The Air Up There: Controversies Regarding the Toxicity of Aircraft Breathing Air

Michael J. Kosnett, MD, MPH
Associate Clinical Professor
Division of Clinical Pharmacology & Toxicology
Department of Medicine
University of Colorado School of Medicine, and
Department of Environmental and Occupational Health
Colorado School of Public Health

Michael.Kosnett@ucdenver.edu
303.571.5778
Adverse health symptoms reported by commercial airline passengers and crew are broad and nonspecific, but often relate to dry eyes and skin, sinus congestion, and sore throat.
The self-reported health of U.S. flight attendants compared to the general population

• Comparison group was age and gender weighted subsets of NHANES 2005-2008, yielding Standardized Prevalence Ratios for different health conditions

Mean age 46.7 ± 9.8 yrs; 80% female; 91% nonsmoker; 12.2% overweight or obese; 41% had 20+ years on the job

• 29% reported sinus congestion lasting 5-7 days over past week
• 55% reported “reactive airways/sinusitis/allergies “ needing medical attention over past 12 months
<table>
<thead>
<tr>
<th>Reported Health Condition</th>
<th>Gender</th>
<th>Standardized Prevalence Ratio (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Bronchitis</td>
<td>Male</td>
<td>3.59 (2.90 – 4.28)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2.75 (2.51 – 2.99)</td>
</tr>
<tr>
<td>Asthma</td>
<td>Male</td>
<td>0.94 (0.75 – 1.12)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.91 (0.82 – 0.99)</td>
</tr>
<tr>
<td>High Blood Pressure</td>
<td>Male</td>
<td>1.0 (0.86 – 1.19)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.54 (0.49 – 0.58)</td>
</tr>
<tr>
<td>Fatigue (almost daily in 1-2 weeks)</td>
<td>Male</td>
<td>2.18 (1.57 – 2.78)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1.83 (1.63 – 2.03)</td>
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[McNeely et al, 2014]
Some toxicological considerations regarding aircraft air:

- Ozone
- Inadequate Ventilation
- Pyrethroid insecticides
- Aircraft Chemicals (jet oil, hydraulic fluid)
Ozone catalytic converter on some aircraft
Commercial aircraft encounter highest levels of ozone at higher (e.g. northerly) latitudes, and during late winter / early spring.

At 35,000 ft, ozone levels of about 500 ppb can be encountered at 50°N in spring months -- an order of magnitude higher than ground level ozone.
At sufficiently high dose, acute ozone exposure can elicit respiratory effects such as cough, chest tightness, and discomfort on deep inspiration.

At rest, 400 ppb x 2 hrs may elicit overt symptoms in healthy adults.

During moderate exercise, 60 ppb x 6.6 hrs:
- reversible subclinical decrements in pulmonary function
- (FEV1) increased pulmonary inflammation in healthy adults

Asthmatics may be more susceptible to the effects of ozone (via enhanced allergic cytokine production and IgE expression)

Older adults and those with COPD may be less susceptible.

- Short-term tolerance to the respiratory effects of ozone develops with consecutive daily exposure during a week.
- Chronic exposure: epidemiological data indicate risk of new or worsening asthma

[EPA ISA for Ozone, 2013]
The current EPA NAAQS for ground-level ozone (8 hour TWA) is 75 ppb, and EPA (2014) has proposed revising it to as low as 60 ppb

- Since 1985, the Federal Aviation Administration (FAA) set a maximum allowable level aboard aircraft of 250 ppb at any time, and an average value of 100 ppb during any 3 hour interval.
- Compliance attempted by use of catalytic converters, or route planning.
The influence of ozone on self-evaluation of symptoms in a simulated aircraft cabin


Setting: full-scale model of 3 row, 21 seat section of Boeing 767 aircraft built inside a climate chamber at Danish university. Seats, used carpet, and window panels taken from actual aircraft; Recorded aircraft cabin noise and cabin lighting.

Blinded cross-over design, comparing subjective and objective measurements in 29 Danish women (age 19-27) exposed to 4 simulated flights with 4 different conditions (variable ozone level, ventilation rate) over a 2 week period.

<table>
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<tr>
<th>Ozone in Cabin (ppb)</th>
<th>Fresh Air Ventilation (L/s/person)</th>
</tr>
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<tbody>
<tr>
<td>&lt; 2</td>
<td>2.4</td>
</tr>
<tr>
<td>61</td>
<td>2.4</td>
</tr>
<tr>
<td>&lt; 2</td>
<td>4.7</td>
</tr>
<tr>
<td>74</td>
<td>4.7</td>
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</table>
Primary analysis compared subjective ratings on visual analog scale or acceptability scale for 29 variables (e.g. ENT irritation, skin dryness, headache, odor, IAQ) after 3.25 hr of simulated flight.

Visual acuity, nasal airflow resistance, and skin dryness measured

*Overall IAQ and 11 symptoms were rated worse for high ozone condition vs low (background) ozone condition.*
Figure 3.

Odour Intensity

12 of the 13 assessments after 3 months of indoor air quality monitoring of ozone levels revealed no significant differences between conditions with and without ozone exposure. However, a significant difference was observed in the incidence of headache, with a higher number of participants reporting headaches in the ozone exposure condition compared to the control condition. The results are shown in the figure below.

**Headache**

- <2 ppb: 13
- 61 ppb: 24
- <2 ppb: 20
- 74 ppb: 20

**P-values:**
- <2 ppb vs. 61 ppb: P<0.009
- <2 ppb vs. 74 ppb: P<0.005

**Flow rates:**
- 2.4 L/s per person
- 4.7 L/s per person

**Eye Irritation**

- No irritation: 2.1
- Slight irritation: 3.6
- Moderate irritation: 2.5
- Strong irritation: 7.2

**P-values:**
- No irritation vs. Slight irritation: P<0.015
- Slight irritation vs. Moderate irritation: P<0.009
- Moderate irritation vs. Strong irritation: P<0.002
- Strong irritation vs. Overpowering irritation: P<0.014

Ozone's impact on aircraft passenger symptoms was also evaluated, with a slight decrease in acceptable conditions with ozone exposure compared to the control condition. The data is shown in the figure below.
Ozone levels in passenger cabins of commercial aircraft on North American and transoceanic routes


- Real-time ozone measurements obtained in 76 flights > 3.5 hrs between 2006-2007. Results were obtained during all seasons, on different types of aircraft (B737, 747, 757, 767, 777, A319, A320)
- Of 68 domestic (USA) flights; 22 were equipped with catalytic converter to diminish ozone.
periods when ozone-rich stratospheric air is injected into lower altitudes. Enhanced vertical mixing of this type can accompany cyclogenesis and the instigation of new weather systems. Appenzeller and Davies (28) describe the structure, direction, and size of stratosphere-to-troposphere intrusions, the pressure and frontal systems that are associated with them, and regions where the intrusions are favored at various times of year. Morgenstern and Marenco (29), via an analysis of ambient airplane ozone measurements collected through the MOZAIC project, affirmed that outliers to the seasonal trend in wintertime ozone are associated with the North Atlantic storm track, an observation consistent with ours.

An effect owing to flight-route latitude is indirectly evident in a comparison of the domestic and transoceanic flight data but is not apparent within our domestic sample. In general, flights at higher latitudes are more likely to cross the tropopause, as the tropopause height diminishes from about 18 km at the equator to about 6 km at the poles. We observed this trend in the form of higher in-cabin ozone on transoceanic versus domestic routes, for converter-equipped aircraft. The domestic routes were restricted to latitudes south of about 50° N (with the exception of two round-trip flights to Anchorage, Alaska), whereas long-haul flights within the northern hemisphere typically follow polar routes, including latitudes north of 50° N. The lack of a clear latitude signal in our domestic data is expected, because although the tropopause altitude can demonstrate an approximately two-fold variation across the United States in both North–South and East–West directions, the change is not linear or constant with time (30).

Higher-occupancy flights might be expected to have lower in-cabin ozone. Experiments in a simulated aircraft cabin (19) showed that approximately 60% of in-cabin ozone removal could be attributed to human occupants. Our data do not exhibit this effect. However, our analysis is constrained by the small number of sampled flights with low occupant density. On 53 out of 72 instances (33 out of 45 instances for domestic flights without converters) where data on occupant density was recorded by the researcher, the aircraft cabin was more than 80% full. Also, occupant density is correlated with season, as planes are more likely to be fully occupied in the summer and to have empty seats in the winter. Because the seasonal effect is strong and in the same direction as the anticipated effect owing to occupancy, and because the measured range in occupancy is narrow, the expected effect of occupancy could not be resolved.

This field investigation substantially adds to the state of knowledge regarding contemporary ozone levels in the passenger cabins of commercial airplanes. Ozone levels were found to vary strongly with the presence or absence of an ozone converter and with season. For aircraft with converters, levels were elevated on flights following long-haul high-latitude routes relative to those restricted to domestic routes. We observed that the risk of elevated cabin ozone levels increases during winter-spring storms, suggesting that these are associated with hot spots of high ambient ozone in the midlatitude air traffic corridor. Emerging epidemiological evidence indicates that ozone exposure can lead to an elevated risk of mortality with no threshold. In combination with evidence on within-cabin production of harmful volatile byproducts of ozone-initiated chemistry, these epidemiological data lend weight to the benefits of using ozone converters to reduce ozone exposure in airplanes, even on domestic routes.

Acknowledgments
This work was funded by the U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine through the Air Transportation Center of Excellence for Airliner Cabin Environment Research (ACER), Cooperative Agreement 04-C-ACE-UCB. Although the FAA has sponsored this project, it neither endorses nor rejects the findings of this research.

One flight without catalytic converter, during cold April day, with winter storms

Flight during cold weather, same week, but in airplane with catalytic converter
ozone greater than 100 ppbv on 15 out of 42 transoceanic flights, Spengler et al. (recently, using passive samplers to determine flight-average ozone levels measured by Bischof et al. (lower than 10 ppbv—on domestic converter flights. On transoceanic flights, and the lognormal fits using these parameters, are presented for each distribution. Levels of 100 ppbv and 250 ppbv are indicated to facilitate comparison with levels specified in Federal Aviation Regulations (FAR) for cabin ozone. Pea frame) and sample-average (lower frame) ozone mixing ratios for aircraft equipped with converters, ozone levels on flights converted in passenger cabins on 68 domestic U.S. flight segments. This difference is statistically significant (k 1 h levels were very low—less than they do on flights restricted to domestic routes (Figure 2). The peak 1 h ozone (GM 2.5 ppbv (1.4, 2.6 ppbv) for converter flights, respectively. For sample-average levels, the weighted GMs (GSDs, AMs) are 20 ppbv (2.1, 28 ppbv) for nonconverter and converters. The presence of an ozone converter is statistically significant (k 1 h ozone and sample-average ozone (GM 3940 ppbv) on transoceanic flights were about 4 times higher than those on continental U.S. flights with following long-haul, high-latitude routes span a greater range for aircraft equipped with converters, ozone levels on flights without converters. Levels are generally, but not always, below the limits specified in the FAR. Since the FAR was chosen to facilitate comparison with a passenger's total ozone exposure during the course of routine activities when not flying. According to a recent analysis, total daily ozone exposures on aircraft can, in a few hours, reach levels comparable to what would be encountered on the ground for both pea contaminants in the supply air. Pea plane—a Boeing 767—had results consistent with ours (Boeing 747–200. Only 20% of the aircraft of this model are estimated to be equipped with a converter (Boeing 747–400 aircraft, which was rolled out in 1988 (soceanic sample: ozone levels were highest on the older planes—a Boeing 767—had results consistent with ours (Boeing 747–200). The only other prior study involving one of these newer planes—a Boeing 767—had results consistent with ours (Spengler et al, 2008) before ozone converters were introduced. Both of these studies were pilot-scale studies and were confirmed by airline personnel to have converters. Our sample of transoceanic flights belonged to newer models of ozone converters on different aircraft models. Aircraft type was chosen to facilitate comparison with levels what would be normally experienced when not flying. In addition to ozone itself, exposure to the products of these contaminants in the supply air.
• Aboard the confined space of an aircraft, passengers are exposed not only to ozone, but to reaction products between ozone and organic chemicals in the cabin, including human skin oils (e.g. squalene).

• Ozone reacts with unsaturated hydrocarbons to yield C3-C10 aldehydes; 6-methyl-5-hepten-2-one (6-MHO); 4 oxopentanal, and other aldehydes, and ketones (e.g. acetone)
In a second set of experiments at DTU, we used multiple analytical methods to characterize the gas-phase products formed when ozone was added to cabin air during simulated four-hour flights that were conducted in the reconstructed section of a B-767 aircraft containing human occupants (Weschler et al., 2007). Two separate groups of 16 females were each exposed to four conditions: low air exchange (4.4 air changes per hour) and low (< 2 ppb) ozone; low air exchange and elevated (61-64 ppb) ozone; high air exchange (8.8 air changes per hour) and low (< 2 ppb) ozone; and high air exchange and elevated (73-77 ppb) ozone. The addition of ozone to the cabin air increased the levels of identified byproducts from ~70 to 130 ppb at the lower air-exchange rate and from ~30 to 70 ppb at the higher air-exchange rate (Figure 7).

Figure 7. Sum of the organic compounds detected in the cabin air for the four different conditions indicated on the horizontal axis.

Most of the increase was attributable to acetone, nonanal, decanal, 4-oxopentanal (4-OPA), 6-methyl-5-hepten-2-one (6-MHO), formic acid, and acetic acid, with 0.25-0.30 moles of quantified volatile product generated per mole of ozone consumed. Figure 8 shows the yields of the major ozone-derived products at both the low and high air exchange rates. Several of these compounds reached levels above their reported odor thresholds. A recent study conducted by researchers at NIOSH indicates that in vitro exposure of pulmonary epithelial cells to 4-OPA results in expression of various inflammatory markers (Anderson et al., 2010). That finding is suggestive that exposure to 4-OPA might have associated health risks. Related research has further advanced the understanding of ozone's reactions with human skin lipids (Wisthaler and...
Thirty-five ppb-hrs is the median ozone total exposure over all 32 flights with ozone byproduct samples. Both plots show the concentrations of these compounds are affected by the presence of ozone as well as the ventilation. The flights with more than 35 ppb-hrs ozone have 6-methyl-5-heptene-2-one on average concentrations four times higher than those with less than 35 ppb ozone. The three other ozone byproducts measured: octanal, nonanal and decanal show similar relationships though not as strong (Figure 22).

The eye and airway irritation of these reactive species need to be evaluated in the context of co-occurring ozone and these compounds.

Figure 20. Cabin ventilation (Liters/second/person) plotted against cabin concentration 6-methyl-5-heptene-2-one (6-MHO), in ppb, for flights with a total ozone exposure less than 35 ppb hrs and flights with a total ozone exposure greater than 35 ppb hrs for 26 of the 32 airline B flights with detectable levels of 6-MHO. 35 ppb hrs was the median total ozone exposure for the 32 flights.

Ventilation was of calculated using a $G(\text{CO}_2)$ value of 18.2 L/hr.

Figure 21. Cabin ventilation (L/s/p) plotted against the sum of the cabin concentrations of 6-methyl-5-heptene-2-one, octanal, nonanal and decanal (in ppb) for flights with a total ozone exposure less than 35 ppb hrs and flights with a total ozone exposure greater than 35 ppb hrs for 26 of 32 airline B flights with detectable levels of the sum of the four compounds. 35 ppb hrs was the median total ozone exposure for the 32 flights. Ventilation was calculated using a $G(\text{CO}_2)$ value of 18.2 L/hr.

Spengler et al, 2012
Ventilation and Fresh Air Supply Rates in Commercial Aircraft

• The air supply in passenger cabins typically is a mixture of 50% fresh outside air and 50% recirculated air.

• The ANSI /ASHRAE standard for aircraft requires a minimum of 3.5 /L/s/of “fresh” outside air per person

• Fresh air supply rate per person (or seat) in aircraft cabins is typically in the range of 3.6 to 7.4 L/s.

In indoor environments, low ventilation rates for fresh air have been associated with a constellation of symptoms that include eye, nose, and throat irritation, headache, and fatigue – “Sick Building Syndrome” (Fisk et al, Indoor Air 2009: 19:159-165)
Quantitative relationship of sick building syndrome symptoms with ventilation rates

Fisk et al, 2009

\[ y = \exp\left(-0.0541981 + 0.00093939x\right) + 0.452511 \]
• Steady state concentrations of carbon dioxide in occupied indoor spaces has often been used as a indicator of the adequacy of ventilation.
• ASHRAE standards allow for a maximum of 1000 ppm CO₂
• However, CO₂ at 500 to 800 ppm has been associated with an increase in SBS type complaints in office buildings [Erdmann & Apte, 2004]

Typical values of CO₂ in aircraft cabin air have been in the range of 1100 to 1700 ppm [NRC 2002]

A recent study sponsored by FAA found average CO₂ level during cruise was 1,404 ppm, (range 863 - 2,056 ppm) (n = 83 flights) [Spengler et al, 2012]
Direct adverse cognitive effects of low/mod CO$_2$?

22 adult subjects were tested inside a chamber in 3 CO$_2$ conditions in separate 2.5 hr sessions in the same day.

For most variables, performance was slightly worse at 1000 ppm and substantially worse at 2500 ppm CO$_2$.

[Satish et al, EHP 120:1671-1677; 2012]
Treatment of aircraft with pyrethroid insecticides

Required by a limited number of countries on either inbound flights while passengers are aboard (e.g. Madagascar, Uruguay), or when aircraft is unoccupied (e.g. Australia, New Zealand). Banned in USA in 1979

Typical agents, per WHO guidelines, consist of 1-2% solution of permethrin or d-phenothrin
Using a wipe sampling technique, permethrin was routinely detected (at low surface loadings) on all interior surfaces of aircraft arriving from countries that required aircraft treatment.

Urine samples were collected from 28 flight attendants, 18 – 65 y.o., with 17 working on flights that were not disinsected with pyrethroid insecticides, and 11 working on disinsected flights. 3 urine samples per person were analyzed for pyrethroid metabolites.
“It is expected that flying public would be similarly exposed to pesticides on those flights…. A review of the risk due to pesticide exposure crew and passengers on aircraft flying into countries required disinsection should be done and alternate approaches to prevent the transport of insects on commercial aircraft should be evaluated.”
Case Study: Analysis of Reported Contaminated Air Events at One Major US Airline in 2009-10

J.T.L. Murawski
Association of Flight Attendants-CWA, AFL-CIO, Washington, DC 20001

41st International Conference on Environmental Systems
17 - 21 July 2011, Portland, Oregon

- “Fume events” reported by flight attendants or pilot to airline or union, or cited in Service Difficulty Difficulty Reports submitted by airline to FAA during 2009 and 2010
- “…an unusual odor, a visible smoke/haze, symptoms consistent with exposure to oil or hydraulic fumes, or some combination thereof”
- 87 “fume events” on 47 aircraft
- 41 recorded in SDR or pilot/maintenance logs
- 44 detected prior to take-off; 20 resulted in cancellation of flight
- 3 with visible smoke or haze in cabin
- In 27 of 87 flights, ≥ 1 crew sought emergency medical care
- In 43 of 87 flights, ≥ 1 crew sought follow-up medical care
Tricresyl Phosphate Esters in Jet Oil and Hydraulic Fluids

Jet engine lubricating oils have often contained 1 – 5% TCP; hydraulic fluids up to 1% TCP; ortho isomers have recently comprised less than 0.2% of all TCP

Since the Prohibition-era “Jamaica Ginger” epidemic, TCPs have been linked to organophosphate induced delayed peripheral neuropathy. The ortho isomers are most potent in this regard: mono>di>tri

- Current toxicology data have not established the ability of TCPs to cause acute CNS effects by inhalation as a fine mist or aerosol
- The capacity of TCPs to cause acute CNS effects at a dose that does not cause delayed peripheral neuropathy is not established
Development of diagnostics in the search for an explanation of aerotoxic syndrome

Lawrence M. Schopfer a,*, Clement E. Furlong b, Olouana Lockridge a

aSpokane Institute, University of Washington Medical Center, Spokane, WA 99258, USA
bDepartment of Medicine, Division of Medical Genetics, and Department of Genome Sciences, University of Washington, Seattle, WA 98195, USA

Abstract

Aerotoxic syndrome is assumed to be caused by exposure to tricresyl phosphate, an additive in engine lubricants and hydraulic fluids that is activated to the toxic 2-(ortho-cresyl)-4H-1,3,2-benzodioxaphosphorin-2-one (CBDP). Currently, there is no laboratory evidence to support intoxication of airline crew members by CBDP. Our goal was to develop methods for testing in vivo exposure by identifying and char-
Carletti et al (2011), reported that CBDP, a TOCP metabolite, was a potent inhibitor of BChE in vitro ($10^7$ - $10^8$ M$^{-1}$ min$^{-1}$), similar to OP nerve agents.

It also significantly inhibited AChE, albeit 1 to 2 orders of magnitude more slowly.
Recent studies have detected measurable quantities of TCPs in the cabin air of commercial and military aircraft.

Crump et al. (2011) from Cranfield University (UK), detected TCPs in 25 of 100 test flights of commercial aircraft.

The 95th percentile for total TCPs for climb phases of all flights was 0.2 µg/m³. Max value was an outlier: 37.7 µg/m³.

No acute CNS symptoms were reported by flight crews.

Spengler (2012) detected TCPs in only 1 of 71 samples in USA (FAA) study of commercial airline flights; the one detect was at a concentration of 0.0015 µg/m³.

The OSHA PEL for TOCP is 100 µg/m³ as an 8 h TWA.

Based on animal studies of TOCP toxicity extrapolated to human, a subchronic NOAEL for a 70 mg adult would be 9 mg/d p.o. (NRC, 2002). The amount inhaled at 40 µg/m³ x 3 h at high resp rate (3.5 m³/h) would be 0.43 mg.
Exposure to tri-o-cresyl phosphate detected in jet airplane passengers.

[Liyasova M et al. Tox Appl Pharm 256:337-347; 2011]

By examining plasma treated with CBDP, the activated metabolite of TOCP, investigators isolated a unique peptide adduct.

- Butyrylcholinesterase purified from 25 ml plasma was treated with varying amounts of CBDP, and then pepsin digested
- Phosphorylated peptide fragments were enriched by binding to titanium oxide beads, and then eluted
- A 9 peptide sequence from the active site of BChE, phosphorylated on Ser198, was quantified by mass spectrometry

Per authors: no other OP or environmental chemical except CBCP derived from TOCP is known to produce this exact phosphorylated peptide.
• Blood from 12 randomly selected jet airplane passengers was tested for the presence of phosphorylated BChE 24 – 48 hours after a flight
• Six of 12 were positive, with 0.05 to 3% of their BChE phosphorylated
• None of the passengers had symptoms, or had detected “fumes” during their flight

Four of 6 positive passengers donated blood for analysis 3 to 7 months after their last flight. All samples were then negative.

Not unexpected, since BChE has a $T_{1/2}$ of 12 days in the blood

• No epidemiological studies using this biomarker on passengers or aircraft pilots or flight attendants have been published to date, but some may be planned or in progress.
Advantages for passengers and cabin crew of operating a gas-phase adsorption air purifier in 11-h simulated flights

• Subjective symptoms in 4 groups of 17 adult subjects were compared in an 11 hour flight in a simulated B767 cabin inside a chamber.
• The tested conditions included lower and higher ventilation rates (2.4 L/s/p v. 3.3 L/s/p), with and without an absorptive filter treating the recirculated air
• Four different conditions were compared, each person serving as their own control

At 10 hours into the flight, subjects experienced less throat irritation and eye dryness with the lower ventilation rate with the filter, compared to the higher ventilation rate without the filter

Based on these findings, Boeing has designed the B787 to include absorptive filters on the recirculated air.
Flatulence on airplanes: just let it go

Hans C Pommergaard, Jakob Burcharoth, Anders Fischer, William E G Thomas, Jacob Rosenberg

- Average healthy person emits 0.7 – 1.0 L intestinal gas per day; with an average of 10 ± 1 emissions per day
- In accordance with the Ideal Gas Law, the volume of intestinal gas will increase at the lower barometric pressure of an aircraft at 8,000 ft (565 mmHg) compared to 760 mmHg at sea level

Figure 2. The ideal gas law

\[ P \times V = n \times R \times T \]
On a more serious note, the physiological responses to distended intestine are elevated blood pressure and pulse, and reduced oxygenation of the blood, which can be serious for people already at risk for cardiovascular complications. Furthermore, flatus retention has been suggested as a major factor in the origin of sigmoid diverticular disease.

With all these factors in mind, the risks and drawbacks of holding back flatus are obvious and there is actually only one reasonable solution for an individual when experiencing the urge to flatulate on an airplane: just let it go.

Letting go—As described earlier, there are several drawbacks in holding back flatus, but it's not without its implications to let it go when on an airplane. Obviously proximity to other passengers may cause conflict and stigmatisation of the flatulating individual. The sound of the fart is unpleasant for the person farting whereas the odour is unpleasant for the co-passengers. Moreover, farting imposes a risk for soiling and may require damage control in the airplane toilet. Strong odour of flatulence may also impair the level of service from the cabin crew and thereby secondarily impair the QOL (quality of life) while onboard the aircraft.

This problem may be even more significant in the cockpit since the pilots may encounter the opposite of a win/win situation. On one hand, if the pilot restrains a fart, all the drawbacks previously mentioned, including diminished concentration, may affect his abilities to control the airplane. On the other hand, if he lets go of the fart his copilot may be affected by its odour, which again reduces safety onboard the flight.

Assistive technologies Luckily solutions exist to diminish the drawbacks of letting go the fart. It is known that letting go the fart through a normal seat cushion (as if sitting on a sofa) can absorb up to 50% of the odour thereby reducing the inconvenience. One effective solution would be the use of rubber pants with an attached air container for the collection of the gas, however this seems somewhat extreme.

Active charcoal has the ability to absorb odours from intestinal gases. Therefore, airline companies can enhance comfort for passengers on airplanes by installing active charcoal in the passenger seats. It has been shown, that charcoaled lined cushions effectively limit the escape of sulphur containing gasses (odour) into the environment. This would be especially relevant to counteract the impact of air holes and turbulence, where passengers are requested to stay in their seats for safety reasons. However being seated at such times may also be advisable for another reason, since, as described earlier, there is a greater risk of uncontrolled flatulence occurring in these situations. However, such charcoal containing cushions may not be effective in all situations, since the effect of the charcoal cushions requires high fart permeability through the trousers or skirt.

When wearing textiles of low fart permeability (e.g., leather pants), the fart cannot escape through the textiles and a “tunnel effect” will be created, when the fart escapes either by the legs of the trousers or at the waist. This problem may also be relevant in thecockpit since the pilots may encounter the opposite of a win/win situation. On one hand, if the pilot restrains a fart, all the drawbacks previously mentioned, including diminished concentration, may affect his abilities to control the airplane. On the other hand, if he lets go of the fart his copilot may be affected by its odour, which again reduces safety onboard the flight.

The authors, from the department of surgery, noted that adverse physiological response to intestinal distention may include increased pulse and blood pressure, reduced oxygenation of the blood, and aggravation of sigmoid diverticular disease.
Summary

• Nonspecific symptoms relating to mucosal and dermal dryness and irritation occur in aircraft passengers, but formal epidemiological investigation is scant. Chronic bronchitis may be elevated among flight attendants.

• Ozone levels in excess of NAAQS is encountered on aircraft without catalytic converters, and may increase the risk of some symptoms; ozone reaction products may be contributory.

• Ventilation supply of fresh air in airplanes is less than that recommended to decrease IAQ complaints in commercial buildings; and high levels of cabin CO$_2$ relative to buildings are common.

• Pyrethroid insecticides applied on certain flights results in occupant exposure; health impact is uncertain.

• “Fume events” have been described aboard aircraft which may be associated with contaminated bleed air. Uncertain impact of TCPs or other chemicals in bleed air on occupant health.

• Use of absorptive filters in cabin air may offer benefits.