ABSTRACT
The indoor air quality at six popular food courts was studied in relation to health and comfort problems among the patrons. Significant environmental findings were high carbon dioxide levels (morning=859ppm; lunch time=1255ppm), high bacterial counts (morning=553 CFU/m3; lunch=639 CFU/m3), and high air temperature (25.8°C; 25.5°C). Overall, patrons perceived the indoor air quality to be good (93%) although there were complaints of poor thermal comfort (too warm, 31%; too cold, 23%), kitchen odours (80%), nose irritation (2%) and sneezing (2%). While baseline levels of air pollutants remained low, there was scope to reduce the bacterial levels, thermal discomfort and food smell problems through improvement of the air distribution, ventilation design and proper maintenance of the kitchen hoods.

INDEX TERMS
Food court, Kitchen, Indoor air quality, Air pollutants; Food smell

INTRODUCTION
Singapore is a tropical city-state with a multi-ethnic Asian heritage and a diversity of culinary fare. An interesting and popular past-time activity among locals and visitors in this urban cultural milieu involves patronising the many hawkers in food courts who offer local food at affordable prices. In addition, the fast-paced economy also compels many working couples to eat out because of the convenience. The specific objectives of this study are to establish baseline levels of indoor air pollutants in air-conditioned food courts, identify discrepancies in the air quality and their association with perceptions of the patrons. The preliminary findings are reported herein.

METHODS
Six food courts frequented by both locals and visitors were randomly selected from a sampling frame of 75 food courts that were stratified on the basis of their popularity and geographical location. The food courts were situated within multi-storey shopping complexes. Their years in operation ranged from 2-15 years and their size comprised between 10 and 30 stalls. For air-conditioning, two food courts were served by centralized air conditioning systems, two by ceiling suspended air handling units and two by fan-coiled units.

A total of 147 sampling sites were identified, including 3 sampling points selected at the eating area of each food court for the measurement of indoor air quality. Spot measurements for carbon dioxide, carbon monoxide, air temperature, relative humidity, respirable dust particle (in accordance with the internationally accepted 4 micrometer with 50 percent cut-off), fine fraction particulate matter (PM 2.5) and total photoionisable volatice organic compounds (TVOCs) were measured both in the morning and in the afternoon during the peak lunch hours. Bacterial and fungal samples were collected at the supply air vent and the breathing zone of the seated patrons. The TVOC level was measured at the serving area of the

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individual stall, based on the heavy and light cooking (Singapore Standard CP13, 1999). Other parameters included nitrogen oxides, sulfur dioxide, air movement, and volume airflow rate.

A questionnaire survey was used to characterise the demographic profile of the patrons and any perceived health or comfort complaints about the food court environment. 894 standardised self-administered survey forms were distributed to patrons for their feedback. The association between the perception of the patrons and environmental parameters were analysed using linear regression.

RESULTS
(I) Environmental findings
Thermal comfort: The mean air temperature in the food courts ranged from 22.4-28.7°C. About a third had temperatures exceeding 26°C. The mean air velocity ranged from 0.09-0.22m/s while the mean relative humidity (RH) ranged from 49-72%. Typically, RH during lunch hour was lower than morning RH. The mean air temperature in the kitchen was generally high, at 31.6 ±4.3°C. The cumulative frequency of the air temperature, air velocity and relative humidity are indicated in Figure 1, 2 and 3.

![Figure 1: Cumulative frequency of air temperature](image1)

![Figure 2: Cumulative frequency of mean air velocity](image2)
Carbon dioxide buildup: Carbon dioxide levels ranged from 720-1,881 ppm. Half of the readings exceeded 1000 ppm in the afternoon (Figure 4).

Biological contaminants: 70% of the samples taken at supply air duct had viable bacterial counts exceeding 500 CFU/m$^3$ while 50% of the air sample collected at breathing zone exceeded that limit (Figure 5). Despite of the presence of moisture damage in the kitchen, the airborne fungal counts were low, ranging from 219 to 298 CFU/m$^3$.

Physical and chemical contaminants: Respirable dust particles and PM 2.5 were observed following a similar trend (Figure 7 and 8). The particulate levels were higher in the morning.
We also found that the heavy cooking activities generated higher TVOC and carbon monoxide levels (Figure 6 and 9).

**Figure 6.** Cumulative frequency for total photoionisable volatile organic compounds (TVOC) level

**Figure 7** Cumulative frequency of respirable dust particle

**Figure 8.** Cumulative frequency of particulate matter 2.5
(II) Questionnaire findings
Based on a total of 894 returned questionnaires, respondents were aged between 16 and 46 years and the male to female ratio was 1:1. The frequency of patronage at the food courts were as follows: daily (16%), at least once week (33%), at least once a month (22%) and less than once a month (29%). The patrons surveyed perceived the indoor air quality to be good (93%). Main complaints involved thermal comfort (too warm, 31%; too cold, 23%) and kitchen odours (80%). Health complaints were minor and involved nose irritation (2%) and sneezing (2%). The significant findings were:

1. The perception of air being too warm was correlated with the air temperature in the afternoon and high carbon dioxide levels in the afternoon;
2. The complaint of kitchen odours at the food court was correlated with high carbon dioxide levels in the afternoon, high viable bacterial counts at the supply air vent, and high TVOC level in the afternoon;
3. The complaint of other odours (smell of furnishing) was correlated with high TVOC in the afternoon; and
4. The perception of air being too damp or too dry was correlated with high air temperature in the afternoon.

DISCUSSION
The health risk factors in Singapore office premises have been investigated and documented (Ooi et al, 1996, 1997, 1998). Because of emerging health concerns associated with other aspects of the built environment, the public health authorities have undertaken studies to look at car parks (1997), MRT train stations (1998), and schools (1999) (Yap and Ooi, 2001). This study represents an extension of the programme into food courts and other places of recreation.

Our study showed that the indoor air quality at the eating areas was generally satisfactory and remained within acceptable limits stipulated in our existing guidelines for common air pollutants, (IEE, 1996). The major environmental findings in the six food courts were high carbon dioxide levels (morning=859±152ppm; lunch time=1255±288ppm), high bacterial counts (morning=553±326 CFU/m³; lunch=639±286 CFU/m³), and high air temperature (25.8±1.5°C; 25.5±1.9°C).

The build-up of carbon dioxide levels and high bacterial counts in the food courts were indicative of inadequate fresh air intake and over-crowding, especially during lunch hour. The
presence of high bacterial counts in specific locations was also a marker of the sanitary condition of the premises and could reflect the presence of food waste as nutrient media (Chan et al, 1995). Respirable dust particles and PM 2.5 were observed in generally similar trends and indicated that most of the respirable dust could constitute of PM 2.5. The particulate levels were higher in the morning, probably because cooking activity was heavier in the morning and thus generated products of incomplete combustion. We also found that the heavy cooking activities generated higher TVOC levels, pointing to the fact that heavy cooking fumes contained higher level of photoionisable gases (Yap et al 1995).

Kitchen odour constituted 80% of the complaints of the patrons. The poor efficiency of the kitchen hood was one of the main contributing factors. The misuse of the kitchen hood by installing a platform in between the hood and stove to place the seasoning bottles cause most of the air could not be extracted by the hood effectively.

Our study showed that while baseline levels of air pollutants in the premises remained low, there was scope to reduce the bacterial levels, thermal discomfort and food smell problems through improvement of the air distribution, ventilation design and proper maintenance of the kitchen hoods.

REFERENCES