Maybe focus on
Indoor Air Quality & the Aircraft Cabin Environment

SMOKING AND AIRCRAFT: A REVIEW OF THE LITERATURE

(1.) Does Matt want a "Don't ban smoking" piece explicitly or could he live w/ a IAQ thrust.

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.

IAQ

(.) If only used 1st 3 1/2 pages would probably be ok, w/some fixing

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 formally institute such bans. Such proposals abandon any effort to accomodate the preferences of both smokers and nonsmokers, and instead merely impose, without scientific justification, a radical "solution" favoured by some anti-smoking activists.

Focus should be on IAQ not ETS, if possible.

More importantly, efforts to ban smoking on board aircraft in no way address fundamental concerns about cabin air quality that have been raised over the years from many sources. By focussing 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.

(.) change title
(.) be careful because this paper will get dated w/ discussion of studies.
IAQ
Probably not accurate accuracy ?

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

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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 concentrations poses a health risk. Re-work

Insert A

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 consists of 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 is at 30 - 50 cfm; whilst in the cockpit levels are at 150 cfm.

If there is poor ventilation (i.e. 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 which dries 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 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 is comprised of 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.

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

Foliart et al (1983) monitored flight attendant blood nicotine on transoceanic flights. Blood nicotine increased from a mean of 1.6 ng/ml to 3.2 ng/ml in five of six women. The authors concluded that physiological effects were unlikely. *Mattson et al (1989)*, similarly, demonstrated that nicotine can be detected as urinary cotinine in the most highly exposed non-smoking passengers and flight attendants.

Muramatsu et al (1984) published the results of a survey of nicotine measurements in the air of various indoor environments, including commercial aircraft. The researchers reported mean nicotine concentrations on seven Japanese domestic aircraft flights of 15.2 ug/m^3 - the equivalent on average of about eight one-thousandths (0.008) of a cigarette per hour. The authors concluded from these results that the exposure of persons to ETS in aircraft is "very small".

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In a more recent study *Muramatsu et al (1987)* found nicotine concentrations at average levels of 13.5 ug/m^3 in the smoking sections, and 5.3 ug/m^3 in the non-smoking section. In describing ETS exposure, Muramatsu et al calculated that a non-smoker exposed to the highest concentration of nicotine measured in a smoking section, at 28.78 ug/m^3, would be exposed to the equivalent nicotine of 0.014 cigarettes per hour.

Oldaker and Conrad (1987) reported measurements of nicotine in smoking and non-smoking section of Boeing 727 and 737 aircraft on domestic flights in the US averaging 55 minutes. Concentrations were reported to be 9.2 ug/m^3 nicotine in smoking sections, versus 5.5 ug/m^3 in non-smoking sections. These concentrations were reported to correspond to estimated mean exposures of 0.0041 and 0.0082 cigarette equivalents per average 55-minute flight, respectively.

Based on these measurements, the authors 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.

The differences in nicotine levels between smoking and non-smoking sections were statistically significant.

Oldaker and co-workers (1988) and *Drake and Johnson (1988)* investigated nicotine levels on JAL flights from New York - Tokyo and Tokyo - Hong Kong. Samples were taken not only of nicotine, but of respirable suspended particles (RSP) and ultraviolet particulate matter (UVPM), an upper estimate of the ETS contribution to RSP.

Mean levels of 7.1 ug/m^3 nicotine were observed in the smoking section, compared to 1.1 ug/m^3 in the non-smoking section. For RSP the mean concentrations were 23 ug/m^3 smoking and 8 ug/m^3 nonsmoking, and for UVPM concentrations were 14 ug/m^3 and 5 ug/m^3, respectively. The difference observed between smoking and non-smoking sections supports the effectiveness of smoker/non-smoker segregation on board aircraft.

In 1988 the US Center for Indoor Air Research funded a study of levels of ETS constituents and other indications of passenger cabin air quality on 48 flights on DC-9 and MD-80 aircraft of another major international carrier, *Malmfors et al (1989)* reported mean levels of nicotine ranging from 5 ug/m^3 in business class non-smoking seats, to 41 ug/m^3 in business class smoking seats.

In 1988, at the request of the US Surgeon General, the Smoking, Tobacco and Cancer programme of the National Cancer Institute conducted a study of ETS exposure on four Air Canada flights. *Mattson et al (1989)* reported a median nicotine level of 2 ug/m^3 in nonsmoking sections and a median nicotine concentration of 12 ug/m^3 in smoking sections. The authors also reported that passenger exposure to nicotine in-flight differed considerably depending on the flight, seating position and, interestingly, on whether the aircraft used 100% fresh air or 50% fresh and 50% recycled air. The personal exposure monitors of passengers on flights with 100% fresh air recorded significantly less nicotine exposure than those on the 50/50 flights. The average hourly exposure for passengers in no smoking sections in this study corresponds to 0.00094 cigarette equivalents, and for flight attendants assigned to smoking areas, to 0.0048 cigarette equivalents.

Oldaker et al (1990) carried out studies on board Boeing 747s between New York and Tokyo or Hong Kong in all classes of service. No statistically significant differences were observed between indicators of ETS exposure in different classes of service. The mean level of nicotine was 2.3 ug/m^3 in the nonsmoking section, and 10.6 ug/m^3 in the smoking section. Respirable suspended particle levels were at mean levels of 15 ug/m^3 in the non-smoking sections, and 38 ug/m^3 in the smoking sections. Ultraviolet particulate matter concentrations (representing the maximum level of particles that could be due to ETS) were at a mean level of 7 ug/m^3 in the nonsmoking, and 26 ug/m^3 in the smoking, sections. These results again support the conclusions that segregation of smoking and nonsmoking areas is effective in significantly reducing exposure to environmental tobacco smoke.

A joint study involving Geomet and the US Department of Transportation *(Nagda et al. 1990)* monitored nicotine and other air components over 92 flights, and reported mean levels between 0.05 ug/m^3 in a non-smoking section, and 13.43 ug/m^3 in smoking sections. The authors concluded that the levels of ETS constituents reported were strongly correlated with smoking rates and with smoking/no smoking areas.

Holcomb, reviewing the results reported above, 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.

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 ug/m^3 over an 8-hour working day; clearly, the nicotine concentrations encountered on board aircraft in no way approach this level. 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.

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