

Influence of environmental characteristics and climatic factors on mites in the dust of air-conditioner filters

Abstract To investigate mites in the dust of air-conditioner filters (MACF) in China, a total of 652 dust samples were collected from six cities: Guangzhou ($n = 129$), Nanchang ($n = 127$), Shanghai ($n = 113$), Xian ($n = 93$), Beijing ($n = 93$), and Shenyang ($n = 79$). *Tarsonemus granarius* was the most dominant species (87.2%). *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* only represented 7.0 and 3.0% of total mites, respectively. With latitude increasing, both mite occurrence rate ($P < 0.001$) and density (mites/g dust) ($P < 0.001$) were significantly decreasing. Multivariate regression analysis suggested that the annual average temperature and minimum temperature in different cities had dominant influences on MACF density. The logistic regression analysis revealed that the presence of MACF was positively associated with air-conditioner age, utilization time and power. Wall and window type air-conditioner had higher risk of finding MACF than the floor type air-conditioner. As far as the cleaning interval time of ACF was concerned, higher risk ratio and the highest density of MACF were found in the time stage of $> 3, \leq 12$ months. It was also suggested that house type could influence the presence of MACF. A negative association between the house floor and the MACF prevalence was found as well.

J. Wu^{1,2,3}, Z. G. Liu², P. X. Ran¹,
B. Wang²

¹The State Key Laboratory of Respiratory Disease, Guangzhou Medical College, China, ²Institute of Allergy and Immunology, Shenzhen University, China, ³Shanghai Entomological Museum, Institute of Plant Physiology and Ecology, Chinese Academy of Sciences, China

Key words: Mites; Air-conditioner filters; Climatic factors; Environmental characteristics; China.

Dr. Z. G. Liu
Institute of Allergy and Immunology
Shenzhen University
3688 Nanhai Road, Nanshan
Shenzhen 518060
China
Tel: +86 755 26538722
Fax: +86 755 26534274
e-mail: lzg@szu.edu.cn

Received for review 18 February 2008. Accepted for publication 4 June 2009.
© Indoor Air (2009)

Practical Implications

Mites present in the dust of air-conditioner filters are potential indoor threat to asthma and allergy sufferers. In this study, we find that the storage mite *Tarsonemus granarius* is the predominant species of mites in the dust of air-conditioner filters (MACF). Thus, the possible clinical importance of *T. granarius* should cause more our attentions in the future. The abundance and distribution of MACF are also found significantly varied in different climatic regions of China. When we try to assess the possible risk of MACF, more attentions should be focused on subtropical region than temperate region. The influence analysis of environmental characteristics on the prevalence of MACF will shed light on the establishment of mite control strategy and the design of mite defense air-conditioner.

Introduction

In recent years, a worldwide increase in the prevalence of allergic diseases, especially atopic asthma and rhinitis, has been reported and caused a serious global health problem (Asher et al., 1998; Bousquet et al., 2007). Many factors could be attributed to this increase, but the alteration of people life-style may be the key: more and more urban people spend the greatest part of their time indoors and are continuously exposed to allergens, bacterial toxins and other biological or physico-chemical contaminants accumulated

in enclosed indoor environment (Apter et al., 1994; Carrer et al., 2001; Gehring et al., 2004).

Dust-mites are generally acknowledged as the most important sources of indoor allergen and have been shown to be a major aggravating factor for asthma and related respiratory allergies (Arlian, 1991; Kaliner and White, 1994). The most common allergy-causing mite species that occur in homes worldwide are *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* (Arlian et al., 2002). In tropical and subtropical regions, *Blomia tropicalis* has been widely reported as another prominent mite species in house-dust samples

with high sensitization prevalence (Chew et al., 1999a,b; Fernández-Caldas et al., 1993). Some storage mites that are commonly found in house dust, such as species in *Acarus*, *Glyciphagus*, *Tyrophagus*, and *Lepidoglyphus* have been proved as triggers of allergic reactions as well (von der Heide et al., 1998; Vidal et al., 2004; Wraith et al., 1979).

Mite allergen avoidance and control have been treated as effective methods to protect sensitized individuals from asthma symptoms (Murray and Ferguson, 1983). Information about mite and relative allergen distribution is important for this purpose and has been addressed in many studies (Macan et al., 2003; Mumcuoglu et al., 1999; Sidenius et al., 2002). From these studies, it is known that dust-mites are preferentially distributed in indoor environments such as mattress, sofa, carpet etc.

Few studies has associated mites with air-conditioner, although the dust-rich filters (situated at the air entrance to protect the indoor evaporator coil from dust particles) of air-conditioner is obvious suitable for mite breeding and has been continuously reported to have negative influence on human health (Clausen, 2004; Grandenz et al., 2005). One recent study, executed in Shenzhen city of Southern China, has suggested that air-conditioner filters (ACF) are important reservoir for mites and the average concentration of mite allergens (Der f1 and f2) in the dust of ACF had exceeded the threshold of sensitization ($> 2 \mu\text{g/g}$ dust) (Liu et al., 2007). The other investigation executed in Huainan city of Anhui province of China also suggested that mite occurrence rate on the surface of ACF was high (Cui and Wang, 2003). While the air-conditioner is running, mite allergens accumulated in the dust of ACF can be continuously disseminated into indoor air and raise the allergy risk for people with asthma living in the room. Lian et al. (2007) ever tested the concentration of major mite allergens (Der f 1, Der p 1, and Der 2) in indoor air of 60 families in Guangzhou city and observed a significant rise of allergen concentration after air conditioner running. Thus, mites in the dust of air-conditioner filters (MACF) may be an important risk for asthma and allergy sufferers, and should be included in the management strategy of indoor allergen avoidance.

In China, there are 15–20 million people suffering asthma (Zhong, 2005) and asthma prevalence in childhood had almost doubled in last decade (Chen, 2003). Meanwhile, the use of air-conditioning systems keeps rising in Chinese cities. It is important to assess the possible risk of MACF for asthma sufferers in China. However, at present, we still know little about how mite is associated with different habitat characteristics of ACF. This information is evidently important for the control of MACF. Furthermore, we also know little about the prevalence condition of MACF in different regions of China. It has been suggested that

the climatic factors varied in different regions play important roles in influencing the distribution and abundance of house dust-mites (Macan et al., 2003; Rijckaert et al., 1981). Nevertheless, climatic influences on MACF are still unknown. All these issues certainly deserve further study.

Thus, the main aim of this study was to characterize the influence of environmental characteristics (both house and air-conditioner) and climatic factors on the distribution and abundance of MACF. Our results may also have general implications in the mite control in other countries.

Materials and methods

Cities examined

To investigate the prevalent condition of MACF in different climatic regions of China, six cities with high popularization rate of air-conditioner (indicated by high economic level) were selected from two main climatic regions of China. These cities with geographic localities are: Guangzhou (113°18'E, 23°10'N), Nanchang (115°53'E, 28°41'N) and Shanghai (121°29'E, 31°14'N) in subtropical region, Xian (108°54'E, 34°16'N), Beijing (116°28'E, 39°54'N), and Shenyang (123°23'E, 41°48'N) in temperate region. Two annual climatic parameters in six sampled cities were selected to reveal the general influence of climatic difference on MACF: annual average temperature and humidity. The influences of two annual extreme temperatures (maximum/minimum) in the sampling year were analyzed as well (Table 1). These two factors can well indicate what MACF had ever experienced in the past winter and summer.

Dust samples collection

Dust samples of ACF were collected from three house types: home, office, and hotel in six selected cities during August and September, 2006. According to Liu et al., 2007; it was known that the quantity of MACF was relative abundant in these sampling period after about 2 months of air-conditioner using. Only those ACF uncleaned at least in a month were sampled. All dust samples were collected from urban central regions

Table 1 Annual climatic parameters in six sampled cities (2006)

City code	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Average humidity (%)
Guangzhou	23.2	37.5	5	72
Nanchang	18.6	37.3	-1.6	71
Shanghai	17.9	37.2	-0.4	70
Xian	15.2	41.2	-8.3	67
Beijing	13.4	37.3	-14.7	53
Shenyang	8.3	32.8	-27.8	68

to reduce the influence of country/city difference. For home sampling, only families living in the normal condo were selected. Eight trained graduated students joined this investigation and were separated into two teams respectively responsible for dust collection and mite isolation. Dust was brushed by one-off plastic tooth brush from ACF into a white plastic plate (42 × 35 cm). Both sides of ACF were carefully brushed until no dust could be brushed down from them. Dust collected in the plastic plate was then transferred into a Petri dish (12 cm) and sealed by adhesive tape (Liu et al., 2007). The following mite isolation was finished in 4–6 h to maximally avoid mite escape.

To detect the possible influence of environmental factors on abundance and distribution of MACF, characteristics of house (house type and floor of sampled house) and air-conditioner (power, type) were recorded. A questionnaire on the air-conditioner age, annual and daily utilization rate, cleaning interval time and whether used in winter for heating was filled by people who live or work in the room of sampled ACF. For hotel, the questionnaire was finished by attendants working there instead.

Mite counting and identification

Each dust sample was weighed (100 mg ± 1 mg) first and then checked under a stereomicroscope to find mites. Mites still existed in the dust were subsequently isolated by a sample floating method. At the first step, dust was suspended in a beaker (100 ml) with 75% alcohol overnight. Then, the sediment was transferred into saturated NaCl solution, warmed at 70°C (10 min) and leached by black filter paper. Mites floating on the fluid surface and present in filter paper were moved by fine needle and mounted in Hoyer's medium for subsequent identification. The number of mites in each positive sample was determined and the mite density was recorded as mites/g dust. The identification was made to species level according to Colloff and Spieksma (1992) and Hughes (1976).

Statistics

The methods of non-parametric tests were used for testing differences (Chi-Square test, Mann–Whitney *U*-test and Kruskal–Wallis test). A stepwise multivariate regression analysis was used to find out which of the climatic parameters in selected cities has a dominant influence on abundance of MACF. Climatic parameters of six selected cities involved in analysis were average values in last 3 years (2003–2005). Mean density of MACF used in our analysis was the arithmetic mean of all samples.

To fit a logistic regression model, the presence or absence of MACF was expressed as a dichotomous

variable (1, 0). All variables included in this analysis were categorical variables. To detect and discuss the possible influence of air-conditioner and house characteristics on MACF, we used *Enter* method for variable selection in which all variables in a block were entered in a single step.

All statistical analyses were performed using SPSS 10.0 (SPSS Inc., 1999). The statistical significance was assumed at $P < 0.05$.

Results

Variation of MACF in different regions

A total of 19 mite species and 2701 individuals were identified from 126 of 652 dust samples (19.3%) (Table 2). The storage mite *T. granarius* was the most prevalence mite species and occupied 87.2% of all identified mites. Pyroglyphid mites *D. pteronyssinus* and *D. farinae* respectively constituted 7.0 and 3.0% of total mites. Other rest mites only constituted less than 3.0% of the mite assemblage.

In different cities, the predominant mite species was significantly varied. *Tarsonemus granarius* was more prevalent in south city of Guangzhou (97.0%), but less occurred in other cities (excluding Xian and Shenyang) ($\chi^2 = 1186.15$, $P < 0.001$). Contrarily, the pyroglyphid mites (almost *D. pteronyssinus* and *D. farinae*) were more common in Nanchang, Shanghai and Beijing than in Guangzhou ($\chi^2 = 1485.25$, $P < 0.001$). The tropical mite species of *B. tropicalis* was only found in south city of Guangzhou (1.3%).

With latitude increasing, both mite occurrence rate ($\chi^2 = 93.49$, $P < 0.001$) and mean density ($\chi^2 = 93.35$, $P < 0.001$) exhibited a significant decreasing trend (Fig. 1). Generally, Guangzhou city in south region had the highest mite occurrence rate (36.4%) and mean density (35.8 mites/g dust). Comparatively, in other two geographically adjacent cities of Nanchang and Shanghai these two values were moderately reduced (Nanchang: 33.9%, 15.0 mites/g dust and Shanghai: 26.5%, 6.9 mites/g dust). However, in the north city of Beijing, these two values sharply decreased to 5.4% and 1.6 mites/g dust. In the east-north city of Shenyang with the highest latitude, only one mite was found in one of 79 dust samples (1.3%). The extreme condition presented in north-west city of Xian where no mite was found from 93 dust samples, although the latitude in this city was lower than Beijing and Shenyang.

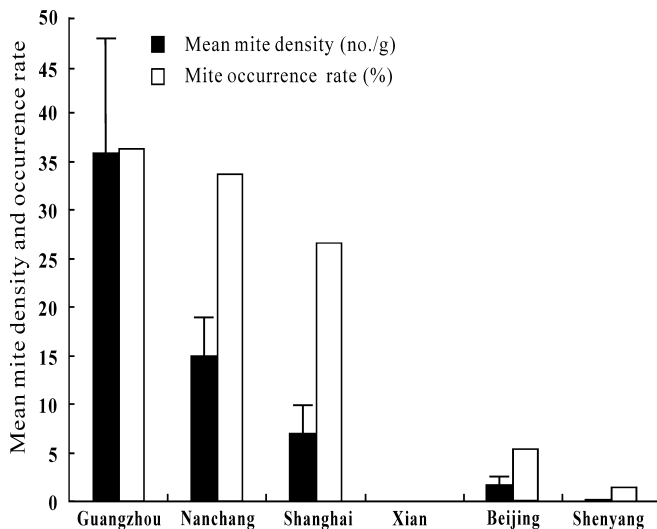
The influence of climatic type on mite abundance was also significant. Mite density in subtropical cities (Guangzhou, Nanchang, and Shanghai) were higher than those in temperate cities (Xian, Beijing, and Shenyang) ($Z = -9.32$, $P < 0.001$).

To reveal the possible relationship between climatic parameters and MACF abundance, the stepwise

Table 2 Mite species present in dust samples collected from six selected cities with different climatic types

Mites		No. mites (%)						Mite density (no./g)	
Order and Family	Species	Guangzhou (n = 129)	Nanchang (n = 127)	Shanghai (n = 113)	Xian (n = 93)	Beijing (n = 93)	Shenyang (n = 79)	Total (n = 652)	Median (range)
Prostigmata									
Tarsonemidae	<i>Tarsonemus granarius</i>	2234 (97.0)	99 (38.2)	18 (14.4)	—	3 (21.4)	—	2354 (87.2)	10.2 (0.6–1246.0)
	<i>Tarsonemus confusus</i>	—	1 (0.4)	—	—	—	—	1 (—)	0.3 (—)
Pyemoidae	<i>Pyemotes herfsi</i>	—	2 (0.8)	2 (1.6)	—	—	—	4 (0.2)	6.7 (3.2–15.4)
Cheyletidae	<i>Cheyletus malaccensis</i>	4 (0.2)	5 (1.9)	—	—	—	—	9 (0.3)	3.7 (1.5–27.8)
Bdellidae	<i>Spinibdella</i> sp.	1 (—)	—	1 (0.8)	—	—	—	2 (0.1)	6.4 (3.6–9.1)
Tydeidae	<i>Tydeus</i> sp.	—	—	1 (0.8)	—	—	—	1 (—)	7.1 (—)
Astigmata									
Pyroglyphidae	<i>Dermatophagoides pteronyssinus</i>	13 (0.6)	116 (44.8)	54 (43.2)	—	6 (42.9)	—	189 (7.0)	13.7 (0.5–164.3)
	<i>Dermatophagoides farinae</i>	8 (0.3)	32 (12.4)	38 (30.4)	—	4 (28.6)	—	82 (3.0)	14.3 (0.4–135.4)
	<i>Euroglyphus maynei</i>	—	—	2 (1.6)	—	—	—	2 (0.1)	3.6 (—)
Acaridae	<i>Acarus siro</i>	—	—	1 (0.8)	—	—	—	1 (—)	10.0 (—)
	<i>Suidasia nesbitti</i>	—	—	—	—	1 (7.1)	—	1 (—)	8.6 (—)
	<i>Tyrophagus putrescentiae</i>	7 (0.3)	—	—	—	—	—	7 (0.3)	8.1 (—)
Glycyphagidae	<i>Blomia tropicalis</i>	30 (1.3)	—	—	—	—	—	30 (1.1)	9.3 (0.4–44.9)
Mesostigmata									
Phytoseiidae	<i>Amblyseius</i> sp.	5 (0.2)	—	—	—	—	—	5 (0.2)	11.3 (5.8–16.9)
Ameroseiidae	sp.	—	—	1 (0.8)	—	—	—	1 (—)	1.7 (—)
Ascidae	<i>Blattisocius keegani</i>	—	—	1 (0.8)	—	—	—	1 (—)	5.0 (—)
Laelapinae	<i>Androlaelape casalis</i>	—	—	—	—	—	1 (100)	1 (—)	0.5 (—)
Cryptostigmata									
Oribitidae	sp.1	—	4 (1.5)	—	—	—	—	4 (0.2)	22.7 (1.3–33.3)
	sp.2	—	—	6 (4.8)	—	—	—	6 (0.2)	1.6 (0.5–6.7)
Total		2302 (100)	259 (100)	125 (100)	0 (0)	14 (100)	1 (100)	2701 (100)	16.1 (0.4–1265.5)

Percentage <0.1% were not shown.

**Fig. 1** The general mite occurrence rate and mean density of six cities. Error bars above mean density denote standard error

multivariate linear regression analysis was performed. The mean density of MACF was used as dependent variable (Y) and the annual average temperature (X_1), maximum temperature (X_2), minimum temperature (X_3), and average humidity (X_4) in sampled cities were used as independent variables. Only the annual average temperature and minimum temperature came into the regression equation (Table 3). These two climatic

factors accounted for 96.0% of the variance in MACF density.

Influence of air-conditioner and house characteristics

The logistic regression model predicting the risk of finding MACF was shown in Table 4. Only samples ($n = 369$) from three subtropical cities (Guangzhou, Nanchang, and Shanghai) were selected because the climatic type had extremely significant influence on abundance and distribution of MACF so that mites were scarcely found from ACF in temperate cities. It was indicated that air-conditioner characteristics had different influence on the presence of MACF. Generally, air-conditioner age, utilization time (annual and daily) and power were positively related to the presence of MACF. Compared with floor type air-conditioner,

Table 3 Correlation between climatic parameters and mean density of MACF (keeping a zero value for Xian with no mites) by stepwise linear multivariate regression analysis

Variable	Regression coefficients	Standard Error	Standardized coefficients	P-value	95%CI
Constant	-152.394	28.580	0	0.013	-243.350–61.438
X_1	8.699	1.468	3.179	0.010	4.027–13.371
X_3	-2.788	0.628	-2.383	0.021	-4.786–0.791

X_1 : annual average temperature; X_3 : annual minimum temperature; CI: confidence interval for regression coefficients.

$R^2 = 0.963$, $F = 19.734$, $P = 0.021$.

Table 4 Logistic regression model predicting the presence risk of mites in the dust of air-conditioner filters in three subtropical cities (Guangzhou, Nanchang, and Shanghai) ($n = 369$)

Variable	No.	P-value	Odds ratio	95%CI
House type				
Home	153		Reference	
Office	102	0.311	0.671	0.311–1.452
Hotel	114	0.018	0.393	0.181–0.853
Floor of sampled house				
<7 floors	307		Reference	
>7 floors	62	0.074	0.526	0.260–1.064
AC type				
Floor type	26		Reference	
Window type	16	0.006	13.851	2.087–91.946
Wall type	327	<0.001	20.411	4.569–91.189
AC power				
≤2 horsepower	317		Reference	
>2 horsepower	52	<0.001	13.752	4.097–38.542
AC age				
≤3 years	201		Reference	
>3 years	168	0.077	1.611	0.949–2.732
AC annual utilization time				
≤4 months	109		Reference	
>4 months	260	0.005	2.519	1.317–4.818
AC daily utilization time				
≤6 h	105		Reference	
>6 h	264	0.743	1.107	0.602–2.038
AC cleaning interval time				
≤3 months	268		Reference	
>3, ≤12 months	43	0.308	1.479	0.697–3.138
>12 months	58	0.367	0.675	0.287–1.588
Using AC in winter for heating				
No	171		Reference	
Yes	198	<0.001	3.421	1.825–6.413

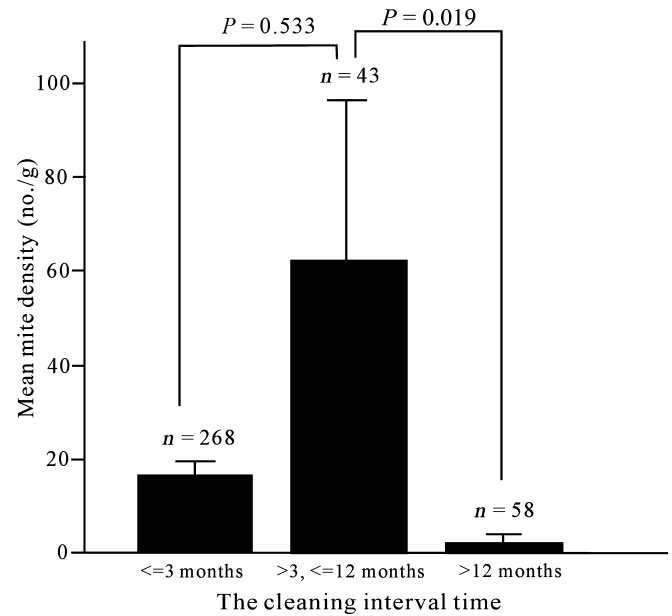
AC, air-conditioner; CI, confidence interval.

type of air-conditioner gave an odds ratio of 13.851 for window type air-conditioner and an odds ratio of 20.411 for wall type air-conditioner. The influence of cleaning interval time was little complicated. The risk of mite presence increased in time stage of >3, ≤12 months, but decreased in following stage of >12 months. The mite density comparison in these three cleaning interval time stages also reflected the similar trend (only data in Guangzhou, Nanchang, and Shanghai were included) (Fig. 2). Mite density was highest in middle stage (>3, ≤12 months), but significantly decreased in the last stage (>12 months) ($P = 0.019 < 0.05$).

House characteristics also could influence the presence of MACF. Compared with home, office and hotel had lower risk of finding MACF. However, mite density comparison of these three house types was not significant ($\chi^2 = 2.88$, $P = 0.237$). The floor of sampled house had a negative influence on the presence risk of MACF.

Discussion

Our results revealed that the storage mite species *T. granarius* was far predominant in the assemblage of

**Fig. 2** Mean mite density in different cleaning interval time stages (only data in Guangzhou, Nanchang, and Shanghai included). Error bars above mean density denote standard error. The sample number (n) in each stage is marked above as well. The P -value represents the result of Mann–Whitney U -test between each two continuous interval time stages

MACF and especially abundant in south city of Guangzhou. In southeast Asia, *T. granarius* have also been reported moderately abundant in house dust collected from mattress, sofa, floor, and carpet (Chew et al., 1999a). However, it is the first time to find that this mite species has extraordinarily large quantity in the dust of ACF. How *T. granarius* (and other mite species) can get into ACF is not very clear because the dispersal ability of domestic mite is still poorly known. Nevertheless, living domestic mites floating in the air were actually reported at least in one study (Li et al., 2002). Thus, it should not be very difficult for mites to disperse to ACF. Although the data on environmental and feeding requirements of *T. granarius* are deficient, it is known that most *Tarsonemus* species are fungivorous. Thus, fungi in the dust of ACF possibly play important role in attracting *T. granarius* to breed. In addition, the water drops on evaporator coil of air conditioner, which are formed during the air-cooling process, also provide a moisture environment for the colonization of *T. granarius*. Further biological study is needed to make these problems clearer.

At present, we still know little about the clinical significance of *T. granarius*. Nevertheless, *Tarsonemus* mites have been found in fresh sputum of people with asthma and respiratory irritation (Carter et al., 1944; Li and Li, 1990). It possibly hints that these mites can live in human lungs and cause asthma (van Woerden, 2004). Furthermore, it is also accepted that 'any mite species present in the human environment in large enough quantities (i.e. more than 100–200 mites/g

dust) could be considered a potential allergen with sensitizing capabilities' (Fernández-Caldas, 1997). Thus, we should pay enough attentions to the potential threat of *T. granarius* to mite-allergic patients.

The pyroglyphid mites *D. pteronyssinus* and *D. farinae* were also found with plentiful amount in the dust of ACF. Nevertheless, different with *T. granarius*, these two species are more prevalent in central, east and north cities of China. This result is also consistent with an investigation executed in Huainan city with climatic condition close to cities of Shanghai and Nanchang, in which the pyroglyphid mites occupied 65.9% of total mites found on the surface of ACF (Cui and Wang, 2003). However, our investigation in Guangzhou city is not consistent with the study conducted in adjacent city of Shenzhen early (Liu et al., 2007), in which no *T. granarius* was collected from ACF in August, 2003. The smaller sample size ($n = 30$ for August) adopted in that study may be a reason for this different evaluation of mite assemblage.

In our study, it is clear that assemblage and abundance of MACF are significantly varied in different climatic regions. Both the density and occurrence rate of MACF are significantly higher in subtropical cities than in temperate cities. Climatic factors in different regions possibly contribute much to this variation of MACF abundance. Especially, it was suggested that the annual average temperature and minimum temperature in winter have dominant influences on MACF density in our study. Compared with minimum temperature, the influence of maximum temperature in summer is not significant. This difference may be explained by the different using frequency of air-conditioner between summer and winter. In hot days of summer, the air-conditioner is always running at high frequency and thus provides a suitable temperature and humidity for MACF. Although air conditioner is also used for heating in winter in many cases, its frequency and running time is greatly low for higher electric power exhaust. As for annual average humidity, its effect on the micro-environment of ACF is possibly less than on other indoor environments. It should be noted that the extreme condition happened in Xian where no mite was recorded in ACF, although the climatic parameters in this city are more suitable for mite breeding than those in Beijing and Shenyang. However, considering mite occurrence rate also very low in the other two temperate cities (Beijing 5.4%; Shenyang 1.3%), the fluctuation in Xian city is possibly caused by the random factors during the sampling. In conclusion, the control of MACF should be strongly recommended in subtropical regions of China.

Except climatic factors, it was suggested that some air-conditioner characteristics have significant influence on the prevalence of MACF. Among them, the influence of air-conditioner type, which actually reflects

the spatial difference of its filters, is especially noticeable for high odds ratio value in windows and wall type air-conditioner. The different fungi composition, nutritional characteristic and humidity-temperature condition in ACF with different spatial position may be the reason. At least, it was observed in our investigation that the dust particles and fibers collected from windows and wall type air-conditioner are thinner than those collected from floor type. This difference undoubtedly can alter the micro-environmental in ACF.

We also notice that the influence of annual utilization time of air-conditioner on the presence of MACF is significant, but the influence of daily utilization time is not significant. It is known that dust-mites could survival in an adverse environment (relative humidity < 50%) for many days if suitable condition was provided in a short time of a day (Arlian et al., 1998, 1999). Thus, the daily utilization time of air-conditioner should have less influence on the survival of MACF. Contrarily, relative longer annual utilization time of air-conditioner can provide long-term suitable habitat for the breeding of MACF. It is also suggested that if air-conditioner was used in winter for heating, the risk of presence of MACF is increased. This result hints that using air-conditioner in winter can reduce the hurt of extremely low temperature on MACF population. This result also reflects the negative effects of minimum temperature on abundance of MACF on the other hand.

Compared with other factors, the cleaning interval time of ACF should have more important influence on mite abundance. However, our study suggested a significant decrease of mite density in longer cleaning interval time stage of > 12 months. The possible mechanism of mite community succession in ACF is still not very clear. However, a mass of dust gradually accumulated on ACF with increasing of cleaning interval time may be an important reason. Dust accumulation can greatly prevent the evaporation of water on evaporator coil of air-conditioner and consequently change the micro-environment of ACF (possibly by reducing temperature and raising humidity). In extreme cases of our investigation, the ice blocks were found under the ACF with thick dust. It is doubtless that ACF will be not suitable for mite survival anymore in these cases. However, a regular cleaning for ACF should still be recommended, especially in subtropical regions. The cleaning interval time should not be longer than 3 months because in the following time stage the mean density of MACF will reach a high level (Fig. 2).

House type has been proved to have influence on the distribution and concentration of mite allergens (Chew et al., 1999a,b,c). In our study, hotel and office has lower occurrence risk of MACF than home in logistic model. However, the abundance of MACF in these

three house types is not statistically significant. Hence, the degree to which people living habitat could influence the distribution of MACF is still needed to be explored in the future. The negative influence of house floor on house dust-mite abundance and allergens concentration has been discussed in previous studies (Luczynska et al., 1998; Suto et al., 1992; Wickman et al., 1991). In our study, it was revealed that house floor has the similar influence on MACF, although this influence is not significant ($P = 0.074$). The relative low humidity in high building may be the key.

Acknowledgements

We are especially grateful to Prof. Xingbao Chen in Bangbu medical college and Mr. Qinggui Yang in medical academy of Anhui University of Science and Technology for their kindly assistances in mite identification. We also would like to thank all the colleagues joining in our investigation. This study was supported by National 863 high technology program of China (No. 2002AA214011, 2006AA02A231) and National natural Science foundation of China (No. 30471505, 30271226).

References

- Apter, A., Bracker, A., Hodgson, M., Sidman, J. and Leung, W.-Y. (1994) Epidemiology of the sick building syndrome, *J. Allergy Clin. Immunol.*, **94**, 277–288.
- Arlian, L.G. (1991) House dust mite allergens: a review, *Exp. Appl. Acarol.*, **10**, 167–186.
- Arlian, L.G., Neal, J.S. and Bacon, S.W. (1998) Survival, fecundity, and development of *Dermatophagoides farinae* (Acari: Pyroglyphidae) at fluctuating relative humidity, *J. Med. Entomol.*, **35**, 962–966.
- Arlian, L.G., Neal, J.S. and Vyszenski-Moher, D.L. (1999) Fluctuating hydrating and dehydrating relative humidities effects on the life cycle of *Dermatophagoides farinae* (Acari: Pyroglyphidae), *J. Med. Entomol.*, **36**, 457–461.
- Arlian, L.G., Morgan, M.S. and Neal, J.S. (2002) Dust mite allergens: ecology and distribution, *Curr. Allergy Asthma Rep.*, **2**, 401–411.
- Asher, M., Anderson, H., Stewart, A. and Crane, J. (1998) Worldwide variations in the prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC), *Eur. Respir. J.*, **12**, 315–335.
- Bousquet, J., Dahl, R. and Khaltaev, N. (2007) Global alliance against chronic respiratory diseases, *Allergy*, **62**, 216–223.
- Carrer, P., Maroni, M., Alcini, D. and Cavallo, D. (2001) Allergens in indoor air: environmental assessment and health effects, *Sci. Total Environ.*, **270**, 33–42.
- Carter, H.F., Wedd, G. and D'Aberera, V.S.E. (1944) The occurrence of mites in human sputum and their possible significance, *Ind. Med. Gaz.*, **79**, 163–168.
- Chen, Y.Z. (2003) A nationwide survey in China on prevalence of asthma in urban children, *Chin. J. Pediatr.*, **41**, 123–127.
- Chew, G.L., Higgins, K.M., Gold, D.R., Muilenberg, M.L. and Burge, H.A. (1999a) Monthly measurements of indoor allergens and the influence of housing type in a northeastern US city, *Allergy*, **54**, 1058–1066.
- Chew, F.T., Zhang, L., Ho, T.M. and Lee, B.W. (1999b) House dust mite fauna of tropical Singapore, *Clin. Exp. Allergy*, **29**, 201–206.
- Chew, F.T., Lim, S.H., Goh, D.Y.T. and Lee, B.W. (1999c) Sensitization to local dust-mite fauna in Singapore, *Allergy*, **54**, 1150–1159.
- Clausen, G. (2004) Ventilation filters and indoor air quality: a review of research from the International Centre for Indoor Environment and Energy, *Indoor Air*, **14**(Suppl 7), 202–207.
- Colloff, M.J. and Spieksma, F.T.M. (1992) Pictorial keys for the identification of domestic mites, *Clin. Exp. Allergy*, **22**, 823–830.
- Cui, Y.B. and Wang, K.X. (2003) Investigation of Acarid mites on the surface of filters in air-conditioning, *Chin. J. Parasitol. Parasitic Dis.*, **16**, 374–376.
- Fernández-Caldas, E. (1997) Mite species of allergologic importance in Europe, *Allergy*, **52**, 383–387.
- Fernández-Caldas, E., Puerta, L., Mercado, D., Lockey, R.F. and Caraballo, L.R. (1993) Mite fauna. Der p 1, Der f 1 and *Blomia tropicalis* allergen levels in a tropical environment, *Clin. Exp. Allergy*, **23**, 292–297.
- Gehring, U., Bischof, W., Borte, M., Herbarth, O., Wichmann, H.E. and Heinrich, J. (2004) Levels and predictors of endotoxin in mattress dust samples from East and West German homes, *Indoor Air*, **14**, 284–292.
- Grandzen, G.S., Oliveira, C.H., Tribess, A., Mendes, C., Latorre, M.R.D.O. and Kalil, J. (2005) Association of air-conditioning with respiratory symptoms in office workers in tropical climate, *Indoor Air*, **15**, 62–66.
- von der Heide, S., Niemeijer, N.R., Hovenga, H., de Monchy, J.G.R., Dubois, A.E. and Kauffman, H.F. (1998) Prevalence of sensitization to the storage mites *Acarus siro*, *Tyrophagus putrescentiae*, and *Lepidoglyphus destructor* in allergic patients with different degrees of sensitization to the house-dust mite *Dermatophagoides pteronyssinus*, *Allergy*, **53**, 426–430.
- Hughes, A.M. (1976) *The Mites of Stored Food and Houses*. London, Ministry of Agriculture, Fisheries and Food, Technical Bulletin no. 9, 400 pp.
- Kaliner, M.A. and White, M.V. (1994) Asthma causes and treatment, *Compr. Ther.*, **20**, 645–650.
- Li, C.P. and Li, L. (1990) Human pulmonary Acariasis in Anhui province: an epidemiological survey, *Chin. J. Parasitol. Parasitic Dis.*, **8**, 41–44.
- Li, C.P., Wu, Q.W. and Gui, H.R. (2002) Studies on air contamination caused by Acarid mites, *J. Huainan Inst. Technol.*, **22**, 69–74.
- Lian, Y.Y., Liu, Z.G., Wang, H.Y., Chai, C.Y. and Liu, X.Y. (2007) Detection of mite allergens in the dust of filter-net and air-conditioned room, *Chin. J. Parasitol. Parasitic Dis.*, **25**, 325–332.
- Liu, Z.G., Bai, Y., Ji, K.M., Liu, X.Y., Cai, C.Y., Yu, H.Q., Li, M., Bao, Y., Lian, Y.Y. and Gao, B. (2007) Detection of *Dermatophagoides farinae* in the dust of air-conditioning filters, *Int. Arch. Allergy Immunol.*, **144**, 85–90.
- Luczynska, C., Sterne, J., Bond, J., Azima, H. and Burney, P. (1998) Indoor factors associated with concentrations of house dust mite allergen. Der p1, in a random sample of houses in Norwich, UK, *Clin. Exp. Allergy*, **28**, 1201–1209.
- Macan, J., Kanceljak, B., Plavec, D. and Miković-Kraus, S. (2003) Differences in mite fauna between the continental and Mediterranean climates of Croatia: microscopy and Dustscreen™ test findings, *Allergy*, **58**, 780–783.
- Mumcuoglu, K.Y., Gat, Z., Horowitz, T., Miller, J., Bar-Tana, R., Ben-Zvi, A. and Naparstek, Y. (1999) Abundance of house dust mites in relation to climate in contrasting agricultural settlements in Israel, *Med. Vet. Entomol.*, **13**, 252–258.
- Murray, A.B. and Ferguson, A.C. (1983) Dust-free bedrooms in the treatment of

- asthmatic children with house dust or house dust mite allergy: a controlled trial, *Pediatrics*, **71**, 418–422.
- Rijckaert, G., van Bronswijk, J.E.M.H. and Linskens, H.F. (1981) House-dust community (Fungi Mites) in different climatic regions, *Oecologia*, **48**, 183–185.
- Sidenius, K.E., Hallas, T.E., Brygge, T., Poulsen, L.K. and Mosbech, H. (2002) House dust mites and their allergens at selected locations in the homes of house dust mite-allergic patients, *Clin. Exp. Allergy*, **32**, 1299–1304.
- SPSS Inc. (1999) *SPSS Base 10.0 for Windows User's Guide*, Chicago, SPSS Inc.
- Suto, C., Sakaki, I., Ito, H. and Mitibata, M. (1992) Influence of floor levels on the prevalence of house-dust mites in apartments in Nagoya, Japan, *Eisei Dobutsu*, **43**, 307–318.
- Vidal, C., Boquete, O., Gude, F., Rey, J., Meijide, L.M., Fernández-Merino, M.C. and González-Quintela, A. (2004) High prevalence of storage mite sensitization in a general adult population, *Allergy*, **59**, 401–405.
- Wickman, M., Perhagen, G., Nordvall, S.L. and Schwartz, B. (1991) House dust mite sensitization in children and residential characteristics in a temperate region, *J. Allergy Clin. Immunol.*, **88**, 89–95.
- van Woerden, H. (2004) Dust mites living in human lungs – the cause of asthma? *Med. Hypotheses*, **63**, 193–197.
- Wraith, D.G., Cunnington, A.M. and Seymour, W.M. (1979) The role and allergenic importance of storage mites in house dust and other environments, *Clin. Allergy*, **9**, 545–561.
- Zhong, N.S. (2005) The prevention and study perspective of asthma in China, *Chin. J. Tuberc. Respir. Dis.*, **28**, 809–811.