Habitat International 33 (2009) 463–471

Contents lists available at ScienceDirect

Habitat International

journal homepage: www.elsevier.com/locate/habitatint

Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong

Siu-Kei Wong [a], Lawrence Wai-Chung Lai [a], Daniel Chi-Wing Ho [a,*], Kwong-Wing Chau [a], Cindy Lo-Kuen Lam [b], Chris Hung-Fai Ng [c]

[a] Department of Real Estate and Construction, The University of Hong Kong, Pokfulam Road, Hong Kong
[b] Family Medicine Unit, Department of Medicine, The University of Hong Kong, Hong Kong
[c] Development Bureau, Hong Kong Special Administrative Region Government, Hong Kong

Keywords:
Health
Environmental quality
Housing
Hong Kong

ABSTRACT

The outbreak of a highly communicable disease, SARS, in Asia in 2003 has revealed the health risk of living in a high-density environment. To show the important connection between human health and environmental quality, this study surveys the prevalence of sick building syndrome (SBS) among apartment residents and their evaluation of indoor environmental quality (IEQ). Based on a sample of 748 households living in Hong Kong, two interesting findings are revealed: (1) nasal discomfort was the commonest home-related SBS symptom despite the absence of any central ventilation system in apartment buildings; (2) noise, rather than ventilation, was the major IEQ problem perceived by residents. Our statistical analysis further showed that residents with SBS symptoms were less satisfied with their IEQ than those without. That is, despite a positive evaluation of specific IEQ criteria with respect to the building residents lived in, if they reported feeling SBS related symptoms, the overall IEQ evaluation of their building could still be negative. This perception bias gives rise to a sample selection problem in measuring perceived IEQ, which has implications on housing management practices and the formulation of a healthy housing policy.

Introduction

Researchers have carried out many studies to investigate the association between the built environment and human health. One important strand lies in sick building syndrome (SBS), which is widely used to describe symptoms experienced inside a building, such as headaches, eye, nose, or throat irritations, itchy skin, and fatigue (e.g. Burge, Hedge, Wilson, Bass, & Robertson, 1987; Finnegan, Pickering, & Burge, 1984). These symptoms, while common in the general population, become more prominent the longer a person stays inside a building, but they tend to disappear when he or she goes out. It is the non-specific and untraceable nature of these symptoms from which the name SBS originated. If the exact causes of these symptoms were known to be a specific component of a building (e.g. the volatile organic compounds [VOC] emitted from finishes), they would have been classified as building-related illnesses (e.g. Menzies & Bourbeau, 1997). According to the World Health Organization (1986), up to 30% of new and remodeled buildings worldwide were potential carriers of SBS. Since then, there have been many cases of SBS, predominantly in sealed office buildings. Although poor indoor environmental quality (IEQ) is often blamed for causing SBS, it is empirically very difficult to locate or single out the source(s) responsible for a particular symptom.

This study, being interdisciplinary by drawing expertise and survey resources from the medical, architectural, building construction and planning fields, aims to explore the prevalence of SBS in apartment buildings and then relate it to the potential bias in occupants' evaluation of IEQ.[1] Apartment buildings are our focus because of the growing concern over their "healthiness", especially after the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003 in Hong Kong. This communicable disease has clearly given a health warning to people who are used to high-density living. Since the SARS outbreak, we have seen an

* Corresponding author. Tel.: +852 2559 9457.
E-mail address: danielho@hkucc.hku.hk (D.C.-W. Ho).

[1] It should be noted that this paper does not seek to establish any causal relationship between SBS and IEQ.

0197-3975/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.habitatint.2009.03.001

increasing amount of research not just in the medical field (e.g. Lee et al., 2003; Tsang et al., 2003; Yu et al., 2004) but also on housing conditions and economic impact (e.g. Ho et al., 2004, 2007; Lai, Chau, Ho, & Lin, 2006a, 2006b; Wong, Cheung, Yau, Ho, & Chau, 2006). However, the healthiness of apartment buildings in Hong Kong remains largely unknown.[2] There is no information on the current status of occupants' health in terms of SBS symptoms. There is also no standardized tool to measure perceived IEQ in residential buildings.[3] A primary contribution of this study is to provide a systematic survey of the types of SBS symptom reported by residents in apartment buildings and the level of satisfaction to the IEQ of their homes.[4]

In the footsteps of Engvall, Norrby, Bandel, Hult, and Norbäck (2000), this study develops a questionnaire that can reliably measure residents' perceptions of SBS and IEQ, and then *draws* implications for devising a healthy housing policy for apartment buildings. Nowadays, apart from field measurements and expert opinions, occupants' feedback often forms an integral part of an IEQ assessment exercise.[5] With the survey data, we can further look into the measurement problem of perceived IEQ when some respondents are prone to SBS. The idea is that if SBS cannot be attributed to a particular source, it is psychologically possible that occupants with SBS are satisfied with every *individual* component of IEQ (e.g. air quality, thermal comfort, lighting, and acoustic performance), but still give their buildings a low *overall* IEQ score. Whether or not this psychological possibility exists in practice is an empirical question. If it does exist, the result of perception-based IEQ assessments could well be biased, leading to a wrong decision for housing improvement, healthy building certification, and legal compliance checks.

As will be shown in next section, sealed office space has been the focus of most SBS literature, whereas the residential environment has been largely ignored. Indeed, residential buildings could provide a useful case for resolving the ongoing debate over whether SBS is building or work-related. In Questionnaire and sample, we reported the nature of a standardized, self-administered questionnaire that we posted to occupants of multi-storey apartment buildings in one of Hong Kong's small districts. Respondents were required to report their SBS symptoms and their perceptions of IEQ. Analysis and results presents and discusses the survey results, with a statistical analysis that casts light on the measurement problem of perceived IEQ. In the Conclusion, the findings are summarized, some health policy implications are noted, and some directions for future research are suggested.

Literature review

This study is related to the concept of "sick building", which is said to cause its occupants to experience and/or complain of ill health more often than may be reasonably expected (Finnegan et al., 1984). It emerged from an increase in the prevalence of certain combinations of symptoms observed in particular buildings during the 1980s (Skov & Valbjørn, 1988). A whole branch of research has contributed to identifying sick buildings (Lahtinen, Huuhtanen, & Reijula, 1998), including SBS. Common SBS symptoms are established, but their exact causes are unknown. Some researchers attributed SBS to ventilation problems in sealed buildings (Letz, 1990), while others argued that SBS can also be work-related (Lyles et al., 1991). Since most early studies on SBS focused on office buildings (Burge et al., 1987; Letz, 1990; Skov & Valbjørn, 1988; Wallace, Nelson, Highsmith, & Dunteman, 1993), whether or not SBS is related to poor building design or work pressure is difficult to discern.

Our study used residential buildings, presumably a warm shelter for most families, as a contrast to the stressful work environment.[6] Previous studies seldom looked at residential buildings because they tend to be naturally ventilated and less prone to SBS (Bardana, 1997; Crawford & Bolas, 1996). However, Letz (1990) pointed out that acute illnesses could occur in residences. Engvall et al. (2000) further confirmed this by a large-scale questionnaire survey (9808 responses out of 14,235 residences) on SBS of apartment buildings in Sweden, and found that symptoms afflicting the eye, nose, throat, and facial skin were common during the time building users stayed home. Such comprehensive evidence allows us to infer that SBS does not only arise in workplaces, but also at home.

Although researchers have yet to pinpoint the exact cause of SBS, they have come out with field studies that suggested poor IEQ is a very probable source affecting the acceptability of the indoor environment (Wong, Mui, & Hui, 2008), the self-reported occurrence of symptoms (Ebbehøj, Hansen, Sigsgaard, & Larsen, 2002; Erdmann & Apte, 2004; Marmot et al., 2006; Menzies, Tamblyn, Nunes, Hanley, & Tamblyn, 1996), or accuracy in task performance (Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandreas, 2006). There are also studies on users' perception of air quality (Wargocki, Wyon, Baik, Clausen, & Fanger, 1999) and other environmental attributes (Engvall et al., 2000). As the use of perception-based assessment becomes more popular, it is worth asking if perceived IEQ could be biased by the presence of SBS. As we pointed out in the Introduction, it is important to understand this bias because if the presence of SBS leads to a divergence between the perceived levels of overall IEQ and individual IEQ components, then the validity of evaluating IEQ based on occupants' subjective assessments would be compromised.

Questionnaire and sample

To study the relationship between SBS and perceived IEQ, a self-administered questionnaire (in Chinese), based on the SBS and IEQ literature, was designed to (1) identify the SBS symptoms occupants have in apartment buildings and (2) assess occupants' perception of specific IEQ components as well as overall IEQ. The details are shown in Appendix.[7] The questionnaire was divided into three parts. The first part collected a respondent's general information like age, sex, education level, and employment status.

[2] Having said that, there was research on urban quality of life (Foo, 2000) and personal and environmental quality of life (Westaway, 2006). But they do not directly examine the SBS and IEQ dimensions.

[3] There exists only an Indoor Air Quality (IAQ) Certification Scheme for office buildings and public places (IAQ Management Group, 2003). This scheme is a voluntary rating system that certifies buildings by measuring various IAQ parameters, such as temperature, relative humidity, air movement, carbon dioxide, etc.

[4] It should be noted that this study is based on residents' self-reported SBS symptoms and perception of IEQ. No objective measurement of SBS or IEQ has been undertaken.

[5] Occupants are often involved in the first and last steps of an IEQ assessment exercise – their opinions are sought both before carrying out costly investigation and after improvement work has been done.

[6] This, of course, depends on work types and family settings, which have been shown to affect conflict between work and family (Bryon, 2005).

[7] In the original questionnaire, some other questions related to personal habits, health problems and building maintenance conditions were asked. They are not reported here since they have no direct relevance to this study.

Table 1
Examples of SBS and IEQ questions

SBS questions (translated from Chinese)
- Do you have eye discomfort (e.g. tearing) while you stay at home?
- Do you have nose discomfort (e.g. running nose, sneezing) while you stay at home?
- Do you have throat discomfort (e.g. coughing, sore throat) while you stay at home?
- Do you have head discomfort (e.g. headache, dizzy) while you stay at home?
- Do you have skin discomfort (e.g. allergy, feeling dry) while you stay at home?
- Do you feel fatigued while you stay at home?

IEQ questions (translated from Chinese)
- Are you disturbed by noise from inside the building (e.g. neighbors or drainage pipes) while you stay at home?
- Are you disturbed by noise from outside the building (e.g. traffic) while you stay at home?
- Do you have enough sunlight in your flat?
- How do you feel about the air ventilation in your flat?
- Overall, are you satisfied with your living environment?

The second part asked the respondent to report his/her health status, in particular the SBS symptoms they experienced while they were staying at home. In many SBS studies, symptoms included discomfort or problems related to the eyes, nose, throat, head, skin, and fatigue (Burge et al., 1987; Finnegan et al., 1984). Respondents were required to answer "never", "sometimes" or "often". The prevalence of these symptoms from respondents in Hong Kong was then compared to another home-SBS study in Sweden by Engvall et al. (2000). Respondents were also asked to report other health-related issues like whether they were smokers and had chronic respiratory problems diagnosed by a Western doctor. These questions were derived from part of a standardized local medical questionnaire called SF-12 (Lam, Tse, & Gandek, 2005). Such health-related information is useful for robustness check in our statistical analysis. Finally, the third part of the questionnaire asked the respondent to evaluate the IEQ of his/her home. In designing the questions, reference was made to the studies by Kahlmeier, Schindler, Grize, and Braun-Fahrländer (2001) and Zagreus, Huizenga, Arens, and Lehrer (2004) to measure perceived indoor environmental quality and asked about the satisfaction of users with individual elements (including the noise, sunlight, and air ventilation levels) as well as their overall perception of their living environment. Respondents could answer "dissatisfied", "neutral" or "satisfied". These answers will form the basis to test if the presence of SBS symptoms could lead to perception bias. Examples of the SBS and IEQ questions, translated from Chinese into English, are shown in Table 1. The questions were designed to be as comprehensible as possible and sometimes

Table 2
Stratification of respondents by sex, age and education level

	%
Sex	
Male	41
Female	59
Age (years)	
18–29	13
30–39	23
40–49	22
50–59	19
60–69	12
Above 70	11
Education level	
Primary education or below	13
Secondary education	52
Tertiary education or above	34

Table 3
Building age distribution of the stratified buildings and subjects

Building age (years)	Questionnaires sent		Questionnaires returned	
	No.	%	No.	%
≤10	466	7.4	77	16.5
11–20	1283	20.5	204	15.9
21–30	1800	28.7	290	16.1
31–40	1821	29.1	229	12.6
>40	892	14.2	81	9.1
Total	6262	100	881	14.1 (average)

assisted with examples because respondents might not have been able to understand complicated questions in a self-administered questionnaire. The questions will be further elaborated and explained in the next section.

The questionnaire was mailed to a random sample of apartment units according to addresses within a small urban district – the Yau Ma Tei-Tsim Sha Tsui-Mongkok (YTM) district – in Hong Kong. YTM is dominated by about 3000 privately-owned, densely-populated apartment buildings. According to the statistics provided by the government's Home Affairs Department in 2006, YTM is characterized by multi-storey buildings of 11 storeys and 34 years old, on average. Each storey usually consists of several flats, and a household typically occupies a flat of less than 100 m^2. In our study, we stratified apartment buildings in YTM into different building age and location sub-groups first before random sampling in each sub-group. A total of 148 buildings were finally selected, which represent 5% of the building stock in YTM.

The medical history of YTM is interesting. According to a large-scale study on standardized mortality ratios (SMRs) of different diseases for all of Hong Kong for the period 1979–1993 (Lloyd, Wong, Wong, & Yu, 1996), some individual diseases and conditions, such as hypertension, tuberculosis, and pneumonia, were found to have significantly higher SMRs for residents living in YTM than in some other districts. Yet, in overall territorial terms, the SMRs for all diseases surveyed in this district were not statistically significant (p.27). Bad living conditions were found to be so significant in some studies that they contributed to the outbreak or even worsening of diseases (Barker, Forsén, Eriksson, & Osmond, 2002; Leung et al., 2004; du Moulin, 1989; Tomson & Lip, 2005). This study would complement previous studies by examining whether residents living in YTM perceived their illnesses to be building-related.

Before sending out the questionnaires, site visits to buildings in YTM were conducted in order to identify any inconsistency between our building address database and the actual use (e.g. subdivisions, mergers, and changes in use).[8] Outdated mailing addresses were corrected and units which had been converted to retail/office use were discarded. Then the questionnaires, written in Chinese, were sent to 6262 residences in YTM. For each flat, an invitation was extended only to the adult household member who spent the longest time inside his/her flat to complete the questionnaire. A total of 881 responses were received, which meant a response rate of 14%. This seemingly low response rate should be viewed in light of the response rates and scale (absolute number of respondents) for studies of similar nature with the cultural specificities of Hong Kong in mind. In the medical study by Wun, Tang, and Chao (2001) using postal questionnaire survey, the response

[8] It is not uncommon for residential units on the lowest floors to convert to retail/office use, especially in older buildings.

Table 4
Characteristics of buildings that yielded valid responses

Variable	Building age (year)	Flat size (m^2)	No. of flats	No. of storeys
	Age	Size	Flat	Storey
Average	29.7	51.5	67.8	12.8
Maximum	52	120.5	420	24
Minimum	3	20.4	8	4
S.D.	11.7	18.1	78.7	5.1

rate was only 9.6% (with a total of 124 responses). The educational or professional background of respondents did not appear to be significant. An e-questionnaire survey for a doctoral thesis that pioneered Hong Kong light pollution research achieved just 4.6% response rate (with a total target population of 11,737 persons) (Chui, 2008). As revealed by the findings of relevant social surveys (Chan & Yung, 2004; Chui, 2008; Dissanayaka & Kumaraswamy, 1999; Hui, 2006; Lee & Chan, 1998; Leung, Lu, & Ip, 2005; Poon, Yu, & Jaillon, 2004; Shen & Tam, 2002; Tam, Tam, & Zeng, 2002; Tam, Tam, Zeng, & Chan, 2006; Wun et al., 2001), surveys administered to the general public tended to have a lower response rate than those administered to specific groups. Besides, there was also an inverse relationship between response rates and the scale of the survey. The response rate of our survey, though not impressive, was compensated by the scale of the successful interviewed information (after Chui, 2008 but on a par with Hui, 2006). To show that we have a general distribution of samples, we provide stratification of respondents according to their sex, age and education as shown in Table 2.

Of the 881 responses, some were incomplete. After following up these cases by telephone, there remained 748 valid responses. The response rates, stratified by different building age groups, are shown in Table 3. One noticeable feature was the relatively low response rate for the building group aged over 40 years. While approximately 16% of the subjects living in buildings no older than 30 years submitted replies, this percentage fell to 9.1% for buildings built more than 40 years ago. This was probably due to the higher vacancy rates for the older buildings and higher illiteracy rates among the older heads of household. Table 4 shows the descriptive statistics of the buildings in which the respondents lived. The sample provides a fair variation in terms of building age, flat size, building size (by the number of flats), and building height (by the number of stories).

Analysis and results

Self-reported SBS symptoms

This section reports how residents, when staying inside their apartment units, rated the frequency of SBS symptoms, including eye, nose, throat, head, skin, and fatigue problems. Frequencies were measures by assigning three scales: "no symptoms," "sometimes," or "often". As with Engvall et al. (2000), "often" means a symptom repeats at least weekly. Respondents who answered "often" were instructed to proceed to the next question, which could be the reason why they perceived such symptoms to be related to their living environments. The results are presented in Table 5.

Table 5
Results of the questionnaire survey on the occurrence of symptoms and the perceived relationship to the living environment

Symptoms	Report of symptoms			If "Often" is chosen, is it related to your living environment?	
	None (%)	Sometimes (%)	Often (%)	Yes (%)	No (%)
Eye	66	30	4	30	70
Nose	35	49	16	62	38
Throat	41	51	8	42	58
Head	46	47	7	32	68
Skin	48	40	12	32	68
Fatigue	28	53	19	34	66

The survey revealed that nose discomfort (e.g. running nose, sneezing) was the most widely-reported symptom that is perceived to be building-related. Forty-nine percent of the respondents chose "sometimes," while 16% rated it as "often". Among the 16% of respondents choosing "often," 62% of them thought it was related to their built environment, which was substantially higher than for other symptoms (see Table 5). Comparing the reported symptom of nose discomfort to the results in Engvall et al. (2000), which was carried out in Stockholm, Sweden, reveals that the reported prevalence of nasal symptoms was only 13% of all participants and 46% among them thought it was building-related (see Table 6). The reason for a stronger perception of building-related nose discomfort in Hong Kong could be that the densely-populated buildings in YTM reduce the air flow within the district, making occupants in apartment buildings more susceptible to air pollution, particular from the heavy traffic. When we conducted the health survey, the daily average of the hourly air pollution index (API) in Mongkok was the third highest[9] among all monitored (14) areas in Hong Kong.

Apart from nose discomfort, Table 5 showed the percentages of other reported symptoms at home, including eye discomfort, throat discomfort (e.g. coughing, sore throat), head discomfort (e.g. headache, dizziness), skin discomfort (e.g. allergy, dry skin) and fatigue. Eye discomfort appears to be the least prevalent, as only 30% respondents chose "sometimes" and 4% "often". Problems in throat, head, and skin were slightly more frequent, with 41–48% respondents reporting no such symptoms (i.e. "none"). Fatigue appears to be the commonest (53% "sometimes" and 19% "often"), though it is not widely perceived to be building-related (only 34% believed so). This is not unreasonable as fatigue is likely to be "brought" from work to home rather than being built up at the home environment. Overall speaking, all these other symptoms were less building-related than noise discomfort, according to the respondents' opinions.

Some further comparisons of the findings of the HK study and those of Engvall et al.'s Swedish study are shown in Table 6. Reports on eye discomfort (30% choosing "sometimes" and 4% choosing "often") were relatively fewer than those of Engvall et al. by 4%. On the other hand, problems of skin seem to be more serious in Hong Kong (12% "often") than in Sweden (8% "often"). For throat problems, the results are quite similar to those of Engvall et al.'s. It was not possible to make comparisons for head discomfort and fatigue because Engvall et al. did not report on them.

In summary, these findings confirm the presence of self-reported SBS symptoms in apartment buildings. A lot of studies have suggested a variety of environmental and personal determinants, on which no consensus has been reached. Suffice it to say that in a high-density urban area in a sub-tropical weather,

[9] The two most polluted districts were Causeway Bay (average 65.8) and Central (average 65.3). API was obtained from the Environmental Protection Department. See daily summary of hourly air pollution index, online at http://www.epd-asg.gov.hk/download/daily/eng/api2005.csv. Note however that Hong Kong's API is significantly at variance with the EU and WHO norms.

Table 6
Comparison table of the HK study and Engvall et al.'s (2000) study

Symptoms	Report of symptoms			Building-related?	
	HK		Engvall et al.	HK	Engvall et al.[a]
	Sometimes (%)	Often (%)	Often (%)	Yes (%)	Yes (%)
Eyes	30	4	8	30	50
Nose	49	16	13	62	46
Throat	51	8	9	42	56
Head	47	7	Not reported	32	Not reported
Skin	40	12	8	32	50
Fatigue	53	19	Not reported	34	Not reported

[a] The prevalence of building-related SBS, originally presented as a percentage of total respondents in Table 5 of Engvall et al.'s study, is expressed as a percentage of respondents choosing "often" in this table for like-with-like comparison with the HKs findings.

dampness and mold could well be an important environmental factor that increases the prevalence of these symptoms, as suggested by Dales, Burnett, and Zwanenburg (1991) and Engvall, Norrby, and Norbäck (2001), although the indoor thermal properties can be adjusted by the use of air-conditioning. Medically, extreme thermal conditions can have an indirect health impact in an affluent Asian context, as in the cases of Japan (Kai, Inoue, Higaki, & Tomokuni, 2008; Wakamori, Katoh, Hirano, Kishimoto, & Ozasa, 2009) and Hong Kong which has a notoriously excessive "air-conditioning culture" in certain public places (Lin & Deng, 2006).[10] Also, at a personal level, the period of stay at home could modify one's reporting of symptoms. But its exact effect is not clear, depending on whether a resident is more or less sensitive to the indoor environment after living in the same premises for a long period of time. Further research is needed to address these issues.

Perceived IEQ

We also asked residents to assess IEQ in terms of both specific criteria and the overall performance of their apartment units. In accordance with Kahlmeier et al. (2001) and Zagreus et al. (2004), we used three specific perceived IEQ criteria: (1) noise (which we split into internal noise inside a building and external noise outside a building with examples), (2) adequacy of sunlight (i.e. natural lighting), and (3) air ventilation. We required residents to state if they were satisfied with these criteria. In the end, occupants needed to rate their overall satisfaction with their living environments. A summary of result is in Table 7.

The survey on IEQ perceptions showed that most residents were disturbed by internal noise. Fifty-eight percent respondents were dissatisfied with it (e.g. from neighbors or drainage pipes in the same building) compared to 17% who were dissatisfied with external noise (e.g. traffic). The high-density living environment of YTM could be a major reason. In 2006, its population density was 40,136 persons per km^2, which placed it third among 18 districts in Hong Kong.[11] In apartment buildings, it is typical to have the window of one flat to be situated very close to the window of another flat. Noise transmission between walls and ceilings is also common. Living in such a small and congested place means that the indoor activities of residents, such as playing mahjong or switching on the TV or radio, can easily affect their neighbors. As for sunlight and air ventilation, residents were generally either neutral or satisfied, with only 24% and 17% dissatisfied, respectively. Finally, perceptions of overall IEQ performance were generally favorable. Only 16% of residents were not satisfied with their overall IEQ.

Statistical analysis

Given the above data on SBS and perceived IEQ, this section tests if residents with SBS symptoms were less satisfied with their overall IEQ than those without. To ensure the robustness of the results to different functional forms, we employed two regression models: Model 1 and Model 2.

In Model 1, we regressed a three-scale overall IEQ perception measure called IEQ_3 ($1=$dissatisfied, $2=$neutral, $3=$satisfied) linearly on six SBS variables and other control variables. The six SBS variables are EYE, NOSE, THROAT, HEAD, SKIN, and FATIGUE, which also follow a three-scale measure ($1=$no symptoms, $2=$sometimes, $3=$often). There are two sets of control variables. The first set is the perception of specific IEQ criteria, as defined in Table 5 (INOISE, ONOISE, LIGHT, and AIR), which equals 1 if a resident was neutral or satisfied with that criterion, and 0 if s/he was dissatisfied. The second set of control variables are the objectively measured building characteristics reported in Table 3 (AGE, SIZE, FLAT, and STOREY). These buildings are located within a small geographical area so that the differential effect of external environment is minimized. Controlling for these intervening variables, which might have a relationship with the dependent variable, allows us to test if the SBS variables had any direct effect on the perception of overall IEQ. The equation depicting the relationship between the variables is as follows.

Model 1

$$\begin{aligned}IEQ_3 = {} & a_0 + a_1{*}\mathrm{INOISE} + a_2{*}\mathrm{ONOISE} + a_3{*}\mathrm{LIGHT} + a_4{*}\mathrm{AIR} \\ & + a_5{*}\mathrm{EYE} + a_6{*}\mathrm{NOSE} + a_7{*}\mathrm{THROAT} + a_8{*}\mathrm{HEAD} \\ & + a_9{*}\mathrm{SKIN} + a_{10}{*}\mathrm{FATIGUE} + a_{11}{*}\mathrm{AGE} + a_{12}{*}\mathrm{SIZE} \\ & + a_{13}{*}\mathrm{FLAT} + a_{14}{*}\mathrm{STOREY} + \varepsilon\end{aligned}$$

In principle, if the overall IEQ perception is driven solely by the satisfaction of individual IEQ criteria and building characteristics, SBS variables should play no part in the model and have insignificant coefficients. *However, if SBS variables turn out to be significant, then the overall IEQ rated by residents is not SBS-neutral.* The implication is that ignorance of SBS would give rise to a biased result for perceived overall IEQ.

[10] In our sample, we were not able to identify whether air-conditioners were actually used in the flats. But it is reasonable to say that their use in residential buildings is much less frequent than in office buildings.

[11] The two highest population density districts, according to the 2006 By-Census, were Kwun Tong (52,123 persons per km^2) and Wong Tai Sin (45,540 persons per km^2).

Table 7
Results of the questionnaire survey on IEQ assessment

IEQ criteria	Variable	Neutral or satisfied (%)	Dissatisfied (%)
Noise from outside the building	ONOISE	83	17
Noise from inside the building	INOISE	42	58
Sunlight	LIGHT	76	24
Air ventilation	AIR	83	17
Overall IEQ	IEQ	84	16

Strictly speaking, IEQ_3 is qualitative in nature, and a linear model like Model 1 might not be appropriate. To relax the restrictive functional assumption, the study re-estimated the data using a probit model, as shown in Model 2. In this model, it treated the perceived overall IEQ as a binary variable called IEQ_2, which equals 1 if a resident is neutral or satisfied with his/her overall IEQ, and 0 if s/he is not. The probability of $IEQ_2 = 1$ was then given by a cumulative standard normal distribution of the same set of independent variables as above.

Model 2

$$\begin{aligned}\text{Prob}(\text{IEQ}_2 = 1) = \Phi(&a_0 + a_1{*}\text{INOISE} + a_2{*}\text{ONOISE}\\ &+ a_3{*}\text{LIGHT} + a_4{*}\text{AIR} + a_5{*}\text{EYE} + a_6{*}\text{NOSE}\\ &+ a_7{*}\text{THROAT} + a_8{*}\text{HEAD} + a_9{*}\text{SKIN}\\ &+ a_{10}{*}\text{FATIGUE} + a_{11}{*}\text{AGE} + a_{12}{*}\text{SIZE}\\ &+ a_{13}{*}\text{FLAT} + a_{14}{*}\text{STOREY})\end{aligned}$$

where Φ is the cumulative standard normal distribution.

The results of Models 1 and 2, which were similar, are shown in Table 8. Among the six symptoms tested, the coefficients of NOSE and HEAD were significant and had negative signs in both models. Residents with nose and head symptoms had a significantly lower rating of their overall IEQ than those without. The negative effects of these two symptoms on the perception of overall IEQ were not due to environmental factors because they were controlled in the models. It follows that SBS could bias residents' rating of overall IEQ – residents' experiences with nose or head symptoms affected their perception of overall IEQ in a way that was different from their perception of individual IEQ criteria or objective building characteristics. This might be due to the fact that residents were not able to locate the exact causes of their nose symptoms due to invisible air pollutants. The same applies to the effect of head symptoms, which might be attributed to environmental factors other than those included in the models. Other symptoms, including problems with the eyes, throat, skin, and fatigue, were insignificant in both models. Eye, throat, and skin problems might be more related to the presence of allergenic substances identifiable in the flats or the external areas, whereas fatigue might be related to the physical condition of the respondents themselves (e.g. older people may experience more fatigue than younger people).

As for the perceived IEQ factors, we found, as expected, residents' satisfaction to noise (both internal and external) and air ventilation contributes positively and significantly to their perception of overall IEQ. However, one's satisfaction with the amount of sunlight was insignificant in both Model 1 and Model 2. It was reckoned that people could manually adjust the amount of light by switching on artificial light in case there was not enough natural lighting, and closing curtains if the sunlight was too strong. These self-adjustments might make the amount of sunlight insignificant to explain the satisfaction of overall IEQ. For the variables concerning building characteristics, building age was negative and significant in both models. Older buildings tend to have more maintenance and hygiene problems. Buildings over 30 years old are the targeted buildings in the government's Mandatory Building Inspection Scheme (MBIS), which was proposed during a public consultation report published by the former Housing, Planning and Lands Bureau (Housing, Planning and Lands Bureau, 2007). Therefore, people living in older buildings may rate their living environments lower. Flat size was positive and significant in Model 1, but not Model 2. This was understandable, as people living in more spacious environments tend to perceive their quality of life as better. The number of flats in a building and the number of stories were insignificant in both models.

Lastly, a check was made of the robustness of the statistical results with respect to smoking habits and pre-existing medical conditions. In the questionnaire, respondents were asked to state whether they were smokers and whether they had respiratory problems diagnosed by a Western doctor such as asthma, emphysema, chronic bronchitis, and other chronic lung diseases. The responses show that 12% were smokers and 23% had respiratory problems. Even if these respondents are excluded from our sample, the results in Table 8, especially for Model 1, remain qualitatively unchanged, with only slight trade-off in goodness-of-fit due to the reduced sample size. Residents with nose and head symptoms are still found to give a significantly lower rating of their overall IEQ than those without.[12] Satisfaction to noise levels and air ventilation remain a significant contributor to the perception of overall IEQ.[13] Therefore, smoking habits and pre-existing respiratory problems do not appear to change our conclusion that SBS symptoms contribute to a perception bias in user-rated IEQ.

Table 8
Results of Model 1 and Model 2

Independent variable	Model 1		Model 2	
	Coefficient	*t*-Statistic	Coefficient	*z*-Statistic
INOISE	0.1607	−2.7513[b]	0.3066	−2.0972[a]
ONOISE	0.2663	−6.0827[b]	0.4045	−3.0066[b]
LIGHT	0.0846	1.5657	0.0448	0.3035
AIR	0.4129	6.6275[b]	0.8220	5.4351[b]
EYE	0.0259	0.6308	0.0914	0.8149
NOSE	−0.1163	−3.0337[b]	−0.2463	−2.3070[a]
THROAT	−0.0415	−0.9775	−0.1269	−1.0585
HEAD	−0.1340	−3.1515[b]	−0.2712	−2.3433[a]
SKIN	0.0067	0.1861	−0.0040	−0.0410
FATIGUE	−0.0365	−0.9854	−0.1446	−1.3715
AGE	−0.0080	−3.0956[b]	−0.0228	−2.9027[b]
SIZE	0.0041	2.5107[a]	0.0062	1.3546
FLAT	0.0002	0.9831	−6.26E-05	−0.0912
STOREY	0.0048	0.7556	0.0029	0.1569
R^2	0.2351		0.1966	
Log likelihood	−708.7000		−272.2190	

[a] and [b] indicate the independent variables which were significant at the 0.05 and 0.01 levels, respectively.

[12] With the reduced sample, the coefficients of NOSE and HEAD in Model 1 are negative and significant at the 5% level. For Model 2, NOSE remains significant at the 5% level, but HEAD becomes insignificant (though still getting the same expected negative coefficient).

[13] With the reduced sample, the coefficients of INOISE, ONOISE and AIR in Model 1 remain positive and significant at the 1% level. Similar results are found in Model 2, except that INOISE becomes insignificant (though still getting the same expected positive coefficient).

Conclusion

Summary of results

The results of the first part of the questionnaire showed that, among various home-related SBS symptoms, nose discomfort (e.g. running nose, sneezing) was the commonest in Hong Kong. The respondents strongly believed that their nose discomfort was building-related despite the absence of any central ventilation system in their apartment buildings. There are two implications. First, the results shed light on the controversy over whether the occurrence of SBS is mostly related to the physical indoor environment or psychosocial factors. Researchers have conducted most of their epidemiological indoor environmental studies in workplaces. The study added insight to the existing literature by arguing that SBS can also occur in residential buildings, which are presumably warm shelters for families and where job pressure should be less severe. Second, the nose symptoms are much commoner in Hong Kong than in Sweden, implying that home SBS could vary from place to place. Such a variation could be due to the fact that homes are generally less self-contained (e.g. rely more on natural lighting and ventilation) than offices so that the SBS exhibited at home depends very much more on the quality of the external environment. Further study is, however, needed to examine how much time people actually spend in the flat with the windows open or without using air-conditioners.

The second part of the questionnaire revealed that noise was the major IEQ problem perceived by residents. In an apartment building, noise usually came internally from neighbors or drainage pipes and externally from traffic or construction sites. The result is consistent with the large number of noise complaints in Hong Kong. It is interesting to note that the respondents were generally satisfied with the ventilation despite their complaints about nose discomfort. This prompted us to carry out a statistical analysis of the relationship between SBS and perceived IEQ.

The regression analysis showed that the occurrence of some of the SBS symptoms, in particular nose and head symptoms that could be attributed to such environmental factors as air quality and density, affected how respondents rated the IEQ of their apartments. Residents with nose and head symptoms gave a significantly lower rating of their overall IEQ than those without. This is the case even after the perception of individual IEQ factors (e.g. the quality of noise, light, and air) and building characteristics have been controlled. This finding has a very important implication for those who base the evaluation of internal spaces on perceived IEQ: the overall IEQ rating would be biased downward if the respondents have SBS symptoms. That is, even if respondents were satisfied with specific IEQ criteria, the overall IEQ could still be unsatisfactory to respondents with self-reported SBS symptoms. This could purely be a perception bias that has no bearing on the actual IEQ or SBS symptoms. Ignoring this bias might lead a housing manager to make a wrong decision on improvement measures. There are two approaches to solving this problem. One is to abandon any attempt to make subjective measurements and to base all improvement decisions solely on objective IEQ investigation. This approach, however, can be very costly if objective measurement is to be carried out frequently. It also undermines the importance of customer satisfaction. The other approach is to correct for the bias in subjective IEQ assessment. This is relatively easy: ask the respondents for their SBS symptoms in addition to their IEQ ratings, and use statistical methods, such as the Heckman's (1979) two-stage estimator, to correct for the bias. In this way, occupants' opinions can be effectively incorporated into the building management process (e.g. before carrying out objective IEQ investigation and after completion of improvement work).

Policy implications

The study has important implications for the development of green and healthy building policies. The current policies are concerned mainly with some physical design features and objective measures of building environmental factors. However, the social purpose of these building designs will not be realized if occupants remain unsatisfied with their IEQ. The present study further developed a perception-based IEQ questionnaire, which has been validated through some perceived IEQ criteria and SBS symptoms. Policymakers can, through an examination of the collected responses, realize what criteria are regarded as important for evaluating overall IEQ satisfaction and enhancing the building designs pertaining to these criteria. From our survey, occupants were more sensitive to air quality and noise problems within their flats and the immediate neighborhood, and hence, perceived nose and head symptoms to be more relevant to their IEQ satisfaction. To deal with this, the IAQ Management Group should consider extending the IAQ Certification Scheme to include residential buildings to raise private developers' concern over IAQ.

Limitations and further research

Due to the difficulty in conducting site measurements in private residences, the researchers were unable to enter respondents' flats to measure some specific environmental attributes, such as temperature, level of carbon dioxide, or the presence of allergens. In the future, respondents may be invited randomly to allow investigators to conduct more detailed on-site surveys on these environmental parameters, including how often residents use air-conditioning to modify the indoor environment. Such a further study could also use the data from this SBS survey to conduct an empirical analysis of the relationship between SBS symptoms and the environmental parameters. The influences of some building characteristics, such as flat areas and window sizes, on the occurrence of SBS symptoms can be considered as well. This will contribute to a better understanding of home SBS and will have important implications for the design and management of residential buildings for sustainable development. Nevertheless, as sources of SBS are difficult to identify, the study showed that architects need to consider the symptoms of SBS when they design a perception-based IEQ questionnaire. Otherwise, they may be unable to account for some unobserved effects of SBS. It is hoped that this study will stimulate research on similar issues that pertain to health and the human habitat.

Acknowledgements

The authors are grateful to Dr. AKC Cheung and Dr. Y Yau at the early stage of this project for their assistance in the health survey and the participants in the Sixth China Urban Housing Conference for their comments on an earlier version of this paper. Financial support was provided by the Research Grants Council of the HKSAR (Project References: HKU 7107/04E and HKU 7131/05E), HKU–UGC Matching Fund, HKU Seed Grant for Strategic Research Theme on Sustainable Cities, HKU Small Project Funding, and HKU Outstanding Young Researcher Award (Professor Lawrence Wai-Chung Lai). The authors are in debt to Dr. Stephen Davies for his editorial advice.

Appendix. Sample questionnaire (translated from Chinese)

General information
1. What is your gender?
   Male/Female
2. What was your age on your last birthday?
   Below 18/18–29/30–39/40–49/50–59/60–69/above 70 years old
3. What is your highest educational level?
   Primary education or below/Secondary education/Tertiary education or above
4. Which is your current employment status?
   Employed/Unemployed/Housewife/Retired/Student/Others: ______

Health status
1. Are you a smoker?
   No/Yes: ____ cigarettes per day
2. Have you ever been diagnosed by a Western doctor to have any of the following respiratory diseases?
   No/Yes: Asthma/Emphysema/Chronic bronchitis/Other chronic lung diseases
3. Do you feel the following symptoms while you stay at home?
   a. Eye discomfort (e.g. tearing) Never/Sometimes/Often (at least weekly)
   b. Nose discomfort (e.g. running nose, sneezing) Never/Sometimes/Often (at least weekly)
   c. Throat discomfort (e.g. coughing, sore throat) Never/Sometimes/Often (at least weekly)
   d. Head discomfort (e.g. headache, dizzy) Never/Sometimes/Often (at least weekly)
   e. Skin discomfort (e.g. allergy, feeling dry) Never/Sometimes/Often (at least weekly)
   f. Fatigue Never/Sometimes/Often (at least weekly)
4. For the symptoms you often feel above, do you think their occurrences are related to your living environment?
   a. Eye discomfort (e.g. tearing) No/Yes/Not applicable
   b. Nose discomfort (e.g. running nose, sneezing) No/Yes/Not applicable
   c. Throat discomfort (e.g. coughing, sore throat) No/Yes/Not applicable
   d. Head discomfort (e.g. headache, dizzy) No/Yes/Not applicable
   e. Skin discomfort (e.g. allergy, feeling dry) No/Yes/Not applicable
   f. Fatigue No/Yes/Not applicable

Environmental quality
1. Are you satisfied with the noise level from inside the building (e.g. neighbors or drainage pipes) while you stay at home?
   Dissatisfied/Neutral/Satisfied
2. Are you satisfied with the noise level from outside the building (e.g. traffic) while you stay at home?
   Dissatisfied/Neutral/Satisfied
3. Are you satisfied with the adequacy of sunlight in your flat while you stay at home?
   Dissatisfied/Neutral/Satisfied
4. Are you satisfied with the air ventilation in your flat while you stay at home?
   Dissatisfied/Neutral/Satisfied
5. Overall, are you satisfied with your living environment?
   Dissatisfied/Neutral/Satisfied

References

Bardana, E. J. (1997). Sick building syndrome: a wolf in sheep's clothing. *Annals of Allergy, Asthma and Immunology, 79*(4), 283–294.

Barker, D. J. P., Forsén, T., Eriksson, J., & Osmond, C. (2002). Growth and living conditions in childhood and hypertension in adult life: a longitudinal study. *Journal of Hypertension, 20*(10), 1951–1956.

Bryon, K. (2005). A meta-analytic review of work–family conflict and its antecedents. *Journal of Vocational Behavior, 67*(2), 169–198.

Burge, S., Hedge, A., Wilson, S., Bass, J. H., & Robertson, A. (1987). Sick building syndrome: a study of 4373 office workers. *The Annals of Occupational Hygiene, 31*(4A), 493–504.

Chan, E. H. W., & Yung, E. H. K. (2004). Is the development control legal framework conducive to a sustainable dense urban development in Hong Kong? *Habitat International, 28*, 409–426.

Chui, J. Y. C. (2008). *Perception of light pollution in Hong Kong: an empirical study*. Unpublished Ph.D. Thesis, Department of Real Estate and Construction, University of Hong Kong.

Crawford, J. O., & Bolas, S. M. (1996). Sick building syndrome, work factors, and occupational stress. *Scandinavian Journal of Work, Environment, and Health, 22*(4), 243–250.

Dales, R. E., Burnett, R., & Zwanenburg, H. (1991). Adverse health effects among adults exposed to home dampness and molds. *American Review of Respiratory Diseases, 143*(3), 505–509.

Dissanayaka, S., & Kumaraswamy, M. (1999). Evaluation of factors affecting time and cost performance in Hong Kong building projects. *Engineering, Construction, Architecture and Management, 6*, 287–298.

Ebbehøj, N. E., Hansen, M.Ø., Sigsgaard, T., & Larsen, L. (2002). Building-related symptoms and molds: a two-step intervention study. *Indoor Air, 12*(4), 273–277.

Engvall, K., Norrby, C., Bandel, J., Hult, M., & Norbäck, D. (2000). Development of a multiple regression model to identify multi-family residential buildings with a high prevalence of sick building syndrome (SBS). *Indoor Air, 10*(2), 101–110.

Engvall, K., Norrby, C., & Norbäck, D. (2001). Sick building syndrome in relation to building dampness in multi-family residential buildings in Stockholm. *International Archives of Occupational and Environmental Health, 74*, 270–278.

Erdmann, C. A., & Apte, M. G. (2004). Mucous membrane and lower respiratory building related symptoms in relation to indoor carbon dioxide concentrations in the 100-building BASE dataset. *Indoor Air, 14*(8), 127–134.

Finnegan, M. J., Pickering, C. A., & Burge, P. S. (1984). The sick building syndrome: prevalence studies. *British Medical Journal, 289*(6458), 1573–1575.

Foo, T. S. (2000). Subjective assessments of urban quality of life in Singapore (1997–1998). *Habitat International, 24*, 31–49.

Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica, 47*(1), 153–161.

Ho, D. C. W., Lai, L. W. C., Chau, K. W., Wong, S. K., Cheung, A. K. C., Yau, Y., et al. (2007). A survey of sick building syndrome (SBS) in private apartment buildings in Hong Kong: preliminary results. In *Proceedings of the Sixth China Urban Housing Conference*, 437–445.

Ho, D. C. W., Leung, H. F., Wong, S. K., Cheung, A. K. C., Lau, S. S. Y., Wong, W. S., et al. (2004). Assessing the health and hygiene performance of apartment buildings. *Facilities, 22*(3/4), 58–69.

HousingPlanning and Lands Bureau. (2007). *Report on the public consultation on mandatory building inspection*. Hong Kong: Housing, Planning and Lands Bureau.

Hui, E. C. M. (2006). BRE Confidence Index for residential property. <http://www.bre.polyu.edu.hk/research/bre_index/>.

IAQ Management Group. (2003). *A guide on indoor air quality certification scheme for offices and public places*. Hong Kong: Indoor Air Quality Management Group, HKSAR.

Kahlmeier, S., Schindler, C., Grize, L., & Braun-Fahrländer, C. (2001). Perceived environmental housing quality and wellbeing of movers. *Journal of Epidemiology and Community Health, 55*(10), 708–715.

Kai, K., Inoue, S., Higaki, Y., & Tomokuni, K. (2008). Effects of a cool environment on the health of female office workers and students. *Journal of Physiological Anthropology, 27*, 153–159.

Lahtinen, M., Huuhtanen, P., & Reijula, K. (1998). Sick building syndrome and psychosocial factors – a literature review. *Indoor Air, 8*(Suppl. 4), 71–80.

Lai, L. W. C., Chau, K. W., Ho, D. C. W., & Lin, V. Y. Y. (2006a). Impact of political incidents, financial crises, and Severe Acute Respiratory Syndrome on Hong Kong property buyers. *Environment and Planning B: Planning and Design, 33*(3), 413–433.

Lai, L. W. C., Chau, K. W., Ho, D. C. W., & Lin, V. Y. Y. (2006b). Impact of political incidents, financial crises, and Severe Acute Respiratory Syndrome on Hong Kong regulators and developers. *Environment and Planning B: Planning and Design, 33*(4), 503–522.

Lam, C. L. K., Tse, E. Y. Y., & Gandek, B. (2005). Is the standard SF-12 health survey valid and equivalent for a Chinese population? *Quality of Life Research, 14*(2), 539–547.

Lee, N., Hui, D., Wu, A., Chan, P., Cameron, P., Joynt, G. M., et al. (2003). A major outbreak of severe acute respiratory syndrome in Hong Kong. *The New England Journal of Medicine, 348*(20), 1986–1994.

Lee, S. C., & Chan, L. Y. (1998). Indoor/outdoor air quality correlation and questionnaire survey at two staff quarters in Hong Kong. *Environment International, 24*, 729–737.

Letz, G. A. (1990). Sick building syndrome: acute illness among office workers – the role of building ventilation, airborne contaminants and work stress. *Allergy Proceedings, 11*(3), 109–116.

Leung, C. C., Yew, W. W., Tam, C. M., Chan, C. K., Chang, K. C., Law, W. S., et al. (2004). Socio-economic factors and tuberculosis: a district-based ecological analysis in Hong Kong. *The International Journal of Tuberculosis and Lung Disease, 8*(8), 958–964.

Leung, M., Lu, X., & Ip, H. (2005). Investigating key components of the facility management of secondary schools in Hong Kong. *Facilities, 23*, 226–238.

Lin, Z., & Deng, S. (2006). A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong. *Energy and Buildings, 38*(1), 1302–1307.

Lloyd, O. L., Wong, T. W., Wong, S. L., & Yu, I. T. S. (1996). *Atlas of disease mortalities in Hong Kong for the three five-year periods in 1979–1993*. Hong Kong: Chinese University Press.

Lyles, W. B., Greve, K. W., Bauer, R. M., Ware, M. R., Schramke, C. J., Crouch, J., et al. (1991). Sick building syndrome. *Southern Medical Journal, 84*(1), 65–76.

Marmot, A. F., Eley, J., Stafford, M., Stansfeld, S. A., Warwick, E., & Marmot, M. G. (2006). Building health: an epidemiological study of "sick building syndrome" in the Whitehall II study. *Occupational and Environmental Medicine, 63*(4), 283–289.

Menzies, D., & Bourbeau, J. (1997). Building-related illnesses. *The New England Journal of Medicine, 337*(21), 1524–1531.

Menzies, D., Tamblyn, R. M., Nunes, F., Hanley, J., & Tamblyn, R. T. (1996). Exposure to varying levels of contaminants and symptoms among workers in two office buildings. *American Journal of Public Health, 86*(11), 1629–1633.

du Moulin, G. (1989). Minimizing the potential for nosocomial pneumonia: architectural, engineering, and environmental considerations for the intensive care unit. *European Journal of Clinical Microbiology and Infectious Diseases, 8*(1), 69–74.

Poon, C. S., Yu, A. T. W., & Jaillon, L. (2004). Reducing building waste at construction sites in Hong Kong. *Construction Management and Economics, 22*, 461–470.

Shaughnessy, R. J., Haverinen-Shaughnessy, U., Nevalainen, A., & Moschandreas, D. (2006). A preliminary study on the association between ventilation rates in classrooms and student performance. *Indoor Air, 16*(6), 465–468.

Shen, L. Y., & Tam, V. W. Y. (2002). Implementation of environmental management in the Hong Kong construction industry. *International Journal of Project Management, 20*, 535–543.

Skov, P., & Valbjørn, O. (1988). The "sick" building syndrome in the office environment: the Danish town hall study. *Environment International, 13*(4), 339–349.

Tam, C., Tam, V., & Zeng, S. (2002). Environmental performance evaluation (EPE) for construction. *Building Research & Information, 30*, 349–361.

Tam, V. W. Y., Tam, C. M., Zeng, S. X., & Chan, K. K. (2006). Environmental performance measurement indicators in construction. *Building and Environment, 41*, 164–173.

Tomson, J., & Lip, G. Y. H. (2005). Blood pressure demographics: nature or nurture genes or environment? *BMC Medicine, 3*(3), 4.

Tsang, K. W., Ho, P. L., Ooi, G. C., Yee, W. K., Wang, T., Chan-Yeung, M., et al. (2003). A cluster of cases of severe acute respiratory syndrome in Hong Kong. *The New England Journal of Medicine, 348*(20), 1977–1985.

Wakamori, T., Katoh, N., Hirano, S., Kishimoto, S., & Ozasa, K. (2009). Atopic dermatitis, dry skin and serum IgE in children in a community in Japan. *Journal of Synchrotron Radiation, 149*, 103–110.

Wallace, L. A., Nelson, C. J., Highsmith, R., & Dunteman, G. (1993). Association of personal and workplace characteristics with health, comfort and odor: a survey of 3948 office workers in three buildings. *Indoor Air, 3*(3), 193–205.

Wargocki, P., Wyon, D. P., Baik, Y. K., Clausen, G., & Fanger, P. O. (1999). Perceived air quality, sick building syndrome (SBS) symptoms and productivity in an office with two different pollution loads. *Indoor Air, 9*(3), 165–179.

Westaway, M. S. (2006). A longitudinal investigation of satisfaction with personal and environmental quality of life in an informal South African housing settlement, Doornkop, Soweto. *Habitat International, 30*(1), 175–189.

Wong, L. T., Mui, K. W., & Hui, P. S. (2008). A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices. *Building and Environment, 43*(1), 1–6.

Wong, S. K., Cheung, A. K. C., Yau, Y., Ho, D. C. W., & Chau, K. W. (2006). Are our residential buildings healthy and safe? A survey in Hong Kong. *Structural Survey, 24*(1), 77–86.

World Health Organization. (1986). *Indoor air quality research: Report on a WHO meeting*. Copenhagen: World Health Organization.

Wun, Y. T., Tang, J. L., & Chao, D. V. K. (2001). Evidence-based management of dyslipidaemia: Hong Kong family physicians' perspective. *Hong Kong Practitioner, 23*, 191–200.

Yu, I. T. S., Li, Y., Wong, T. W., Tam, W., Chan, A. T., Lee, J. H. W., et al. (2004). Evidence of airborne transmission of the severe acute respiratory syndrome virus. *The New England Journal of Medicine, 350*(17), 1731–1739.

Zagreus, L., Huizenga, C., Arens, E., & Lehrer, D. (2004). Listening to the occupants: a Web-based indoor environmental quality survey. *Indoor Air, 14*(Suppl. 8), 65–74.