

Indoor environment of residential homes in Hong Kong — relevance to asthma and allergic disease

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Summary

Background The prevalence of asthma and allergic disease has been increasing in Hong Kong and environmental factors are thought to play a major role.

Aim To define the distribution of common inhaled allergens and air pollutants inside residential homes in Hong Kong.

Methods Forty randomly selected residential homes were visited and surveyed. Dust samples were collected from mattress, bedroom floor, lounge room floor and kitchen floor for assays of Der p 1, Fel d 1, and Bla g 2. Nitrogen dioxide (NO₂) levels were measured by stationary samplers left in the bedroom, lounge room and kitchen over a 1-week period.

Result All 40 homes were apartments in high-rise buildings and the mean age of the homes was 7.6 ± 4.8 years. Visible dampness and mould patches were present in 27.5% of homes and the main fuel for cooking was gas (97.5%). Der p 1, Fel d 1 and Bla g 2 were detectable in at least 1 niche in over 85% of homes. In particular, all dust samples from mattress and bedroom floor contained Der p 1, and over 50% had levels $\geq 2 \mu\text{g/g}$. The (geometric) mean Der p 1 level in mattress dust was 8.8 (0.3–157.8) $\mu\text{g/g}$. Fel d 1 and Bla g 2 were present in low levels throughout the homes with respective (geometric) means of 0.3 (0–3.7) $\mu\text{g/g}$ and 0.1 (0–1.1) Unit/g in mattress dust. NO₂ was readily detected in all niches but the highest level was in the kitchen with mean exposure of 48.7 ppb which was 1.5 times higher than that in the bedroom and lounge room.

Conclusion Major allergens of mite, cat and cockroach, and NO₂ are present in varying quantities in residential homes in Hong Kong. Exposure to these environmental factors could be important in the development of asthma and allergic diseases in susceptible individuals.

Keywords: mite, cat, cockroach, nitrogen dioxide, environment, asthma, allergy, allergen, air pollution

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Introduction

Hong Kong is a modern and westernized city of subtropical climate inhabited by 6.5 million people consisting of 98% ethnic Chinese. Between 1992 and 1995, the lifetime prevalence of asthma and wheeze in schoolchildren increased from 6.6% to 11.2% and from 3.7% to 12.4%, respectively

[1]. A similar increase of 65% in wheeze ever and 57% in rhinitis ever was observed in young adults between 1989 and 1994 [2]. Up to 5% of the elderly population over the age of 70 years are said to suffer from diagnosed asthma [3].

One postulated reason for the rapid rise in asthma and allergic disease in recent years is some change in environmental factors rendering susceptible individuals more likely to develop symptoms. As most populations are spending significant amounts of time indoors, searches for relevant indoor environmental factors have been contemplated in a

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number of centres. Exposure to indoor allergens, in particular those derived from house dust mite, cockroach and domestic cat, have been associated with airway inflammation and asthma symptoms [4,5]. A synergistic effect on bronchial hyperresponsiveness has also been shown between mite allergen inhalation and nitrogen dioxide (NO₂) exposure [6,7]. In this paper, we report the characteristics of 40 randomly selected residential homes in Hong Kong, the distribution of major allergens of house dust mite [Der p 1], German cockroach [Bla g 2] and domestic cat [Fel d 1] in house dust samples, and exposure to NO₂ by stationary monitors. The aim of the study is to provide baseline data on characteristics of home environments in Hong Kong which will be used for future comparative studies of indoor environmental factors between populations with contrasting asthma prevalence, and for time trend study of asthma epidemiology in the territory.

Methods

Home survey

A collaborative study between The Chinese University of Hong Kong and Environmental Protection Department, Hong Kong on environmental risk factors on asthma has been underway to compare relevant factors between residential homes in Hong Kong and Guangzhou, China. A total of 40 residential homes were randomly selected from different districts in Hong Kong to participate in the home environment survey. Verbal consent was obtained from one respondent in each household by telephone, and a home visit was arranged. During the home visit, a home survey questionnaire was completed which included information on the type and age of the home, presence of carpets, pets, smokers and air-conditioners, the types of fuels used for heating and cooking, the type and age of pillows and mattress the respondents used, and the presence of damp patches in the subject bedroom. The temperature and relative humidity both inside the homes and outdoors were recorded at the time of the home visits.

Allergen exposure

Dust samples were collected from four sites in each home — mattress of the subject, bedroom floor, lounge room floor, and kitchen floor. Dust collection was performed as per standard protocol by Tovey using a modified Makita 701D portable vacuum cleaner [8]. Dust samples were collected from a 1 m² area in each site for 2 min. After collection, the samples were preserved at -20 °C before they were analysed batchwise for Der p 1, Fel d 1 and Bla g 2 by enzyme-linked immunosorbent assays (Indoor

Biotechnologies, Deeside, Clwyd, UK). Large dust particles were first removed by sieving through a 400 µm mesh plate and the resultant fine dust was extracted in phosphate buffered saline, pH 7.4 containing 1% bovine serum albumin and 0.05% Tween 20 for 2 h at room temperature. The assays involved incubation of dust extracts in microtitre wells coated with monoclonal antibodies against the three allergens, followed by reaction with biotinylated or peroxidase-conjugated second antibodies and fluorometric measurement. Der p 1 and Fel d 1 concentrations were reported as µg allergen/g of dust, and Bla g 2 in U/g (1 Unit = 40 ng), with corresponding detection limits at 0.1 µg/g, 0.01 µg/g and 0.1 U/g according to the reagent manufacturer standardization.

Table 1. Characteristics of 40 residential homes in Hong Kong

%		
Years of inhabitation (mean ± sd)		7.6 ± 4.8
Number of bedrooms		
1	22.5	9
2	50.0	20
3	25.0	10
4	2.5	1
Pet ownership		
Cat	2.5	1
Dog	2.5	1
Bird	2.5	1
Types of pillow		
Synthetic	72.5	29
Feather	2.5	1
Both	22.5	9
Types of quilt		
Synthetic	75.0	30
Feather	0	0
Unspecified	25.0	10
Age of mattress (mean ± sd, in years)		4.1 ± 2.9
Visible patches of dampness on bedroom walls	27.5	11
Visible patches of mould growth on bedroom walls	27.5	11
Removal of pets because of allergy in family members	10.0	4
Alteration in bedroom because of allergy	12.5	5
Types of fuels used for cooking		
Gas	97.5	39
Electricity	2.5	1
Types of fuels used for heating		
No home heating	55.0	22
Electricity	45.0	18
Presence of smokers	25.0	10

NO₂ exposure

Stationary NO₂ samplers [Gradko International, Winchester, UK] were placed in three fixed sites in each home — respondents' bedroom next to the head of the bed, lounge room and kitchen. The sampling tubes were left open for 1 week and were promptly sealed at the time of collection to avoid prolonged exposure. The saturated samplers were kept in the refrigerator at 4 °C and sent to the manufacturers for analysis in batches within 4 weeks of collection. The tube samplers collect NO₂ by passive diffusion and measure the adsorbed NO₂ by spectrophotometry, the sampling and analysis method is approved by the Department of Trade and Industry for the National Survey in the UK [9].

Statistical analysis

Data were categorized and analysed using SPSS for Windows [10]. The Kruskal–Wallis test was used to compare the levels of each of the three allergens and indoor NO₂ in different areas of the homes. Spearman correlation statistics was used to correlate the relationship between allergen levels in different sites of the homes with the age of the homes, and between Der p 1 levels on mattress with the age of the mattress, indoor and outdoor humidity, and indoor and outdoor temperature.

Results

The characteristics of the 40 homes in the survey are summarized in Table 1. Home visits were conducted between the months of June and August, 1996 with an average outdoor temperature and relative humidity of 29 °C and 70.2%, respectively. The average indoor temperature was 28.6 °C and the relative humidity was 66.3%. Over 90% of surveyed homes were apartments in high-rise buildings, either privately owned or as part of public housing estates. These homes were situated from first to 40th floor, 31 (76%)

of which had two bedrooms or more. Although current pet ownership was low at 2.5%, 10% of the homes visited had removed domestic cats or dogs in the past for allergic complaints in one or more members of the household. Similarly, five of the 40 homes had alterations in the bedroom for allergies in the occupants previously. Mould patches were commonly seen and were present on the bedroom walls in 27.5% of the homes. The main fuel used for cooking was gas (97.5%).

The distribution of indoor allergens is shown on Table 2. All three inhaled allergens assayed were widely distributed within the homes; 85% of dust samples from the four sites contained detectable levels of one or more of the three allergens. In particular, Der p 1 was present in all the dust samples collected from the mattress and the bedroom floor. More importantly, over 50% of samples from these two sites contained levels of Der p 1 $\geq 2 \mu\text{g/g}$, the proposed threshold for mite sensitization to develop [11]. Der p 1 levels were higher in mattress samples than the other three sites ($P < 0.05$). On the other hand, although Fel d 1 was also readily detectable in the majority of samples from all niches, the levels were low and did not exceed the critical level of $8 \mu\text{g/g}$ of dust in any of the samples [4]. The cockroach allergen, Bla g 2, was present in low levels ranging from 0.1 to 0.6 U/g of dust, with the highest level found in the kitchen. All of the 40 homes contained detectable levels of all three allergens in at least one site within the homes. There was no correlation between the age of the homes with any of the three allergens in the various sites in the homes. Der p 1 levels on mattress did not vary with the age of the mattress, or with temperature and humidity both indoor and outdoor.

NO₂ is an emission product from gas cooking and was detected in the kitchens, lounge rooms and bedrooms in all 40 homes. The mean levels in the lounge room [31.7 ppb] and bedroom [30.9 ppb] were about 1.5 times lower than the mean level in the kitchen [48.7 ppb]. The highest concentration recorded [157.9 ppb] was from a kitchen sample.

Table 2. Distribution of common indoor allergens in residential homes in Hong Kong

Sites	Der p 1					Fel d 1					Bla g 2			
	%		$\mu\text{g/g}$			%		$\mu\text{g/g}$			%	units/g		
	+ve	>2 μg	AM	M	Max	+ve	>8 μg	*AM	M	Max		*AM	M	Max
Mattress	100	80	22.9	8.83	157.8	87.5	0	0.3	0.06	3.7	92.5	0.1	0.09	1.1
Bedroom floor	100	50	2.5	1.59	7.9	95	0	0.3	0.08	2.7	90	0.2	0.14	1.4
Lounge room	92.5	35	2.0	1.27	11.0	90	0	0.4	0.09	7.6	92.5	0.3	0.16	1.0
Kitchen	90	20	1.6	0.74	19.5	85	0	0.2	0.06	4.2	92.5	0.6	0.20	9.1

Table 3. Distribution of indoor NO₂ in residential homes in Hong Kong

Sites	% + ve	NO ₂ Min	Level (ppb)	
			Mean	Max
Bedroom	100	10.1	30.9	69.1
Lounge room	100	6.5	31.7	73.7
Kitchen	100	20.5	48.7	157.9

Discussion

Our study defined for the first time the distribution of common inhaled allergens and indoor air pollutants, namely Der p 1, Fel d 1 and Bla g 2 and NO₂ in 40 residential homes in Hong Kong. We found that over 85% of the homes contained at least one of the three common inhaled allergens. Der p 1 was present in all homes with the highest concentrations in mattress dust. However, the (geometric) mean level of 8.8 µg/g is nearly three times lower than the mean level of 22.5 µg/g reported in coastal Sydney, Australia where mite atopy was found to confer a five times risk for bronchial hyperresponsiveness and seven times risk for current asthma [12]. In Sydney, the prevalence of current wheeze in schoolchildren is 23.9% [13] which is twice as high as the rates of 12.4% in Hong Kong as reported by Leung *et al.* [1]. On the other hand, the mite atopy rates were similar between the two populations and were even higher in Hong Kong (55.5% vs 34.4%) [12,14]. It seems therefore that once exposure to mite allergens exceeds the proposed threshold, sensitization is likely to develop in sensitized subjects, and further exposure to higher levels of mite allergens is a poor predictor for the clinical manifestation of asthma symptoms in mite sensitive subjects. The lack of association between levels of mite exposure and asthma activity in mite sensitive asthmatics has previously been described [15].

Compared with other south-east Asian populations, Hong Kong has one of the highest recorded Der p 1 levels. In Singapore where prevalence of asthma in children is higher than Hong Kong [16], Der p 1 levels in residential homes are much lower with a mean (geometric) level in mattress dust of 1.2 µg/g only [17]. In a survey of house dust mite fauna in Thailand, of the 630 mattress dust samples assayed, 86.8% contained Der p 1 > 2 µg/g [14]. The mean level was however, low compared to Hong Kong (11.8 vs 22.5 µg/g, arithmetic mean). In tropical countries, the glycyphagid mite, *Blomia tropicalis* is often the predominant species and has been found in 85–96% of house dust samples [17–19]. In Singapore, up to 97% of mattress dust samples contained detected levels of the major allergens of *B. tropicalis* [17]. *B. tropicalis* contains at least 25 allergens

[20], many of which show little crossreactivity with allergens of *D. pteronyssinus* [19]. Although it may be the predominant dust mite in the tropics, *B. tropicalis* has been detected in high numbers in subtropical populations including Hong Kong [21]. We did not measure *B. tropicalis* allergens in our survey as the assay is not available in Hong Kong, but considering their ubiquitous presence and potential importance in causing sensitization, future studies of indoor environment in Hong Kong should include its measurement by appropriate assays.

The home visits were performed in summer months when average temperature and relative humidity exceed 26 °C and 80%, respectively, on most days, an ideal climate for dust mite growth. The relatively steady climatic condition is reflected in little variation in Der p 1 levels in our study. There is currently no data on seasonal variation in Der p 1 levels in Hong Kong and studies are currently underway to measure mite allergens levels during winter months when the relative humidity often remains below 50% for a considerable period. This is important as asthma hospitalization peaks in November and December each year in Hong Kong and it would be interesting to test its relation with Der p 1 levels.

Pet ownership was found to be low in Hong Kong and this could be partly biased by previous removal of domestic pets to reduce allergic complaints in four households. In general, domestic pet ownership is higher in temperate climates (reaching 50% in some countries [22]) than in tropical and subtropical populations [17]. Nevertheless, we could detect the major cat allergen, Fel d 1, in dust samples from 85% or more of the homes albeit at low levels. This could be due to contamination and subsequent carriage of Fel d 1 on clothing from places with cats by human activities as previously shown [22]. Alternatively, a speculative explanation would be that low levels of Fel d 1 are capable of causing sensitization through interaction with other adjuvant factors such as indoor air pollutants. Levels of Fel d 1 can indeed be very high on upholstered seats in public places [23] and trigger asthma symptoms in sensitized subjects [24]. Although exposure to ≥ 8 µg/g of Fel d 1 has been proposed as critical [4], cumulative exposure even at a lower dose is also an important factor in determining sensitization and symptom development [25].

We found low levels of Bla g 2 in various niches within the homes with the highest levels found in the kitchen. In Singapore, low levels of Bla g 1, another major allergen of the German Cockroach, were detected in 25% of mattresses and in 69% of kitchens with respective mean levels of 2.5 U/g and 5.1 U/g [17]. Using extracts containing allergens from a mixture of different cockroach species, positive skin tests were found in 25.7% of unselected schoolchildren [14] and in 40.7% of adults with asthma in Hong Kong [26]. The discrepancy between the low Bla g 2 levels in homes and the

high rate of sensitization to cockroach allergens suggests either cockroach allergens are so potent that even low exposure is capable of sensitizing susceptible individuals or the German cockroach from which Bla g 2 derives is not the predominant species causing sensitization. Indeed there is evidence to suggest that American cockroach (*Periplaneta americana*) is the predominant species in south-east Asia [Wu, pers. comm.]. A recent study of 250 consecutive acute asthma admissions to a teaching hospital in Hong Kong showed that over 60% of subjects contained specific IgE to one of the major allergens of *P. americana*, Per a 1, in the sera [Wu, pers. comm.].

In Hong Kong, since outdoor monitoring of air pollutants began in 1983, the annual mean ambient concentration of NO₂ has remained reasonably steady between 40 and 50 ppb [Environmental Protection Department, Hong Kong]. It is now recognized that NO₂ sources at home, e.g. from gas-fuelled cooking stoves and kerosene space heaters, are the primary determinants of total personal exposure [27]. Cooking with a gas stove can generate concentrations of 200–400 ppb of NO₂, with transient peaks as high as 1000 ppb. Using personal NO₂ samplers, a previous study in Hong Kong showed that the average exposure over a 24 h period was about 18–20 ppb, with higher levels in those exposed to stoves powered by piped gas as opposed to LPG or kerosene [28]. In the same study, incense burning was also found to increase personal exposure to NO₂ whilst the use of a ventilation fan in the kitchen significantly reduced exposure. We found the NO₂ levels in the kitchen were about 1.5 times higher than that recorded in the bedroom and lounge room, a phenomenon most likely caused by gas cooking with poor ventilation. A few early epidemiological studies showed that children exposed to high concentration of NO₂ from gas stoves at home had more respiratory infection than those children with electric stoves and lower exposure to NO₂ [27]. High concentration of NO₂ has also been shown to cause clinically significant lung damage [27]. Some asthmatics had increased airway responsiveness following experimental exposure to NO₂ at concentrations found in urban indoor environment [29], although a more recent study failed to demonstrate such findings [30]. High personal exposure to NO₂ has been associated with allergic rhinitis and chronic bronchitis but not self-reported asthma in non-smoking adults [28]. In asthmatics with mite allergy, the bronchoconstrictive effects of mite allergens may be synergistic with air pollutants such as NO₂ and sulphur dioxide (SO₂) [6,7]. In Hong Kong where coexposure to moderate to high levels of mite allergens and NO₂ are frequently encountered within residential homes, the threshold of allergen exposure needed to develop sensitization and allergic manifestations may be reduced in predisposed individuals thereby rendering their airways more susceptible to allergic inflammation and bronchoconstriction.

In conclusion, we have determined the distribution of the common inhaled allergens and NO₂ in residential homes in Hong Kong. Der p 1, Fel d 1 and Bla g 2 are ubiquitously present but levels are generally low except for Der p 1 which frequently exceeds the threshold for sensitization. The level of exposure to NO₂ has increased compared to previous data. These findings will be used in future studies to compare indoor environment between populations with contrasting asthma prevalence and to determine the time trend of asthma prevalence and morbidity in the territory.

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