



Household indoor air quality and its associations with childhood asthma in Shanghai, China: On-site inspected methods and preliminary results

Chen Huang^a, Xueying Wang^{a,1}, Wei Liu^{a,*}, Jiao Cai^a, Li Shen^b, Zhijun Zou^a, Rongchun Lu^a, Jing Chang^{a,c}, Xiaoyang Wei^a, Chanjuan Sun^a, Zhuohui Zhao^d, Yuexia Sun^e, Jan Sundell^{a,f}

^a School of Environment and Architecture, University of Shanghai for Science and Technology, Shanghai, China

^b R&B Technology (Shanghai) Company Limited, Shanghai, China

^c Department of Thermal Energy and Power Engineering, Shandong Jiaotong University, Jinan, China

^d Department of Environmental Health, School of Public Health, Fudan University, Shanghai, China

^e School of Environmental Science and Engineering, Tianjin University, Tianjin, China

^f Department of Building Science, Tsinghua University, Beijing, China

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ABSTRACT

Few studies were conducted for associations of home environment with childhood health by on-site inspection in China. During 2013–2014, we conducted a case-control study with home inspection among 454 children (186 asthma children and 268 non-asthma children) in Shanghai, China. In this paper, we detailedly described the inspected methods and analyzed the preliminarily collected data. Except in winter, most residences meet the national standard for indoor temperature and relative humidity. Most living rooms had ≤ 1000 ppm CO₂, whereas over half of the child's bedrooms had slightly > 1000 ppm CO₂ during night. Most residences had notably lower than 2500 cfu/m³ airborne culturable fungi and ≤ 100 μ g/m³ formaldehyde. More than 70% of the child's bedrooms had ≤ 75 μ g/m³ PM_{2.5} and ≤ 150 μ g/m³ PM₁₀. Indoor and outdoor concentrations of particulate matters had strong linear correlations ($r=0.891$ – 0.922 ; p -value < 0.001). Most differences between cases and controls were not significant with respect to CO₂, culturable fungi, formaldehyde, and particulate matters. Before and after adjusted for potential confounders, indoor averaged concentration of CO₂ and particulate matters generally had negative associations with childhood history of doctor-diagnosed asthma in spring, summer, and autumn. Only in winter, indoor CO₂ concentration was significantly associated with the increased odds of childhood asthma. Our results indicated that air quality among most residences in Shanghai could meet the national standard for indoor air quality in warm seasons; but household air quality and ventilation status in winter should be greatly improved. We suspected that those "unexpected" negative associations could exist due to changes in lifestyle behaviors regarding indoor air quality after the child being diagnosed asthma by a doctor.

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1. Introduction

Previous literatures have consistently suggested that prevalences of childhood asthma among young children were rapidly increased in many developing countries (Asher et al., 2006) and in China (Huang et al., 2015; Zhang et al., 2013a). Populations in China are so big that burden of childhood asthma could be heavier

and heavier if the prevalence continuously increased. Therefore, it is important to find out the potential risk factors for childhood asthma and to provide a practical guidance for its prevention in China.

Because children spend more than 80% of their time in the residence, many studies worldwide have reported that indoor air quality of the residence could play an important role on the children's respiratory health (Brunekreef and Holgate, 2002; Dales et al., 2008; Gordon et al., 2014; Jones, 1999; Sundell, 2004). In China, with the rapid development of both economy and construction technology in the past 30 years, more and more artificial building materials and modern-style furniture have been used in

* Corresponding author.

E-mail addresses: lsc198708@hotmail.com, liuw@st.usst.edu.cn (W. Liu).

¹ These authors contributed equally for this paper.

the residential building in China (Huang et al., 2015; Zhang et al., 2013a). Indoor air quality of the residence in China perhaps have been greatly changed, and people here started paying more attention to the effect of indoor air quality of the residence on their health than before (Zhang et al., 2013a). With regard to associations of indoor environment and childhood asthma, allergy, and airway diseases, two large-scale questionnaire-based studies were conducted in China: One was Seven Northeast Cities (SNEC) study in Northeast China (Dong et al., 2011), and another was the China, Children, Homes, Health (CCHH) study in more than ten large cities of China (Zhang et al., 2013a). A few studies on indoor air quality of the residence with on-site inspection and measurement were also conducted in China (Lu et al., 2010; Wang et al., 2008, 2010; Wu et al., 2008; Yoshino et al., 2006; Zhang and Smith, 2007; Zhang et al., 2015; Zheng et al., 2011; Zhu et al., 2015). Specifically, in 2008, Lu et al. (2010) conducted an on-site measurement in 100 Shanghai residences and found that the formaldehyde level in summer-autumn was higher than in winter-spring. During spring of 2013, Zhu et al. (2015) inspected indoor pollutants in 10 homes of schoolchildren in Wuhan, China and reported that unhealthy children had higher averaged concentration of carbon dioxide (CO₂) in the living room than health children. In 2006–2007, Wang et al. (2008) inspected indoor air quality in the 120 residences of young schoolchildren in Lanzhou, China during heating and non-heating seasons, and suggested that these residences had worst situation of PM₁₀ when compare to other pollutants and exposures to indoor air pollutants could be significantly associated with the children's respiratory health.

The type of residential building, outdoor climate, lifestyles, and cultural behaviors has substantial differences between China and the other countries (Huang et al., 2015; Zhang et al., 2013b). Indoor air quality and its impacts on childhood respiratory health in China could be different with in the other countries (Brunekreef and Holgate, 2002; Dales et al., 2008; Gordon et al., 2014). However, few studies investigated indoor air quality and its associations with childhood health in large sample size in China (Wang et al., 2008; Wu et al., 2008). To our best knowledge, none study was conducted to investigate associations of household air quality with the odds of childhood asthma by case-control design and on-site inspection in Mainland China. From 2013 to 2014, as phase two of the CCHH study in Shanghai, we conducted a case-control study and on-site inspected indoor air quality in 454 residences in Shanghai, China. In the present paper, we aimed to: 1) detailedly introduce the inspected methods; 2) preliminarily analyze the on-site measured data for indoor air quality of the residences in different inspected seasons; 3) compare our results of indoor air quality to the similar studies from other cities and countries. For the on-site measured data, we investigated correlations between indoor and outdoor concentration of particulate matters (PM_{1.0}, PM_{2.5}, PM_{4.0}, and PM₁₀), as well as correlations among six analyzed indicators/pollutants (temperature, relative humidity, carbon dioxide (CO₂), formaldehyde, airborne fungi, and particulate matters). We compared differences of these indicators/pollutants between cases and controls. We also investigated associations of these indicators/pollutants with the odds of childhood asthma. We hypothesized that the status of these analyzed indicators/pollutants has notable differences among different seasons and has robust correlations between each other, as well as has significant differences between cases and controls and has significant associations with increased odds of childhood asthma.

2. Methods

2.1. Study design and participants

The CCHH study in Shanghai included two phases: a questionnaire-based cross-sectional study (phase one) and on-site home inspection-based case-control study (phase two). From April 2011 to April 2012, we conducted the cross-sectional study in 88 randomly selected kindergartens from Shanghai's six districts (four urban districts: Yang-Pu, Hong-Kou, Zha-Bei, and Jing-An; two suburban districts: Bao-Shan and Feng-Xian) and collected 16,948 valid questionnaires from parents of 1–8 year-old children. Methods for participant selection and questionnaire survey in the cross-sectional study have been detailedly introduced in our previous articles (Huang et al., 2015; Hu et al., 2014; Liu et al., 2015a). Herein children from the pilot survey of phase one in the Yang-Pu district, were not included in the analyses of associations between home environment and childhood health by data in this phase, but were included in the selection of the inspected residences in the case-control study. In the cross-sectional study, we obtained information for dwelling environment and family lifestyle behaviors via parents by a modified questionnaire which was derived from the previous and similar studies in several countries (Bornehag et al., 2004; Naydenov et al., 2008; Sun and Sundell, 2013) and in other cities of China (Zhang et al., 2013a; Wang et al., 2013a,b). Parents also reported information for the child's history of asthma, allergy, and airway diseases by an improved questionnaire that was derived from the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 1995). These information would be used to select cases and controls. A previous article has provided the whole questions in the questionnaire as [Supplemental materials](#) (Zhang et al., 2013a). Herein question for the childhood history of asthma was that “has your child been diagnosed with asthma by a doctor (yes vs. no)”. We also asked parents that whether they would agree to have on-site home inspection in the case-control study (phase two) in the questionnaires. From March 2013 to December 2014, we conducted the case-control study via contacting parents who were willing to cooperate with our inspection and on-site inspecting household air quality.

The questionnaire and detailed proposals for the CCHH study in Shanghai were approved by the ethical committee in the School of Public Health, Fudan University in Shanghai, China. We informed the participants of the purpose of the study by written explanation. Before on-site inspection, both inspector and participant signed an informed consent form (one same copy for each). All participants voluntarily responded to the questionnaire and on-site inspection. The ethical committee approved this procedure for obtaining consent. We carried out the questionnaire and on-site inspection in strict accordance with the approved guidelines.

2.2. Selection of cases and controls

In the case-control study, those people who have developed the disease we were interested in were defined as cases, and a representative sample of people from the same population who do not have that disease were defined as controls; and then their home-related environmental exposures we were interested in were asked or on-site inspected (Webb and Bain, 2011). In the present study, we selected children who had history of doctor-diagnosed asthma in childhood as cases and children who did not have doctor-diagnosed asthma as controls. A total of 10,182 parents agreed to cooperate with the following home inspection and provided phone numbers in the cross-sectional study (phase one). Herein 1216 children (11.9% of the total 10,182 participants) who had history of doctor-diagnosed asthma were considered as potential cases group. All the rest 8651 children who did not have

history of doctor-diagnosed asthma were considered as potential controls group. Firstly, we contacted a family in the potential cases group to cooperate with our inspection by phone. If the family agreed our on-site home inspection, we contacted families who lived in the same community in the potential controls group and thus tried to obtain two matched control children. Because the number of families who lived in the same community was generally small, a part of cases only had one matched control child. All families in the potential cases group were contacted by phone. Ultimately, 186 cases and 268 controls were inspected by this process. Fig. S1 shows the flowchart for selection of the cases and controls. These inspected residences were not changed and/or redecorated after the cross-sectional survey. Each selected residence was on-site inspected once. Since data for the childhood asthma, allergies, and airway diseases was reported by parents in both phase one and phase two of the CCHH study in Shanghai via the improved ISAAC questionnaire (Asher et al., 1995), we could define cases and controls by different items with respect to childhood asthma, allergies, and airway diseases/symptoms in the future analyses.

2.3. On-site inspection and equipment

Before on-site inspection in the child's residence, a pilot study was conducted and we inspected dwelling characteristics and dampness-related indicators in four residences of teachers who had young children. Our senior members trained a total of six inspectors, as well as introduced and uniformed judgments on these studied factors. Six trained inspectors were stratified into two groups to inspect the selected residences. Herein, in each group, one inspector was assigned to collect home dusts, and two other inspectors were assigned to report building characteristics of the residence and home dampness-related exposures. About one hour was spent in each residence. Each of the inspectors visited about half of the selected residences. All inspectors did not know the health status (case or control) of children during home inspection.

Table 1 summarized our measured/sampled methods and equipment for different inspected items. We on-site measured three types of indoor pollutants, which included formaldehyde, airborne culturable fungi, inspirable particulate matters. In order to measure the scope concentration of airborne fungi, general culture petri dishes which was passed by air sample were cultivated in 35 °C thermostats for 48 h, as required in the national standard for indoor air quality of China (GAQS, 2002). We continuously measured daily (24 h) temperature (T) and relative humidity (RH), as well as carbon dioxide (CO₂) in the child's bedroom, living room, and ambient outdoor. To best match the child's breathing zone, we tried to set the sampler at a height of about one meter and as close to the room center as possible. In the present study, we used the 24 h and 6 h (00:00–06:00) averaged concentrations of CO₂ as proxies of daily and night ventilation status in the child's bedroom (Bekö et al., 2011; Bornehag et al., 2005). From December 2013 to December 2014, we also measured ambient concentrations of particulate matters close to the child's bedroom. Besides, air sample was continuously collected in seven days in the child's bedroom for the analysis of indoor volatile organic compounds (VOCs). Household dusts were collected samples for the analysis of indoor semi-volatile organic compounds (SVOCs) and household dust allergens in the current residences. Morning urine of each child was also collected for measuring metabolites of phthalates. But these collected air, dust, and urine samples were not analyzed and thus results for VOCs, SVOCs, and metabolites of phthalates did not present in the present study. The instruments for on-site measurement and sample-collecting were checked every week, and were calibrated every month. Due to

Table 1
Measured/sampled methods and equipment for different inspected items.

Items	Location (sampled points)	Total duration/number	Equipment	Detection range; accuracy; resolution
Formaldehyde	Child's bedroom (room center, one meter above the floor)	24 h (one value per 30 min)	Formaldehyde Multimode Monitor (SHINYEI Inc., Japan)	20–1000 ppb (12–800 µg/m ³); ± 10% at 40, 80, 160 ppb; 1 ppb
T, RH, CO ₂	Child's bedroom (room center, one meter above the floor; living room (room center, one meter above the floor; ambient (outdoor balcony)	24 h (one value per 10 min)	HUMLOG20 (E+E Inc., Austria)	T: –20 to +50 °C; ± 0.3 °C; 0.1 °C RH: 10–95%; ± 2%; 0.5% CO ₂ : 0–5000 ppm; ± 50 ppm; 1 ppm
PM _{1.0} , PM _{2.5} , PM _{4.0} , PM ₁₀	Child's bedroom (room center, one meter above the floor); ambient (outdoor balcony)	10 samples (one sample per one minute)	Aerosol Mass Monitor 831 (Met One Instruments, Inc., USA)	0–1000 µg/m ³ ; NA; 0.1 µg/m ³
Airborne culturable fungi	Child's bedroom (room center, one meter above the floor); living room (room center, one meter above the floor)	10 min (1 m ³ air)	Microflow (AQUARIA Inc., Italy)	NA
Air samples (for VOCs)	Child's bedroom (room center, one meter above the floor)	7 days	Ring (AQUARIA Inc., Italy)	NA
First morning urine (for metabolites of phthalates)	Home, bathroom	2 samples (8 ml per sample)	Polystyrene medical sampling tube	NA
Dust (for SVOCs, dust allergens and mites)	Child's bedroom (floor; bedding and pillow; door frame and desk-face); living room (floor; door frame and desk-face); Kitchen (floor)	6 samples (collected in about 10 min per sample)	Household vacuum cleaner (MC-DL20, Panasonic Inc., Japan); Polypropylene fiber dust filter membrane (diameter: 90 mm)	NA

T, temperature; RH, relative humidity; NA, not available.

some families refused us to set instruments for on-site measurement in the residences and/or to collect air, dust, and urine samples, the sums of children who had valid data for various measured air indicators/pollutants may not be equal to the total 454 children.

2.4. Statistical analyses

We used Statistical Product and Service Solutions (SPSS) version 17.0 (SPSS Ltd., USA) to perform the statistical analyses. Pearson's chi-square test was applied to compare the numbers and percentages of the residences, where values of the inspected indicators and concentrations of air pollutants in the child's bedroom and/or living room were higher than values in the national standards for air quality of China (GAQS, 2002, 2012), among different inspected seasons (Spring: March to May; Summer: June to August; Autumn: September to November; Winter: December to February) as well as between cases and controls. Pearson's correlation coefficients, between inspirable particulate matter in indoor (the child's bedroom) and in outdoor, as well as between each two analyzed indicators/pollutants, were calculated and their statistical significances (two-tailed) were tested by bivariate correlation analysis.

By one-sample Kolmogorov-Smirnov test, we had found that values of temperature and relative humidity and concentrations of the studied pollutants were not normally distributed. Hence, non-parametric test was used to compare averaged values of temperature and relative humidity and averaged concentrations of the studied pollutants among different seasons as well as between cases and controls. For seasonal differences, the multi-sample Kruskal-Wallis test was used; for differences between cases and controls, the two sample Kolmogorov-Smirnov test was used (Hoffman, 2015).

Logistic regression models were used to analyze associations between the measured indicators/pollutants of indoor air quality and the risk of childhood asthma. We used exposure "levels" instead of continuous variables in the models by stratifying the sampled children according to the four quartiles of values for each measured indicators/pollutants. We consistently took the children in the first quartiles as reference, to compare the risk of childhood asthma among children in second, third, and fourth quartiles. In the crude logistic regression analyses, the child's health status (cases vs. controls) was set as dependent variate and the exposure "levels" of each studied indicators/pollutants was set as independent variate (first vs. second vs. third vs. fourth quartile). In the multiple logistic regression analyses, the crude associations were adjusted for eight factors (all as covariates in the regression model). These factors were suspected to be significantly associated with childhood asthma in the previous analyses (Bornehag et al., 2004; Clausen et al., 2012; Hu et al., 2014) and included age (5 vs. 6 vs. 7 vs. 8 vs. 9 vs. 10 year-old), sex (boys vs. girls), located district of residence (Jing-An vs. Zha-Bei vs. Hong-Kou vs. Yang-Pu vs. Bao-Shan vs. Feng-Xian district), family history of atopy (yes vs. no), ownership of the current residence (owner vs. renter), household environmental tobacco smoke (ETS) (yes vs. no), household dampness-related exposures (yes vs. no), and the inspection season (spring vs. summer vs. autumn vs. winter). Herein, family history of atopy was defined as at least one of the child's family members (siblings, parents, and/or grandparents) having had at least one of the following diseases: asthma, eczema, and allergic nose or eye problems. We considered ownership of the current residence as an indicator of high socioeconomic status. Household dampness-related exposures were defined as a report of at least one of the following indicators: visible mold spots, visible damp stains, water damage, and moldy odor by at least one of the inspectors during home inspections. Household ETS was defined as

at least one smoker among family members living in the current residence. Furthermore, these associations were investigated among children from residences inspected in different seasons by the same statistical methods, and all of these above covariates were adjusted except for the inspection season. Associations were indicated by odds ratio (OR) and adjusted odds ratio (AOR) with 95% confidence interval (CI). Significance in all statistical analyses was set at p -value < 0.05 .

3. Results

3.1. Basic characteristics and health information of the inspected children

Table 2 shows the demographic characteristics of all inspected children, as well as for cases group and controls group. Ages of these children ranged from 5 to 10 years-old and mainly were in 6–8 years-old. Numbers between boys and girls, as well as numbers among children from different districts (except Yang-Pu district), had little difference. Numbers of children inspected in spring and summer were slightly more than in autumn and winter.

Among these inspected children, according to health survey during home inspection, 35.0%, 23.6%, and 41.4% had history of doctor-diagnosed asthma, allergic rhinitis, and pneumonia during lifetime-ever, respectively; as well as 23.8%, 48.5%, and 65.9% of

Table 2
Demographic characteristics of the inspected children.

Items	Total, n (%)	Cases, n (%)	Controls, n (%)	p-Value ^a
(1) Age (year-old)				
5	33 (7.3)	10 (5.4)	23 (8.6)	0.167
6	141 (31.1)	54 (29.0)	87 (32.5)	
7	162 (35.7)	67 (36.0)	95 (35.4)	
8	77 (17.0)	35 (18.8)	42 (15.7)	
9	34 (7.5)	19 (10.2)	15 (5.6)	
10	7 (1.5)	1 (0.5)	6 (2.2)	
(2) Sex				
Boys	234 (51.5)	105 (56.5)	129 (48.1)	0.081
Girls	220 (48.5)	81 (43.5)	139 (51.9)	
(3) Located district of residence				
Jing-An district	87 (19.2)	34 (18.3)	53 (19.8)	0.886
Zha-Bei district	78 (17.2)	36 (19.4)	42 (15.7)	
Hong-Kou district	63 (13.9)	26 (14.0)	37 (13.8)	
Yang-Pu district	36 (7.9)	16 (8.6)	20 (7.5)	
Bao-Shan district	96 (21.1)	39 (21.0)	57 (21.3)	
Feng-Xian district	94 (20.7)	35 (18.8)	59 (22.0)	
(4) Family history of atopy				
Yes	169 (37.8)	95 (52.5)	74 (27.8)	< 0.001
No	278 (62.2)	86 (47.5)	192 (72.2)	
(5) Ownership of the current residence				
Owner	341 (76.1)	137 (74.5)	204 (77.3)	0.492
Renter	107 (23.9)	47 (25.5)	60 (22.7)	
(6) Household environmental tobacco smoke				
Yes	235 (52.9)	105 (57.4)	130 (49.8)	0.116
No	209 (47.1)	78 (42.6)	131 (50.2)	
(7) Household dampness-related exposures				
Yes	361 (83.8)	146 (82.5)	215 (84.6)	0.550
No	70 (16.2)	31 (17.5)	46 (22.5)	
(8) Inspection season				
Spring	130 (28.6)	53 (28.5)	77 (28.7)	< 0.001
Summer	127 (28.0)	75 (40.3)	52 (19.4)	
Autumn	104 (22.9)	27 (14.5)	77 (28.7)	
Winter	93 (20.5)	31 (16.7)	62 (23.1)	

^a In the Pearson's chi-square test (two-tailed) for differences in proportions of cases and controls among different options in various items ($n \times 2$ tables), herein n is the number of options for various items.

them had parent-reported eczema, wheeze, and rhinitis during lifetime-ever, respectively. Besides, a total of 13.4%, 22.2%, and 43.0% of these children had eczema, wheeze, and rhinitis in the last year before case-control study. According to the definition of cases and controls with respect to doctor-diagnosed asthma in the present study, cases group and controls group had no significant differences in the proportions of the inspected children in different age and sex, from different district, from the owned or rented residences, and with different household ETS and dampness-related exposures. Significant higher proportion of children in cases group had family history of atopy than in controls group. Proportions of children who were inspected in different seasons also had significant difference between cases and controls. More children in cases group than in controls group were inspected in summer (Table 2).

3.2. Temperature and relative humidity

A total of 445 children's bedrooms and 449 children's living rooms had valid data for temperature and relative humidity (Table 3). The 24 h and 6 h averaged temperatures in the child's bedroom were significantly higher among cases than among controls. In the living room, the 24 h and 6 h averaged temperatures as well as the 24 h averaged relative humidity were significantly higher among cases than among controls, whereas significantly lower proportion of residences with 30%~60% relative humidity was found among cases than among controls. However, we did not find significant differences for these indicators between cases and controls within different seasons (Table S1).

Significant differences of temperatures and relative humidity were found among different seasons (Table S1). In summer, a total

of 45.2% and 66.9% of the child's bedrooms meet the national standard for indoor temperature in 24 h and 6-h averaged, respectively; and most of the child's bedrooms in spring, summer, and autumn meet the national standard of indoor relative humidity for summer. But in winter, a large proportion of bedroom did not meet the national standard of indoor temperature and relative humidity for winter (GAQS, 2002). The temperature and relative humidity in the child's bedroom in summer were significantly higher than those in other seasons; and average relative humidity in winter was higher than the upper limit (60%) of relative humidity in winter in the nation standard. The similar results were found in the inspected living room.

3.3. Carbon dioxide (CO₂)

A total of 445 and 449 children had valid data for CO₂ in the child's bedroom and living room, respectively (Table 4). The 24 h averaged CO₂ concentrations in about one-fourth of the child's bedroom, and the 6 h averaged CO₂ concentrations in over half of the bedroom, were > 1000 ppm. In the living room, averaged CO₂ concentration was lower than 1000 ppm and most of the living room had ≤ 1000 ppm CO₂. No significant differences in averaged CO₂ concentrations and in proportions of room with ≤ 1000 ppm CO₂ were found between cases and controls.

Among the residences which were inspected in different seasons (Table S2), the averaged CO₂ concentrations in the child's bedroom in spring and winter were significantly higher than in summer and autumn; and the averaged CO₂ concentrations in winter were significantly higher than in spring. The proportions of bedrooms with > 1000 ppm CO₂ in spring and winter also higher than those in summer and autumn. In the living room, the 24 h

Table 3
Comparisons of averaged temperature (T) and relative humidity (RH) between cases and controls.

Items		Total	Cases	Controls	p-Value ^a
1. In the child's bedroom (N=445)					
(1) T-24 h	Mean ± SD (°C)	21.4 ± 6.6	22.6 ± 6.3	20.5 ± 6.6	0.010
	22–28 ^b °C, n (%)	134 (30.1)	58 (31.7)	76 (29.0)	0.543
	16–24 ^c °C, n (%)	143 (32.1)	55 (30.1)	88 (33.6)	0.432
(2) T-6 h (00:00–06:00)	Mean ± SD (°C)	21.1 ± 6.4	22.2 ± 6.1	20.3 ± 6.5	0.024
	22–28 ^b °C, n (%)	168 (37.8)	71 (38.8)	97 (37.0)	0.704
	16–24 ^c °C, n (%)	277 (62.2)	58 (31.7)	92 (35.1)	0.453
(3) RH-24 h	Mean ± SD (%)	64.6 ± 10.8	65.8 ± 10.6	63.7 ± 10.9	0.066
	40–80% ^b , n (%)	409 (91.9)	167 (91.3)	242 (92.4)	0.673
	30–60% ^c , n (%)	153 (34.4)	55 (30.1)	98 (37.4)	0.108
(4) RH-6 h (00:00–06:00)	Mean ± SD (%)	67.0 ± 11.2	67.6 ± 11.4	66.6 ± 11.1	0.217
	40–80% ^b , n (%)	391 (87.9)	160 (87.4)	231 (88.2)	0.815
	30–60% ^c , n (%)	126 (28.3)	51 (27.9)	75 (28.6)	0.862
2. In the living room (N=449)					
(1) T-24 h	Mean ± SD (°C)	21.5 ± 6.8	22.8 ± 6.6	20.7 ± 6.9	0.039
	22–28 ^b °C, n (%)	123 (27.4)	50 (27.0)	73 (27.7)	0.884
	16–24 ^c °C, n (%)	141 (31.4)	54 (29.2)	87 (33.0)	0.397
(2) T-6 h (00:00–06:00)	Mean ± SD (°C)	21.3 ± 6.8	22.4 ± 6.5	20.4 ± 6.9	0.019
	22–28 ^b °C, n (%)	140 (31.2)	59 (31.9)	81 (30.7)	0.785
	16–24 ^c °C, n (%)	145 (31.9)	55 (29.7)	90 (34.1)	0.331
(3) RH-24 h	Mean ± SD (%)	64.3 ± 11.4	65.9 ± 11.0	63.1 ± 11.6	0.020
	40–80% ^b , n (%)	408 (90.9)	168 (90.8)	240 (90.9)	0.972
	30–60% ^c , n (%)	171 (38.1)	59 (31.9)	112 (42.4)	0.024
(4) RH-6 h (00:00–06:00)	Mean ± SD (%)	66.3 ± 12.0	67.4 ± 11.8	65.6 ± 12.2	0.145
	40–80% ^b , n (%)	391 (87.1)	161 (87.0)	230 (87.1)	0.977
	30–60% ^c , n (%)	139 (31.0)	49 (26.5)	90 (34.1)	0.086

^a p-Value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. Bold indicates statistical significance.

^b Required range in summer in IAQS of China (GAQS, 2002).

^c Required range in winter in IAQ standard of China (GAQS, 2002).

Table 4
Comparisons of averaged CO₂ concentration between cases and controls.

Items		Total	Cases	Controls	p-Value ^a
1. In the child's bedroom (N=445)					
(1) CO ₂ -24 h	Mean ± SD (ppm) ≤ 1000 ^b ppm, n (%)	814 ± 378 341 (76.6)	821 ± 391 135 (73.8)	809 ± 370 206 (78.6)	0.599 0.234
(2) CO ₂ -6 h (00:00–06:00)	Mean ± SD (ppm) ≤ 1000 ^b ppm, n (%)	1123 ± 741 242 (54.4)	1137 ± 789 98 (53.6)	1111 ± 696 144 (55.0)	0.266 0.769
2. In the living room (N=449)					
(1) CO ₂ -24 h	Mean ± SD (ppm) ≤ 1000 ^b ppm, n (%)	643 ± 290 406 (90.4)	627 ± 251 169 (91.4)	657 ± 332 237 (89.8)	0.235 0.576
(2) CO ₂ -6 h (00:00–06:00)	Mean ± SD (ppm) ≤ 1000 ^b ppm, n (%)	707 ± 481 380 (84.6)	681 ± 424 157 (84.9)	724 ± 509 223 (84.5)	0.403 0.909

^a p-Value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls.

^b Upper limit of daily-averaged concentration in IAQS of China (GAQS, 2002).

and 6 h averaged concentration of CO₂ in winter and the proportions of living room with > 1000 ppm CO₂ were significantly higher than in other seasons. No significant differences in averaged CO₂ concentrations and in proportions of room with ≤ 1000 ppm CO₂ were found between cases and controls within different seasons, except for significantly higher proportion of living room with ≤ 1000 ppm CO₂ among cases than among controls in spring (100.0% vs. 90.9%; p-value=0.024).

3.4. Airborne culturable fungi

A total of 450 and 445 children had valid data for airborne culturable fungi in the children's bedroom and living room (Table 5). The averaged concentrations of airborne culturable fungi in both the child's bedroom and living room were about 300 cfu/m³. Most of the inspected residences meet the requirement (≤ 2500 cfu/m³) in indoor air quality standard for airborne culturable fungi in China (GAQS, 2002), and only one bedroom and two living rooms had > 2500 cfu/m³ airborne culturable fungi in spring. No significant differences were found in averaged fungi concentrations and in proportions of room with ≤ 2500 cfu/m³ fungi between cases and controls in the whole inspected residences (Table 5) and when the children were stratified by

Table 5
Comparisons of airborne culturable fungi between cases and controls.

Items	Total	Cases	Controls	p-value ^a
1. In the child's bedroom (N=450)				
Mean ± SD (cfu/m ³)	310 ± 311	300 ± 286	316 ± 328	0.616
≤ 2500 ^b cfu/m ³ , n (%)	449 (99.8)	185 (100.0)	264 (99.2)	0.403
2. In the living room (N=445)				
Mean ± SD (cfu/m ³)	301 ± 287	276 ± 318	194 ± 336	0.864
≤ 2500 ^b cfu/m ³ , n (%)	443 (99.6)	184 (100.0)	259 (99.2)	0.234

^a p-Value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls.

^b Upper limit of daily-averaged concentration in IAQS of China (GAQS, 2002).

Table 6
Comparisons of formaldehyde in the child's bedroom between cases and controls (N=409).

Items	Total	Cases	Controls	p-value ^a
(1) Formaldehyde-24 h				
Mean ± SD (μg/m ³)	21.5 ± 13.0	21.6 ± 14.5	21.5 ± 11.9	0.356
≤ 100 ^b μg/m ³ , n (%)	407 (99.3)	164 (98.8)	242 (99.6)	0.356
(2) Formaldehyde-6 h (00:00–06:00)				
Mean ± SD (μg/m ³)	22.2 ± 17.9	22.4 ± 20.8	22.1 ± 15.7	0.351
≤ 100 ^b μg/m ³ , n (%)	406 (99.0)	163 (98.2)	242 (99.6)	0.159

^a p-Value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls.

^b Upper limit of daily-averaged concentration in IAQS of China (GAQS, 2002).

inspected seasons (Table S3), except for significantly higher averaged fungi concentrations among cases than among controls in autumn (296 vs. 258 cfu/m³; p-value=0.027). We also did not find significantly seasonal differences in averaged fungi concentrations and in proportions of room with ≤ 2500 cfu/m³ fungi (Table S3).

3.5. Formaldehyde

A total of 410 residences had valid data for formaldehyde in the child's bedroom (Table 6). Most bedrooms had ≤ 100 μg/m³ formaldehyde; and only three bedrooms had > 100 μg/m³ formaldehyde in 24 h averaged and 6 h averaged (two in summer and one in autumn). We did not find significant differences in averaged formaldehyde concentrations and in proportions of room with ≤ 100 μg/m³ formaldehyde between cases and controls. With respect to different seasons (Table S4), the averaged concentration of formaldehyde (27.7 μg/m³) and proportion of room with ≤ 100 μg/m³ formaldehyde in winter was significantly higher than that in other seasons (p-value < 0.001). No significant differences were found in averaged formaldehyde concentrations and in proportions of room with ≤ 100 μg/m³ formaldehyde between cases and controls within different seasons.

3.6. Inspirable particulate matters

A total of 449 children's bedrooms had valid data for particulate matter (Table 7). The averaged concentrations for PM_{1.0}, PM_{2.5}, PM_{4.0}, and PM₁₀ were 6.1, 61.0, 87.4, and 133.4 μg/m³, respectively. The concentrations of PM_{2.5} and PM₁₀ in 77.7% and 74.6% of the inspected bedrooms meet the national standard for ambient second level for PM_{2.5} and PM₁₀ in AAQS of China (GAQS, 2012), which is equivalent to IAQS of China for PM₁₀ (GAQS, 2002). The concentration of PM_{2.5} and PM₁₀ in 43.2% and 30.7% of the inspected bedrooms meet the national standard for ambient first level of AAQS of China. No significant differences between cases and controls were found in averaged particulate matter concentrations and in proportions of bedrooms which meet the national standard for particulate matter concentrations.

When bedrooms were stratified by the inspected season (Table S5), we found that the averaged concentrations of inspirable particulate matters in all different equivalent diameters among the bedroom inspected in winter were significantly higher than in other seasons (p-value < 0.001); and children's bedrooms inspected in autumn had the lowest concentrations of all particulate matters. The proportions of bedroom where averaged concentrations of PM_{2.5} and PM₁₀ meet the different national standards in winter were significantly lower than those in other seasons. The highest proportion of bedroom which were inspected in summer meet the national standard (second and first level) of China for ambient PM_{2.5} and PM₁₀, whereas the concentration of PM_{2.5} in

Table 7

Comparisons of inspirable particulate matter concentration in the child's bedroom between cases and controls (N=449).

Items		Total	Cases	Controls	p-Value ^a
(1) PM _{1.0}	Mean ± SD (μg/m ³)	6.1 ± 6.2	6.3 ± 6.7	6.0 ± 5.9	0.225
(2) PM _{2.5}	Mean ± SD (μg/m ³)	61.0 ± 66.7	61.7 ± 66.5	60.5 ± 67.0	0.115
	≤ 75 ^b μg/m ³ , n (%)	349 (77.7)	141 (76.2)	208 (78.8)	0.519
	≤ 35 ^c μg/m ³ , n (%)	194 (43.2)	81 (43.8)	113 (42.8)	0.836
(3) PM _{4.0}	Mean ± SD (μg/m ³)	87.4 ± 89.8	88.0 ± 88.2	87.1 ± 91.0	0.089
(4) PM ₁₀	Mean ± SD (μg/m ³)	133.4 ± 118.7	132.9 ± 115.0	133.7 ± 121.5	0.154
	≤ 150 ^{b,d} μg/m ³ , n (%)	335 (74.6)	137 (74.1)	198 (75.0)	0.821
	≤ 75 ^c μg/m ³ , n (%)	138 (30.7)	64 (34.6)	74 (28.0)	0.138

^a p-Value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls.

^b Upper limit of daily-averaged concentration in the second level of AAQS of China (GAQS, 2012).

^c Upper limit of daily-averaged concentration in the first level of AAQS of China (GAQS, 2012).

^d Upper limit of hour-averaged concentration in the IAQS of China (GAQS, 2002).

about half (77.4% in winter) of the children's bedrooms was higher than the first level in the AAQS of China. We also did not find significant differences in averaged particulate matter concentrations and in proportions of bedroom which meet the national standard for particulate matter concentrations between cases and controls within different seasons.

Besides, a total of 266 had valid data both for indoor and outdoor concentration of particulate matters. Strong linear correlations were found between indoor and outdoor concentration of particulate matters in all different equivalent diameters (Pearson's correlation coefficient: $r=0.891$ – 0.922 ; p -value < 0.001) (Fig. 1). These linear correlations were robust in different seasons; but these correlations in autumn were weaker than in other seasons (Figs. S2–S5). According to that the slopes of the best linear fitted curves for outdoor concentration (as independent variable) and indoor concentration (as dependent variable) were bigger than one in summer (Fig. S3), we found that indoor concentrations of

particulate matters in summer could be higher than outdoor concentrations.

3.7. Correlations of various indicators/pollutants

Temperature has positive correlations with relative humidity both in the child's bedroom and in the living room. Temperature both in the child's bedroom and in the living room had negative correlations with CO₂, formaldehyde, and inspirable particulate matters; and relative humidity had negative correlations with formaldehyde. However, relative humidity had positive correlations with inspirable particulate matters. We also found weak positive correlations of CO₂ with formaldehyde and airborne culturable fungi, as well as between airborne culturable fungi in the child's bedroom and in the living room. There were positive correlations between each pairs of particulate matters (Table S6).

Furthermore, in spring (Table S7), temperature has negative

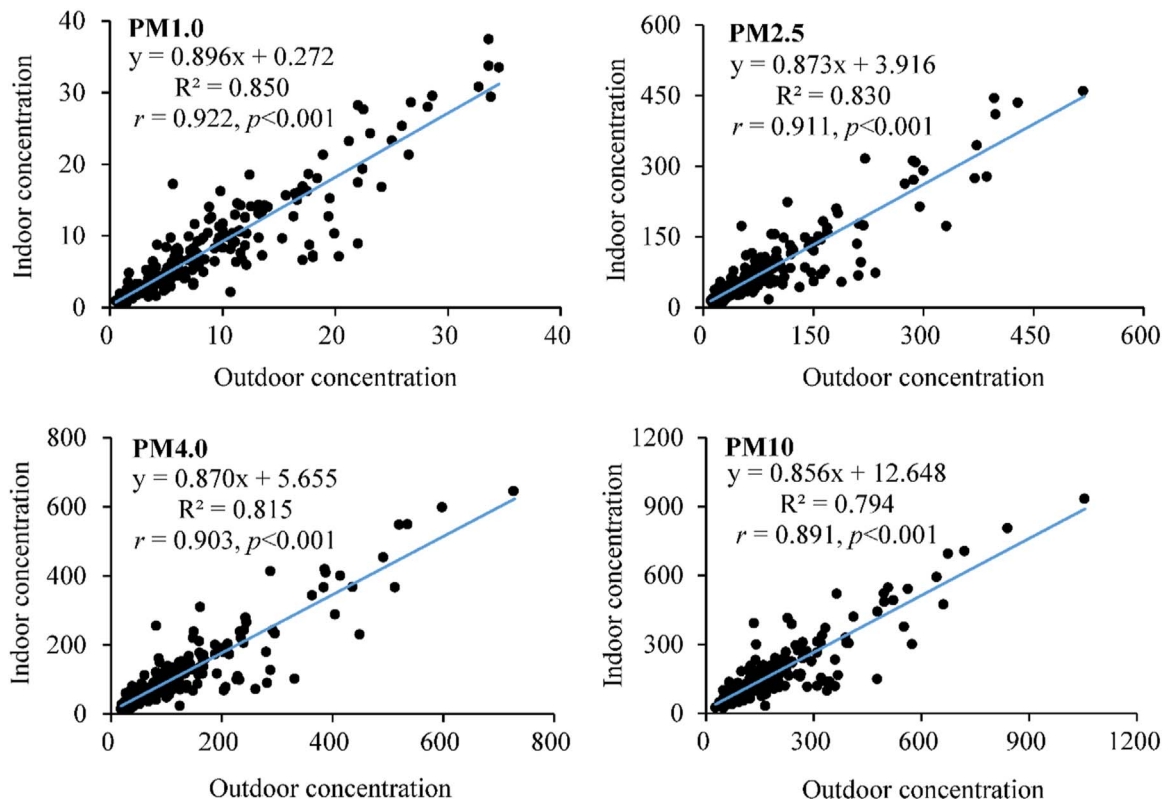


Fig. 1. Correlations between indoor (the child's bedroom) and outdoor concentration (μg/m³) of particulate matter (N=266).

correlations with CO₂, but not formaldehyde and inspirable particulate matters. In summer (Table S8), relative humidity had negative correlations with CO₂ and formaldehyde. Formaldehyde also had negative correlations with inspirable particulate matters. CO₂ had positive correlations with formaldehyde in the child's bedroom. In autumn (Table S9), temperature had negative correlations with formaldehyde and inspirable particulate matters. CO₂ had positive correlations with inspirable particulate matters in the child's bedroom. In winter (Table S10), both temperature and relative humidity had negative correlations with formaldehyde in the child's bedroom, but positive correlations with CO₂. There were consistently significant and positive correlations between each two inspirable particulate matters; and relative humidity consistently had positive correlations with particulate matters in different seasons.

3.8. Associations of indicators/pollutants with childhood asthma

Among the residences with different 24 h averaged temperature in the child's bedroom, as well as the residences with different 24 h averaged temperature and relative humidity, prevalences of case children had significant different (Table 8). The higher the temperature and relative humidity, the higher the proportions of cases. Before and after adjusted for the potential confounders, temperature and relative humidity had significant and positive associations with increased odds ratios of childhood asthma; however, CO₂ and inspirable particulate matters generally had negative associations with childhood asthma. No other significant associations were found (Table 8).

When the inspected residences were stratified by inspected seasons, we found several inconsistent associations between the analyzed indicators/pollutants and the odds of childhood asthma (Tables S12–S15). In spring (Table S12), summer (Table S13), and

autumn (Table S14), as for the total children, both temperature and relative humidity had positive associations, and CO₂ and inspirable particulate matters had negative associations, with the odds of childhood asthma. However, in winter (Table S15), the night 6 h averaged concentration of CO₂ in the living room had significant associations with the increased odds ratios of childhood asthma (third quartiles vs. first quartiles (reference): AOR, 95% CI: 2.24, 1.01–6.72; fourth quartiles vs. first quartiles (reference): AOR, 95% CI: 2.11, 1.07–4.18); Airborne culturable fungi, PM_{2.5}, PM_{4.0}, and PM₁₀ in the child's bedroom also partly had associations with increased odds ratios of childhood asthma.

4. Discussion

4.1. Main findings

Most of the child's bedroom and living room meet the national standard of indoor relative humidity and temperature (except in winter). The night 6 h averaged concentrations of CO₂ in over half of the child's bedrooms were slightly > 1000 ppm; but most of the living rooms had ≤ 1000 ppm averaged concentrations of CO₂ in different seasons. Most residences meet the requirement of IAQS for airborne culturable fungi and formaldehyde in China (GAQS, 2002). The child's bedrooms inspected in winter had higher concentrations of CO₂, formaldehyde, particulate matters than inspected in other seasons. About half (77.4% in winter) of the child's bedrooms could not meet the first level of PM_{2.5} in the AAQS of China (GAQS, 2012). Indoor and outdoor concentration of particulate matters had strong linear correlations. Indoor temperature had negative correlations with CO₂, formaldehyde, and particulate matters, and relative humidity had negative correlations with formaldehyde. But relative humidity had positive correlations with

Table 8
Associations between the measured indicators/pollutants of indoor air quality and childhood asthma.

Items	Quartiles of the measured value for indicators/pollutants ^a									
	1st (reference)		2nd		3rd		4th			
	Case, n (%)	OR, 95%CI	Case, n (%)	OR, 95%CI	Case, n (%)	OR, 95%CI	Case, n (%)	OR, 95%CI	Case, n (%)	OR, 95%CI
In the child's bedroom										
T-24 h	37 (32.7)		42 (37.8)	1.25, 0.72–2.17	1.50, 0.70–3.22	48 (42.9)	1.24, 0.95–1.63	1.16, 0.83–1.61	56 (51.4)^c	1.30, 1.08–1.55
T-6 h	36 (32.1)		44 (39.3)	1.37, 0.79–2.37	1.62, 0.76–3.43	54 (47.4)	1.38, 1.05–1.81	1.32, 0.94–1.86	49 (45.8)	1.21, 1.01–1.46
RH-24 h	37 (33.0)		45 (40.2)	1.36, 0.79–2.35	1.55, 0.84–2.87	49 (43.8)	1.26, 0.96–1.65	1.27, 0.94–1.72	52 (47.7)	1.23, 1.02–1.47
RH-6 h	47 (41.6)		36 (32.4)	0.67, 0.39–1.16	0.69, 0.38–1.26	49 (44.1)	1.05, 0.81–1.37	1.09, 0.80–1.47	51 (46.4)	1.07, 0.89–1.27
CO ₂ -24 h	49 (44.1)		45 (40.2)	0.85, 0.50–1.45	0.86, 0.47–1.59	38 (34.2)	0.81, 0.62–1.06	0.84, 0.62–1.13	51 (45.9)	1.03, 0.86–1.22
CO ₂ -6 h	52 (47.3)		39 (34.5)	0.59, 0.34–1.01	0.61, 0.33–1.11	44 (39.6)	0.86, 0.66–1.12	0.90, 0.68–1.21	48 (43.2)	0.95, 0.79–1.13
F-24 h	39 (43.3)		45 (43.3)	1.00, 0.56–1.76	1.21, 0.60–2.45	45 (35.4)	0.85, 0.64–1.12	0.89, 0.64–1.24	37 (42.0)	0.98, 0.81–1.20
F-6 h	43 (42.6)		52 (42.3)	0.99, 0.58–1.68	1.07, 0.55–2.08	30 (31.3)	0.78, 0.59–1.05	0.89, 0.62–1.29	41 (46.1)	1.05, 0.87–1.27
Fungi	48 (41.0)		45 (40.9)	1.00, 0.59–1.69	1.20, 0.65–2.20	51 (45.5)	1.10, 0.84–1.42	1.20, 0.89–1.61	41 (36.9)	0.94, 0.79–1.13
PM _{1.0}	56 (48.7)		39 (35.5)	0.58, 0.34–0.99	0.51, 0.28–0.93	42 (37.2)	0.79, 0.61–1.03	0.75, 0.55–1.03	48 (43.2)	0.93, 0.78–1.11
PM _{2.5}	53 (47.3)		40 (35.4)	0.61, 0.36–1.04	0.64, 0.35–1.10	43 (38.4)	0.83, 0.64–1.09	0.78, 0.57–1.07	49 (43.8)	0.95, 0.80–1.14
PM _{4.0}	55 (48.7)		35 (31.3)	0.48, 0.28–0.83	0.51, 0.28–0.92	47 (42.0)	0.87, 0.67–1.14	0.85, 0.62–1.16	48 (42.9)	0.93, 0.78–1.10
PM ₁₀	53 (47.3)		40 (35.4)	0.61, 0.36–1.04	0.73, 0.41–1.31	45 (40.2)	0.87, 0.66–1.13	0.89, 0.65–1.21	47 (42.0)	0.93, 0.78–1.11
In the living bedroom										
T-24 h	38 (33.6)		41 (36.6)	1.14, 0.66–1.97	1.02, 0.47–2.18	47 (41.6)	1.19, 0.91–1.55	1.17, 0.83–1.63	59 (53.2)^c	1.31, 1.09–1.57
T-6 h	39 (33.6)		43 (38.1)	1.21, 0.71–2.08	1.18, 0.56–2.47	45 (41.3)	1.18, 0.90–1.55	1.18, 0.85–1.64	58 (52.3)^c	1.29, 1.08–1.55
RH-24 h	35 (31.0)		43 (38.4)	1.39, 0.80–2.41	1.76, 0.95–3.27	55 (47.8)	1.43, 1.09–1.87	1.42, 1.06–1.91	52 (47.7)^c	1.27, 1.06–1.52
RH-6 h	39 (34.5)		43 (38.4)	1.18, 0.69–2.04	1.41, 0.76–2.62	53 (47.3)	1.31, 1.00–1.71	1.29, 0.95–1.74	50 (44.6)	1.15, 0.96–1.38
CO ₂ -24 h	56 (49.6)		37 (33.0)	0.50, 0.29–0.86	0.50, 0.27–0.91	49 (43.8)	0.89, 0.68–1.16	0.87, 0.65–1.16	43 (38.4)	0.86, 0.72–1.03
CO ₂ -6 h	55 (47.8)		40 (36.4)	0.62, 0.37–1.06	0.57, 0.32–1.04	44 (38.9)	0.83, 0.64–1.09	0.79, 0.59–1.06	46 (41.4)	0.92, 0.77–1.09
Fungi	47 (42.0)		50 (44.2)	1.10, 0.65–1.86	1.55, 0.83–2.87	40 (36.7)	0.90, 0.68–1.17	1.01, 0.75–1.36	47 (42.3)	1.01, 0.84–1.20

^a Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; T, temperature; RH, relative humidity; F, formaldehyde; PM, particulate matter; h, hour. The quartiles for different indicators/pollutants were presented in Table S6. Bold indicates statistical significance.

^b Adjusted factors in the multiple logistic regression analyses included age, sex, located district of residence, family history of atopy, ownership of the current residence, household environmental tobacco smoke (ETS), household dampness-related exposures, and the inspection season.

^c $p < 0.05$ in the Pearson's chi-square test for differences of case proportions among children in different quartiles of the measured value for indicators/pollutants (4*2 tables).

particulate matters. These correlations were slightly different in different inspected seasons. Most differences in CO₂, culturable fungi, formaldehyde, and particulate matters were not significant between cases and controls. Both temperature and relative humidity had positive associations with childhood history of doctor-diagnosed asthma; but CO₂ and inspirable particulate matters had negative associations with childhood asthma in spring, summer, and autumn (positive associations in winter).

4.2. Comparisons of indoor air quality to previous studies

Several studies on household indoor air quality using on-site inspection were conducted in Shanghai and other cities of China, as well as in cities of other countries or regions. Table 9 summarized comparison of results in these previous studies to the present study. Our results are similar to most of these previous studies in Shanghai and for the residence in other cities of China; with regard to most studied pollutants, Shanghai residences had lower averaged concentrations than cities from the developing countries, and had similar concentrations to the cities from developed countries.

Our findings, that indoor averaged levels of CO₂, formaldehyde, and particulate matters in winter were notably higher than in other seasons, were consistent with several previous studies (Lu et al., 2010; Massey et al., 2012; Wang et al., 2008; Zhu et al., 2015). This probably was due to that indoor natural ventilation rate would be lower and indoor averaged levels of these air pollutants would be easier to be cumulated in winter than in other seasons. These findings suggests that the household averaged levels of CO₂, formaldehyde, and airborne culturable fungi in most of the urban residences were low and could meet the national standard for indoor air quality in different seasons, but household air quality in winter should be paid more attention. Our findings, that indoor averaged relative humidity was higher in all four seasons, and that indoor averaged air temperature in many residences in summer was higher than whereas in winter was lower than requirements in IAQS (GAQS, 2002) and requirements for thermal comfort in ASHRAE standard (ASHRAE, 2013), were consistently with the findings for Shanghai residences from Yoshino et al. (2006).

4.3. Correlations of indoor and outdoor particulate matters

Many studies investigated the correlation (Indoor/Outdoor ratio: I/O ratio) of indoor and outdoor concentration of particulate matters. Most of these studies found that indoor concentration was highly correlated with outdoor level of particulate matters (Colbeck et al., 2010; Custódio et al., 2014; Hasheminassab et al., 2014; Hassanvand et al., 2014; Jung et al., 2010; Massey et al., 2012; Meier et al., 2015; Mullen et al., 2011; Rivas et al., 2014; Zhao et al., 2015; Zhu et al., 2015).

During November 2005 to February 2006, Colbeck et al. (2010) measured indoor and outdoor concentrations of PM_{1.0}, PM_{2.5}, and PM₁₀ in ten urban residences in Pakistan and found indoor concentrations of these particulate matters were notably higher than outdoor concentrations. Studies both in Portuguese residences (Custódio et al., 2014) and in Switzerland (Meier et al., 2015) found that outdoor air pollutants probably were the main source of indoor air pollutants, and Gall et al. (2015) suggested that about half of exposures to PM_{2.5} and PM₁₀ were from outdoor origin among nationally ventilated homes in Singapore. However, Hassanvand et al. (2014) found many sources for PM₁₀, but not for PM_{1.0} and PM_{2.5}, were in indoor of a retirement home from Tehran, Iran. Hasheminassab et al. (2014) stated that vehicular emissions were the major contributor to indoor and outdoor PM_{2.5} in Los Angeles Basin, USA. Jung et al. (2010) suggested I/O ratio of PM_{2.5} in heating season were higher than in non-heating season among

334 residences in the New York City, USA, as Massey et al. (2012) found that I/O ratios of PM_{1.0}, PM_{2.5}, PM_{5.0}, and PM₁₀ in winter were higher than in summer among five urban residences in the Agra, India. Mullen et al. (2011) also found averaged concentration of PM_{2.5} in indoor was lower than in outdoor for four high-rise apartments during summer in Beijing.

However, in the present study, our results indicate that I/O ratios of particulate matters in summer would be higher than in winter. Generally speaking, outdoor averaged concentrations of particulate matters in summer are low and in winter are high (Jung et al., 2010; Zhang et al., 2013b). Due to burning natural gas or coal for cooking and common family activity in the inspected residences in summer, indoor level of particulate matters probably would be higher than in outdoor (Colbeck et al., 2010; Zhang and Smith, 2007). Nevertheless, many previous studies (Hasheminassab et al., 2014; Jung et al., 2010; Massey et al., 2012; Rivas et al., 2014; Zhao et al., 2015; Zhu et al., 2015) supported that strong correlations would be existed between indoor and outdoor concentrations of particulate matters.

4.4. Correlations among various indoor air pollutants/indicators

As in the present study, several studies were conducted on correlations of indoor temperature, relative humidity and/or ventilation with formaldehyde, airborne culturable fungi, and/or particulate matters (Brown et al., 2015; Crawford et al., 2015; Du et al., 2015; Escobedo et al., 2014; Jo and Sohn, 2009; Liao and Yang, 2013; Liu et al., 2014c; Ramalho et al., 2015; Wolkoff et al., 2007; Zhang and Yoshino, 2010).

Du et al. (2015) suggested positive correlation between indoor relative humidity and temperature among 94 apartments from Finland, in consistent with our findings; but they also found negative correlation between these indicators among 96 apartments from Lithuania during heating season. During September 2003 and December 2005, Brown et al. (2015) inspected 567 dwellings in France and found that indoor temperature had positive correlations with indoor formaldehyde, and indoor absolute humidity had positive correlations with both indoor formaldehyde and airborne culturable fungi. Crawford et al. (2015) also found positive correlation between indoor relative humidity and some types of household airborne fungus in 103 homes from Syracuse, New York, USA. However, we found that indoor concentration of formaldehyde has negative and weak correlations with indoor temperature and relative humidity. We also found that airborne culturable fungi had no significant correlations with these two indicators in different seasons. These findings in the present study could be supported by findings from Korea, where Jo and Sohn (2009) found that the concentration measurements were inversely proportional to or no clear relationship with indoor temperature and humidity in some cases according to inspected data from 158 newly built apartments in during August 2004 to September 2005.

Furthermore, Liao and Yang (2013) suggested that natural ventilation through window opening could be quick and applicable in control of indoor concentration of formaldehyde in the real buildings. Ramalho et al. (2015) found that the weekly averaged concentration of CO₂ was positively and significantly correlated with indoor concentration of formaldehyde during both heating and non-heating seasons in the main bedroom of 567 dwellings from France during 2003–2005. These findings were consistent with our findings that CO₂ had positive correlations with formaldehyde in the child's bedroom in autumn. According to on-site measured data in 24 homes from Xi'an, China during spring of 2013, Liu et al. (2014c) found positive correlation between fungus and particulate matters (PM₁₀ and PM_{2.5}) concentration and suggested that the correlation coefficient between fungal concentrations and PM_{2.5} was larger than between fungal concentrations

Table 9

Comparison of indoor air quality in the present study to the previous studies.

Literature	City, country	Inspected Date	Location (sample size)	Pollutant/indicator (present) ^a
Yoshino et al. (2006)	Shanghai, China	1998.01; 1998.08; 2003.07	Living room and bedroom (winter: 6; summer: 23)	Winter: T: 10.0–17.0 (12.2) °C; RH: NA. Summer: T: 26–33 (28.4) °C; RH: 48–86 (68.8)%
Lu et al. (2010)	Shanghai, China	2008	Living room and bedroom (100)	Summer-autumn: CO ₂ : 530 (668) ppm; formaldehyde: 61.2 (19.7) µg/m ³ ; PM ₁₀ : 143.1 (110.9) µg/m ³ Winter-spring: CO ₂ : 560 (802) ppm; formaldehyde: 43.9 (24.4) µg/m ³ ; PM ₁₀ : 162.1 (162.0) µg/m ³
Zhang et al. (2015)	Shanghai, China	2010.12–2011.01	Dorm room (3)	Winter: T: 8.7 (12.2) °C; RH: 61.2 (62.4)%; CO ₂ : > 2000 ppm in several occasions (978 ppm)
Wang et al. (2008)	Lanzhou, China	2006.11–2007.01; 2007.07–09	Household (120)	Summer: formaldehyde: 110 (19.7) µg/m ³ ; PM ₁₀ : 130 (109.6) µg/m ³ Winter: formaldehyde: 150 (27.7) µg/m ³ ; PM ₁₀ : 390 (195.1) µg/m ³
Zheng et al. (2011)	Beijing, China	2010.01–04	Master bedroom (60)	Winter: T: 19.9 (12.2) °C; RH: 30.1 (62.4)%; CO ₂ : 840 (818) ppm; formaldehyde: 40.0 (27.7) µg/m ³ ; PM ₁₀ : 56.0 (128.8) µg/m ³ .
Zhu et al. (2015)	Wuhan, China	2013	Living room and bedroom (10)	Autumn: T: 19.5 (23.9) °C; RH: 60.0 (64.1) %; CO ₂ : 525 (644) ppm; formaldehyde: 19.0 (19.7) µg/m ³ ; PM _{1.0} : 297.0 (4.7) µg/m ³ ; PM _{2.5} : 301.8 (46.5) µg/m ³ ; PM ₁₀ : 339.0 (112.1) µg/m ³ ; Airborne culturable fungi: 417 (261) cfu/m ³ Winter: T: 12.7 (12.2) °C; RH: 55.0 (61.9)%; CO ₂ : 748 (878) ppm; formaldehyde: 15.6 (20.4) µg/m ³ ; PM _{1.0} : 613.5 (9.3) µg/m ³ ; PM _{2.5} : 626.3 (94.6) µg/m ³ ; PM ₁₀ : 674.0 (195.1) µg/m ³ ; Airborne culturable fungi: 109 (318) cfu/m ³ . Summer: T: 29.6 (28.5) °C; PM _{2.5} : 52.0 (50.0) µg/m ³
Mullen et al. (2011)	Beijing, China	2009.06–08	High-rise apartment (4)	
Liu et al. (2014c)	Xi'an, China	2013. 03–04	Living room and bedroom (24)	Spring: T: 16.2 (19.3) °C; RH: 39.0 (62.2) %; CO ₂ : 788 (725) ppm; Airborne culturable fungi: 564 (349) cfu/m ³
Kotol et al. (2014)	Sisimiut, Greenland	2011.07–08; 2012.01–02	Bedroom (79 in summer and 70 in winter)	Summer: CO ₂ : 1142 (773) ppm; Winter: CO ₂ : 1307 (978) ppm
Mentese and Tasdibi (2014)	Çanakkale, Turkey	2012.10; 2012.12–2013.01; 2013.03	Household (33, inspected in each season)	Autumn: T: 23.6 (23.9) °C; RH: 79.3 (64.1) %; Airborne culturable fungi: 448 (261) cfu/m ³ Winter: T: 7.8 (12.2) °C; RH: 84.6 (61.9) %; Airborne culturable fungi: 364 (318) cfu/m ³ . Spring: T: 11.7 (19.3) °C; RH: 63.3 (62.2)%; Airborne culturable fungi: 385 (349) cfu/m ³ .
Pastuszka et al. (2000)	Upper Silesia, Poland	1996–1998	Household (43 moldy homes and 27 non-moldy homes)	Airborne culturable fungi: Summer: moldy and non-moldy homes: 834 and 225 (288) cfu/m ³ Winter: moldy and non-moldy homes: 256 and 59 (318) cfu/m ³
Haas et al. (2014)	South-eastern Austria	2011–2013	Household (185 non-moldy homes)	Spring: T: 20.7 (19.3) °C; RH: 51.9 (62.2) %; Airborne culturable fungi: 710 (261) cfu/m ³ . Summer: T: 25.1 (28.5) °C; RH: 55.6 (68.8) %; Airborne culturable fungi: 760 (288) cfu/m ³ Autumn: T: 19.8 (23.9) °C; RH: 58.7 (64.1) %; Airborne culturable fungi: 520 (261) cfu/m ³ Winter: T: 19.1 (12.2) °C; RH: 50.9 (61.9)%; Airborne culturable fungi: 690 (318) cfu/m ³
Langer and Bekö (2013)	Sweden	2007.10–2008.05	Household (305 homes)	Winter (heating season): T: 21.9 (12.2) °C; RH: 32.5 (61.9) %; formaldehyde: 20.5 (27.7) µg/m ³
Du et al. (2015)	Finland and Lithuania	2011.12–2013.04	Household (94 from	Finland (period-averaged): T: 21.6 (21.4) °C; RH: 26.8 (65.7) %; CO ₂ : 701 (729) ppm; formaldehyde: 17.5 (21.5) µg/m ³ ; PM _{2.5} : 9.0 (61.0) µg/m ³ ; PM ₁₀ : 22.5 (133.4) µg/m ³ . Lithuania (period-averaged): T: 18.8 (21.4) °C; RH: 46.0 (65.7)%; CO ₂ : 1027 (729) ppm; formaldehyde: 23.2 (21.5) µg/m ³ ; PM _{2.5} : 11.6 (61.0) µg/m ³ ; PM ₁₀ : 21.9 (133.4) µg/m ³

Table 9 (continued)

Literature	City, country	Inspected Date	Location (sample size)	Pollutant/indicator (present) ^a
Molloy et al. (2012)	Melbourne, Australia	2008–2009	Finland and 96 from Lithuania) Household (40 homes, twice per home)	Period-averaged: T: 21.2 (21.4) °C; RH: 50.9 (65.7) %; CO ₂ : 536 (729) ppm; formaldehyde: 12.2 (21.5) µg/m ³ ; PM _{2.5} : 8.4 (61.0) µg/m ³ ; PM ₁₀ : 20.4 (133.4) µg/m ³ .
Yassin et al. (2012)	Kuwait	2011	Living room and bed-room (10)	Summer: PM _{2.5} : 44.0 (50.0) µg/m ³ .
Escobedo et al. (2014)	Colorado, USA	2012	Living room (30)	Summer: PM _{2.5} : 7.0 (50.0) µg/m ³
Vanker et al. (2015)	South Africa	2011.03–2014-05	Living room (592)	Period-averaged: PM ₁₀ : 33.1 (133.4) µg/m ³ .
Colbeck et al. (2010)	Pakistan	2005.11–2006.02	Living room (urban: 1)	Winter: PM _{1.0} : 362.0 (9.3) µg/m ³ ; PM _{2.5} : 402.0 (94.6) µg/m ³ ; PM ₁₀ : 533.0 (195.1) µg/m ³
Massey et al. (2012)	Agra, India	2007.10–2009.09	Living room (5)	Summer: PM _{1.0} : 87.0 (5.2) µg/m ³ ; PM _{2.5} : 119.0 (50.0) µg/m ³ ; PM ₁₀ : 218.0 (109.6) µg/m ³ Winter: PM _{1.0} : 138.0 (9.3) µg/m ³ ; PM _{2.5} : 207.0 (94.6) µg/m ³ ; PM ₁₀ : 304.0 (195.1) µg/m ³

Abbreviation: T, temperature; RH, relative humidity; NA, not available.

^a The values in the Parenthesis are the corresponding results in the present study.

and PM₁₀.

However, we did not find any significant correlations between fungal concentrations and particulate matters in different equivalent diameters. Indoor concentrations of formaldehyde and fungus were low in the present study, and indoor relative humidity in Shanghai was high during most times in different seasons. It may suggested that relative humidity have limited effects on concentrations of formaldehyde and fungus when their concentrations were low or when relative humidity was high in different cases. Besides, our findings that indoor relative humidity had positive and significant correlations with particulate matter, may indicated that relative humidity would play important role in forming particulate matters in different equivalent diameters (Wolkoff and Kjergaard, 2007).

4.5. Associations of indoor air pollutants and childhood asthma

Around the world, many studies have investigated the associations of various air pollutants in indoor and childhood asthma (Bornehag et al., 2005; Brunekreef and Holgate, 2002; Clausen et al., 2012; Dales et al., 2008; Dong et al., 2011; Gordon et al., 2014; Jones, 1999; Liu et al., 2014c; McGwin et al., 2010; Mentese et al., 2015; Sundell, 2004; Wang et al., 2008; Zhu et al., 2015). However, several findings in these studies are inconsistent (Brunekreef and Holgate, 2002; Dales et al., 2008; Jones, 1999; Sundell, 2004).

In Sweden, Bornehag et al. (2005) found that low household ventilation rate, which was calculated by CO₂-based track-gas method, could be a risk factor for allergic symptoms among children in a nested case-control study. But Holme et al. (2010) did not find any associations between the spore concentration of airborne culturable fungi in indoor air and childhood asthma/allergies. In China, Liu et al. (2014c) found that household relative humidity and fungal concentration, but not indoor temperature and averaged concentration of CO₂, among children with respiratory diseases were significantly higher than among children without these diseases during spring in Xi'an. Zhu et al. (2015) found that among five children with respiratory diseases, indoor averaged concentrations of CO₂ and formaldehyde both in the child's bedroom and living room were lower, whereas indoor averaged concentrations of PM_{1.0}, PM_{2.5}, and PM₁₀ were higher, than among another five children without these diseases both in autumn and in winter; and no consistent results were found with regard to fungal concentration among these children in different rooms and in different seasons in Wuhan. Besides, McGwin et al. (2010) summarized seven studies and concluded that formaldehyde was significantly and positively associated with asthma in children.

In the present study, childhood asthma had significant and positive associations with indoor temperature and relative humidity, but not CO₂, airborne culturable fungi, formaldehyde, particulate matters; the results even indicated CO₂, airborne culturable fungi, formaldehyde, particulate matters could be associated with reduced risk of childhood asthma in spring, summer, and autumn. Some of these findings were consistent with findings by Holme et al. (2010), Liu et al. (2014c), and Zhu et al. (2015) summarized in above. It makes sense that indoor temperature and relative humidity positively associated with childhood asthma, for that high temperature and moisture in indoor air could have notably effect on the occupants' health status (Dales et al., 2008; Hu et al., 2014; Jones, 1999; Sundell, 2004; Wolkoff and Kjergaard, 2007). It is also possible that indoor concentrations of airborne culturable fungi and formaldehyde have no significant associations with childhood asthma, for that the averaged concentrations of these two pollutants in the present study are largely lower than the requirement in IAQS of China (GAQS, 2002), thus they may had no notable effect on childhood asthma. This finding also suggests

indoor concentrations of indoor airborne culturable fungi and formaldehyde may have dose-response relationships with, and have a threshold for their effects on, childhood asthma (McGwin et al., 2010).

Besides, our finding, that indoor concentrations of CO₂ and particulate matters in winter had associations with the increased odds of childhood asthma, were consistent with findings by Bornehag et al. (2005) for household ventilation (calculated according to indoor concentration of CO₂) in Sweden and Zhu et al. (2015) for particulate matters in winter in Wuhan, China. The outdoor temperature (24 h averaged 9.4 °C and night 6 h averaged 8.0 °C from our inspection) was low during winter in Shanghai. People generally closed the windows and doors to keep indoor warm, especially during night (Liu et al., 2014a). Besides, since cold air could aggravate or induce the asthmatic symptoms (Guo et al., 2012; Zhang et al., 2014), more parents whose children were diagnosed asthma might close the windows to keep indoor warm than parents with health children during cold winter (proportion of family who closed the windows: 53.8% vs. 32.8%; *p*-value=0.062). Thus indoor ventilation status could be worse and indoor CO₂ concentration was higher during winter among cases than among controls. This finding also indicates the current air quality and ventilation status of Shanghai residences in cold winter should be pay more attention to improving to decrease the risk of childhood asthma, than in warm seasons.

It seems unlikely that exposures in higher concentration of CO₂, airborne culturable fungi, formaldehyde, and particulate matters in spring, summer, and autumn could reduce the risk of asthma. We suggest a probable explanation as that parents whose children with asthma or with family history of atopy may have stronger awareness in these warm seasons, than parents without sick children, to try to reduce indoor air pollutants by improving household ventilation (Fabi et al., 2012), increasing frequency of home cleaning, and/or using household air cleaner (Liu et al., 2014b, 2015a), a behavior analogous to avoidance behavior on keeping pets (Huang et al., 2013) and eating fast foods (Liu et al., 2015b). Consequently, indoor concentration of CO₂, airborne culturable fungi, formaldehyde, and particulate matters among children with asthma could be lower than among children without asthma. This deduction could be supported by the findings from parent-reported questionnaire during home inspection, that notably more families with asthmatic children have household air cleaner than family with health children [59 (34.9%) vs. 55 (24.2%); *p*=0.020], and 45.8% of family with asthmatic children buy household air cleaner after the children were sick. This explains, at least partially, the "unexpected" reverse association between these pollutants and childhood asthma. Thus, we suggest that change of behaviors for indoor air quality and lifestyle habits should be considered in the design of retrospective cross-sectional and case-control study for associations of home environment and lifestyle habits with childhood health. To our best knowledge, no other epidemiological studies have reported change of behaviors for indoor air quality as in the present report. More studies on this topic are warranted.

4.6. Limitation and strength

This study had some limitations. Firstly, airborne culturable fungi and particulate matters only actively measured and sampled once during home inspection; temperature, relative humidity, CO₂, and formaldehyde were passively measured 24 h. These data may have low validity in representing the long-term exposure levels for the child's lifetime. Secondly, although we stated that the "asthma" should be diagnosed by a physician during childhood in the questionnaire, data reported by parents still could be influenced by report error and/or bias. Thirdly, some control children likely

had asthma-associated airway diseases/symptoms but were not diagnosed or underdiagnosed asthma by a doctor. Therefore some bias in case-control classification could be introduced in the analyses. Selection bias also could be introduced in the obtaining of cases and controls due to that only about 15.3% (186/1216) of families in the potential case group took part in our home inspection and that controls were yielded via match with cases. Fourthly, the data missing in the measured indicators/pollutants among some residences may affect results in the studied associations, although the proportion of children whose data were missed among cases and controls had no notable difference.

This study had several strengths. Firstly, to our best knowledge, the present study is the first study on home environment and childhood asthma using on-site inspection in the large sample size in China. The large sample size makes our measured results higher in validity, as well as more representation and comparable for the Shanghai residences. Secondly, validity of the ISAAC questionnaire we used for the child's health status with respect to asthma was validated in the previous study, which confirmed that parents reported data for child's health status is highly matched with physician-diagnosed status (Jenkins et al., 1996). Hence we considered that parents reported data in the present study could have high reliability for the child's health status with respect to asthma. Thirdly, on-sited inspected methods and questionnaire for home environment and lifestyle habits were improved from similar studies in Sweden (Bornehag et al., 2005; Clausen et al., 2012; Langer and Bekö, 2013) and Denmark (Bekö et al., 2011). Comparisons between our results to findings from these studies were reasonable. Fourthly, for the associations between indoor air pollutants/indicators and childhood asthma, we have considered the factors which have been presented to be significantly associated with childhood asthma in the previous analyses as covariates, thus our results may be not confounded by these covariates and indicate the exact associations between indoor air indicators/pollutants and childhood asthma.

5. Conclusions

Our results indicated that indoor level of airborne culturable fungi and formaldehyde among most of the residences in Shanghai could meet the national standard for indoor air quality. Indoor relative humidity was high in most of the Shanghai residences in different seasons. Indoor and outdoor levels of particulate matters are highly correlated; and indoor humidity could play important role in forming particulate matters in different equivalent diameters. Household air quality and ventilation status in winter should be paid more attention to improve than in other seasons. Family's changes in behaviors regarding indoor air quality and lifestyle habits also should be considered in designing retrospective study for associations of home environment and lifestyle habits with childhood health.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.envres.2016.07.036>.

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Supplemental Materials

Household Indoor Air Quality and Its Associations with Childhood Asthma in Shanghai, China: On-Site Inspected Methods and Preliminary Results

Chen Huang, Xueying Wang, Wei Liu*, Li Shen, Jiao Cai, Zhijun Zou, Rongchun Lu, Jing Chang, Xiaoyang Wei, Chanjuan Sun, Zhuohui Zhao, Yuexia Sun, Jan Sundell

* Corresponding email: lsc198708@hotmail.com; liuw@st.usst.edu.cn

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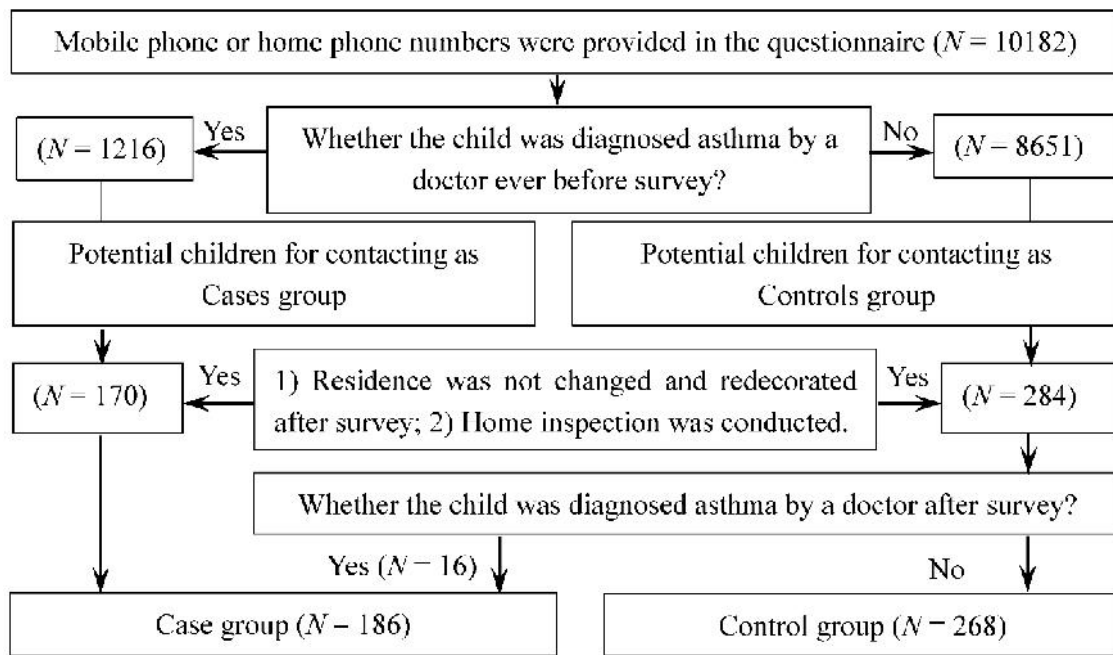


Figure S1. Flowchart for the selection of the inspected residences.

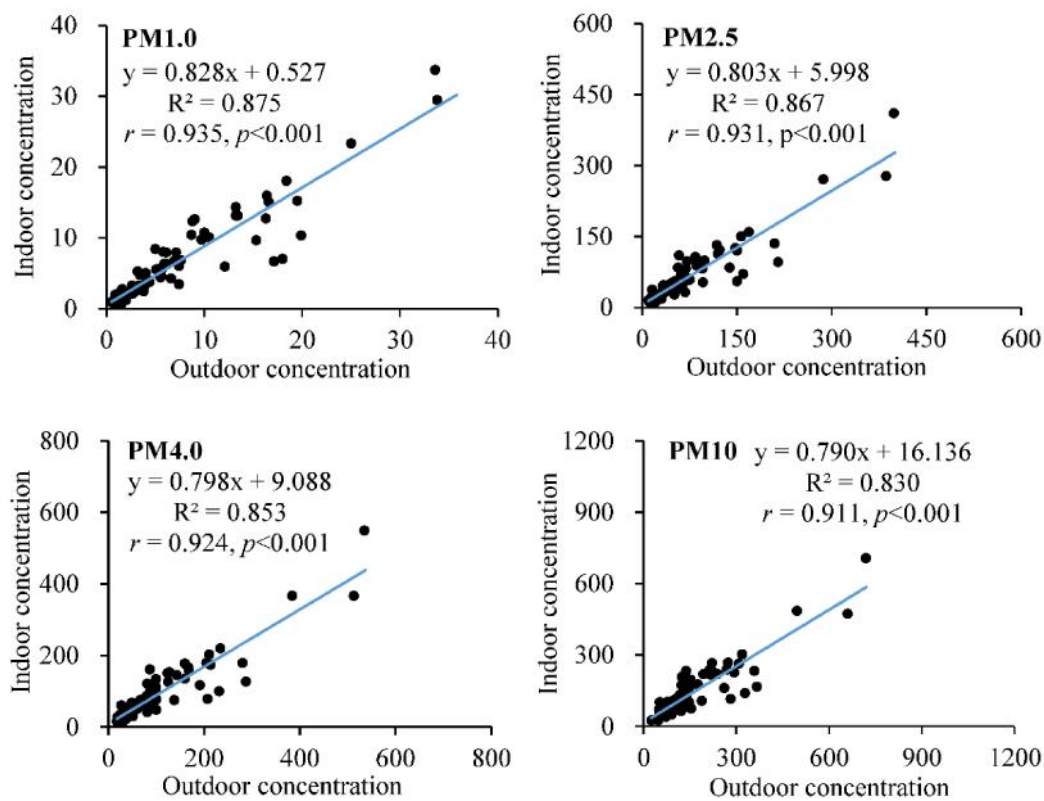


Figure S2. Correlations between indoor (the child's bedroom) and outdoor concentration ($\mu\text{g}/\text{m}^3$) of particulate matter in spring ($N = 87$).

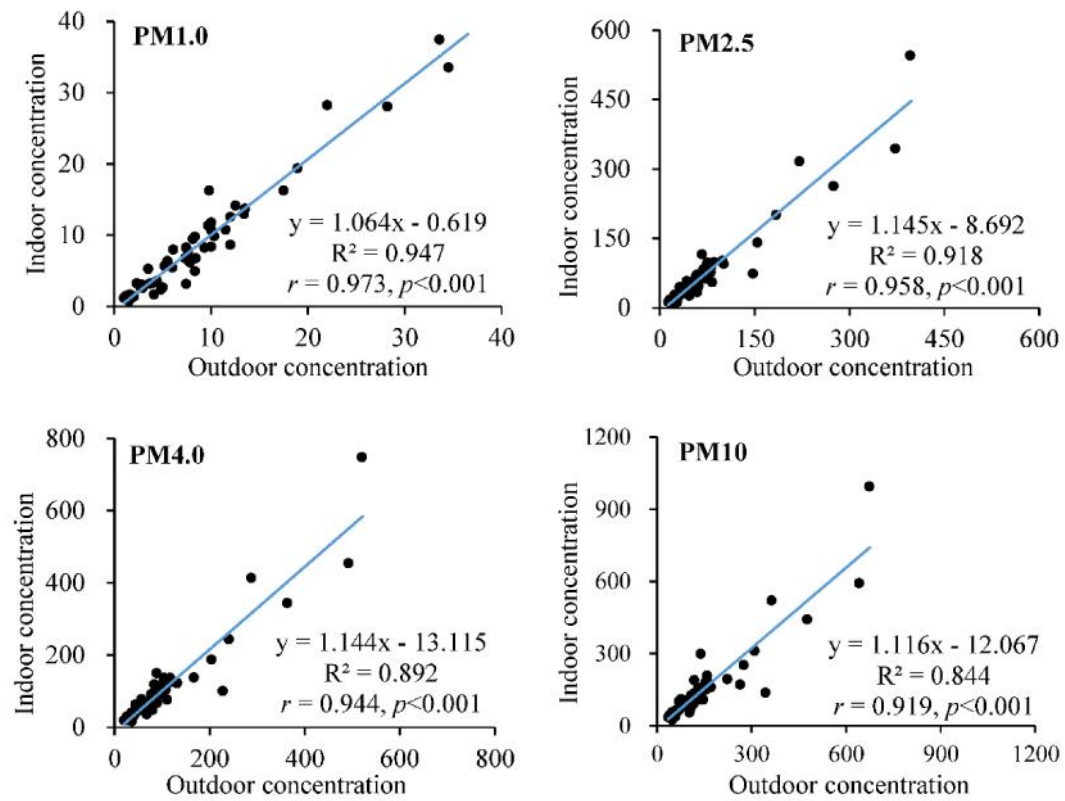


Figure S3. Correlations between indoor (the child's bedroom) and outdoor concentration ($\mu\text{g}/\text{m}^3$) of particulate matter in summer ($N = 52$).

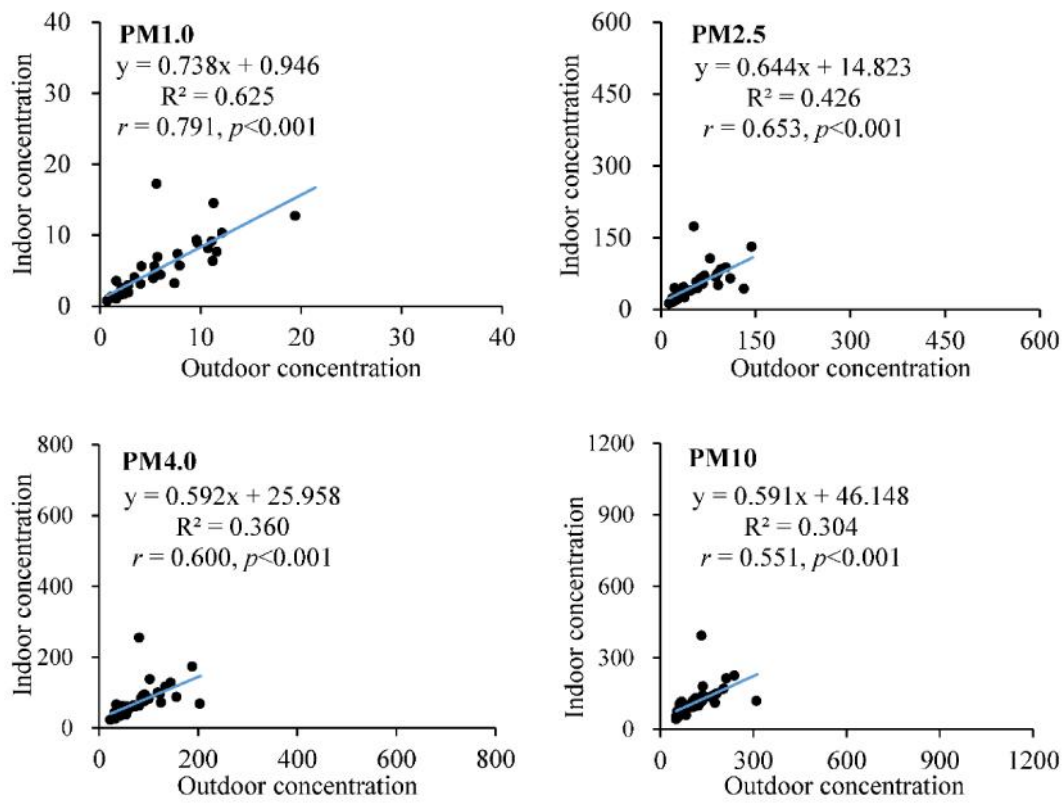


Figure S4. Correlations between indoor (the child's bedroom) and outdoor concentration ($\mu\text{g}/\text{m}^3$) of particulate matter in autumn ($N = 39$).

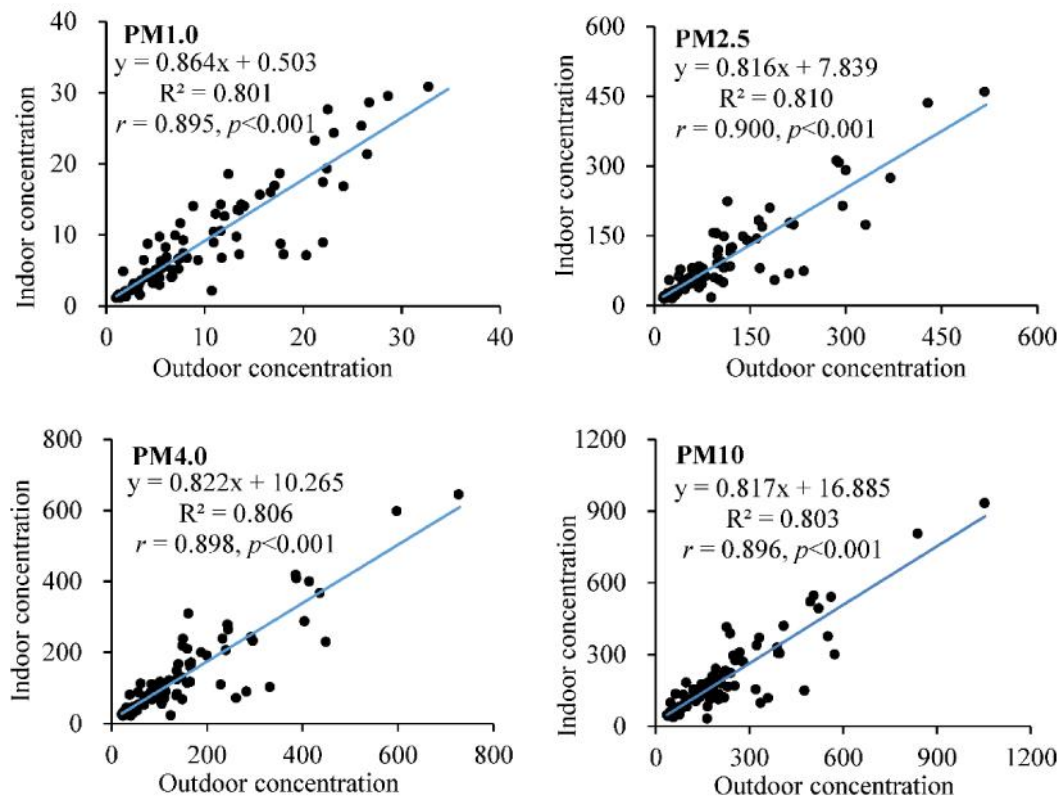


Figure S5. Correlations between indoor (the child's bedroom) and outdoor concentration ($\mu\text{g}/\text{m}^3$) of particulate matter in winter ($N = 88$).

Table S1. Comparisons of averaged temperature (T) and relative humidity (RH) between cases and controls, stratified by the season for on-site measurement.

Items		Spring				Summer				Autumn				Winter				<i>p</i> -value ^b
		Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	
1. In the child's bedroom (N=445)																		
(1) T-24h	Mean ± SD (°C)	19.2 ± 3.6	19.9 ± 3.3	18.7 ± 3.7	0.189	28.1 ± 2.3	28.3 ± 2.1	27.9 ± 2.6	0.602	23.9 ± 4.2	23.7 ± 4.3	24.0 ± 4.2	0.615	12.2 ± 2.8	12.8 ± 2.6	12.0 ± 2.9	0.121	<0.001
	22~28 ^c °C, <i>n</i> (%)	27 (21.1)	15 (28.8)	12 (15.8)	0.075	56 (45.2)	32 (43.2)	24 (48.0)	0.602	50 (49.0)	11 (42.3)	39 (51.3)	0.428	1 (1.1)	0 (0.0)	1 (1.7)	0.470	<0.001
	16~24 ^d °C, <i>n</i> (%)	91 (71.1)	40 (76.9)	51 (67.1)	0.229	0 (0.0)	0 (0.0)	0 (0.0)		44 (43.1)	12 (46.2)	32 (42.1)	0.719	8 (8.8)	3 (9.7)	5 (8.3)	0.830	<0.001
(2) T-6h (00:00-06:00)	Mean ± SD (°C)	19.2 ± 3.6	19.9 ± 3.4	18.7 ± 3.7	0.327	27.4 ± 2.1	27.3 ± 2.3	27.5 ± 1.9	0.118	23.7 ± 4.2	23.6 ± 4.3	23.7 ± 4.2	0.705	12.2 ± 3.1	12.6 ± 2.5	12.0 ± 3.3	0.078	<0.001
	22~28 ^c °C, <i>n</i> (%)	27 (21.1)	14 (26.9)	13 (17.1)	0.181	83 (66.9)	45 (60.8)	38 (76.0)	0.078	57 (55.9)	12 (46.2)	45 (59.2)	0.247	1 (1.1)	0 (0.0)	1 (1.7)	0.470	<0.001
	16~24 ^d °C, <i>n</i> (%)	91 (71.1)	38 (73.1)	53 (69.7)	0.682	6 (4.8)	5 (6.8)	1 (2.0)	0.226	43 (42.2)	12 (46.2)	31 (40.8)	0.633	10 (11.0)	3 (9.7)	7 (11.7)	0.774	<0.001
(3) RH-24h	Mean ± SD (%)	62.6 ± 11.6	63.8 ± 11.3	61.9 ± 11.9	0.294	68.3 ± 10.3	69.5 ± 9.5	66.6 ± 11.1	0.376	64.5 ± 10.2	63.5 ± 9.4	64.9 ± 10.5	0.478	62.4 ± 10.0	62.6 ± 10.7	62.3 ± 9.7	0.980	<0.001
	40%~80% ^c , <i>n</i> (%)	118 (92.2)	48 (92.3)	70 (92.1)	0.967	108 (87.1)	64 (86.5)	44 (88.0)	0.805	95 (93.1)	25 (96.2)	70 (92.1)	0.481	88 (96.7)	30 (96.8)	58 (96.7)	0.978	0.075
	30%~60% ^d , <i>n</i> (%)	52 (40.6)	18 (34.6)	34 (44.7)	0.252	31 (25.0)	15 (20.3)	16 (32.0)	0.139	34 (33.3)	9 (34.6)	25 (32.9)	0.872	36 (39.6)	13 (41.9)	23 (38.3)	0.739	0.042
(4) RH-6h (00:00-06:00)	Mean ± SD (%)	65.7 ± 11.2	66.2 ± 11.3	65.4 ± 11.2	0.287	68.8 ± 10.3	69.8 ± 11.5	67.3 ± 12.8	0.236	67.4 ± 10.3	65.7 ± 10.0	68.0 ± 10.4	0.563	66.1 ± 10.7	66.4 ± 11.8	65.9 ± 10.2	0.687	0.134
	40%~80% ^c , <i>n</i> (%)	114 (89.1)	48 (92.3)	66 (86.8)	0.331	104 (83.9)	61 (82.4)	43 (86.0)	0.596	91 (89.2)	24 (92.3)	67 (88.2)	0.556	82 (90.1)	27 (87.1)	55 (91.7)	0.489	0.452
	30%~60% ^d , <i>n</i> (%)	42 (32.8)	16 (30.8)	26 (34.2)	0.684	31 (25.0)	17 (23.0)	14 (28.0)	0.526	29 (28.4)	9 (34.6)	20 (26.3)	0.418	24 (26.4)	9 (29.0)	15 (25.0)	0.679	0.549
2. In the living room (N=449)																		
(1) T-24h	Mean ± SD (°C)	19.3 ± 3.6	19.9 ± 3.4	18.9 ± 3.7	0.113	28.8 ± 2.5	28.8 ± 2.3	28.8 ± 2.7	0.104	23.9 ± 4.3	23.5 ± 4.2	24.0 ± 4.4	0.471	12.3 ± 2.8	12.6 ± 2.2	12.1 ± 3.1	0.199	<0.001
	22~28 ^c °C, <i>n</i> (%)	29 (22.3)	16 (30.2)	13 (16.9)	0.073	46 (37.1)	21 (28.4)	25 (50.0)	0.014	47 (45.6)	13 (48.1)	34 (44.7)	0.760	1 (1.1)	0 (0.0)	1 (1.6)	0.474	<0.001
	16~24 ^d °C, <i>n</i> (%)	90 (69.2)	38 (71.7)	52 (67.5)	0.613	2 (1.6)	2 (2.7)	0 (0.0)	0.241	43 (41.7)	12 (44.4)	31 (40.8)	0.741	6 (6.5)	2 (6.5)	4 (6.6)	0.985	<0.001
(2) T-6h (00:00-06:00)	Mean ± SD (°C)	19.1 ± 3.7	19.6 ± 3.6	18.7 ± 3.7	0.409	28.5 ± 2.6	28.4 ± 2.4	28.6 ± 2.8	0.334	23.6 ± 4.3	23.3 ± 4.3	23.7 ± 4.3	0.471	12.0 ± 3.0	12.4 ± 2.2	11.8 ± 3.3	0.197	<0.001
	22~28 ^c °C, <i>n</i> (%)	29 (22.3)	15 (28.3)	14 (18.2)	0.173	55 (44.4)	29 (39.2)	26 (52.0)	0.159	55 (53.4)	15 (55.6)	40 (52.6)	0.794	1 (1.1)	0 (0.0)	1 (1.6)	0.474	<0.001
	16~24 ^d °C, <i>n</i> (%)	88 (67.7)	36 (67.9)	52 (67.5)	0.963	6 (4.8)	5 (6.8)	1 (2.0)	0.226	45 (43.7)	12 (44.4)	33 (43.4)	0.927	6 (6.5)	2 (6.5)	4 (6.6)	0.985	<0.001
(3) RH-24h	Mean ± SD (%)	61.8 ± 11.8	63.5 ± 11.5	60.6 ± 12.0	0.210	69.4 ± 10.0	70.7 ± 8.9	67.5 ± 11.2	0.257	63.7 ± 11.3	61.3 ± 11.0	64.6 ± 11.4	0.645	61.4 ± 10.6	62.5 ± 10.6	60.8 ± 10.6	0.984	<0.001
	40%~80% ^c , <i>n</i> (%)	117 (90.0)	48 (90.6)	69 (89.6)	0.858	110 (88.7)	66 (89.2)	44 (88.0)	0.837	93 (90.3)	25 (92.6)	68 (89.5)	0.638	88 (95.7)	29 (93.5)	59 (96.7)	0.481	0.335
	30%~60% ^d , <i>n</i> (%)	57 (43.8)	18 (34.0)	39 (50.6)	0.060	27 (21.8)	12 (16.2)	15 (30.0)	0.068	43 (41.7)	14 (51.9)	29 (38.2)	0.215	44 (47.8)	15 (48.4)	29 (47.5)	0.939	<0.001
(4) RH-6h (00:00-06:00)	Mean ± SD (%)	64.2 ± 11.5	65.3 ± 11.7	63.3 ± 11.5	0.216	71.1 ± 11.7	72.0 ± 10.7	69.7 ± 13.1	0.353	65.8 ± 12.0	62.5 ± 11.5	67.0 ± 12.0	0.189	63.6 ± 11.5	64.2 ± 11.6	63.3 ± 11.5	0.889	<0.001
	40%~80% ^c , <i>n</i> (%)	119 (91.5)	47 (88.7)	72 (93.5)	0.331	98 (79.0)	62 (83.8)	36 (72.0)	0.114	90 (87.4)	24 (88.9)	66 (86.8)	0.783	84 (91.3)	28 (90.3)	56 (91.8)	0.812	0.012
	30%~60% ^d , <i>n</i> (%)	43 (33.1)	13 (24.5)	30 (39.0)	0.086	23 (18.5)	11 (14.9)	12 (24.0)	0.199	37 (35.9)	13 (48.1)	24 (31.6)	0.123	36 (35.6)	12 (38.7)	24 (39.3)	0.953	0.004

^a *p*-value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. ^b *p*-value in the multi-sample Kruskal-Wallis test for differences of mean values among different seasons or in the Pearson's chi-square test for differences of percentages among different seasons. Bold indicates statistical significance. ^c Required range in summer in IAQS of China (GAQS, 2002). ^d Required range in winter in IAQ standard of China (GAQS, 2002).

Table S2. Comparisons of averaged CO₂ concentration between cases and controls, stratified by season for on-site measurement.

Items		Spring				Summer				Autumn				Winter				<i>p</i> -value ^b
		Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	
1. In the child's bedroom (N=445)																		
(1) CO ₂ -24h	Mean ± SD (ppm)	818 ± 350	824 ± 382	814 ± 329	0.450	773 ± 341	770 ± 370	776 ± 296	0.578	713 ± 294	694 ± 285	720 ± 302	0.720	978 ± 483	1044 ± 453	943 ± 499	0.585	<0.001
	≤ 1000 ^c ppm, n (%)	95 (74.2)	38 (73.1)	57 (75.0)	0.807	97 (78.2)	58 (78.4)	39 (78.0)	0.960	89 (87.3)	21 (80.8)	68 (89.5)	0.251	60 (65.9)	18 (58.1)	42 (70.1)	0.255	0.005
(2) CO ₂ -6h (00:00-06:00)	Mean ± SD (ppm)	1147 ± 770	1186 ± 899	1121 ± 673	0.640	1052 ± 692	1052 ± 722	1054 ± 653	0.263	1014 ± 675	1010 ± 679	1017 ± 679	0.323	1307 ± 807	1365 ± 809	1267 ± 769	0.782	<0.001
	≤ 1000 ^c ppm, n (%)	68 (53.1)	28 (53.8)	40 (52.6)	0.892	73 (58.9)	43 (58.1)	30 (60.0)	0.834	62 (60.9)	16 (61.5)	46 (60.5)	0.927	39 (42.9)	11 (35.5)	28 (46.7)	0.307	0.054
2. In the living room (N=449)																		
(1) CO ₂ -24h	Mean ± SD (ppm)	632 ± 248	575 ± 156	671 ± 290	0.167	612 ± 246	595 ± 259	637 ± 226	0.219	575 ± 202	569 ± 215	578 ± 199	0.193	778 ± 418	839 ± 292	756 ± 517	0.021	<0.001
	≤ 1000 ^c ppm, n (%)	123 (94.6)	53 (100.0)	70 (90.9)	0.024	113 (91.1)	70 (94.6)	43 (86.0)	0.099	99 (96.1)	25 (92.6)	74 (97.4)	0.270	71 (77.2)	21 (67.7)	50 (82.0)	0.124	<0.001
(2) CO ₂ -6h (00:00-06:00)	Mean ± SD (ppm)	693 ± 431	596 ± 241	761 ± 514	0.109	677 ± 437	673 ± 504	683 ± 316	0.098	618 ± 321	618 ± 366	619 ± 307	0.324	867 ± 683	901 ± 450	844 ± 755	0.151	0.024
	≤ 1000 ^c ppm, n (%)	112 (86.2)	49 (92.5)	63 (81.8)	0.084	107 (86.3)	64 (86.5)	43 (86.0)	0.938	94 (91.3)	24 (88.9)	70 (92.1)	0.611	67 (72.8)	20 (64.5)	47 (77.0)	0.202	0.003

^a *p*-value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. ^b *p*-value in the multi-sample Kruskal-Wallis test for differences of mean values among different seasons or in the Pearson's chi-square test for differences of percentages among different seasons. ^c Required upper limited concentration in IAQS of China (GAQS, 2002).

Table S3. Comparisons of averaged airborne fungi concentration between cases and controls, stratified by season for on-site measurement.

Items	Spring				Summer				Autumn				Winter				<i>p</i> -value ^b
	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	
1. In the child's bedroom (N=450)																	
Mean ± SD (cfu/m ³)	366 ± 477	323 ± 410	394 ± 518	0.830	284 ± 207	276 ± 233	296 ± 162	0.100	268 ± 140	296 ± 129	258 ± 143	0.027	313 ± 264	324 ± 256	307 ± 271	0.432	0.968
≤ 2500 ^c cfu/m ³ , <i>n</i> (%)	128 (99.2)	52 (100.0)	76 (98.7)	0.409	126 (100.0)	75 (100.0)	51 (100.0)		104 (100.0)	27 (100.0)	77 (100.0)		91 (100.0)	31 (100.0)	60 (100.0)		0.476
2. In the living room (N=445)																	
Mean ± SD (cfu/m ³)	332 ± 401	253 ± 137	387 ± 504	0.503	292 ± 208	284 ± 215	303 ± 199	0.277	254 ± 130	237 ± 91	260 ± 141	0.864	323 ± 319	329 ± 269	320 ± 344	0.658	0.954
≤ 2500 ^c cfu/m ³ , <i>n</i> (%)	122 (98.4)	51 (100.0)	71 (97.3)	0.233	126 (100.0)	75 (100.0)	51 (100.0)		104 (100.0)	27 (100.0)	77 (100.0)		91 (100.0)	31 (100.0)	60 (100.0)		0.158

^a *p*-value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. ^b *p*-value in the multi-sample Kruskal-Wallis test for differences of mean values among different seasons or in the Pearson's chi-square test for differences of percentages among different seasons. ^c Required upper limited concentration in IAQS of China (GAQS, 2002).

Table S4. Comparisons of averaged formaldehyde concentration between cases and controls, stratified by season for on-site measurement.

Items	Spring				Summer				Autumn				Winter				<i>p</i> -value ^b
	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	
(1) Formaldehyde-24h																	
Mean ± SD (µg/m ³)	20.4 ± 10.3	20.2 ± 11.5	20.6 ± 9.4	0.938	19.7 ± 17.9	20.1 ± 16.7	19.0 ± 19.6	0.786	19.2 ± 12.6	21.7 ± 20.8	18.3 ± 8.6	0.994	27.7 ± 5.8	26.7 ± 4.9	28.2 ± 6.1	0.938	<0.001
≤ 100 ^c µg/m ³ , n (%)	118 (100.0)	50 (100.0)	68 (100.0)		108 (98.2)	63 (98.4)	45 (97.8)	0.813	92 (98.9)	70 (100.0)	21 (95.5)	0.073	89 (100.0)	30 (100.0)	59 (100.0)		0.325
(2) Formaldehyde-6h (00:00-06:00)																	
Mean ± SD (µg/m ³)	21.9 ± 15.3	22.8 ± 19.2	21.3 ± 11.8	0.927	19.8 ± 23.1	19.0 ± 19.1	20.9 ± 28.0	0.829	20.1 ± 19.9	24.7 ± 36.2	18.6 ± 10.7	0.997	27.7 ± 7.7	27.2 ± 6.0	28.0 ± 8.5	0.965	<0.001
≤ 100 ^c µg/m ³ , n (%)	117 (99.2)	49 (98.0)	68 (100.0)	0.242	108 (98.2)	63 (98.4)	45 (97.8)	0.813	92 (98.9)	70 (100.0)	21 (95.5)	0.073	89 (100.0)	30 (100.0)	59 (100.0)		0.634

^a *p*-value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. ^b *p*-value in the multi-sample Kruskal-Wallis test for differences of mean values among different seasons or in the Pearson's chi-square test for differences of percentages among different seasons. ^c Required upper limited concentration in IAQS of China (GAQS, 2002).

Table S5. Comparisons of averaged particle matters concentration between cases and controls, stratified by season for on-site measurement.

Items	Spring				Summer				Autumn				Winter				<i>p</i> -value ^b
	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	Total	Cases	Control	<i>p</i> -value ^a	
(1) PM _{1.0} Mean ± SD (μg/m ³)	5.9 ± 5.8	5.6 ± 6.4	6.1 ± 5.5	0.659	5.2 ± 6.3	5.2 ± 6.5	5.2 ± 6.0	0.660	4.7 ± 4.4	6.2 ± 6.4	4.2 ± 3.2	0.197	9.3 ± 7.4	10.1 ± 7.0	8.9 ± 7.5	0.221	<0.001
(2) PM _{2.5} Mean ± SD (μg/m ³)	58.8 ± 59.4	57.4 ± 59.8	67.1 ± 54.0	0.574	50.0 ± 67.6	50.7 ± 61.4	49.1 ± 76.7	0.539	46.5 ± 36.6	57.5 ± 54.9	42.6 ± 26.8	0.144	94.6 ± 87.1	99.4 ± 75.9	92.2 ± 92.8	0.777	<0.001
≤ 75 ^c μg/m ³ , <i>n</i> (%)	97 (75.8)	41 (78.8)	56 (73.7)	0.503	107 (85.6)	64 (85.3)	43 (86.0)	0.917	90 (87.4)	20 (74.1)	70 (92.1)	0.015	55 (59.1)	16 (51.6)	39 (62.9)	0.296	<0.001
≤ 35 ^d μg/m ³ , <i>n</i> (%)	54 (42.2)	22 (42.3)	32 (42.1)	0.982	72 (57.6)	40 (53.3)	32 (64.0)	0.237	47 (45.6)	14 (51.9)	33 (43.4)	0.450	21 (22.6)	5 (16.1)	16 (25.8)	0.293	<0.001
(3) PM _{4.0} Mean ± SD (μg/m ³)	84.8 ± 79.2	82.8 ± 89.0	86.2 ± 72.3	0.697	71.1 ± 89.6	71.9 ± 79.0	69.9 ± 104.3	0.247	68.8 ± 50.0	82.4 ± 74.4	64.0 ± 37.3	0.144	134.2 ± 118.8	142.4 ± 102.2	130.3 ± 126.7	0.795	<0.001
(4) PM ₁₀ Mean ± SD (μg/m ³)	128.8 ± 102.6	127.1 ± 130.0	114.9 ± 94.1	0.574	109.6 ± 116.0	110.5 ± 101.1	108.2 ± 136.5	0.722	112.1 ± 70.0	127.0 ± 101.5	106.8 ± 54.6	0.230	195.1 ± 159.4	201.7 ± 135.6	191.8 ± 171.0	0.777	<0.001
≤ 150 ^e μg/m ³ , <i>n</i> (%)	93 (72.7)	40 (76.9)	53 (69.7)	0.370	104 (83.2)	61 (81.3)	43 (86.0)	0.494	89 (86.4)	20 (74.1)	69 (90.8)	0.029	49 (52.7)	16 (51.6)	33 (53.2)	0.883	<0.001
≤ 75 ^d μg/m ³ , <i>n</i> (%)	38 (29.7)	17 (32.7)	21 (27.6)	0.538	57 (45.6)	33 (44.0)	24 (48.0)	0.660	27 (26.2)	10 (37.0)	17 (22.4)	0.137	16 (17.2)	4 (12.9)	12 (19.4)	0.437	<0.001

^a *p*-value in the two-sample Kolmogorov-Smirnov test for differences of mean values between cases and controls or in the Pearson's chi-square test for differences of percentages between cases and controls. ^b *p*-value in the multi-sample Kruskal-Wallis test for differences of mean values among different seasons or in the Pearson's chi-square test for differences of percentages among different seasons. ^c Upper limit of daily-averaged concentration in the second level of AAQS of China (GAQS, 2012). ^d Upper limit of daily-averaged concentration in the first level of AAQS of China (GAQS, 2012). ^e Upper limit of hour-averaged concentration in the IAQS of China (GAQS, 2002).

Table S6. Correlations between each two measured indicators/pollutants.

Items	Pearson's correlation coefficient, <i>r</i>																		
	In the child's bedroom												In the living bedroom						
	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	F-24h	F-6h	Fungi	PM1.0	PM2.5	PM4.0	PM10	T-24h	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	Fungi
In the child's bedroom																			
T-24h	0.985[#]	0.215[#]	0.107[*]	-0.232[#]	-0.156^{**}	-0.250[#]	-0.173^{**}	-0.047	-0.217[#]	-0.185[#]	-0.193[#]	-0.207[#]	0.972[#]	0.966[#]	0.309[#]	0.282[#]	-0.228[#]	-0.146^{**}	-0.085
T-6h		0.221[#]	0.122[*]	-0.222[#]	-0.145^{**}	-0.240[#]	-0.160^{**}	-0.052	-0.211[#]	-0.184[#]	-0.192[#]	-0.207[#]	0.960[#]	0.958[#]	0.312[#]	0.292[#]	-0.221[#]	-0.146^{**}	-0.084
RH-24h			0.941[#]	0.040	0.044	-0.147^{**}	-0.107[*]	-0.055	0.181[#]	0.122[*]	0.112[*]	0.078	0.206[#]	0.210[#]	0.879[#]	0.820[#]	0.044	0.065	-0.022
RH-6h				0.075	0.090	-0.100[*]	-0.069	-0.063	0.208[#]	0.144^{**}	0.135^{**}	0.106[*]	0.094[*]	0.103[*]	0.791[#]	0.786[#]	0.071	0.095[*]	-0.010
CO ₂ -24h					0.908[#]	0.161^{**}	0.107[*]	-0.033	0.079	0.091	0.091	0.083	-0.205[#]	-0.201[#]	0.000	0.020	0.608[#]	0.561[#]	0.099[*]
CO ₂ -6h						0.095	0.054	-0.058	0.068	0.073	0.072	0.061	-0.126^{**}	-0.121[*]	0.011	0.037	0.438[#]	0.457[#]	0.066
F-24h							0.923[#]	0.042	0.013	0.009	0.008	0.006	-0.221[#]	-0.212[#]	-0.165^{**}	-0.145^{**}	0.158^{**}	0.085	0.047
F-6h								0.081	0.000	-0.002	-0.004	-0.006	-0.148^{**}	-0.138^{**}	-0.133^{**}	-0.120[*]	0.105[*]	0.038	0.049
Fungi									0.072	0.051	0.055	0.071	-0.046	-0.050	-0.032	-0.036	0.098[*]	0.098[*]	0.190[#]
PM1.0										0.926[#]	0.916[#]	0.898[#]	-0.220[#]	-0.222[#]	0.153^{**}	0.153^{**}	0.098[*]	0.090	-0.018
PM2.5											0.999[#]	0.988[#]	-0.184[#]	-0.187[#]	0.105[*]	0.103[*]	0.077	0.072	-0.024
PM4.0												0.994[#]	-0.192[#]	-0.195[#]	0.094[*]	0.093	0.078	0.072	-0.020
PM10													-0.207[#]	-0.210[#]	0.060	0.062	0.078	0.072	-0.006
In the living bedroom																			
T-24h														0.996[#]	0.263[#]	0.243[#]	-0.208[#]	-0.139^{**}	-0.079
T-6h															0.269[#]	0.252[#]	-0.206[#]	-0.137^{**}	-0.087
RH-24h																0.960[#]	0.052	0.078	-0.018
RH-6h																	0.079	0.115[*]	-0.005
CO ₂ -24h																		0.925[#]	0.087
CO ₂ -6h																			0.078

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter, h, hour. * 0.01 ≤ *p* < 0.05, ** 0.001 ≤ *p* < 0.01, [#] *p* < 0.001

Table S7. Correlations between each two measured indicators/pollutants in spring.

Items	Pearson's correlation coefficient, <i>r</i>																		
	In the child's bedroom												In the living bedroom						
	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	F-24h	F-6h	Fungi	PM1.0	PM2.5	PM4.0	PM10	T-24h	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	Fungi
In the child's bedroom																			
T-24h	0.991[#]	0.222[*]	0.157	-0.349[#]	-0.283^{**}	-0.048	0.051	0.154	0.096	0.102	0.092	0.081	0.911[#]	0.885[#]	0.299^{**}	0.299^{**}	-0.255^{**}	-0.184[*]	0.015
T-6h		0.229^{**}	0.165	-0.321[#]	-0.253^{**}	-0.047	0.052	0.126	0.086	0.092	0.082	0.067	0.892[#]	0.872[#]	0.304[#]	0.310[#]	-0.248^{**}	-0.174[*]	0.036
RH-24h			0.952[#]	0.030	0.028	-0.027	0.025	-0.008	0.304^{**}	0.267^{**}	0.257^{**}	0.209[*]	0.198[*]	0.208[*]	0.908[#]	0.853[#]	0.057	0.049	-0.043
RH-6h				0.155	0.181[*]	-0.024	0.004	-0.050	0.280^{**}	0.248^{**}	0.239^{**}	0.195[*]	0.139	0.154	0.834[#]	0.839[#]	0.125	0.125	-0.033
CO ₂ -24h					0.926[#]	-0.036	-0.053	-0.161	-0.023	-0.014	-0.016	-0.023	-0.307[#]	-0.276	-0.075	-0.020	0.445[#]	0.447[#]	-0.017
CO ₂ -6h						-0.038	-0.057	-0.134	-0.034	-0.025	-0.026	-0.032	-0.248	-0.221	-0.080	-0.013	0.322[#]	0.370[#]	0.006
F-24h							0.935[#]	-0.005	-0.084	-0.113	-0.113	-0.108	-0.034	-0.025	-0.063	-0.088	-0.026	-0.028	0.066
F-6h								0.097	-0.068	-0.096	-0.099	-0.099	0.074	0.082	-0.014	-0.063	-0.053	-0.065	0.057
Fungi									0.109	0.072	0.070	0.079	0.155	0.139	0.036	0.022	0.037	0.033	0.093
PM1.0										0.971[#]	0.965[#]	0.943[#]	0.101	0.088	0.272^{**}	0.260^{**}	0.060	0.045	-0.002
PM2.5											0.998[#]	0.984[#]	0.098	0.082	0.232^{**}	0.219[*]	0.035	0.016	-0.005
PM4.0												0.992[#]	0.086	0.069	0.221[*]	0.209[*]	0.036	0.017	0.001
PM10													0.070	0.049	0.177[*]	0.167	0.033	0.016	0.017
In the living bedroom																			
T-24h														0.991[#]	0.219[*]	0.227^{**}	-0.215[*]	-0.146	0.004
T-6h															0.234^{**}	0.245^{**}	-0.192[*]	-0.120	0.018
RH-24h																0.955[#]	0.032	0.020	0.034
RH-6h																	0.102	0.113	0.053
CO ₂ -24h																		0.921[#]	-0.001
CO ₂ -6h																			0.030

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter, h, hour. * 0.01 ≤ *p* < 0.05, ** 0.001 ≤ *p* < 0.01, [#] *p* < 0.001.

Table S8. Correlations between each two measured indicators/pollutants in summer.

Items	Pearson's correlation coefficient, <i>r</i>																		
	In the child's bedroom												In the living bedroom						
	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	F-24h	F-6h	Fungi	PM1.0	PM2.5	PM4.0	PM10	T-24h	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	Fungi
In the child's bedroom																			
T-24h	0.694[#]	-0.273[*]	-0.235[*]	-0.194[*]	-0.180[*]	-0.048	-0.021	-0.116	-0.334[#]	-0.205[*]	-0.195[*]	-0.187[*]	0.674[#]	0.601[#]	-0.221[*]	-0.171	-0.176[*]	-0.077	-0.088
T-6h		-0.204[*]	-0.095	-0.187[*]	-0.197[*]	0.058	0.111	-0.093	-0.251[*]	-0.172	-0.164	-0.160	0.557[#]	0.583[#]	-0.169	-0.062	-0.122	-0.129	-0.111
RH-24h			0.955[#]	-0.179[*]	-0.163	-0.268[*]	-0.257[*]	-0.067	0.341[#]	0.239^{**}	0.232[*]	0.215[*]	-0.515[#]	-0.477[#]	0.899[#]	0.820[#]	-0.045	0.025	-0.011
RH-6h				-0.215[*]	-0.228[*]	-0.195[*]	-0.179[*]	-0.079	0.333[#]	0.235^{**}	0.228[*]	0.216[*]	-0.481[#]	-0.419[#]	0.840[#]	0.813[#]	-0.048	0.003	-0.016
CO ₂ -24h					0.934[#]	0.305^{**}	0.258^{**}	0.174	0.110	0.164	0.163	0.159	0.156	0.109	-0.144	-0.135	0.568[#]	0.484[#]	0.218
CO ₂ -6h						0.234[*]	0.188[*]	0.083	0.080	0.136	0.137	0.135	0.195 [*]	0.161	-0.105	-0.087	0.488[#]	0.450[#]	0.151
F-24h							0.925[#]	0.103	-0.192[*]	-0.176[*]	-0.182[*]	-0.199[*]	0.126	0.153	-0.270	-0.205	0.229	0.096	0.021
F-6h								0.102	-0.170	-0.152	-0.157	-0.172	0.132	0.174	-0.264	-0.184	0.189	0.051	0.026
Fungi									0.017	-0.049	-0.054	-0.059	-0.091	-0.113	-0.072	-0.089	0.294^{**}	0.259^{**}	0.466[#]
PM1.0										0.900[#]	0.889[#]	0.878[#]	-0.298^{**}	-0.308^{**}	0.259^{**}	0.248^{**}	0.070	0.066	-0.135
PM2.5											0.999[#]	0.993[#]	-0.146	-0.159	0.196[*]	0.183^{**}	0.024	0.014	-0.126
PM4.0												0.996[#]	-0.135	-0.148	0.191[*]	0.178[*]	0.018	0.009	-0.126
PM10													-0.125	-0.140	0.174	0.163	0.008	0.001	-0.121
In the living bedroom																			
T-24h														0.947[#]	-0.488[#]	-0.374[#]	-0.061	-0.100	-0.083
T-6h															-0.422[#]	-0.284^{**}	-0.127	-0.191[*]	-0.132
RH-24h																0.949[#]	-0.109	-0.034	0.010
RH-6h																	-0.136	-0.091	-0.031
CO ₂ -24h																		0.923[#]	0.338[#]
CO ₂ -6h																			0.311[#]

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter, h, hour. * 0.01 ≤ *p* < 0.05, ** 0.001 ≤ *p* < 0.01, [#] *p* < 0.001.

Table S9. Correlations between each two measured indicators/pollutants in autumn.

Items	Pearson's correlation coefficient, <i>r</i>																		
	In the child's bedroom												In the living bedroom						
	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	F-24h	F-6h	Fungi	PM1.0	PM2.5	PM4.0	PM10	T-24h	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	Fungi
In the child's bedroom																			
T-24h	0.989[#]	0.243[*]	0.208[*]	-0.135	-0.022	-0.294^{**}	-0.203	-0.237[*]	-0.275^{**}	-0.387[#]	-0.416[#]	-0.468[#]	0.982[#]	0.981[#]	0.342[#]	0.364[#]	-0.252[*]	-0.128	-0.290^{**}
T-6h		0.276^{**}	0.231[*]	-0.108	0.001	-0.288^{**}	-0.197	-0.227[*]	-0.259^{**}	-0.372[#]	-0.400[#]	-0.455[#]	0.961[#]	0.964[#]	0.362[#]	0.376[#]	-0.245[*]	-0.123	-0.278^{**}
RH-24h			0.957[#]	0.135	0.157	-0.004	0.030	-0.147	0.235[*]	0.140	0.121	0.059	0.250[*]	0.260^{**}	0.932[#]	0.884[#]	0.093	0.103	-0.125
RH-6h				0.186	0.203	0.059	0.084	-0.184	0.260^{**}	0.155	0.135	0.079	0.216[*]	0.228[*]	0.867[#]	0.852[#]	0.141	0.153	-0.112
CO ₂ -24h					0.937[#]	0.155	0.093	0.079	0.291^{**}	0.222[*]	0.201[*]	0.162	-0.153	-0.140	0.107	0.115	0.441[#]	0.430[#]	0.302
CO ₂ -6h						0.036	0.005	0.016	0.328^{**}	0.241[*]	0.214[*]	0.160	-0.042	-0.032	0.133	0.122	0.278^{**}	0.296^{**}	0.189
F-24h							0.948[#]	0.063	0.224[*]	0.211[*]	0.195	0.167	-0.289^{**}	-0.279^{**}	-0.038	0.005	0.287^{**}	0.263[*]	0.128
F-6h								0.054	0.146	0.131	0.119	0.096	-0.206^{**}	-0.199	0.002	0.031	0.207[*]	0.186	0.090
Fungi									-0.096	-0.026	0.001	0.064	-0.234[*]	-0.238[*]	-0.179	-0.163	0.204^{**}	0.173	0.344[#]
PM1.0										0.955[#]	0.925[#]	0.848[#]	-0.266^{**}	-0.272^{**}	0.139	0.091	0.088	0.069	0.018
PM2.5											0.995[#]	0.957[#]	-0.381[#]	-0.387[#]	0.043	-0.010	0.108	0.077	0.047
PM4.0												0.980[#]	-0.410[#]	-0.416[#]	0.024	-0.027	0.119	0.085	0.048
PM10													-0.464[#]	-0.470[#]	-0.040	-0.079	0.141	0.107	0.071
In the living bedroom																			
T-24h														0.998[#]	0.347[#]	0.371[#]	-0.245[*]	-0.117	-0.264^{**}
T-6h															0.359[#]	0.384[#]	-0.228[*]	-0.098	-0.268^{**}
RH-24h																0.972[#]	0.138	0.161	-0.176
RH-6h																	0.183	0.223[*]	-0.152
CO ₂ -24h																		0.909[#]	0.281[*]
CO ₂ -6h																			0.215[*]

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter, h, hour. * $0.01 \leq p < 0.05$, ** $0.001 \leq p < 0.01$, [#] $p < 0.001$.

Table S10. Correlations between each two measured indicators/pollutants in winter.

Items	Pearson's correlation coefficient, <i>r</i>																		
	In the child's bedroom												In the living bedroom						
	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	F-24h	F-6h	Fungi	PM1.0	PM2.5	PM4.0	PM10	T-24h	T-6h	RH-24h	RH-6h	CO ₂ -24h	CO ₂ -6h	Fungi
In the child's bedroom																			
T-24h	0.937[#]	-0.005	-0.044	0.270[*]	0.242[*]	-0.252[*]	-0.184	-0.142	0.142	0.092	0.080	0.054	0.800[#]	0.792[#]	0.128	0.101	0.218[*]	0.223[*]	-0.085
T-6h		-0.055	-0.087	0.273^{**}	0.260[*]	-0.278^{**}	-0.243[*]	-0.168	0.139	0.089	0.075	0.046	0.747[#]	0.735[#]	0.078	0.068	0.217[*]	0.223[*]	-0.102
RH-24h			0.923[#]	0.333^{**}	0.330^{**}	-0.235[*]	-0.177	-0.061	-0.028	-0.064	-0.072	-0.104	0.196	0.185	0.705[#]	0.644[#]	0.196	0.186	0.105
RH-6h				0.307^{**}	0.348^{**}	-0.231[*]	-0.171	0.018	0.020	-0.025	-0.032	-0.062	0.139	0.143	0.630[#]	0.613[#]	0.164	0.183	0.115
CO ₂ -24h					0.889[#]	-0.133	-0.156	-0.066	-0.136	-0.102	-0.097	-0.101	0.162	0.174	0.288^{**}	0.276^{**}	0.733[#]	0.682[#]	0.078
CO ₂ -6h						-0.158	-0.161	-0.115	-0.111	-0.086	-0.084	-0.096	0.130	0.150	0.294^{**}	0.292^{**}	0.561[#]	0.609[#]	0.025
F-24h							0.797[#]	0.107	-0.100	-0.044	-0.034	-0.004	-0.230[*]	-0.221[*]	-0.236[*]	-0.264[*]	-0.111	-0.145	-0.049
F-6h								0.124	-0.041	0.010	0.021	0.046	-0.126	-0.113	-0.232[*]	-0.288^{**}	-0.131	-0.156	0.033
Fungi									0.113	0.169	0.188	0.242[*]	-0.189	-0.156	-0.005	0.020	0.068	0.105	0.217
PM1.0										0.962[#]	0.954[#]	0.931[#]	0.071	0.075	0.113	0.140	-0.018	0.027	-0.021
PM2.5											0.999[#]	0.987[#]	0.020	0.030	0.055	0.078	-0.001	0.055	-0.021
PM4.0												0.993[#]	0.008	0.020	0.044	0.066	0.004	0.061	-0.012
PM10													-0.020	-0.004	0.013	0.036	0.007	0.061	0.013
In the living bedroom																			
T-24h														0.982[#]	0.011	-0.015	0.213[*]	0.201	-0.068
T-6h															-0.004	-0.034	0.227[*]	0.231[*]	-0.131
RH-24h																0.966[#]	0.281^{**}	0.286^{**}	-0.016
RH-6h																	0.307^{**}	0.341^{**}	0.030
CO ₂ -24h																		0.932[#]	-0.019
CO ₂ -6h																			-0.052

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter, h, hour. * 0.01 ≤ *p* < 0.05, ** 0.001 ≤ *p* < 0.01, [#] *p* < 0.001.

Table S11. Quartiles of the value for measured indicators/pollutants.

Items	1st quartile	2nd quartile	3rd quartile	4th quartile
In the child's bedroom				
T-24h, °C	6.7-16.2	16.3-21.9	22.0-27.5	27.6-31.8
T-6h, °C	5.6-16.2	16.3-21.9	22.0-26.7	26.8-34.9
RH-24h, %	35.5-56.2	56.3-65.0	65.1-73.3	73.4-87.5
RH-6h, %	37.0-58.8	58.9-67.9	68.0-75.4	75.5-95.6
CO ₂ -24h, ppm	372-544	545-739	740-978	979-3592
CO ₂ -6h, ppm	367-574	574-919	920-1429	1429-4161
F-24h, µg/m ³	6.8-12.2	12.3-19.6	19.7-27.5	27.6-110.7
F-6h, µg/m ³	6.8-12.2	12.3-19.6	19.7-27.5	27.6-182.8
Fungi, cfu/m ³	6-152	153-234	235-343	344-3184
PM1.0, µg/m ³	0.3-1.9	2.0-3.8	3.9-8.1	8.2-41.3
PM2.5, µg/m ³	6.5-24.3	24.4-40.3	40.4-69.4	69.5-909.9
PM4.0, µg/m ³	10.4-37.8	37.9-61.6	61.7-96.7	96.8-1242.5
PM10, µg/m ³	17.5-66.2	66.3-100.9	101.0-153.5	153.6-1610.2
In the living bedroom				
T-24h, °C	6.7-16.0	16.1-21.9	22.0-27.6	27.7-35.5
T-6h, °C	5.7-15.9	16.0-22.0	22.1-27.3	27.4-34.7
RH-24h, %	36.9-55.7	55.8-64.4	64.5-73.6	73.7-95.0
RH-6h, %	34.7-57.5	57.6-66.9	67.0-75.7	75.8-97.4
CO ₂ -24h, ppm	368-453	454-569	570-751	752-3054
CO ₂ -6h, ppm	366-419	420-567	568-789	790-4161
Fungi, cfu/m ³	19-147	148-234	235-338	339-3044

Abbreviation: T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter; h, hour.

Table S12. Associations of measured indicators/pollutants and childhood asthma in spring.

Items	Quartiles of the measured value for indictors/pollutants ^a									
	1st (reference)	2nd			3rd			4th		
	Case, n (%)	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI
In the child’s bedroom										
T-24h	7 (26.9)	30 (40.0)	1.81, 0.68-4.83	1.96, 0.61-6.26	15 (57.7)	1.92, 1.08-3.44	2.18, 1.03-4.62	0 (0.0)	NA	NA
T-6h	6 (24.0)	32 (42.1)	2.30, 0.83-6.42	2.19, 0.68-7.12	13 (54.2)	1.94, 1.05-3.56	1.81, 0.87-3.75	1 (33.3)	1.17, 0.50-2.75	1.90, 0.55-6.62
RH-24h	15 (34.9)	8 (33.3)	0.93, 0.33-2.68	0.69, 0.20-2.41	20 (54.1)	1.48, 0.95-2.33	1.25, 0.72-2.17	9 (37.5)	1.04, 0.74-1.47	0.95, 0.64-1.40
RH-6h	16 (40.0)	7 (23.3)	0.64, 0.25-1.67	0.30, 0.08-1.07	19 (61.3)	1.37, 0.90-2.09	1.24, 0.68-2.25	10 (37.0)^c	0.98, 0.68-1.42	0.93, 0.64-1.35
CO ₂ -24h	14 (50.0)	12 (35.3)	0.55, 0.20-1.52	0.96, 0.26-3.63	10 (32.3)	0.69, 0.41-1.17	0.51, 0.25-1.07	16 (45.7)	0.94, 0.68-1.32	0.99, 0.64-1.55
CO ₂ -6h	13 (48.1)	13 (37.1)	0.64, 0.23-1.76	1.23, 0.32-4.78	12 (36.4)	0.78, 0.47-1.32	0.70, 0.35-1.43	14 (42.4)	0.93, 0.66-1.30	0.83, 0.51-1.35
F-24h	2 (33.3)	26 (45.6)	1.68, 0.28-9.90	4.50, 0.34-60.04	13 (41.9)	1.20, 0.48-3.02	1.41, 0.40-4.90	9 (37.5)	1.06, 0.57-1.99	1.09, 0.47-2.52
F-6h	0 (0.0)	31 (41.9)	1.00 (reference)	1.00 (reference)	6 (40.0)	0.93, 0.30-2.87	1.07, 0.27-4.23	13 (48.1)	1.14, 0.73-1.77	1.57, 0.87-2.81
Fungi	15 (42.9)	12 (38.7)	0.84, 0.31-2.26	0.57, 0.11-2.81	12 (41.4)	0.97, 0.59-1.60	0.92, 0.48-1.79	13 (38.2)	0.94, 0.68-1.29	0.88, 0.58-1.33
PM _{1.0}	14 (50.0)	13 (34.2)	0.52, 0.19-1.41	0.38, 0.12-1.26	15 (45.5)	0.91, 0.55-1.51	0.49, 0.23-1.04	10 (34.5)	0.81, 0.57-1.15	0.61, 0.38-0.90
PM _{2.5}	13 (50.0)	11 (30.6)	0.44, 0.16-1.25	0.34, 0.09-1.25	16 (48.5)	0.97, 0.58-1.62	0.66, 0.32-1.37	12 (36.4)	0.83, 0.59-1.18	0.64, 0.40-1.02
PM _{4.0}	14 (48.3)	10 (29.4)	0.45, 0.16-1.26	0.38, 0.10-1.40	16 (51.6)	1.07, 0.64-1.77	0.76, 0.38-1.53	12 (35.3)	0.84, 0.60-1.17	0.67, 0.43-1.03
PM ₁₀	14 (45.2)	12 (35.3)	0.66, 0.24-1.80	0.82, 0.24-2.74	14 (48.3)	1.07, 0.64-1.77	0.99, 0.52-1.87	12 (35.3)	0.87, 0.63-1.22	0.77, 0.52-1.17
In the living bedroom										
T-24h	7 (30.4)	30 (39.0)	1.46, 0.54-3.96	1.01, 0.32-3.20	16 (55.2)	1.68, 0.94-2.98	2.66, 1.17-6.03	0 (0.0)	NA	NA
T-6h	8 (32.0)	31 (40.3)	1.43, 0.55-3.72	1.03, 0.46-2.33	14 (51.9)	1.51, 0.86-2.66	1.81, 0.75-4.34	0 (0.0)	NA	NA
RH-24h	13 (30.2)	12 (38.7)	1.46, 0.55-3.86	1.71, 0.55-5.31	17 (51.5)	1.57, 0.98-2.51	1.44, 0.81-2.56	11 (47.8)	1.28, 0.91-1.82	1.17, 0.79-1.74
RH-6h	12 (31.6)	12 (34.3)	1.13, 0.43-3.00	0.90, 0.34-2.37	22 (59.5)	1.78, 1.11-2.86	2.18, 1.21-3.91	7 (35.0)	1.05, 0.72-1.54	0.96, 0.59-1.56
CO ₂ -24h	14 (48.3)	18 (46.2)	0.92, 0.35-2.41	0.93, 0.31-2.77	12 (42.9)	0.90, 0.53-1.51	0.71, 0.35-1.43	9 (26.5)	0.73, 0.51-1.03	0.61, 0.39-0.96
CO ₂ -6h	15 (51.7)	14 (41.2)	0.65, 0.24-1.77	0.64, 0.18-2.28	14 (41.2)	0.81, 0.49-1.33	0.71, 0.39-1.30	10 (30.3)	0.74, 0.52-1.05	0.50, 0.29-0.85
Fungi	13 (36.1)	13 (59.1)	2.56, 0.86-7.59	0.52, 0.08-3.49	11 (34.4)	0.96, 0.59-1.59	1.07, 0.59-1.95	14 (41.2)	1.07, 0.78-1.48	1.52, 0.95-2.42

^a Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter; h, hour. The quartiles for different indicators/pollutants were presented in Table S6. Bold indicates statistical significance.

^b Adjusted factors in the multiple logistic regression analyses included age, sex, located district of residence, family history of atopy, ownership of the current residence, household environmental tobacco smoke (ETS), and household dampness-related exposures.

^c $p < 0.05$ in the Pearson's chi-square test for differences of case proportions among children in different quartiles of the measured value for indicators/pollutants (4*2 tables).

Table S13. Associations of measured indicators/pollutants and childhood asthma in summer.

Items	Quartiles of the measured value for indicators/pollutants ^a									
	1st (reference)	2nd			3rd			4th		
	Case, n (%)	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI
In the child's bedroom										
T-24h	0 (0.0)	0 (0.0)	NA	NA	24 (60.2)	1.00 (reference)	1.00 (reference)	50 (59.7)	1.01, 0.47-2.18	0.88, 0.35-2.18
T-6h	0 (0.0)	0 (0.0)	NA	NA	33 (66.0)	1.00 (reference)	1.00 (reference)	41 (55.4)	0.64, 0.30-1.35	0.62, 0.26-1.47
RH-24h	7 (43.8)	19 (55.9)	1.63, 0.49-5.39	1.72, 0.34-8.64	16 (61.5)	1.43, 0.76-2.70	0.97, 0.42-2.25	32 (66.7)	1.37, 0.93-2.01	1.16, 0.66-2.08
RH-6h	15 (53.6)	12 (48.0)	0.80, 0.27-2.36	0.48, 0.12-1.88	19 (70.4)	1.44, 0.82-2.50	0.93, 0.44-1.95	28 (63.6)	1.15, 0.83-1.58	0.98, 0.54-1.78
CO ₂ -24h	22 (64.7)	22 (57.9)	0.75, 0.29-1.95	0.59, 0.17-2.07	14 (56.0)	0.83, 0.49-1.41	0.69, 0.36-1.30	16 (59.3)	0.93, 0.65-1.31	0.85, 0.53-1.36
CO ₂ -6h	24 (75.0)	17 (43.6)	0.26, 0.09-0.71	0.23, 0.07-0.79	16 (59.3)	0.70, 0.40-1.21	0.71, 0.35-1.43	17 (65.4)	0.86, 0.59-1.25	0.77, 0.48-1.26
F-24h	31 (54.4)	11 (52.4)	0.92, 0.34-2.51	1.36, 0.43-4.27	6 (66.7)	1.30, 0.62-2.72	1.33, 0.52-3.42	16 (69.6)	1.24, 0.88-1.75	1.79, 1.07-3.01
F-6h	36 (54.5)	11 (68.8)	1.83, 0.57-5.87	2.97, 0.80-10.95	5 (55.6)	1.02, 0.51-2.06	1.00, 0.35-2.82	12 (63.2)	1.13, 0.79-1.60	1.56, 0.95-2.55
Fungi	24 (66.7)	19 (70.4)	1.19, 0.40-3.49	2.89, 0.69-12.17	15 (51.7)	0.73, 0.44-1.21	1.05, 0.53-2.06	17 (50.0)	0.79, 0.58-1.10	1.13, 0.71-1.82
PM _{1.0}	29 (64.4)	18 (51.4)	0.58, 0.24-1.44	0.54, 0.18-1.66	14 (70.0)	1.14, 0.64-2.00	0.77, 0.35-1.70	14 (56.0)	0.89, 0.64-1.24	0.77, 0.49-1.20
PM _{2.5}	27 (57.4)	21 (60.0)	1.11, 0.46-2.71	2.16, 0.66-7.07	14 (63.6)	1.14, 0.68-1.92	0.91, 0.44-1.89	13 (61.9)	1.06, 0.75-1.51	0.87, 0.57-1.34
PM _{4.0}	30 (61.2)	15 (46.9)	0.56, 0.23-1.38	0.82, 0.26-2.67	17 (73.9)	1.34, 0.78-2.32	1.22, 0.57-2.58	13 (61.9)	1.01, 0.71-1.43	0.79, 0.51-1.22
PM ₁₀	28 (58.3)	18 (54.5)	0.86, 0.35-2.10	1.30, 0.42-4.04	15 (65.2)	1.16, 0.69-1.94	1.21, 0.63-2.33	14 (66.7)	1.13, 0.79-1.61	1.06, 0.70-1.60
In the living bedroom										
T-24h	0 (0.0)	0 (0.0)	NA	NA	19 (48.7)	1.00 (reference)	1.00 (reference)	55 (64.7)	1.93, 0.89-4.17	1.59, 0.62-4.05
T-6h	0 (0.0)	0 (0.0)	NA	NA	21 (53.8)	1.00 (reference)	1.00 (reference)	53 (62.4)	1.42, 0.66-3.06	1.05, 0.43-2.59
RH-24h	4 (33.3)	14 (53.8)	2.33, 0.56-9.72	4.43, 0.49-40.46	24 (68.6)	2.09, 1.04-4.20	1.53, 0.61-3.88	32 (62.7)	1.50, 0.96-2.33	1.29, 0.73-2.27
RH-6h	8 (47.1)	11 (50.0)	1.13, 0.32-3.99	1.51, 0.13-17.05	22 (68.8)	1.57, 0.86-2.88	1.19, 0.58-2.45	33 (62.3)	1.23, 0.85-1.78	1.13, 0.69-1.84
CO ₂ -24h	27 (73.0)	13 (48.1)	0.34, 0.12-0.98	0.42, 0.12-1.46	22 (61.1)	0.76, 0.47-1.25	0.95, 0.54-1.69	12 (50.0)	0.72, 0.50-1.03	0.58, 0.35-0.96
CO ₂ -6h	26 (78.8)	15 (48.4)	0.25, 0.09-0.75	0.34, 0.09-1.31	17 (53.1)	0.55, 0.32-0.95	0.58, 0.29-1.15	16 (57.1)	0.71, 0.49-1.03	0.55, 0.30-0.98
Fungi	21 (65.6)	20 (62.5)	0.87, 0.31-2.43	1.03, 0.29-3.65	15 (53.6)	0.78, 0.46-1.31	0.93, 0.51-1.72	19 (55.9)	0.87, 0.63-1.22	0.98, 0.64-1.50

^a Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter; h, hour. The quartiles for different indicators/pollutants were presented in Table S6. Bold indicates statistical significance.

^b Adjusted factors in the multiple logistic regression analyses included age, sex, located district of residence, family history of atopy, ownership of the current residence, household environmental tobacco smoke (ETS), and household dampness-related exposures.

Table S14. Associations of measured indicators/pollutants and childhood asthma in autumn.

Items	Quartiles of the measured value for indicators/pollutants ^a									
	1st (reference)	2nd			3rd			4th		
	Case, n (%)	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI
In the child's bedroom										
T-24h	1 (50.0)	10 (33.3)	0.50, 0.03-8.85	0.59, 0.02-23.76	9 (20.0)	0.50, 0.12-2.10	0.44, 0.08-2.43	6 (24.0)	0.68, 0.26-1.80	NA
T-6h	1 (20.0)	10 (35.7)	2.22, 0.22-22.70	2.25, 0.15-33.72	8 (20.5)	1.02, 0.32-3.25	1.26, 0.34-4.68	7 (23.3)	1.07, 0.49-2.34	1.14, 0.42-3.10
RH-24h	6 (23.1)	9 (34.6)	1.77, 0.52-5.97	2.51, 0.56-11.17	6 (21.4)	0.95, 0.50-1.81	1.26, 0.58-2.71	5 (22.7)	0.99, 0.63-1.56	1.29, 0.69-2.41
RH-6h	7 (31.8)	9 (29.0)	0.88, 0.27-2.87	1.44, 0.32-6.48	5 (17.9)	0.68, 0.35-1.32	1.01, 0.41-2.49	5 (23.8)	0.88, 0.56-1.37	0.66, 0.33-1.34
CO ₂ -24h	13 (32.5)	3 (15.0)	0.37, 0.09-1.48	0.39, 0.08-1.92	4 (16.7)	0.65, 0.34-1.21	0.67, 0.33-1.38	6 (33.3)	1.01, 0.68-1.50	1.12, 0.71-1.76
CO ₂ -6h	13 (31.7)	1 (5.9)	0.14, 0.02-1.13	0.13, 0.01-1.22	5 (22.7)	0.80, 0.44-1.45	0.73, 0.37-1.42	7 (31.8)	1.00, 0.69-1.45	1.12, 0.74-1.70
F-24h	6 (22.2)	6 (27.3)	1.31, 0.36-4.84	0.97, 0.22-4.36	8 (23.5)	1.04, 0.57-1.90	0.66, 0.22-1.97	2 (22.2)	1.00, 0.55-1.83	NA
F-6h	7 (21.2)	7 (30.4)	1.63, 0.48-5.50	1.76, 0.43-7.30	4 (18.2)	0.91, 0.46-1.80	0.70, 0.24-2.04	4 (28.6)	1.14, 0.71-1.84	1.47, 0.65-3.31
Fungi	2 (10.5)	7 (21.9)	2.38, 0.44-12.87	3.97, 0.53-29.58	14 (43.8)	2.57, 1.14-5.79	2.86, 1.10-7.41	4 (19.0)^c	1.26, 0.69-2.32	1.11, 0.37-3.33
PM _{1.0}	10 (29.4)	5 (22.7)	0.71, 0.20-2.44	0.61, 0.13-2.89	3 (10.0)	0.52, 0.26-1.04	0.42, 0.18-0.96	9 (52.9)^c	1.39, 0.93-2.08	1.44, 0.91-2.30
PM _{2.5}	10 (37.0)	5 (16.1)	0.33, 0.10-1.13	0.13, 0.02-0.82	4 (13.8)	0.52, 0.27-1.01	0.41, 0.18-0.92	8 (50.0)^c	1.19, 0.79-1.81	1.16, 0.72-1.86
PM _{4.0}	9 (39.1)	6 (17.1)	0.32, 0.10-1.08	0.12, 0.02-0.76	5 (16.1)	0.55, 0.29-1.03	0.43, 0.19-0.98	7 (50.0)^c	1.16, 0.74-1.81	1.16, 0.68-1.97
PM ₁₀	9 (40.9)	5 (15.2)	0.26, 0.07-0.92	0.08, 0.01-0.57	6 (17.6)	0.56, 0.30-1.03	0.43, 0.19-0.96	7 (50.0)^c	1.13, 0.72-1.77	1.16, 0.66-2.02
In the living bedroom										
T-24h	2 (50.0)	9 (30.0)	0.43, 0.05-3.53	0.38, 0.02-7.66	12 (27.3)	0.61, 0.22-1.72	0.78, 0.24-2.49	4 (16.0)	0.58, 0.27-1.21	0.69, 0.22-2.14
T-6h	2 (33.3)	10 (33.3)	1.00, 0.17-6.42	2.70, 0.22-32.53	10 (23.8)	0.79, 0.32-1.98	1.02, 0.35-2.95	5 (20.0)	0.79, 0.41-1.53	0.90, 0.32-2.53
RH-24h	8 (30.8)	8 (27.6)	0.86, 0.27-2.75	1.14, 0.25-5.15	7 (30.4)	0.99, 0.54-1.82	1.32, 0.62-2.80	4 (16.0)	0.75, 0.48-1.19	0.78, 0.45-1.36
RH-6h	8 (30.8)	12 (37.5)	1.35, 0.45-4.05	1.21, 0.52-2.83	3 (15.0)	0.63, 0.30-1.32	0.71, 0.32-1.56	4 (16.0)	0.75, 0.48-1.19	0.50, 0.20-1.21
CO ₂ -24h	14 (40.0)	1 (4.2)	0.07, 0.01-0.54	0.06, 0.01-0.55	7 (25.0)	0.71, 0.41-1.22	0.60, 0.32-1.13	5 (31.3)^c	0.88, 0.58-1.34	0.83, 0.47-1.46
CO ₂ -6h	12 (36.4)	4 (16.7)	0.35, 0.10-1.27	0.22, 0.05-1.10	6 (19.4)	0.65, 0.37-1.15	0.59, 0.31-1.15	5 (33.3)	0.96, 0.62-1.47	0.95, 0.56-1.63
Fungi	5 (31.3)	11 (28.2)	0.86, 0.24-3.07	0.68, 0.12-3.77	7 (21.9)	0.79, 0.40-1.54	0.87, 0.39-1.95	4 (23.5)	0.88, 0.53-1.47	0.48, 0.18-1.31

^a Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter; h, hour. The quartiles for different indicators/pollutants were presented in Table S6. Bold indicates statistical significance.

^b Adjusted factors in the multiple logistic regression analyses included age, sex, located district of residence, family history of atopy, ownership of the current residence, household environmental tobacco smoke (ETS), and household dampness-related exposures.

^c $p < 0.05$ in the Pearson's chi-square test for differences of case proportions among children in different quartiles of the measured value for indicators/pollutants (4*2 tables).

Table S15. Associations of measured indicators/pollutants and childhood asthma in winter.

Items	Quartiles of the measured value for indicators/pollutants ^a									
	1st (reference)	2nd			3rd			4th		
	Case, n (%)	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI	Case, n (%)	OR, 95%CI	AOR ^b , 95%CI
In the child's bedroom										
T-24h	29 (34.5)	2 (33.3)	0.95, 0.16-5.49	1.56, 0.17-14.05	0 (0.0)	NA	NA	0 (0.0)	NA	NA
T-6h	29 (35.4)	2 (25.0)	0.61, 0.12-3.21	0.65, 0.09-4.67	0 (0.0)	NA	NA	0 (0.0)	NA	NA
RH-24h	9 (33.3)	9 (32.1)	0.95, 0.31-2.92	1.22, 0.28-5.32	7 (33.3)	1.00, 0.55-1.83	1.14, 0.53-2.45	6 (40.0)	1.10, 0.71-1.70	1.26, 0.67-2.39
RH-6h	9 (39.1)	8 (32.0)	0.73, 0.22-2.40	0.75, 0.16-3.50	6 (24.0)	0.70, 0.38-1.30	0.79, 0.34-1.86	8 (44.4)	1.08, 0.71-1.63	1.35, 0.72-2.53
CO ₂ -24h	0 (0.0)	8 (40.0)	1.00 (reference)	1.00 (reference)	10 (32.3)	0.71, 0.22-2.30	1.19, 0.22-6.54	13 (41.9)	1.04, 0.59-1.84	1.35, 0.68-2.70
CO ₂ -6h	2 (20.0)	8 (36.4)	2.29, 0.39-13.51	1.38, 0.12-16.34	11 (37.9)	1.56, 0.66-3.70	1.45, 0.52-4.01	10 (33.3)	1.26, 0.71-2.24	1.11, 0.54-2.26
F-24h	0 (0.0)	2 (50.0)	1.00 (reference)	1.00 (reference)	18 (34.0)	0.51, 0.07-3.96	0.60, 0.04-9.95	10 (31.3)	0.67, 0.24-1.92	0.61, 0.15-2.41
F-6h	0 (0.0)	3 (30.0)	1.00 (reference)	1.00 (reference)	15 (30.0)	1.00, 0.23-4.40	0.30, 0.03-2.87	12 (41.4)	1.28, 0.59-2.77	1.25, 0.42-3.67
Fungi	7 (25.9)	7 (35.0)	1.54, 0.44-5.42	1.27, 0.18-8.95	10 (45.5)	1.54, 0.85-2.82	1.98, 0.86-4.54	7 (31.8)	1.10, 0.73-1.67	0.95, 0.56-1.62
PM _{1.0}	3 (37.5)	3 (20.0)	0.42, 0.06-2.82	NA	10 (33.3)	0.91, 0.41-2.05	0.94, 0.15-5.89	15 (37.5)	1.00, 0.59-1.69	0.90, 0.45-1.81
PM _{2.5}	3 (25.0)	3 (27.3)	1.13, 0.18-7.24	NA	9 (32.1)	1.19, 0.56-2.56	NA	16 (38.1)	1.23, 0.76-1.99	1.35, 0.77-2.36
PM _{4.0}	2 (16.7)	4 (36.4)	2.86, 0.41-20.14	NA	9 (33.3)	1.58, 0.67-3.73	NA	16 (37.2)	1.44, 0.83-2.48	1.65, 0.86-3.16
PM ₁₀	2 (18.2)	5 (38.5)	2.81, 0.42-18.74	NA	10 (38.5)	1.68, 0.71-3.97	NA	14 (32.6)	1.30, 0.75-2.25	1.42, 0.74-2.72
In the living bedroom										
T-24h	29 (33.7)	2 (40.0)	1.31, 0.21-8.29	1.06, 0.11-10.08	0 (0.0)	NA	NA	0 (0.0)	NA	NA
T-6h	29 (34.1)	2 (33.3)	0.97, 0.17-5.59	1.13, 0.15-8.68	0 (0.0)	NA	NA	0 (0.0)	NA	NA
RH-24h	10 (31.3)	9 (34.6)	1.17, 0.39-3.50	1.70, 0.43-6.67	7 (29.2)	0.95, 0.53-1.70	1.06, 0.52-2.18	5 (50.0)	1.30, 0.80-2.11	1.26, 0.68-2.33
RH-6h	11 (34.4)	8 (34.8)	1.02, 0.33-3.14	1.09, 0.24-5.05	6 (26.1)	0.82, 0.45-1.48	1.00, 0.49-2.02	6 (42.9)	1.13, 0.73-1.73	1.17, 0.69-2.00
CO ₂ -24h	1 (8.3)	5 (22.7)	3.24, 0.33-31.54	1.08, 0.25-4.60	8 (40.0)	2.71, 0.89-8.27	NA	17 (44.7)	2.07, 1.01-4.24	5.13, 0.96-27.31
CO ₂ -6h	2 (10.0)	7 (33.3)	4.50, 0.81-25.12	13.28, 1.00-176.41	7 (43.8)	2.65, 1.10-6.39	2.24, 1.01-6.72	15 (42.9)	1.89, 1.11-3.23	2.11, 1.07-4.18
Fungi	8 (28.6)	6 (30.0)	1.11, 0.62-1.99	1.37, 0.30-6.27	7 (41.2)	1.72, 0.95-3.12	1.72, 0.75-3.93	10 (38.5)	1.28, 0.81-2.00	1.64, 0.88-3.04

^a Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; T, temperature; RH, relative humidity; F, formaldehyde; PM, particle matter; h, hour. The quartiles for different indicators/pollutants were presented in Table S6. Bold indicates statistical significance.

^b Adjusted factors in the multiple logistic regression analyses included age, sex, located district of residence, family history of atopy, ownership of the current residence, household environmental tobacco smoke (ETS), and household dampness-related exposures.