# SMOKING AND AIRCRAFT: A REVIEW OF THE LITERATURE

Airline passengers and flight attendants are increasingly complaining about eye irritation, headaches, nose and throat irritation and breathing discomfort as a result of flying. Tobacco smoke has been pointed to as one very visible component of air on board aircraft, and therefore has been suggested to be the major cause of these symptoms. This, along with claims about the effects of environmental tobacco smoke (ETS) on health, has led to the banning of smoking on board commercial aircraft in many countries around the world

For many years now, air travellers have been provided by almost all airlines with the choice of seating either in smoking or nonsmoking sections of the aircraft. Although this approach has worked well over the years for the vast majority of passengers, and despite the lack of scientific justification for altering the situation, many airlines are considering banning smoking on board their aircraft, and many governments are proposing legislation to institute such bans formally. Such proposals abandon any effort to accommodate the preferences of both smokers and nonsmokers, and instead merely impose, without good scientific justification, a radical "solution" favoured by some anti-smoking activists.

More importantly, efforts to ban smoking on board aircraft in no way address fundamental concerns about cabin air quality that have been raised by many groups over the years. By focusing solely on environmental tobacco smoke, critical constituents of the aircraft environment such as ozone, cosmic radiation, low humidification, respirable suspended particles, and microbial aerosols, are being ignored, as are problems with aircraft ventilation or filtration. Whilst many see banning smoking as a "quick fix" to a complex problem, those who have seriously considered the scientific issues (ranging in the United States, for example, from the National Academy of Sciences to the Department of Transportation) appear to agree that responsible regulatory action in this area depends on careful consideration of the complex mix of elements in cabin air, not merely on observation of any single component.

In fact, studies of ETS in airline passenger cabins consistently find that average concentrations of ETS are very low - and significantly lower in nonsmoking sections than in smoking sections. These reported concentrations of ETS constituents such as nicotine are so low that they are well below, for example, the maximum exposure levels set by the US Occupational Safety and Health Administration (OSHA). Although some nonsmoking passengers may report being annoyed by exposure to ETS even at these very small levels, there is no scientific data indicating that exposure to ETS at these or any other levels poses a health risk. In fact, the data strongly suggest that it is poor ventilation, low humidity, and a build-up of substances such as ozone in the cabin that cause passenger discomfort and the symptoms noted above.

## Air Quality Problems on Board Aircraft

Just as in "sick buildings", the lack of adequate ventilation in aircraft reduces air quality by permitting pollutants to accumulate. Some of these substances and some of their sources include carbon dioxide, produced by human breathing and dry ice in airplane galleys; atmospheric ozone; fibres and dust; nitrogen oxides; volatile organic compounds from fuel, cleaning fluids and other sources; bacteria, fungi and viruses from food and passengers.

The ventilation system that is intended to dilute these substances generally utilises outside air brought through the engines. The air is frequently recycled, however, mixing the outside air with "used" air from the cabin.

Most aircraft today would be adequately ventilated if their systems were allowed to operate at capacity. But because reducing ventilation saves fuel, the systems are increasingly being cut back to use more recycled air and less fresh air. In response to the fuel crisis, McDonnell Douglas issued a report in 1980 contending that reducing fresh air cabin intake in its DC-10s by 50 per cent would save 0.8 per cent on fuel, and that the airlines could save a maximum of 62,000 gallons of fuel per year by installing recycled air systems in their aircraft. However, a closer examination shows the savings from reduced ventilation to be shortsighted. For example, on board the average Boeing 747 aircraft, increasing ventilation from 10 cubic feet per minute (cfm) to a minimum recommended rate of 20 cfm per passenger on a five-hour flight on board a full plane would result in a total cost increase of US $ 240, or approximately 60 cents per passenger.

In the United States both ASHRAE (the Association of Heating, Refrigeration and Air-Conditioning Engineers) and BOCA (the Building Officials and Code Administrators) have set ventilation standards for buildings. Both recommend a minimum amount of 20 cfm of fresh air per person. However, the *US National Academy of Sciences* in 1986 observed that in a typical Boeing 747 flight, passengers in economy class received less than 7 cfm - only 1/3 of that recommended in buildings. The rest of the air was recycled from the cabin. In first class, because of the smaller density of passengers, fresh air was provided at the rate of 30 - 50 cfm, whilst in the cockpit fresh air was provided at the rate of 150 cfm.

If there is poor ventilation (e.g. insufficient outside air in the overall mix), a build-up of carbon dioxide results, which makes the cabin stuffy and can cause headaches and lethargy. The *US National Academy of Sciences*, in its 1986 report, found carbon dioxide levels on aircraft well in excess of limits recommended by ASHRAE and NIOSH (the US National Institute for Occupational Safety and Health); studies on Lufthansa showed levels more than twice the standard when operating air packs at 50 percent capacity. Similarly, the US Department of Transport, in a study in 1989 (see *Nagda et al, 1991*), noted that on 87 out of 92 flights studied, the average carbon dioxide levels exceeded ASHRAE standards. Overall air quality inevitably suffers as a result and chemical constituents build up to levels that can cause discomfort.

Most review studies have reported that, with few exceptions, low humidity and ozone were the most likely causes of the most commonly reported symptoms by passengers and flight attendants. The level of water vapour in the atmosphere is between 70 to 80 percent, although most people are comfortable with a 30-65 percent level. However, on commercial aircraft monitored by the US FAA, the *National Academy of Sciences* found relative humidities on board aircraft to be extremely low: from 2 to 23 percent. At values less than 40 percent relative humidity, symptoms include dry mucous membranes, respiratory and skin irritation and irritated eyes. Flights of 3-4 hours in the 5-10 percent humidity range will cause irritation of the eyes, throat and lungs.

Low humidity is caused by outside air drying as moisture is removed when the engine compressors treat the cold air. Airborne viruses flourish in low humidity, so planes can become highly infectious places if the ventilation system is inefficient. Bacteria and fungal spores are also carried by air and may lodge in seat fabric, staying active for days.

Eleven percent of flights monitored by the FAA and reported in the NAS report violated FAA standards for ozone levels, with average levels well beyond the FAA limits of 0.25 per passenger mile and some levels more than eight times higher than recommended. Excess ozone exposure, even at levels below this maximum, can

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produce symptoms of discomfort in eyes, nose and throat, can bring on a persistent cough, and cause breathing difficulties.

In contrast to these findings, the 1986 NAS report and other studies have found no excessive levels of carbon monoxide, nicotine or airborne particulates, all of which have been linked to tobacco smoke as a source. Studies of nicotine on board aircraft showed levels, both in smoking and nonsmoking sections, to be well below ASHRAE and OSHA standards.

## Environmental Tobacco Smoke

Environmental tobacco smoke is produced when tobacco products are smoked. ETS is a combination of exhaled mainstream smoke (the smoke that is exhaled after a puff is taken) and sidestream smoke (the smoke that comes off the burning end of the cigarette between puffs). Before exposure occurs, both forms of smoke undergo a variety of changes - often referred to as "aging". Even more significantly, ETS is progressively diluted in the air until it leaves the particular environment by ventilation or is adsorbed onto surfaces. Like all other forms of smoke, ETS comprises gases and particles.

Banning airline smoking on health grounds cannot be justified by the available data. ETS has not been shown to cause disease in nonsmokers or to present a significant health risk to nonsmokers with pre-existing medical problems (see, for example, *Ecobichon & Wu, 1990)*.

A number of studies have been carried out that measure levels of nicotine in the air on board aircraft, to give an indication of the levels of ETS to which people are exposed, and the extent to which ETS influences overall air quality. The results are summarised in Table 1.

Many authors have attempted to compare their measurements of nicotine in the air with the amount of nicotine that the average smoker takes in from smoking one cigarette. From the reported studies, it has been suggested that nonsmoking passengers in nonsmoking sections are exposed to between the equivalent nicotine of 0.00094 *(Mattson et al, 1989)* and 0.0082 *(Oldaker et al, 1987)* cigarettes per hour. *Oldaker & Conrad (1987)* in fact estimated that it would take eight 28-hour round-trip flights from New York to Tokyo for a passenger seated in a no-smoking seat to be exposed to the nicotine equivalent of one cigarette. This amounts to 224 hours: just over one-quarter of the average flight attendant's annual in-flight time.

Studies have also measured exposure to respirable suspended particles (RSPs) in the air i.e. particles that are small enough to be breathed in. However, such particles are not unique to ETS, but occur from a variety of other sources on board aircraft. Those studies have therefore made another measurement: ultraviolet particulate matter (UVPM), which is believed to give a more accurate reflection of the portion of RSPs due to ETS. UVPM, however, may still occur from other sources and give an overestimate of particles that can be attributed to ETS. Nevertheless, the results from the studies that have looked at this are summarised in Table 2; again, the significant differences in both RSP and UVPM between smoking and nonsmoking sections of aircraft suggest that present policies of segregation work effectively.

One further type of study has been carried out: those that have measured levels of nicotine in the body fluids of flight attendants and passengers *(Foliart et al, 1983; Mattson et al, 1989)*. One group of authors *(Foliart et al, 1983)* concluded that physiological effects were unlikely from the low levels of nicotine observed.

The results of these studies have been summarised by *Holcomb* in 1988, who concluded that:-

> "The available scientific evidence does not support the prohibition of smoking on commercial aircraft. The data that are available reveal low concentrations of substances that can be traced to ETS in smoking sections, and even lower concentrations in non-smoking sections, thus confirming the efficacy of current in-flight smoking policies.
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> "The available data also suggest that factors or substances other than ETS may be major contributors to subjective complaints of discomfort by passenger and flight crew. Finally, given the limited and intermittent occasions for exposure, even in the case of compromised individuals and flight attendants, adverse health effects from exposure to ETS aboard aircraft are highly unlikely."

It is interesting to note that US occupational standards recommend a maximum exposure of 500 micorgrammes of nicotine per cubic metre of air over an 8-hour working day; clearly, the results in Table I indicate that levels of nicotine on board aircraft in no way approach this level, ranging from averages of 0.05-21.0 microgrammes per cubic metre of air in nonsmoking sections, to averages of 7.1-41.0 microgrammes per cubic metre of air in smoking sections of aircraft. It is therefore difficult to conclude, as many anti-smoking activists have, that tobacco smoking on board aircraft is a major contributor to poor air quality and a major source of discomfort to nonsmoking passengers seated in the nonsmoking sections of the aircraft. Given the potential for other major air quality problems on board aircraft - in particular the poor ventilation rates and low humidity levels - it is difficult to justify the suggestion that banning tobacco smoking on board aircraft is a major priority.

**Fire Safety on Board Aircraft**

A review of the causes of aircraft fires between 1962 and 1992 (using 63 different data sources representing the most comprehensive and authoritative aviation accidents and incident compilations, widely used by aviation safety professionals and the world aviation technical community, including technical and research papers prepared by fire safety experts) indicates that, over the 30-year period records were produced for 5980 accidents and incidents, less than 4 % of which involved fire as the principal factor. The great majority of fires involved engine/powerplant fires and smoke/fire with electrical system origin. However, of the 250 in-flight fire occurrences, only one has been officially attributed to a fire started by a passenger's cigarette. This was in the case of a Russian-built Ilushyn IL-18 aircraft, which did not incorporate advanced fire resistant materials or stringent in-flight regulations regarding cabin safety.

Two additional cases, although not confirmed or stated in official reports of findings, could have involved the careless use of cigarettes or, indeed, a match or overheated wiring or another cause of ignition; however, in one of those the airline had not complied with even the minimal requirements for fire protection and this was considered to be the primary causal factor.

In fact, it has been widely suggested that if smoking is totally banned on board aircraft, passengers who wish to smoke may be more likely to do so in places such as aircraft lavatories, where for safety reasons it is currently forbidden.

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**Competitive and Economic Considerations**

The sheer number of airlines who, having introduced smoking bans on board their aircraft, have found it necessary to rescind those bans because of passenger pressure, indicates the extent to which airline passengers believe that present policy of provision for both smokers and nonsmokers is the correct one.

A number of individual airlines (Virgin Atlantic, Lufthansa, Turkish Airlines, Qantas, Swissair, Lauda Air, Guernsey Airlines and KLM) have decided not to go ahead with such bans. Guernsey Airlines commented that the airline felt it was wrong to impose a ban when approximately one-third of the British population smokes. Smoking bans in some countries, introduced by government legislation, have also been withdrawn: in December 1990, for example, the Brazilian Supreme Court of Justice overturned the legislated smoking ban of domestic flights of two hours or less. Smoking is now permitted on a segregated basis.

Bans on smoking by individual airlines have on occasion been rescinded for reasons of competition and economics, as well as passenger pressure, in the fear that smoking passengers will simply select another airline. Bans on domestic flights in individual countries or within regions have also caused concern because of the possibility that passengers who wish to smoke may switch to alternative forms of transport.

Recent surveys by Canadian Airlines prior to a proposal to legislate smoking bans on all Canadian carriers' internal or international flights, estimated that such a ban would lead to 15 % of their customers switching to foreign airlines who would not be required to impose such a ban. They also indicated that there would be no more than a 3 % market share gain from nonsmokers, which would in no way compensate for the loss in business. On Pacific routes alone, Canadian Airlines predicted a 12 % drop in smoking passengers. Canadian Airlines also estimated that on their Japan to Canada route 53 % of its passengers are smokers and therefore the lost revenue in business class alone would be Canadian $ 16-24 million. They believed they would lose a substantial proportion of their revenue as a result of such a ban, as over 50 % of their operating income comes from international routes. Air Canada also confirmed that the ban would cost them up to Canadian $ 40 million in lost revenue. The Canadian carriers claimed that they would be forced into operating at a commercial disadvantage compared to foreign airlines with routes out of Canada. However, the introduction of smoking bans in Canada on international flights of Canadian carriers is to be deferred until 1993, rather than being implemented immediately. Canadian carriers claim that the ban would undermine the competitiveness of the industry at a time when airlines are already facing serious economic pressures.

## Conclusions

The situation regarding smoking on board aircraft can be summarised as follows:

- Previous attempts by individual airlines and by governments to introduce smoking bans have generally been unpopular with a significant proportion of airline customers;
- Smokers, although in most countries a minority, nevertheless represent a significant proportion of the population (in the EEC, for example, there are an estimated 100 million smokers in a total population of 300 million);
- Exposure to other people's tobacco smoke has not been conclusively proven to cause disease in nonsmokers;
- Tobacco smoke has not been shown the be the major contributor to poor cabin air quality; indeed, inadequate ventilation allowing build-up of substances from many different sources, together with low humidity, have been suggested to be the major causes of air quality problems on board aircraft;
- Available data suggests that factors such as poor ventilation and low humidity, along with high levels of substances such as ozone, are in fact the major contributors to passenger discomfort on board aircraft, which are commonly attributed by passengers to ETS;
- Measurement of levels of ETS constituents on board aircraft shows them to be extremely low, well within US occupational standards, and significantly lower in nonsmoking areas than smoking areas, indicating that segregation works well in reducing nonsmoker exposure to ETS;
- It has been estimated that a nonsmoker seated in a nonsmoking section would have to take eight 28-hour round-trip flights from New York to Tokyo to be exposed to the nicotine equivalent of smoking a single cigarette;

- A thorough review of the causes of fires on board aircraft does not provide evidence for the claim that cigarettes represent a major fire hazard, or that cigarettes are a significant contributor to aircraft fires over the past 30 years.

It is therefore difficult to justify the suggestion that smoking should be banned on board aircraft. The present system of providing both smoking and nonsmoking sections ensures that all passengers are catered for, and has worked well for many years now. The insistence of pressure groups on the necessity for smoking bans on board aircraft when the evidence simply does not justify it, indicates a continuance of their attempts to undermine the relationship between smokers and nonsmokers that has always been based upon common sense, tolerance and courtesy.

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## TABLE ONE

*CONCENTRATIONS OF NICOTINE ON BOARD AIRCRAFT*

| AUTHORS | NICOTINE ug/m³ SMOKING SECTION | NICOTINE ug/m³ NON-SMOKING SECTION | NICOTINE ug/m³ WHOLE AIRCRAFT |
|---|---|---|---|
| Muramatsu et al 1984 | | | 15.2 |
| Muramatsu et al 1987 | 13.5 | 5.3 | |
| Oldaker & Conrad 1987 | 9.2 | 5.5 | |
| Oldaker et al 1988 | 7.1 | 1.1 | |
| Drake & Johnson 1988 | 10.48 | 2.54 | |
| Malmfors et al 1989 | 41.0 business<br>32.0 tourist | 5.0<br>21.0 | |
| Mattson et al 1989 | 12.0 | 2.0 | |
| Oldaker et al 1990 | 10.6 | 2.3 | |
| Nagda et al 1990 | 13.43 | 0.05 | |
| Ogden et al 1989 | | | |

## TABLE TWO

*CONCENTRATIONS OF RESPIRABLE SUSPENDED PARTICLES (RSP) AND ULTRAVIOLET PARTICULATE MATTER (UVPM) ON BOARD AIRCRAFT*

| AUTHORS | RSP ug/m³ SMOKING SECTION | RSP ug/m³ NON-SMOKING SECTION | UVPM ug/m³ SMOKING SECTION | UVPM ug/m³ NON-SMOKING SECTION |
|---|---|---|---|---|
| Oldaker et al 1988 | 23.0 | 8.0 | 14.0 | 5.0 |
| Oldaker et al 1990 | 39.0 | 15.0 | 26.0 | 7.0 |
| Drake & Johnson 1988 | 37.5 | 13.48 | 23.9 | 6.69 |
| Nagda et al 1990 | 75.8 | 34.8 | | |