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Indoor Air Quality Investigation on Commercial Aircraft

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Abstract Sixteen flights had been investigated for indoor air quality (IAQ) on Cathay Pacific aircraft from June 1996 to August 1997. In general, the air quality on Cathay Pacific aircraft was within relevant air quality standards because the average age of aircraft was less than 2 years. Carbon dioxide (CO_2) levels on all flights measured were below the Federal Aviation Administration (FAA) standard (30,000 ppm). The CO_2 level was substantially higher during boarding and de-boarding than cruise due to low fresh air supply. Humidity on the aircraft was low, especially for long-haul flights. Minimum humidity during cruise was below the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) minimum humidity standard (20%). The average temperature was within a comfortable temperature range of 23±2°C. The vertical temperature profile on aircraft was uniform and below the International Standard Organization (ISO) standard. Carbon monoxide levels were below the FAA standard (50 ppm). Trace amount of ozone detected ranged from undetectable to 90 ppb, which was below the FAA standard. Particulate level was low for most non-smoking flights, but peaks were observed during boarding and de-boarding. The average particulate level in smoking flights (138 $\mu g/m^3$) was higher than non-smoking flights (7.6 $\mu g/m^3$). The impact on IAQ by switching from low-mode to high-mode ventilation showed a reduction in CO_2 levels, temperature, and relative humidity.

Key words Aircraft; Indoor air quality; Questionnaire survey; Carbon dioxide; Respirable particulate matter; Relative humidity.

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Introduction

The air quality in passenger cabins is important to the comfort and health of passengers and flight attendants during flight. The increasing number of air travellers in recent years has increased the concern of air quality in aircraft. Concern for the quality of air in the passenger cabins of commercial airliners has been publicized, but it has focused on occupational exposures of cabin crews. Rising fuel costs might have prompted airlines to reduce the amount of outside air in the ventilation of passenger cabins to conserve fuel, consequently adversely affecting the air quality. New models of aircraft use re-circulation of cabin air to a greater degree than older models in the fleet. Specific concerns regarding the quality of cabin air include not only the amount of outside air, but also the adverse effects that might result from exposure to this confined environment. In aircraft, people are exposed to a particular combination of low relative humidity, reduced air pressure, presence of ozone and other pollutants (some of which have been demonstrated to be harmful to human health), and increased cosmic radiation. A number of studies on aircraft air quality had been investigated (Dechow et al., 1997; Nagda et al., 1990; Nagda et al., 1991; NRC, 1986) on commercial airlines.

Spengler (1994) studied indoor air pollutant levels of carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), bacteria, particulate and dust, relative humidity (RH), temperature, volatile organic compounds (VOCs), allergens, etc. in 22 flights with aircraft manufactured by McDonnell-Douglas, Boeing and Airbus. Average CO_2 levels during flight with partially re-circulated air were twice the levels measured on flight with 100% outdoor air systems during cruise. CO_2 levels averaged at 1,500 parts per million (ppm) during flights with re-circulation indicating that each passenger was receiving 8–10 cubic feet per minute (cfm) outdoor air. During boarding and de-boarding, CO_2 concentrations were substantially higher than during cruise, with levels of 2,000 to 2,500 ppm being typical. About 10 to 20% of the flights had either the 3-hour or flight-integrated ozone levels exceeding 100 parts per billion (ppb). None of the 55 targeted VOCs found onboard were sufficiently high for concern. Analysis of the carpet and seat dust samples revealed the presence of allergens and irritants. Bacterial counts ranged from

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Table 1 Regulations and comfort standards for aircraft

Parameters	Federal Aviation Administration	ASHRAE, 62–1988, 55–1989	International Standard Organization 7730
Carbon dioxide (ppm)	30,000 continuous	1,000 continuous	
Carbon monoxide (ppm)	50 continuous		
Ozone (ppb)	250 above 9.8 km continuous, 100 above 8.2 km, 3 hour interval		
Relative humidity (%)		20 minimum	
Temperature (°C)		19–23, winter 23–26, summer	Vertical temp. difference between ankles and head 3°C; floor temp: 19–26°C

46 to 9,936 colony forming units (CFUs)/m^3, which were slightly higher in the terminal or during flight. RHs range from 10 to 20%. Planes with ventilation systems tend to have higher RHs than those with 100% outdoor air systems. O'Donnell et al. (1991) carried out a similar investigation in 45 flights from seven same model aircraft. CO_2, CO, nitrogen dioxide (NO_2), formaldehyde, VOCs, total particulates, temperature, RH, outdoor air supply, etc. were measured in non-smoking short-haul flights. The CO_2 concentrations did not exceed the Federal Aviation Administration (FAA) regulation, but the average CO_2 levels exceeded the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standard 62–1989 of 1,000 ppm when 68% of the aircraft were occupied. RH reached an uncomfortably low level at 4.6%. Temperature measured fell within the ASHRAE office building standard and International Standard Organisation (ISO) standard. Ozone levels were below 26% of the limits allowed by FAA health regulations. Chemical contaminant levels were found to be within the regulations aimed. The total particulate levels (average 105 μg/m^3) exceeded the comfort criteria (75 μg/m^3) even though on non-smoking flights. When the passenger occupancy exceeds 34%, the average quantity of outdoor air does not satisfy the FAA guideline of 10 cfm/person and 66% of the flights did not satisfy the ASHRAE standard of 15 cfm/person for comfort. Formaldehyde was measured at 20% of the level allowed by the most severe comfort standard (120 μg/m^3).

Malmfors et al. (1989) carried out indoor air quality measurements in 48 European aircraft of respirable suspended particulate (RSP), nicotine, CO_2, CO, temperature, RH, pressure, etc. There were some smoking flights in this study. CO concentrations were about one-tenth of the standard for general indoor air and CO_2 were about a quarter of the standard for working environment. Some passengers and cabin crews have experienced eye and upper respiratory tract irritation. These health effects could be caused by low humidity, high temperature, and high CO_2 levels. The aircraft cabin air quality was similar to indoor air quality, except for particularly low RH, low air pressure, and low oxygen partial pressure.

Indoor Air Quality Survey

Relevant indoor air quality (IAQ) standards and regulations for aircraft were summarized in Table 1, and other indoor air quality standards relevant to this

Table 2 Indoor air quality guidelines (HK)

Pollutant	Concentration	Time	Source
CO	3 ppm 9 ppm	1 h 8 h	HKAQO
CO_2	1,000 ppm 5,000 ppm	Continuous 8 h	ASHRAE OSHA
SO_2	0.32 ppm 0.14 ppm 0.03 ppm	1 h 24 h 1 year	ASHRAE
NO_2	0.15 ppm 0.07 ppm 0.04 ppm	1 h 24 h 1 year	HKAQO
O_3	0.05 ppm	Continuous	ASHRAE
Respirable Suspended Particulate	180 μg/m^3 55 μg/m^3	24 h 1 year	HKAQO
Microbiological Organisms	1000 CFU/m^3	Action level	HKIAQ
Ventilation Rate	15 cfm/person for residential units, 20 cfm/person for office, 10 cfm/person for aircraft	Minimum requirement	ASHRAE

HKAQO: Hong Kong Air Quality Objectives
ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers
OSHA: Occupational Safety and Health Administration
HKIAQ: Interim Indoor Air Quality Guidelines for Hong Kong

study were summarized in Table 2. Air temperature and humidity are comfort parameters. Temperature is controlled by the cabin crew, and RH inside cabins during cruise depends on moisture given off by passengers and crew in the form of respiratory vapour and perspiration. Other water sources are from food and lavatory areas. RH in the cabin is inversely proportional to the quantity of outdoor air supply, because outside air is dry. An increase in ambient CO_2 in the aircraft resulted from the metabolism of the passengers released by exhalation. Therefore, an increase in the passenger occupancy raises the CO_2 concentration in the aircraft. Carbon dioxide levels at 50,000 ppm can cause headaches, dizziness and visual distortions. Symptoms relating to fatigue, headaches and stuffiness can be associated with levels between 3,200 to 50,000 ppm. According to the FAA, CO_2 levels should be kept below 30,000 ppm. ASHRAE recommends an indoor air quality guideline for CO_2 of 1,000 ppm compared with its previous recommendation of 2,500 ppm. Carbon monoxide is a chemical asphyxiant, while NO_2 and sulphur dioxide (SO_2) can cause irritation to the lung tissues. The major source of these contaminant gases is combustion of the engine fuel. According to the FAA, CO levels should be less than 50 ppm. Ozone is prevalent at an altitude of approximately 11 km in the middle latitudes during summer. In certain areas above 40° latitude, during given times of the year and under certain atmospheric conditions, aircraft operating at altitudes above 9 km may encounter atmospheric O_3 concentrations sufficient to affect air quality adversely. Ozone enters the cabin with the outside supply air through the engines. The major acute and chronic health risk from inhalation exposure to O_3 is irritation of the respiratory tract and lung tissue. According to the FAA standard, O_3 should be under 200 $\mu g/m^3$ (3-h interval above 8.2 km) and 490 $\mu g/m^3$ (continuous above 9.8 km). Ozone concentration in an airstream can be reduced by an absorption process, a chemical reaction with a filter surface, or a catalytic decomposition process.

Particulate matters are derived from the passenger's clothing and belongings and from the activity on the runway during embarkation and dis-embarkation from the non-smoking aircraft. Smoking flights have higher level of particulate from smoking activities. Crew and passenger compartments should be ventilated whenever the aircraft is in operation, except for brief periods when all engine power is needed to produce thrust. Outside air ventilation rates as low as 2.4 l/s per person is adequate. Actual ventilation rates (re-circulating plus outdoor air) in commercial aircraft range from 6 to 12 l/s. The pilot decides whether to set the ventilation rate to high or low mode, depending upon the number of passengers on board. Under normal circumstances, low-mode ventilation is in operation to save fuel. According to the FAA guideline, 10 cfm (l/s)/person is required and ASHRAE has suggested 15 cfm/person for comfort.

Airborne bacteria in the cabin may cause skin or respiratory tract infections, and fungi may cause problems of hypersensitivity. Airborne bacteria and fungi were collected during the flight (immediately after take-off, mid-distance and before landing).

Indoor Air Quality Questionnaire

In the face of the knowledge of these acute and chronic exposures to pollutants with proven health effects, very few studies have been done to characterize either the quality of the air in cabins or the potential health effects of exposure to that environment. Many airline travellers have complained about cabin air quality. The nature and reasons for their complaints are important clues to the problem. Complaints from airline passengers about catching colds or experiencing other health problems as a result of air travel are common. Concern about the possible relation of this smoking environment to acute exacerbation of underlying chronic diseases, such as allergic rhinitis or asthmatic attacks, and about the adequacy of onboard medical equipment and the availability on every flight of trained personnel to handle emergency situations (Holcomb, 1988). For years, flight attendants have reported various health problems, from chronic bronchitis to difficulties in pregnancy, which they have attributed to their occupational exposures. Furthermore, a larger portion of the general public, some with health conditions that might make them more susceptible to the airliner cabin environment, are now travelling via airplane. It is therefore important to understand the potential for adverse health effects of chronic exposure to airliner cabin air.

The aims of this project are to assess the indoor air quality on Cathay Pacific Airways Limited (CPA) aircraft. To compare the IAQ levels with existing standards including FAA, ASHRAE, ISO, and Hong Kong Air Quality Objectives (HKAQO), and to evaluate the health and comfort of cabin crews through an IAQ questionnaire survey.

Method

Sampling strategies and methodologies employed are summarized in Table 3. One sampling location on each flight was used and the location of sampling equipment was usually at the Business Class area, but when

Table 3 Aircraft sampling methodology and strategy

Parameters	Measurement Technique	Detection limit	Sampling frequency	Flight(s) measured
Carbon monoxide	Electro-chemical	1 ppm	Every 5 min during each flight	I, J, K, L, M, N, O, P
Carbon dioxide	Non-dispersive Infrared	1 ppm	Every 5 min during each flight	All
Temperature	Thermistor	0.1°C	Every 5 min during each flight	All
Relative humidity	Thin-film capacitive	0.1% RH	Every 5 min during each flight	All
Sulphur dioxide	Airbag/Pulse Fluorescence SO_2 Analyzer	1 ppb	Twice per flight	F, H, J, K, P
Nitrogen dioxide	Airbag/Chemiluminescence NO_x Analyzer	1 ppb	Twice per flight	F, H, J, K, P
Ozone	Passive ozone badges or Bio-check enzyme	0.02 ppm	Integrated sample taken in the test flight	F, H, J, K, P
Respirable Suspended Particulate	Light-scattering	1 $\mu g/m^3$	Every 5 min during each flight	E, F, K, L, M, N, O, P
Total hydrocarbon	Flame Ionisation Detector by Total Hydrocarbon Analyzer	1 ppm	Twice per flight	F, H, J, K, P
Microbiological Organisms	Burkard air sampler with agar plates	10 CFU/m^3	Up to twice per flight	H, J, L

Table 4 IAQ auditing flight information

Flight	Date	Duration (hour:minute)	Type of aircraft	Passenger occupancy (%)
A	September 2, 1996	11:29	747–400	–
B	September 5, 1996	13:05	747–400	–
C	September 19, 1996	12:52	Airbus 340	–
D	September 24, 1996	11:30	747–400	–
E	January 13, 1997	12:35	747–400	93
F	January 15, 1997	11:35	747–400	88
G	January 24, 1997	13:15-stopover-1:20	747–400	83-stopover-33
H	January 28, 1997	1:20-stopover-11:50	747–400	32-stopover-78
I	February 28, 1997	3:20	Airbus 330	100
J	March 2, 1997	3:11	747–400	69
K*	May 8, 1997	1:25-stopover-3:00	747–400	60
L*	May 13, 1997	5:00	747–400	67
M	June 8, 1997	14:15	Airbus 340	34
N	June 12, 1997	6:55-stopover-12:50	747–400	–
O*	June 28, 1997	1:25	747–400	91
P	June 28, 1997	1:25	747–400	–

* Smoking flight

seats were unavailable the location was at the centre of the Economy Class. The maximum passenger capacity for Boeing 747–400 on CPA aircraft was 387, for Airbus 330 it was 249, and for Airbus 340 it was 249. The number of crew on each flight was not considered, but was 20 for Boeing 747–400, and 12 for Airbus 330 and Airbus 340. Sampling and analysis of chemical and gas contaminants were performed according to standard methods acquired from American Society for Testing Materials, American Conference Governmental Industrial Hygienists, American Public Health Association, and National Institute for Occupational Safety and Health. Laboratory validation of field data was done for quality assurance (QA). Duplicate samples were taken for every ten IAQ samples. The IAQ questionnaire surveys the CPA crew on cabin lighting, cabin quietness, humidity, cigarette smoke, odour, air movement and temperature, etc. Details of the sixteen flights used for IAQ measurements are listed in Table 4, some flights with stopover were also indicated.

Results and Discussions

Indoor Air Quality Survey

All of the measured CO_2 concentrations were below 30,000 ppm (FAA standard). However, the average

Table 5 Comparison of CO_2 levels, relative humidity, and temperature on different flights

Flight	Carbon dioxide (ppm)	Relative humidity (%)	Temperature (°C)
A	1,170 (629–2,195)	23.6 (7.6–47.7)	23.5 (21.3–26.2)
B	906 (612–1,565)	23.8 (5.3–43.6)	22.7 (19.8–25.5)
C	868 (642–1,492)	– (4.9–55.5)	24.1 (20.4–26.7)
D	1,557 (855–2,900)	– (10.1–36.0)	21.3 (17.8–25.3)
E	1,052 (1,052–2,368)	26.1 (14.4–50.4)	23.4 (23.4–26.1)
F	1,097 (863–2,043)	10.0 (5.8–42.5)	23.6 (19.5–25.8)
G	716 (479–1,826)	12.2 (6.8–44.5)	22.7 (19.0–24.7)
H	728 (423–1,911)	11.1 (6.2–37.2)	24.6 (20.4–25.5)
I	967 (760–1,491)	26.8 (14.3–49.9)	22.5 (20.0–24.7)
J	701 (538–1,347)	22.8 (10.0–48.9)	23.2 (21.7–25.1)
K*	884 (418–4,752)	42.6 (16.7–76.8)	24.5 (22.9–27.1)
L*	868 (530–4,088)	18.8 (10.4–53.5)	23.0 (21.6–25.8)
M	683 (509–2,303)	14.4 (6.7–50.6)	22.3 (20.3–26.3)
N	733 (427–1,489)	14.7 (7.8–51.5)	22.0 (19.3–23.9)
O*	1,024 (624–1,994)	38.2 (16.7–55.3)	22.6 (20.4–24.3)
P	1,000 (702–1,946)	28.7 (16.3–44.5)	25.3 (23.6–29.8)

* Smoking flight
( ) Data ranges

CO_2 levels measured exceeded the ASHRAE standard 62–1989 of 1,000 ppm. Average, maximum, and minimum CO_2, RH, and temperature levels were summarized in Table 5. Average CO_2 concentrations ranged from 629 to 1,097 ppm while maximum concentrations ranged from 1,347 to 4,725 ppm. The results showed that the temporal variation pattern of CO_2 concentrations was dominated by the occurrence of elevated levels at the beginning and end of the trip, that is, during boarding, de-boarding, take-off and landing. Whenever there was a stopover (e.g. F, H and O), a sharp rise of CO_2 concentration was observed. A possible source for these elevated CO_2 concentrations was exhaust gases in the airport. It was also observed that CO_2 concentrations remained at a low and steady level during flight, therefore indoor emission was not the dominant CO_2 source. CO_2 concentration was higher during boarding and de-boarding than during cruise with typical levels of 2,000 to 2,500 ppm. Low fresh air supply during boarding and de-boarding resulted in elevated CO_2 levels.

The air was quite dry, with RH in the range of 4.9 to 76.8%. RH in the aircraft decreased during cruise and increased as the plane descended. Average RH ranged from 11.1 to 26.8 % while the minimum RH ranged from 5.3 to 16.7%. It is worth noting that, among all the flights, the maximum RH reached 76.8% only. As far as the minimum and the average RH levels were concerned, the air inside the cabin was quite dry during cruise. The temporal variation in RH was dominated by its gradual decrease during the beginning and increase at the end of the trip. Wherever there was a transition during the trip (e.g., N and O), there was a sharp rise in RH. This was due to intake of moist air during these periods. As the aircraft reached a higher altitude, the moisture content of intake air decreased, leading to low and constant RH levels during the trip. Relative humidity reached uncomfortable levels at 4.9%, which was far below the minimum ASHRAE humidity of 20%.

Among the audited flights, the average temperature was 21.9°C, which was within comfortable temperatures (23±2°C). Temperatures in each zone of the aircraft were controlled between 18 and 24°C by flight attendants. The temperatures measured agreed with the ASHRAE office building standard and ISO standard. Temperature on the aircraft ranged from 19.3 to 27.1°C. Compared with the other pollutants and comfort parameters measured in this study, temperature variation was relatively stable during cruise. However, Flights J, O and L showed a high variation in temperatures. The cause of such fluctuation is unknown.

Carbon monoxide concentrations measured were low (<1 ppm) during flights (Table 6). Smoking flights had higher CO levels (3–5 ppm) than non-smoking flights, but they were not of concern. CO levels ranged from 1 to 6 ppm (Table 6). The average CO concentrations, 2 to 3 ppm did not exceed any relevant standards. The temporal variation of the CO concentration showed a constant and smooth pattern, which suggested that there was no dominant CO sources inside the aircraft or from air intake.

RSP levels averaged from 1 to 17 $\mu g/m^3$ were low for the non-smoking flights. In general, RSP levels on non-smoking flights seemed very low. RSP levels were high for the three smoking flights averaged from 71 to 264 $\mu g/m^3$, and the average exceeded the HKAQO RSP standard (55 $\mu g/m^3$). The average particulate level (138 $\mu g/m^3$) in smoking flights was 1,815% higher that of non-smoking flights (7.6 $\mu g/m^3$). All measurements showed a similar temporal variation pattern dominated by the occurrence of the non-systematic peaks which were substantially higher than that of the averaged concentration levels. Such high values were due to the human activities inside the aircraft. All the measured O_3 concentrations were lower than the FAA regulation of 100 ppb. About 10% to 20% of O_3 measured ranged from 10 to 90 ppb.

The impact of high-mode and low-mode ventilation on indoor air quality was investigated on flight A. CO_2 levels were reduced by 29%, temperature by 0.7% and humidity by 27.6%. This showed that when ventilation was at high mode for 30 min, CO_2 level was reduced but humidity was worsened.

All concentration of pollutants measured using air bags were at normal levels except for those on Flight

Table 6 Comparison of average pollutant levels and their ranges on different flights

Flight	Carbon monoxide (ppm)	Respirable Suspended Particulate (μg/m^3)	NO (ppb)	NO_2 (ppb)	NO_x (ppb)	SO_2 (ppb)	THC (ppm)
E	N/A	7 (nd–550)	N/A	N/A	N/A	N/A	N/A
F	N/A	6 (nd–1,980)	0.3 2.4 5.3	4.0 7.3 13.8	4.3 9.7 19.1	2.0 1.0 1.0	2.1 2.3 2.6
H	N/A	N/A	80.7[1] 0.5 1.2	31.8[1] 4.3 9.0	112.5[1] 4.8 10.2	3.0[1] 2.0 2.0	2.0[1] 2.0 1.8
I	2.1 (1.0–3.0)	N/A	N/A	N/A	N/A	N/A	N/A
J	1.9 (1.0–3.0)	N/A	0.6 1.4	3.9 3.9	4.5 5.3	1.0 1.0	N/A N/A
K*	2.57 (2.0–3.0)	71 (1–551)	37.6	11.3	48.9	2.0	N/A
L*	2.2 (2.0–6.0)	264 (nd–1,313)	N/A	N/A	N/A	N/A	N/A
M	2.0 (1.0–3.0)	7 (nd–158)	N/A	N/A	N/A	N/A	N/A
N	2.0 (1.0–4.0)	1 (nd–74)	N/A	N/A	N/A	N/A	N/A
O*	3.0 (2.0–5.0)	81 (nd–3,159)	N/A	N/A	N/A	N/A	N/A
P	2.39 (2.0–4.0)	17 (1–107)	37.7	11.9	49.6	2.0	N/A

nd: Not detected
N/A: Not Applicable
* Smoking flight
[1] Smoke fumes at airport
( ) Data ranges

H (Table 6) with NO at 80.7 ppb, NO_2 at 31.8 ppb, NO_x at 112.5 ppb, SO_2 at 3.0 ppb, THC at 2 ppm. Maximum CO_2 was detected at 1,980 ppm during stopover. The reason for the unusually high pollutant levels was suspected to be caused by exhaust gases outside the aircraft.

Three flights were selected for bacteria and fungi measurements (Table 7). Bacterial counts ranged from 33 to 93 CFU/m^3 while fungi levels ranged from 17 to 107 CFU/m^3. The concentrations were slightly higher at the beginning and towards the end of the flight when compared with mid-flight. The highest bacterial and fungal counts occurred during boarding and deboarding as passengers were retrieving luggage and leaving. Bacteria species recovered were those typically shed from human skin and mucous membranes, and concentrations were within the normal range found in schools and office buildings. Bacterial samples collected during boarding, averaged at 53 to 79 CFU/m^3, and were slightly higher than those during mid-flight (44 to 76 CFU/m^3). Overall bacterial counts were less than the HKIAQ standard of 1,000 CFU/m^3. This implied biological contaminant levels on Cathay Pacific aircraft were very low.

The impact of flight time on IAQ had also been investigated. There was significant difference on minimum and average humidity on long-haul, medium-haul, short-haul and very short-haul flights. Both average humidity and minimum humidity dropped as flight time increased. For very short-haul flights (P), the minimum humidity was 16.3% compared with the long-haul flights (M) at 6.7%. It showed that the longer the flight, the lower the humidity on the aircraft.

Table 7 Comparison of Bacteria and Fungi concentrations on different flights

Flight	Time series	Bacteria (CFU/m^3)	Fungi (CFU/m^3)
H	Boarding	74	43
	Immediately after takeoff	48	17
	Mid of flight	76	107
	End of flight	93	81
	Whole trip average	64	60
J	Boarding	79	77
	Immediately after takeoff	61	26
	Mid of flight	44	31
	End of flight	65	36
	Whole trip average	57	31
L*	Boarding	53	44
	Immediately after takeoff	49	38
	Mid of flight	48	68
	End of flight	54	69
	Whole trip	50	58

* Smoking flight
Hong Kong Interim Indoor Air Quality Guidelines: 1,000 CFU/m^3

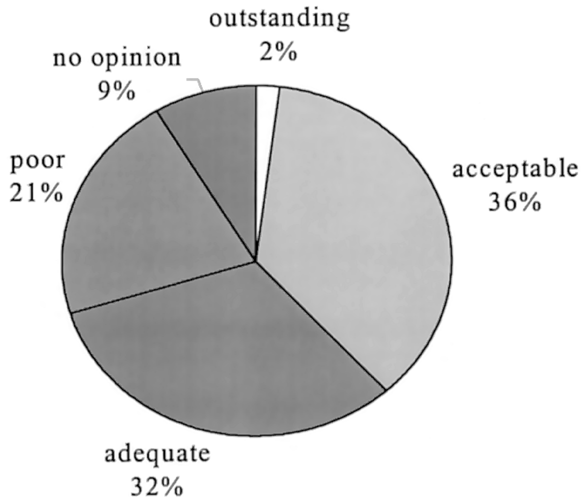

Fig. 1 Rating of overall air quality by the crew

Questionnaire Analysis

Cabin crew completed 185 questionnaires and the results were summarized. The crew rated the overall air quality in the flights surveyed acceptable (36%) and adequate (32%) (Figure 1). Twenty-one per cent of the crew rated the overall air quality at poor. This implied that there are room for improvement to increase the quality of air on aircraft. The most significant air quality issues were odour, cigarette smoke, and humidity. About 50% of the respondents felt that the aircraft had distinct, unpleasant odour although the source could not be identified. The odour problem on board was more serious during the summer season; and was more serious on an older aircraft. More than 60% of the cabin crew (especially for long-haul flights) felt that the cabin humidity was low and caused discomfort. The low RH measured on various flights in this study explained this. Though smoking in most flights have been banned, it is still allowed in certain routes. Eighty per cent of the crew felt that cigarette smoke on smoking flights deteriorated the cabin air quality. Cabin crew felt that the air quality was the best in First Class, followed by Business Class (upper deck), then Business Class (lower deck), and lastly Economy Class. Cabin crew prefer non-smoking flights to smoking flights, and feel that the crew's rest room was too dry. Passengers frequently complained about humidity, temperature, odour, and noise. The potential odour sources on board were from toilet(s), passengers, food, personal luggage, carpet, etc.

Conclusion

A total of sixteen in-flight air quality audits on CPA aircraft were carried out in this project. In general, the aircraft air quality on Cathay Pacific aircraft were within relevant air quality standards. Carbon dioxide levels on all of the flights were less than the FAA maximum limit of 30,000 ppm. During boarding and deboarding, CO_2 levels were substantially higher than during cruise, with levels of 2,000 to 2,500 ppm being typical. Low fresh air supply during boarding and deboarding resulted in the elevated CO_2 levels. Relative humidity measured on the aircraft were low, especially for long-haul flights. The minimum humidity detected during cruise was 4.9%, which was lower than the ASHRAE minimum humidity standard (20%). The average temperature was 21.9°C, which is within comfortable ASHRAE temperature range (within 23±2°C). Temperature variation was relatively stable during cruise. The measured CO levels were below FAA standard (50 ppm). Trace ozone was detected on aircraft which ranged from 0–90 ppb. Particulate levels were low for most of the non-smoking flights, but spikes were observed during passenger boarding and de-boarding. Particulate levels on smoking flights exceeded the HKAQO standard. The average RSP level (138 $\mu g/m^3$) on smoking flights was 1,815% higher that of non-smoking flights (7.6 $\mu g/m^3$). By switching from low-mode to high-mode ventilation, CO_2 levels were reduced by 29%; temperature by 0.7% and humidity by 27.6%. Overall bacterial counts on Cathay Pacific aircraft were below the Hong Kong proposed IAQ standard at 1,000 CFU/m^3. Bacteria recovered were those typically shed from human skin and mucous membranes, and levels were within the normal range in public environments. The bacterial samples collected during boarding, averaged from 53 to 79 CFU/m^3, and were higher than those during mid-flight (44 to 76 CFU/m^3). Significant differences were observed in minimum humidity and average humidity on long-haul, medium-haul, short-haul and very short-haul. Both average humidity and minimum humidity decreased as flight time increased.

A total of 185 questionnaires were completed and analyzed. The important air quality issues were odour, cigarette smoke on smoking flights, and humidity. The potential odour sources on board were from toilet(s), passengers, food, personal luggage, and carpet, etc. More than 60% of the cabin crew (especially for long-haul flights) felt that the cabin humidity was low. Eighty per cent of the respondents felt that cigarette smoke on smoking flights render cabin air quality uncomfortable. The air in the crew's rest room was too dry. From the IAQ questionnaire survey, the top three symptoms that were frequently experienced were: (i) dry itchy or irritated eyes; (ii) dry or stuffy nose; and (iii) skin dryness or irritation. The cabin crew preferred non-smoking flight to smoking flight. Humidity (too dry), temperature (too hot or too cold), odour and noise were the most frequent complaints from passengers.

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