Indoor Aır Quality in Commercial Aircrafts

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OUTLINE

1. INDOOR AIR QUALITY

The cleanliness of the air in a space defines the indoor air quality of that space.

Clean air, is air that does not contain pollutants higher than a level defined by standards and not causing disturbance for people breathing this air.

This definition has been done by ASHREA (American Society of Heating, Refrigerating and Air-Conditioning Engineers)

In this study, current Environmental Control Systems have been briefly studied and the risks have been emphasized relating to;

- air pollutants,
- health,
- and comfort within the context of indoor air quality.

In addition, various recent studies have also been touched upon in the text

Recently, the number of passengers who prefer traveling by aircraft has increased substantially.

These passengers are people who probably suffer various ailments and are from various age groups

Today's commercial aircrafts run different **atmospheres**, having different **temperatures**, **pressures** and **humidity** changes.

Aircraft cabins have indoor characteristics similar to those in **houses** and **office buildings**.

…….Houses and office buildings.

Indoor Air Quality characteristics (Similar)

……..Aircraft cabins

But still these cabins differ from other buildings in some respects, such as:

- available space per person,
- pressurizing requirements and
- activity levels within the cabin.

Passengers are exposed to atmospheric factors such as:

- low-humidity,
- reduced air pressure,
- various air pollutants (ozone, carbon monoxide and other organic chemicals and biological structures).

2. ENVORIVENTAL CONTROL SYSTEM IN AIRCRAFT

Modern aircraft are equipped with **Environmental Control Systems** (ECS) to provide:

- safe,
- healthy and
- comfortable flight conditions for both passengers and crew.

In this system, **outside air** is taken from the power system of the aircraft and mixed with **the filtered indoor air** before being introduced into the cabin.

-safe,
-healthy and
-comfortable
flight conditions

→ outside air + indoor cabin air + filtered → mixed → Cabin

ECS's has been designed to reduce the air pollutants that can possibly enter the cabin and to control:

- temperature,
- pressure,
- humidity and
- ventilation of the cabin air.

The environment that today's aircraft travel in, is not an atmosphere with physical conditions that people can live in without any protection.

For this reason, rather advanced ECS systems are used in modern commercial aircraft.

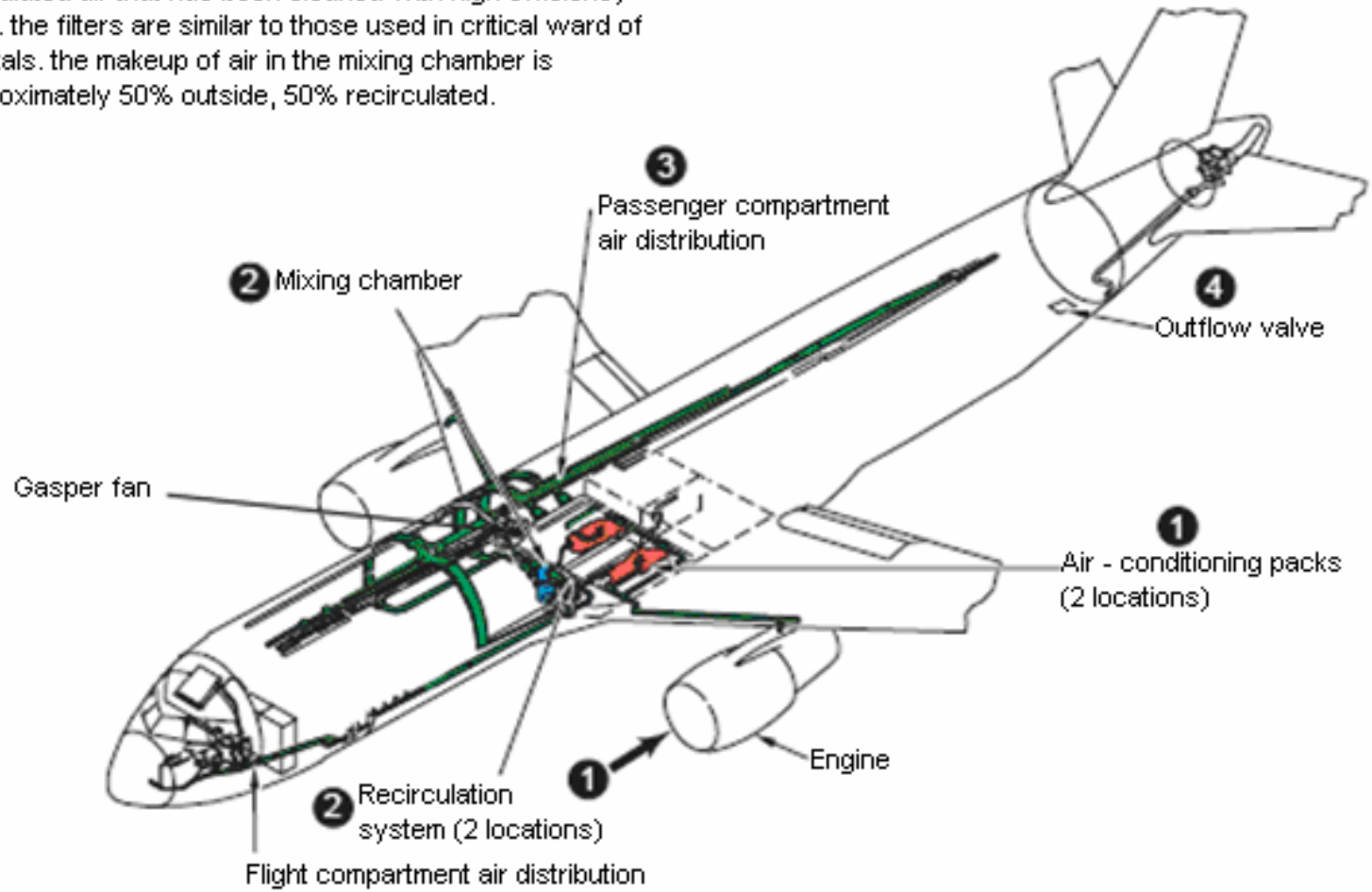
Environmental control systems (ECS) have been designed to meet psychological needs of human beings in any flight condition and to provide definite comfort levels during flights (Elwood, H.H., et al, 1995).

1. Outside air continuously enters engine where it is compressed. It then passes through cooling packs to a mixing chamber.

2. Outside air entering the mixing chamber is mixed with recirculated air that has been cleaned with high efficiency filters. the filters are similar to those used in critical ward of hospitals. the makeup of air in the mixing chamber is apporoximately 50% outside, 50% recirculated.

3. Air from the mixing chamber is then supplied to the cabin from overhead outlets on a continuous basis.

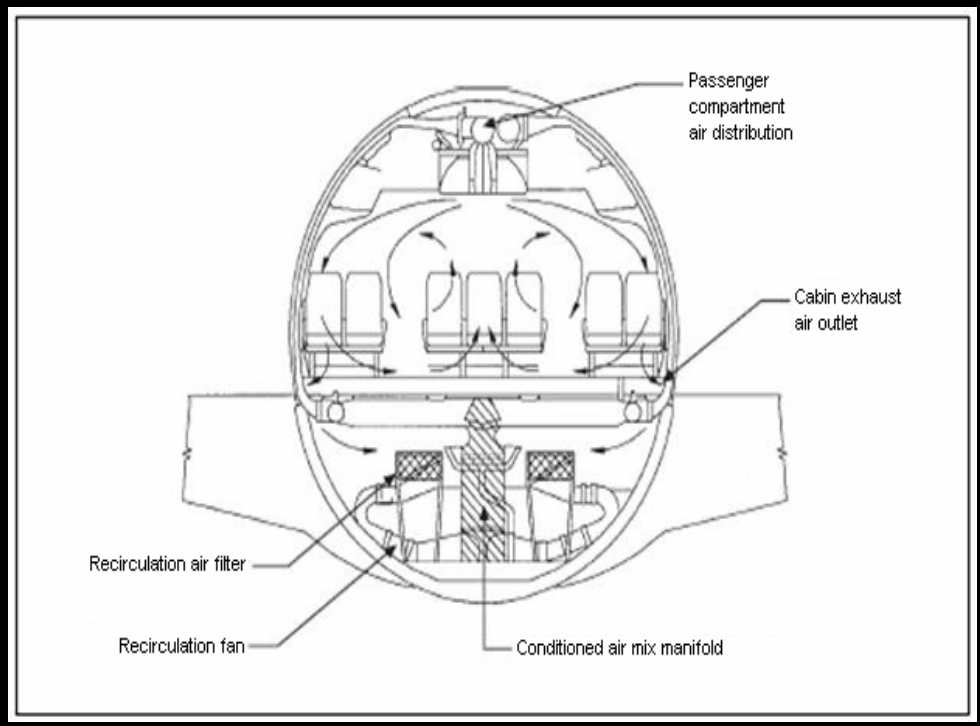
4. As outside air enters the airplane, it is being continuously exhausted.



The design of the cabin ventilation system is based on:

- introducing ventilated air into a row of seats and
  - •collecting and discharging the air from the same row

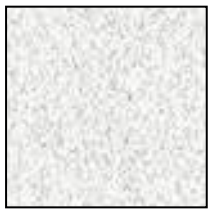
Such an approach essentially reduces the risk of spreading infections within the aircraft cabin



3. FACTORS INFLUENCING INDOOR AIR QUALITY IN AIRCRAFT

There are several factors influencing IAQ in aircrafts which can be classified into five categories:

1. Pressure
2. Oxygen
3. Temperature
4. Humidity
5. Air contaminants



Inadequate fresh air, instant changes in the levels or interaction between these factors can cause deterioration of indoor air quality and consequently negative effects on the health of both passengers and crew.

Pressure: Since the density of the air at high altitude is low, aerodynamic drag forces on an aircraft is also low.

This condition makes it more efficient to fly at higher altitudes.

For this reason, almost all commercial aircraft cabins are pressurized for the safety of both the crew and the passengers (Anon, 2002).

Pressure:

Even though the cabin pressure is intended to be held constant at 2450 m, this level of pressure is lower than that at sea-level.

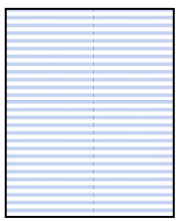
These lower pressures have some negative effects on the physiology of passengers.

The reduced pressure causes expansion of the air trapped in body cells and creates some minor sicknesses while in sensitive metabolisms it can cause more serious health risks

Oxygen: In steady atmosphere, the value of atmospheric pressure is 760 mm Hg at sea level. Under these circumstances, the partial pressure of oxygen (PO_2) is 160 mmHg (approx. 21 %).

But, since the percentages of carbon-dioxide and water vapor increases, the partial pressure of oxygen reduces to about 105 mmHg.

Thus, the partial pressure level that human body has got used to is 105 mmHg.



In the situation when the partial pressure of oxygen is lower than that level, ingress of oxygen to the blood is reduced and the usual rhythm of the body fails (Zaim C., Cetingüc M., 2000).

Temperature:

- In general, the temperature of the cabin is taken not as a health issue but, mostly as a **comfort issue**.
- However, it can cause health problems together with other physical and biological factors.
- Temperature affects the liquid loss of the passengers and the crew.
- Furthermore, the humidity that is directly related with temperature, also affects thermal comfort.

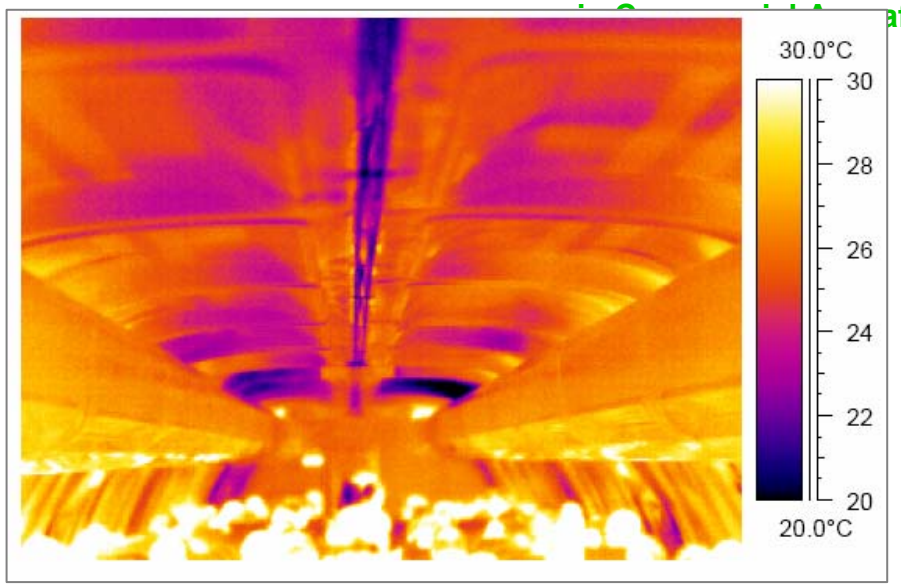
As is well known, high temperatures and low humidity cause sick building syndrome (SBS).

SBS reveals itself as

- exhaustion,
- headache and
- irritation of the skin and mucous membrane; all acute symptoms.

- Temperature also affects the perception of air quality.
- When temperature increases, the air enclosed in a space may be perceived as being more polluted by the occupants.
- Temperature also has substantial effects on the emission rate of volatile organic compounds (VOC) that principally originate from the human body and cabin materials.
- Consequently, pollutant concentration in the cabin air will also increase.

It is widely known that temperature affects health and air quality indirectly.



- Since people show a tendency to be less active in higher temperatures, the risk of deep vein thrombosis (DVT) is affected by cabin temperature.

- A combination of temperature and humidity can affect the viability of airborne pathogens and the immune system of the body against diseases

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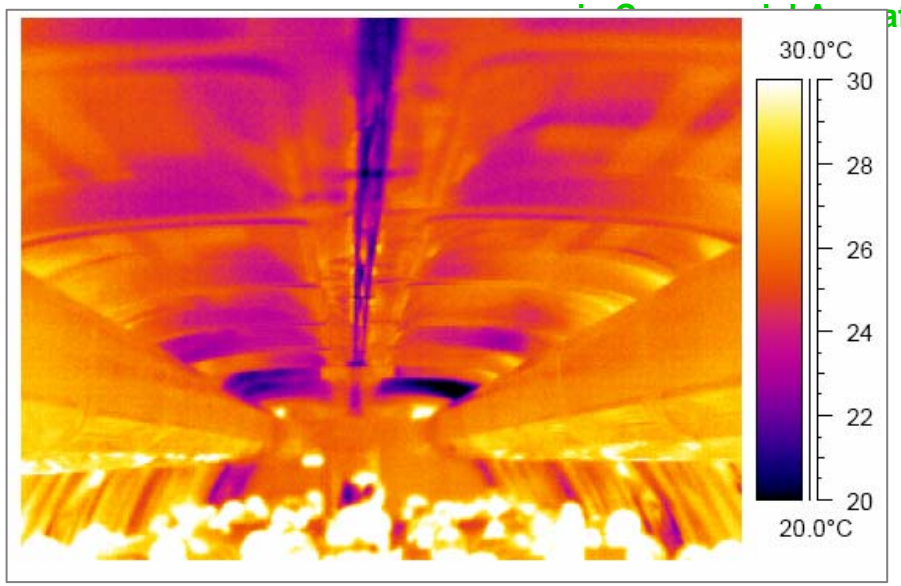


- The effects of jet lag with high temperature are:

  - ❑ Fatigue and reduced alertness / concentration
  - ❑ Impairment of mental performance, including memory loss
  - ❑ Nausea / digestion problems

Humidity:

- Relative humidity of cabin air has two significant characteristics with regard to indoor air quality; **passenger comfort** and **aircraft structure and safety** .

- *Particularly in high temperatures*, relative humidity in the aircraft cabin (when it is higher than 70 %) creates a displeasing environment for passengers.

- In this situation, condensation occurs in the cabin and water droplets can cause corrosion that is harmful to the aircraft structure.

- Enhanced ECS systems in today's modern aircraft, dry the air taken from outside using moisture separators.

- Thus, the main source of the humidity in the cabin is the respiration of passengers, and evaporation from the human body .

- By mixing outside air and recirculated of air from the cabin, a relative humidity of approximately 10~20 % is achieved.

In many aircraft cabins, depending on the aircraft type, the humidity varies between 15 % and 19 %.

Lower humidity can cause:

→ drying of body surfaces (mucous membranes and skin) and

→ irritation in eyes.

Drying in mucous membrane and eyes particularly causes the eyes to become watery and painful.

Lower humidity can seriously affect people who suffer from asthma, respiratory illnesses and trachea disease.

It has been stated that a small increase in humidity gives positive results.

It is also stated that this increase in humidity will not affect the safety of the aircraft body and will not cause corrosion on its materials
(Nagda N. L., 2000, Nagda N. L., Hodgson M., 2001).

Cabin air pollutants:

- The pollution of indoor air is eliminated by the ventilation air that is taken from outside.
- After the pollution of indoor air has been reduced by the ventilation air, it is discharged to the outside.
- The flow rate of the outside air has an important effect on air pollution in the cabin.

a. *Pollution from outdoor sources:*

- Ventilation air introduced to the cabin is taken from outside the aircraft. So, any pollutant can enter the passenger cabin.

- Most airports are situated near to big cities which often have significant air pollution problems. Furthermore, exhaust emissions at airports are also another pollution source.

- During aircraft landings, exhaust gases and vapors from de-icing chemicals entering through open doors, can form a serious risk to health (Anon, 2002).

Since most flights are at high altitudes, pollutants in the outdoor air are at very low levels. At these high altitudes the main pollution source is ozone (O3).

Ozone causes respiratory problems, increases asthmatic complaints and damages the body's immune system.

b. Internal pollution sources:

Pollution from internal sources is caused by viruses, bacterial organisms and other microorganisms from the crew and the passengers.

This type of pollution can be generated by clothing or respiration from the body (Atmaca F., et al., 2005).

Passengers and crew are the sources of various bacterium, viruses and allergic agents.

In addition to this, the most important pollution source is carbon dioxide, a by-product of respiration.

Seat covers and carpets on aircraft floors may contain dust, microorganisms and allergic agents and are another cause for indoor air pollution (Anon, 2002).

Between flights aircraft cabins are cleaned. During the cleaning process various cleaning agents, detergents and solvents are used.

These cleaning agents create pollution on cabin surfaces and in the indoor air through vaporization (Atmaca F., et al., 2005).

To protect the aircraft from insects and the like, various pesticides are used.

Many countries, insist on the elimination of these insects from aircraft that take off from countries where malaria and such like are prevalent.

These chemicals, used unsatisfactorily can cause a risk to heath.

4. POSSIBLE HEALTH PROBLEMS CAUSES BY CABIN ATMOSPHERE

Hypoxia:

Hypoxia, is the weakening of bodily functions is caused by a shortage of oxygen in blood cells and tissues.

This shortage of oxygen can be due to various causes.

Hypoxia may reveal definite symptoms, while sometimes there may be no symptoms.

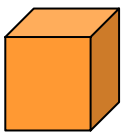
If hypoxia occurs with no symptoms, this is the worst situation for passengers, since passengers can not be aware of the reduction in their bodily functions and the following effects can be experienced:

- Slowing down in thinking and wrong calculations
- Weakening of the memory and longer response time
- Higher number of breaths and cyanosis
- Weakening in reasoning
- Coordination degradation in muscles

Deep vein thrombosis (DVT):

Deep vein thrombosis is a blood clot in deep veins of the leg, although it can occur in other parts of the body.

The danger, however, is that part of the clot can break off (embolism) and travel to the lung circulation, where it lodges and blocks one of the pulmonary arteries (pulmonary thromboembolizm)(PTE)



The possible results are, low oxygen levels in the blood, circulatory failure, collapse and even death .

Studies focused on DVT have shown that this sickness occurs during long flights and particularly in older passengers.

In long distance air travel, it causes symptoms either in the first few hours just after takeoff, or after days of the flight, an average 4 days later (www.gata.edu.tr, 2006).

DVT is generally dependent on factors such as,

- lack of exercise,
- cramp,
- seating position,
- dehydration and
- pressure in the cabin.

However, this illness is not only a risk in air travel but also a risk in rail and road travel.

Precautions and for prevention of DVT (www.hvtd.org, 2006):

The suggestions below are for all passengers:

- Moving the legs up and down and back and forth at regular intervals, walking in the cabin for 5 minutes every hour, and taking deep breaths.
- Not maintaining the same position in the seat when sleeping, frequently changing the lying down position. Drugs, causing drowsiness, and alcohol must not be used during the flight (Drugs causing inactivity, and alcohol increase fluid loss)
- Before and during the flight, beverages must be consumed frequently (water loss resulting from sweating and breathing increases the risk of blood coagulation)
- Clothing worn should be loose and comfortable.

Transmission of infection:

In some long distance flights, many complaints have been made concerning infectious diseases contracted by passengers and crew of aircraft.

Many passengers are anxious about being infected by the nearby passengers or **recirculated air in the cabin.**

It is clear that there is an increased risk of infection caused by viruses and pathogens on long distance flights

The main sources of infection transmission in aircraft cabins are

- contaminated water and food,
- toilets
- direct contact with people or body fluids (sweat saliva and such like) insect vectors and
- airborne person-to-person infection.

Cabin air in aircraft is established by mixing used air with ventilation air in a 50:50 ratio.

If the filters do not operate effectively,
or there is no maintenance at regular intervals,
the risks increase regarding indoor air quality.

These filters can eliminate the viruses and bacteria in cabin air effectively

Using regular checks, it must be established that there are no microorganisms in cabin air.

5. CASE STUDY

In the context of this study, the questionnaire forms have been prepared for passengers and crew of various airlines in Turkey (Table 1 and Table 2).

A literature survey and questionnaire process is the first stage of this study.

The second step will cover the various measurements that will be conducted in the airlines operating in Turkey regarding indoor air quality.

This questionnaire will realize next month.

Table 1. Questionnaire for cabin crew.

Aircraft Type	: ……		
Flight Duration	: ……	☐ Night	☐ Day
Rest Duration	: ……		
Service Location	☐ Front Galley	☐ Mid Galley	☐ Rear Galley
Service year	: ……		

The temperature conditions of the places below					
Galley	☐ Very Hot	☐ Hot	☐ Normal	☐ Cold	☐ Very Cold
Cabin	☐ Very Hot	☐ Hot	☐ Normal	☐ Cold	☐ Very Cold
Crew Rest Room	☐ Very Hot	☐ Hot	☐ Normal	☐ Cold	☐ Very Cold

Cabin comfort			
Humidity	: ☐ Low	☐ Normal	☐ High
Noise	: ☐ Low	☐ Normal	☐ High
Pressure	: ☐ Comfortable		
If Uncomfortable	: ☐ Take off-landing	☐ Cruise	
Unpleasant Odour	: ☐ Yes	☐ No	
İf Unpleasant Odour (Chemical, toilet, food, exhaust) : ……		• Any malfunction in the toilet? : …… ……	

Table 1 cont.

Problems when leaving a crew rest period :			
Dizziness	☐ Never	☐ Seldom	☐ Always
Exhaustion	☐ Never	☐ Seldom	☐ Always
Stomach Upset	☐ Never	☐ Seldom	☐ Always
Breathing Difficulties	☐ Never	☐ Seldom	☐ Always
Headache	☐ Never	☐ Seldom	☐ Always
Dry eyes	☐ Never	☐ Seldom	☐ Always

Do you have any symptoms of flu currently?	☐ Yes	☐ No
Do you suffer from asthma ?	☐ Yes	☐ No
Did you any experience heartburn during this flight?	☐ Yes	☐ No

Do you smoke?

☐ No

☐ 1–5 cigarettes / day ☐ 6–10 cigarettes / day ☐ 11–20 cigarettes / day

Were there any complaints from the passengers about the heating or ventilation of the cabin?

……...

……...

Table 2. Questionnaire for passengers.

1. Occupation **:** .....

2. Education **:**

☐ Literate	☐ Elementary School	☐ Junior High School
☐ High School	☐ University or Master Degree	

3. How many times have you flown?

☐ First time	☐ 2- 3	☐ 4- 5	☐ more than 6 times

4. What concerns, if any, do you have about comfort issues in the aircraft cabin environment?

Temperature	**:**	☐ Low	☐ Normal	☐ High
Humidity	**:**	☐ Low	☐ Normal	☐ High
Noise	:	☐ Low	☐ Normal	☐ High
Pressure	**:** ☐ Comfortable	If Uncomfortable	: ☐ Take off-landing	☐ Cruise
Unpleasant Odour	**:**	☐ Yes	☐ No	
Unpleasant	**:**	☐ Chemical ☐ Toilet ☐ Food ☐ Exhaust	• Any malfunction in the toilet ?)	
Seat Comfort	:	☐ Comfortable	☐ Uncomfortable	

Table 2 cont.

5. Have you had any health problems during this flight?

Dizziness	☐ Yes	☐ No	Breathing Difficulties	☐ Yes	☐ No
Exhaustion	☐ Yes	☐ No	Headache	☐ Yes	☐ No
Stomach Upset	☐Yes	☐ No	Dry eyes	☐ Yes	☐ No

6. Have you ever had other health problems after your flights? Explain these problems for bothshort and long flights

Long flights

.....

.....

Short flights

.....

.....

Do you have any symptoms of flu currently?	☐ Yes	☐ No
Do you suffer from asthma ?	☐ Yes	☐ No
Did you experience any heartburn during this flight?	☐ Yes	☐ No

8. Do you smoke?

☐ No ☐ 1–5 cigarettes / day ☐ 6–10 cigarettes / day ☐ 11–20 cigarettes / day

9. Have you consumed any alcoholic beverage during this flight?
(This question is asked because alcohol may incite certain problems caused by cabin atmosphere)

☐ Yes ☐ No

Table 2 cont.

10. Have you ever had any health problems caused by jet lag?
(Jet lag is a problem associated with long distance travel, and related to disturbed biorhythms such as fatigue, stress, nausea, loss of concentration and performance.)

Explain, if you have.
.....
.....

Have you taken any drug for jet lag before this flight? ☐ Yes ☐ No

About the seat comfort

• Distance between you and the seat in front?	☐ ☺	☐ 😐	☐ ☹
• Does your seat function well?	☐ ☺	☐ 😐	☐ ☹
• Is your seat cover clean?	☐ ☺	☐ 😐	☐ ☹
• Are there any tears in your seat cover?	☐ ☺	☐ 😐	☐ ☹

About the cabin comfort

• Video-music system?	☐ ☺	☐ 😐	☐ ☹
• General view of the cabin?	☐ ☺	☐ 😐	☐ ☹

- Flight Class ☐ Business ☐ Economy
- Please indicate your seat row number to enable a better understanding of seat comfort. (e.g. 10)

.....

During the second stage of the study,

- indoor air temperature
- humidity, vibration, noise, and
- the level of bacterial growth that can cause the transmission of infectious diseases

will be measured using sensors placed in various areas of the cabin.

The results of this study and the values from readings will also be revealed.

6. CONCLUSIONS

This paper concentrated on the discussion of some current IAQ aspects in terms of air pollutants, health and comfort.

Future studies in this area, no doubt, will be helpful in establishing a desirable IAQ in aircraft and these efforts will lead to the preparation of IAQ standards for aircraft to provide high comfort without health and safety risks.

For a case study is included to identify the potential issues that passengers and crew face, relating to

the flight,

cabin environment,

(pressure and humidity),

airborne particulates contaminants,

(cleaning agents, hydraulic fluids, ozone) and

psychological effects.

(fatigue, noise, passengers sitting too closely together and jet lag)

Airlines claim that
the provision of the ASHREA
recommended levels of
7 liter/second
of outside air to the passenger cabin
is expensive,
without being specific.

Reduce the outside air provide
per passenger from 7 to 2.3 liter/second
saves the airline an average of
11 cents per passenger per hour.
(Hocking, 2000)

For 4 hour (10 hour) flights this would amount to an average of 48 cents ($ 1.2) per passenger for the trip.
(Hocking, 2000)

I agree to pay $2 extra for enough fresh air.

Thank You For Your Attention