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IMPACT OF ENVIRONMENTAL TOBACCO SMOKE ON AIRLINE CABIN AIR QUALITY

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ABSTRACT

A number of commercial airlines have moved recently, under pressure from government or on their own initiative, to ban smoking on at least some flights. Yet measurements of the constituents of environmental tobacco smoke ("ETS") fail to support claims that exposure levels in aircraft affect adversely the health of non-smoking passengers or crew. It appears, moreover, that the discomfort that can be caused by pollutants or environmental conditions aboard commercial aircraft often is misattributed to ETS because of ETS's visibility.

INTRODUCTION

Considerable controversy surrounds the question of whether ETS, in the many settings where it is found, adversely affects the health of non-smokers. Where scientific evidence is lacking, assumptions and opinion often fill the vacuum. The controversy concerning ETS has been fueled in significant part by the news media, which frequently fail to recognise faulty research methodology or to distinguish between subjective symptomatic reports and scientifically established facts. Even when objective research counters subjective impressions, moreover, public pressure has induced some decision makers to ignore pertinent scientific findings.

Some countries have imposed restrictions or outright bans on smoking aboard commercial aircraft. Some airlines also have developed restrictive smoking policies. Such strictures have been based on the assumption that in-flight exposure to ETS often is a cause of discomfort or can harm the health of non-smoking passengers or crew.

The purpose of this review is to examine the available data on cabin air quality. Scientific data is reviewed in four categories:

1. Studies of Air Quality on Commercial Aircraft;

2. Other Significant Findings;

3. Health Effects of In-Flight Cabin Air; and

4. Effects of Ventilation and Air Filtration.

1. Studies of Air Quality on Commercial Aircraft

Few studies to date have comprehensively examined the possible health effects of ETS in conjunction with other factors affecting breathable in-flight air. This review summarizes the limited data that are available.

Carbon Monoxide: FAA/NIOSH (8) reported a mean of 2.8 ppm carbon monoxide with a maximum of 5.0 ppm. Several individual observers as well as airline data reported by the National Academy of Science ("NAS") in the U.S. (14) and Lufthansa (10) note values never exceeding 5.0 ppm. A French study (23) recorded a maximum of 5.0 ppm "at the end of the longest day flights when a large number of smokers were on board". These concentrations were far below France's then 50 ppm maximum standard and the standards set by the Environmental Protection Agency ("EPA") and the Occupational Safety and Health Administration ("OSHA") in the United States.

Particulate Matter: FAA/NIOSH (8) reported a mean of 40 $\mu g/m^3$ with a maximum of 120 $\mu g/m^3$ for particulates. Drake (4) reported an arithmetic mean of 41 $\mu g/m^3$ in smoking sections and 14 $\mu g/m^3$ in non-smoking sections of wide-body aircraft on long distance flights.

Several other individual observations and airline data have been reported by NAS (14) and Lufthansa (10). Aside from the FAA/NIOSH data, most NAS data (range of 10 to 1000 $\mu g/m^3$) are sketchy at best. The methodology and interpretation of such data must be viewed with caution.

Connor, et al. (3), have described a method for estimating the upper bounds of the fraction of particulate matter attributable to ETS. Using that method, Oldaker, et al. (17), in their wide-body study, reported a geometric mean ultraviolet particulate matter ("UV-PM") concentration in smoking sections of 34 $\mu g/m^3$ and in non-smoking sections of 12 $\mu g/m^3$.

Also well below EPA, OSHA and international standards, particulate exposure at the levels noted above should pose no significant health threat.

Nicotine: Nicotine, which is essentially specific to tobacco, has been used by some as a surrogate to measure ETS exposure. Muramatsu, et al. (12), reported an arithmetic mean of 15.2 $\mu g/m^3$ after measuring nicotine in seven commercial aircraft. More recently, Muramatsu, et al. (13), found an arithmetic mean of 13.5 $\mu g/m^3$ in smoking sections compared to 5.3 $\mu g/m^3$ in non-smoking sections.

Oldaker and Conrad (16) reported 9.2 $\mu g/m^3$ nicotine in smoking sections, as the geometric mean, versus 5.5 $\mu g/m^3$ in non-smoking sections of narrow-body aircraft. Drake and Johnson (5) found 13.8 and 2.8 $\mu g/m^3$, respectively, as the arithmetic mean in smoking and non-smoking sections of wide-body aircraft.

Such data show that smokers as well as non-smokers are exposed to minimal amounts of ETS, or at least to the nicotine component of ETS, on commercial aircraft with reasonably well operated ventilation systems. They also tend to confirm the efficacy of separating smoking and non-smoking passengers on commercial flights.

Oxides of Nitrogen and Ammonia: NO/NO_2 levels measured by Lufthansa (10) showed concentrations less that one-fourth of the West German occupational TLV. Another observer, cited by NAS (14), observed levels of 0-40 ppb for NO_2. FAA/NIOSH (8) reported less than 0.02 ppm for ammonia.

Carbon Dioxide: NAS (14) reported a personal observation of 550-1200 ppm for CO_2. Those values bracket most reported by Lufthansa (10), although Lufthansa reported some values near 2500 ppm when operating at 35,000 feet, particularly at reduced ventilation.

2. Other Significant Findings

Other chemical substances not associated with or relevant to ETS are commonly found in studies of cabin air quality. Some have been associated with reported symptoms by passengers and flight crew. Ozone has been associated with eye discomfort, chest pain or tightness, breathing difficulty, nasal irritation, persistent cough and sore throat.

Low cabin humidity has been observed to contribute to dry, irritated eyes, especially in the case of contact lens wearers. Several researchers (6, 11) have documented ozone and dry cabin effects, which at high altitudes often occur in conjunction with reduced oxygen.

The effects of these conditions as well as the possible presence of substances other than ETS are critical in distinguishing the causes of subjective symptoms. The available data suggest that what passengers and crew report as "allergy" to ETS may be irritation attributable more to ozone and low humidity than to ETS components. Since ETS is easy to smell and see, however, passengers and crew naturally tend to ascribe their symptoms to the most apparent substance.

Ozone: Though not an ETS constituent, ozone in sufficient concentrations is known to create physical discomfort. Few studies document aircraft ozone concentrations. NAS (14) has reported that with a 0.3 ppm concentration, eye discomfort, headache and nose and throat irritation occur. Decreased pulmonary function also may occur. In addition, NAS has reported asthmatic symtoms at 0.15 ppm.

According to NAS, 11 percent of FAA-monitored flights from 1978-1979 violated the ozone standard -- generally at altitudes of 30,000 to 40,000 feet. The FAA ozone standard limits exposure to 0.25 ppm above 32.000 feet or 0.1 ppm during any three-hour flight. Catalytic convertors, now found on most commercial airliners, can reduce ozone but must be properly maintained to be effective.

Relative Humidity: Dry cabin air is recognised as a major source of passenger and crew discomfort. At flight altitudes, cold, dry air is brought into the aircraft and heated, resulting in low humidity. At values less than 40 percent relative humidity, symptoms include dry mucous membranes and irritated eyes. Blinking to relieve dryness can produce further irritation and even increase sensitivity, which may mistakenly be reported as an "allergic" reaction.

FAA/NIOSH (8) reported relative humidity of 10-20 percent on commercial aircraft. Lufthansa (10) reported 8.5-25.0 percent. Vieillefond, et al. (23), noted an average of 12 percent in French airliners. These values fall well below the suggested 40 percent symptom threshold.

Other Chemicals or Vapors: Other potential irritants noted in cabin air include vapors from refuelling, outside and interior exhaust vapors and galley or toilet odors that could contribute to passenger discomfort. NAS (14) suggested that a variety of ground fumes sometimes invade commercial aircraft cabins. These include CO, NO_2, aldehydes (including formaldehyde), particulates and polynuclear aromatics.

FAA/NIOSH (8), however, found no aldehydes or volatile hydrocarbons above ppm detection limits. FAA/NIOSH did discover polynuclear benzo-[a]-pryene at a maximum concentration of a fraction of 1 $\mu g/m^3$. Lufthansa (10) measured what was described as Kerosin (toluol), reporting 5 ppm in cabin air for 30 minutes after take off.

Airborne Biological Pollutants: While NAS (14) conjectured that bacteria, fungi a[illegible] viruses could pollute enclosed cabin environments, no systematic investigations ha[illegible] yet been reported on that topic. NAS (14) as well as the U.S. Department [illegible] Transportation, in the latter's 1987 report to Congress (22), did describe o[illegible] confirmed instance of a communicable disease -- influenza -- spreading within a[illegible] airplane having an inoperable ventilation system. Further study of this issu[illegible] obviously is needed.

3. Health Effects of In-Flight Cabin Air

The following review of health effects in relation to cabin air quality concentrate[illegible] on three populations:

- passengers without compromising medical conditions;
- passengers with compromising medical conditions; and
- flight attendants.

In considering the possible health significance of cabin air quality, an importan[illegible] temporal ingredient must be borne in mind. Even the most frequent travelers seldo[illegible] spend more than 10 hours per month on average in a commercial aircraft. For mos[illegible] passengers, the average flight time is considerably less than 10 hours per month. Airline cabin crews undoubtedly receive the most exposure to cabin conditions of th[illegible] three populations noted above. NAS (14) reported that 80 percent of U.S. fligh[illegible] attendants in 1984 flew 70 to 80 hours per month, which is less than one half of th[illegible] time used for the development of most occupational standards. Additionally, since attendant hours cover extended periods when smoking is not permitted (loading and unloading, take off and landing, airfield delays), ETS exposure -- though not exposure of other cabin conditions -- is limited to the times passenger smoking is permitted. In light of such limited and intermittent exposure, a health effec[illegible] involving ETS would not be expected.

Air transportation can present a variety of problems to people suffering from various illnesses -- including chronic cardiovascular disease, pulmonary conditions such as cystic fibrosis, chronic emphysema, cyanotic congenital heart disease, chronic asthma and coronary insufficiency. As a consequence, the American Medical Association (1), among others, has recommended that certain compromised individuals contemplating air travel should seek medical advice before traveling. In some circumstances, air travel by compromised individuals may be contraindicated.

No effects of ETS on ill or compromised individuals has been documented. The U.S. Surgeon General (20) reviewed key respiratory and cardiovascular data but found no adverse health effects resulting even from long-term ETS exposure. No relationship was found between the incidence of cough, phlegm or wheezing in non-smokers exposed to ETS. Regarding asthma, the report uncovered no adverse impacts in reviewing research studies. Of cardiovascular disease and ETS, the report stated that more detailed research was required before any conclusions could be reached. The NAS report (15) confirmed these findings.

The available data indicate that flight attendants -- the most heavily exposed group -- receive minimal doses of ETS constituents. Foliart, et al. (9), studied flight attendants on a transoceanic flight. Blood nicotine increased from a mean 1.6 ng/ml in five of six women to 3.2 ng/ml. After comparing these values to the 15-45 ng/ml in typical smokers, the authors concluded that physiologic effects were unlikely.

4. Effects of Ventilation and Filtration

Dispersing, segregating or removing pollutant concentrations depends largely on the ventilating systems inside aircraft. The concentration of all pollutants are diminished as a function of the number of air changes that occur, the efficiency of filtration, the amount of fresh air brought into the cabin and the overall level of hygiene associated with the ventilation system. Zoned or stratified ventilating systems, venting air more forcefully from specific sections of the cabin, can remove or dilute vapors or gases to improve overall air quality.

Several recent studies (4, 5, 10, 14, 16) have reviewed the movement and density of pollutant concentrations as a function of ventilation. Those studies have shown that three air-conditioning units or packs govern the amount of fresh air intake and interior venting in most commercial airliners. Each usually operates independently -- at off, half capacity or full capacity. Because of the design of most aircraft ventilation systems, there is little mixing of air from one air treatment zone to another. Cabin air typically moves from ceiling to floor, with only a slight flow from the front of the cabin to the rear. Although air sometimes recirculates within zones, the design of most systems prevents the recirculation of air from one zone in the cabin to another.

FAA/NIOSH (8) reported that average air exchanges were about three to four minutes, or about 15 to 20 per hour. Oldaker and Conrad (16) reported 22.7 to 26.5 air exchanges per hour. Drake and Johnson (5) found that all three air conditioning packs were operated automatically at full rate throughout the flights on which they measured air quality.

NAS (14) claimed that passenger smoking patterns cause highly transient concentrations of ETS in non-smoking sections. But it offered no scientific references to support the claim. The report also implied that ETS is recirculated in the cabin -- yet data presented elsewhere in the NAS report indicate that such recirculation may be far less common than implied. As noted previously, moreover, there is little air movement in the modern commercial aircraft between compartments or zones.

Results of Oldaker and Conrad (16) and Drake and Johnson (5) show that air quality models must account for the unique ventilation characteristics of aircraft. Models assuming the complete mixing of ETS in passenger cabins (19) have been shown by these recent reports to be inappropriate for B727-200, B737-200, B737-300, B747-100, B747-200 and similar aircraft.

Commercial airliner ventilating systems provide fresh air at rates that generally exceed standards for non-aviation environments recommended by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (7). Examining seven transport aircraft in 1981, FAA determined that ventilating systems provide 17.2 to 25.7 cubic feet of fresh air per passenger per minute. This exceeds the proposed rate of 15 cfm/person for all transport modes now under consideration by ASHRAE.

CONCLUSION

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 passengers and flight crew. Finally, given the limited and intermittent occasions for exposure, even in the case of compromised individuals and cabin attendants, adverse health effects from exposure to ETS aboard aircraft are highly unlikely.

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LETTERS

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CONTENTS