess their association with different features of flights (which might provide clues to methods of prevention and assist planning of further studies). Such associations could be explored using a case-control approach. Importantly, a study of this type would not require collation of all of the collected information in a single dataset. For example, one database might hold routine information about times and places of departure and arrival for each flight, and the identity of the plane. A second database might record details of each plane and its engines, including year of manufacture and service history. A third database could cover fume incidents, including the places and times of departure and arrival and identity of the plane, as well as information about the nature, timing and consequences of the fume incident. Information could then be abstracted from these databases and linked, but only for flights in which fume incidents occurred and a representative sample of control flights (a few hundred at the most).

x. As an extension to the above study, a case-control approach could also be used to investigate associations of fume incidents with operational parameters of the sort that were ascertained in the project previously commissioned by DfT, but this time restricted to those measured before the incident occurred. This might give further clues to aspects of engine operation that predispose to fume events.

xi. Another possible extension to a systematic study of fume incidents would be to collect and store samples of urine, and possibly blood, from crew members within 48 hours (the earlier the better) after such events. These could then be analysed for biomarkers of potential toxic pollutants, as in the studies by Schindler at al. (2013) and Liyasova et al. (2011). Again, this could provide evidence of exceptionally high levels of chemical contamination that might be sufficient to cause acute toxicity.

xii. Since 2007, there have been significant advances in the technology that is available for air-monitoring, and in theory it should now be possible to develop a compact, battery-powered automated system, in which a particle counter would run continuously, and trigger other sampling instruments if and when a fume incident occurred. The samples collected could then be used to identify any chemicals that occurred at exceptionally high concentrations during the

fume incident, and the levels at which they occurred.   To have a good chance of detecting at least one major fume incident, sampling would need to be carried out in many aircraft over many flights, and this would make data collection extremely expensive (possibly >£10m). Costs would be importantly reduced, however, if a way could be found to induce fume events experimentally, or if circumstances could be identified in which their incidence was much higher than the overall average.

xiii.   All of the options for research that have been described would require care in design and execution, and if wished, members of the COT with relevant expertise would be pleased to advise on the specification of calls for proposals and to provide peer-review of proposals that are received.

13.   Finally, it should be emphasised that illness can be disabling whether it occurs through toxicity or through nocebo effects, and therefore there is a continuing imperative to minimise the risk of fume incidents that give rise to symptoms.

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