

On Associations between Housing Characteristics, Dampness and Asthma and Allergies among Children in Northeast Texas

Yuexia Sun^{a,b} Jan Sundell^{c,d}

^aSchool of Environmental Science and Engineering, Tianjin University, Tianjin, China

^bTexas Institute of Allergy, Indoor Environment and Energy (TxAIRE), University of Texas at Tyler, Tyler, TX, USA

^cDepartment of Building Science, School of Architecture, Tsinghua University, Beijing City, China

^dThe Faculty of Urban Construction and Environmental Engineering, Chongqing University, Chongqing City, China

Key Words

Asthma and allergy · Air-conditioning system · Child · Dampness · Housing characteristics

Abstract

A cross-sectional study on the home environment and children's health in Northeast Texas was carried out in 2008–2009. Two thousand eight hundred and nineteen (2,819) parents of children (1–8 years) reported their housing characteristics, home interior surface materials, dampness and children's health status. The response rate was 71%. Health outcomes studied were wheeze, dry cough, rhinitis, eczema in the last 12 months and diagnosed asthma and hay fever. Dampness was significant risk factor for wheeze and rhinitis with adjusted odds ratio (AOR) 1.3–1.7. Mould/damp spot, condensation and suspected moisture problems were more commonly reported in buildings with flat roof and pier/beam foundation in hot and humid Northeast Texas. Compared to single family houses, trailers were associated with more dampness,

consequently a significant increased prevalence of asthma (AOR 1.5 with 95% confidence interval (CI) 1.0–2.3), rhinitis (AOR 1.4, 95% CI 1.0–2.0) and hay fever (AOR 1.5, 95% CI 1.1–2.1). Central air-conditioning system, which re-circulates indoor air, was associated with less dampness problems. However, an increment trend of allergic symptoms was found in homes with air-conditioning system, especially for rhinitis (AOR 1.6, 95% CI 1.1–2.2). Carpet as floor covering and laminated panel as wall covering were associated with rhinitis (AOR 1.6, 95% CI 1.0–2.5) and wheezing (AOR 4.7, 95% CI 1.8–12.7), respectively.

Introduction

The prevalence of asthma and allergies in the world varies largely, with the highest prevalence of asthma about 20 times higher than the lowest [1]. USA is among the high prevalence countries [2]. In 2006, 9.9 million US children

under 18 years of age (14%) have been diagnosed with asthma, with 6.8 million children (9%) still having asthma [3]. Asthma is responsible for about 500,000 hospitalizations, 5,000 deaths and 134 million days of restricted activity a year in USA [4,5].

Outdoor as well as indoor pollutants have been suggested as risk factors for the development of asthma. Outdoor air pollutants have been declining in many industrialized countries during the last decades [6,7], but this has not resulted in a decline in the incidence of asthma. Therefore, indoor pollutants might be of greater importance in influencing the health status of children. The home environment has changed considerably during the past three decades because of a rapid change in building technology, as well as in the type of materials used for interior decorations, furniture and textiles. A US study demonstrated that changes in heating and air-conditioning systems are associated with the increased prevalence of asthma [8]. In modern buildings, carpet or polyvinyl chloride (PVC) flooring have often replaced wooden flooring. PVC furnishing materials at home have been associated with asthma and allergies among children [9,10]. In a case-control study, the risk of asthma in adults was related to the presence of wall-to-wall carpet at work, in particular in the presence of mould problems [11].

Unfortunately, despite growing evidence showing that residential exposures have dramatic impacts on children's health, housing is largely ignored as a public health problem in USA. Limitations in exploring the links between health and housing are that many studies have health data but no data on housing characteristics, or vice versa, and that studies with data on both housing and health almost exclusively are on low-income populations. Data on the home environment and health for the general population are largely missing.

A study of the home environment and asthma and allergies among children aged 1–8 years, representative of the general population, in Northeast Texas, USA, was carried out in 2008–2009. This study is part of the global Damp Building and Health (DBH) study which has been carried out in Sweden, Bulgaria, Singapore, Taiwan, Denmark, South Korea and China. These studies have been conducted with similar questionnaires and protocols in order to establish comparable data sets. The overall aim with such global study is to picture a global map on the prevalence of asthma and allergy in children as well as on characteristics of homes and indoor environmental exposures. A further aim is to identify not only general risk and protection factors for asthma and allergy but also region-specific factors due to climate, culture, traditions, etc.

The present paper focuses on housing characteristics, dampness and their associations with asthma and allergies in children in US.

Materials and Methods

The study is a population-based cross-sectional study during which self-administrated questionnaires were delivered to parents of children (1–8 years) in Northeast Texas through Women, Infants and Children (WIC) agencies, independent school systems, daycare centres, hospitals, clinic centres and churches. Participants were from nine cities (Cayuga, Flint, Hawkins, Henderson, Larue, Lindale, Longview, Palestine and Tyler), which covered seven counties (Anderson, Gregg, Harrison, Henderson, Rusk, Smith and Wood) in Northeast Texas. The contents of the questionnaire is described in detail in a previous paper [12]. The medical part of the questionnaire follows the ISAAC study [13], which consisted of wheeze, dry cough, rhinitis, eczema in the last 12 months and doctor-diagnosed asthma and hay fever. Housing characteristics investigated were housing type, housing age, type of foundation, roof, windows, ventilation system and interior surface materials. The social-economic status (SES) of participants was indicated by housing ownership. Dampness indicators were mould/damp spot, floor moisture, water leakage, condensation on window pane in winter and suspected moisture problem.

In order to find whether there is a selection bias between respondents and non-respondents, 527 people who did not respond to the survey were reached by a short questionnaire which consisted of questions on wheezing in the last 12 months, house type, visible mould on walls/ceilings and environmental tobacco smoke at home.

Statistic Analysis

Comparisons of dampness indicators in different housing type and housing construction period were analyzed by Chi-square tests. Odds ratios (ORs) of housing foundation, roof, window, ventilation system and interior furnishing material for dampness were calculated in logistic regression models with adjustment for housing type and construction period. ORs of dampness for health outcomes were calculated with adjustments for gender, age, allergic symptoms in the family and SES. Racial disparity of asthma and allergy, as well as housing type, was observed in Northeast Texas [12]. The ORs of housing characteristics were calculated with adjustment for gender, age, allergic symptoms in

family, SES, race and housing type. Statistical Package for the Social Sciences (SPSS) software 15.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. A *p* value less than 0.05 indicates a significant level. This study was approved by the Institutional Review Board of University of Texas at Tyler, Texas.

Results

This cross-sectional study obtained responses from 3,766 participants. After excluding children who did not meet the age criteria (i.e. aged 1–8 years), 2,819 responses were involved in the analysis. The demographic information of involved children is shown in Table 1. One thousand four hundred and forty-two participants indicated their ethnicity, among whom 255 (18%) were Mexicans, 178 (12%) Afro-Americans, 40 (3%) Asian-Americans and 969 (67%) Caucasians. The comparison between participants with and without racial information on housing type, dampness, gender, age and health outcomes is shown in the online supplementary Table S1. There was no significant difference between these two subgroups. The prevalence of symptoms of wheezing, dry cough, rhinitis and eczema in the last 12 months was 28%,

20%, 51% and 15%, respectively. Doctor-diagnosed asthma and hay fever were 16% and 27%.

Housing characteristics are shown in the online supplementary Table S2. Common housing characteristics in Northeast Texas are a concrete slab foundation, gable roof, carpet flooring, dry walls (also known as plaster-board or gypsum board which is a panel made of gypsum plaster pressed between two thick sheets of paper) and aluminium frame windows. Air-conditioning units were installed in more than 80% of homes. Compared to single family houses, more trailers had a pier and beam as foundation, a flat roof, vinyl flooring and panel walls. Trailers also had natural ventilation system more often (single family houses 18% vs. trailers 28%). Single family houses constructed after 1983 had more concrete slab as building foundation, more gable roofs, more carpets, more aluminium window frames and more air-conditioning than older buildings.

The frequencies of dampness problems are shown in Table 2. Dampness indicators were reported in 10%–30% families. Trailers, as well as old buildings, had more dampness problems. AORs of housing foundation, roof, window, ventilation system and interior furnishing material for dampness are shown in Table 3. Pier/beam as foundation, flat roof, aluminium window and natural ventilation system were associated to an increase of dampness indicators. PVC floor and carpet, as well as wallpaper, were related to more suspected damp problems.

Associations between dampness indicators and asthma and allergies are shown in Table 4. Dampness index were associated significantly with wheeze, dry cough, rhinitis, hay fever and eczema. There were non-significant associations of some dampness index with diagnosed asthma. Associations between housing characteristics and asthma and allergy are shown in Table 5. Living in trailers was associated with diagnosed asthma (AOR 1.5 with 95% confidence interval (CI) 1.0–2.3). This means the risk of children in trailers to have asthma was 1.5 times as high as

Table 1. Demographic information of 2,819 children aged 1–8 years, 2008–2009

	<i>n</i> (%)
Age	
Age 1–2	548 (19.4)
Age 3–4	778 (27.6)
Age 5–6	768 (27.2)
Age 7–8	725 (25.7)
Gender	
Boy	1,421 (50.7)
Girl	1,380 (49.3)
Allergy in family	
Yes	1,477 (53.9)

Table 2. Dampness problems in Northeast Texas homes, 2008–2009

Dampness	All, <i>n</i> (%)	Housing type			<i>p</i> ^a	Housing construction period		<i>p</i>
		Single family house	Trailer	Apartment		After 1983	Before 1983	
Mould/damp spot	390 (14.9)	240 (13.4)	94 (17.3)	41 (22.0)	0.001	131 (10.9)	179 (20.2)	0.000
Floor moisture	293 (11.3)	171 (9.6)	81 (15.2)	34 (18.5)	0.000	88 (7.3)	133 (15.1)	0.000
Water leakage	269 (10.5)	180 (10.2)	60 (11.2)	18 (10.2)	0.828	124 (10.3)	111 (12.8)	0.081
Condensation	717 (31.4)	468 (29.8)	179 (38.3)	53 (32.9)	0.002	296 (27.4)	306 (38.6)	0.000
Suspected moisture problem	293 (12.2)	167 (10.1)	79 (16.0)	41 (24.3)	0.000	84 (7.4)	146 (18.0)	0.000

^aPearson Chi-square test.

Table 3. Associations between housing characteristics and dampness in Northeast Texas, 2008–2009

	Adjusted odds ratios (95% confidence interval) ^a				
	Mould/damp spot	Floor moisture	Water leakage	Condensation	Suspected moisture problem
Foundation: ref. concrete					
Pier, beam	1.75 (1.29, 2.38)	1.51 (1.06, 2.13)	0.92 (0.64, 1.32)	1.80 (1.40, 2.31)	1.59 (1.12, 2.24)
Roof: ref. gable					
Flat	1.21 (0.82, 1.79)	1.62 (1.07, 2.43)	1.22 (0.79, 1.89)	1.01 (0.73, 1.39)	1.19 (0.77, 1.85)
Window frame: ref. wooden					
Aluminium	1.21 (0.92, 1.60)	0.76 (0.56, 1.03)	1.43 (1.05, 1.95)	1.28 (1.03, 1.59)	1.39 (1.01, 1.90)
Ventilation: ref. natural ventilation system					
Air conditioning	0.58 (0.42, 0.78)	0.77 (0.54, 1.10)	0.92 (0.63, 1.34)	0.66 (0.50, 0.86)	0.72 (0.50, 1.03)
Flooring: ref. wooden floor					
Carpet	0.97 (0.62, 1.54)	0.73 (0.45, 1.18)	1.24 (0.71, 2.19)	0.98 (0.68, 1.42)	2.04 (1.07, 3.91)
PVC floor	0.79 (0.37, 1.68)	0.78 (0.33, 1.82)	1.52 (0.69, 3.35)	1.92 (1.04, 3.56)	1.00 (0.42, 2.39)
Wall covering: ref. wallpaper					
Drywall	0.68 (0.41, 1.13)	0.58 (0.33, 0.99)	1.41 (0.75, 2.67)	0.87 (0.58, 1.35)	0.51 (0.30, 0.87)
Laminated panel	0.29 (0.08, 1.01)	0.42 (0.14, 1.29)	0.90 (0.34, 2.38)	1.26 (0.61, 2.58)	0.11 (0.01, 0.83)

^aAdjust for housing type and housing construction period.

Table 4. Association between dampness and asthma and allergies among children in Northeast Texas, 2008–2009

	Adjusted odds ratios (95% confidence interval) ^a					
	Wheeze	Dry cough	Diag. asthma	Rhinitis	Diag. hay fever	Eczema
Mould/damp spot	1.39 (1.09, 1.78)	1.67 (1.29, 2.16)	1.30 (0.97, 1.74)	1.63 (1.28, 2.08)	1.48 (1.15, 1.90)	1.65 (1.12, 2.45)
Floor moisture	1.49 (1.13, 2.96)	1.75 (1.31, 2.34)	1.34 (0.97, 1.85)	1.58 (1.20, 2.08)	1.56 (1.18, 2.07)	1.57 (1.00, 2.47)
Water leakage	1.33 (1.00, 1.76)	1.27 (0.94, 1.73)	0.92 (0.65, 1.31)	1.56 (1.17, 2.07)	1.17 (0.87, 1.55)	1.09 (0.67, 1.77)
Condensation	1.42 (1.16, 1.75)	1.42 (1.13, 1.77)	0.98 (0.76, 1.27)	1.30 (1.07, 1.58)	1.23 (1.00, 1.52)	1.40 (0.99, 1.97)
Suspected moisture problem	1.69 (1.28, 2.23)	1.81 (1.36, 2.42)	1.16 (0.82, 1.62)	1.59 (1.20, 2.10)	1.78 (1.34, 2.36)	1.70 (1.07, 2.71)

^aAdjusted to gender, age, allergic symptom in family, environmental tobacco smoke, and social-economic status.

those in single family house. Air-conditioning system was a significant risk factor for rhinitis (AOR 1.6 with 95% CI 1.1–2.2), and it was associated with a trend of increment of other allergic symptoms. Carpet as floor covering and laminated panel as wall covering were significantly associated with an increment of rhinitis and wheeze, respectively. Five hundred and twenty-seven (527) non-respondents answered short questionnaires. Four hundred and fifty-one (451) children met the age criteria. There were no significant differences in prevalence of wheezing, housing type and environmental tobacco smoke among respondents and non-respondents. However, more mould spots were reported from children's room of non-respondents.

Discussion

This study is subject to the limitations inherent in any cross-sectional survey. Data used for the analysis were

collected retrospectively and relied on parental reports and thus could be subject to recall bias. However, the questions on outcomes and exposures in the present study have been validated in previous studies [14–17]. Some studies demonstrated that parental reports of childhood asthma can identify more than 94% cases of diagnosed asthma [18,19]. Non-respondents were reached by short surveys. There were no significant differences regarding reports of wheezing, house type and environmental tobacco smoke among respondents and non-respondents. Higher percentage of mould spot reported by non-respondents, compared to respondents, indicates that moisture-related problems may be underestimated. However, the response rate was as high as 71%. This means that selection bias could only be a minor problem. Ownership of dwellings was used as a proxy of SES. There may be variations in SES among non-owners and among owners. However, the strong association between housing characteristics, dampness and health outcomes should not be due to misclassification of SES.

Table 5. Associations between housing characteristics and health status among children in Northeast Texas, 2008–2009

	Wheeze	Adjusted odds ratios (95% confidence interval)			Diag. hay fever	Eczema
		Dry cough	Diag. asthma	Rhinitis		
House type: ref. single family house ^a						
Trailer	1.15 (0.82, 1.60)	1.13 (0.80, 1.62)	1.53 (1.03, 2.26)	1.41 (1.03, 1.95)	1.49 (1.06, 2.08)	1.32 (0.87, 1.98)
Apartment	0.56 (0.31, 1.03)	0.86 (0.47, 1.58)	0.87 (0.44, 1.73)	1.23 (0.73, 2.09)	1.28 (0.72, 2.30)	1.03 (0.52, 2.03)
Construction period: ref. after year 1983 ^b						
Before 1983	0.87 (0.64, 1.17)	1.34 (0.98, 1.83)	0.95 (0.66, 1.37)	1.13 (0.86, 1.49)	0.87 (0.65, 1.16)	1.00 (0.69, 1.45)
Foundation: ref. concrete ^b						
Pier, beam	0.88 (0.61, 1.26)	1.15 (0.80, 1.67)	0.81 (0.52, 1.28)	0.73 (0.53, 1.02)	0.86 (0.60, 1.23)	1.09 (0.70, 1.68)
Roof: ref. gable ^b						
Flat roof	1.39 (0.93, 2.08)	1.17 (0.77, 1.77)	1.40 (0.87, 2.25)	0.79 (0.54, 1.15)	0.99 (0.65, 1.49)	0.84 (0.50, 1.41)
Window frame: ref. wood ^b						
Aluminium	1.12 (0.83, 1.50)	1.09 (0.80, 1.49)	0.88 (0.61, 1.26)	1.20 (0.92, 1.57)	1.10 (0.82, 1.46)	0.72 (0.50, 1.04)
Ventilation: ref. natural ventilation system ^b						
Air conditioning	1.46 (0.98, 2.18)	1.06 (0.71, 1.60)	1.36 (0.84, 2.18)	1.57 (1.10, 2.24)	1.10 (0.75, 1.61)	1.00 (0.62, 1.60)
Floor covering: ref. wooden floor ^b						
Carpet	0.79 (0.49, 1.27)	0.71 (0.44, 1.17)	1.10 (0.59, 2.05)	1.58 (1.00, 2.50)	1.17 (0.70, 1.96)	0.96 (0.51, 1.79)
PVC	0.84 (0.35, 2.00)	0.83 (0.34, 2.01)	1.77 (0.69, 4.54)	1.13 (0.55, 2.34)	0.69 (0.28, 1.67)	0.66 (0.22, 1.98)
Wall covering: ref. wallpaper ^b						
Drywall	1.43 (0.77, 2.63)	1.71 (0.88, 3.32)	1.00 (0.53, 1.90)	0.92 (0.55, 1.54)	0.98 (0.56, 1.68)	1.44 (0.69, 3.01)
Laminated panel	4.72 (1.75, 12.68)	1.09 (0.39, 3.04)	2.00 (0.60, 6.70)	1.68 (0.58, 4.86)	0.90 (0.33, 2.43)	0.80 (0.20, 3.26)

^aAdjusted for gender, age, allergic symptom in family, social-economic status, environmental tobacco smoke exposure, and races.

^bAdjusted for gender, age, allergic symptom in family, social-economic status, environmental tobacco smoke exposure, races, and housing type.

Thirty-one percent (31%) of families in this study reported to have condensation on windowpane in winter. This is consistent with a prior study in Seattle, which showed that 34% of 925 participating families reported to have water condensation [20]. However, we found less mould/mildew spots in Northeast Texas families (18%) compared to those in Seattle (54%) and in Boston (38%) [20,21]. This was probably due to the cold weather in North USA regions, which cause more condensations on the cold surface of building enclosures.

The risk effect of dampness in our study is consistent with previous studies which show that relative risks of dampness for health effects in the airways are in the range of OR 1.4–2.2 [22]. In the very extensive Swedish study “Dampness in Buildings and Health” (DBH), with the aim of identifying what agents in indoor air are responsible for the associations between “dampness” and allergies and asthma, so far it has not been able to identify these agents [23]. Moreover, Larsson et al. [24] recently showed that the associations between dampness and health in cross-sectional studies disappear in a longitudinal study. Studies with sophisticated design and objective measurement on dampness are needed to discover what “dampness” means to health.

According to the US census Bureau, trailers accounted for nearly a quarter of all new single-family houses during

the 1990s. Trailers (manufactured homes) built today often use materials and mechanical systems that could potentially contribute to poor indoor air quality and low durability. Trailers in hot and humid locations still use and install vinyl covered gypsum, which often results in problems with mould and mildew [25]. In the present study, trailer, compared to single family houses, was related to more dampness, consequently, more asthma and allergic symptoms. Old housing had more dampness problems probably due to poor maintenance. This finding is consistent with those in Sweden, Finnish and American studies [26–28]. The Swedish and Finnish studies reported a common leakage problem associated with flat roof [26,27]. This was confirmed in our Texas study. However, our study in hot and humid Texas found that pier/beam as foundation was risk type of construction for dampness, which was against the finding from the previous study in cold and dry Sweden [26]. In the present study, aluminium frame window was associated with increased report of condensation on windowpanes in winter. Aluminium window may make the building tighter compared to wooden frame windows. However, the moisture content could not be removed efficiently by ventilation, thus cause more dampness problems. This is consistent with a previous study in China, which shows that PVC frame windows were related to less air change rate and more

condensations [29,30]. Our study found that natural ventilation system compared to air-conditioning system could cause more dampness indicators. Future studies in hot and humid climate are needed to verify these findings.

The present study shows that, compared to natural ventilation system, air-conditioning system (which mainly re-circulates indoor air) is associated with an increased prevalence rate of wheeze, diagnosed asthma and hay fever and are significantly associated to an increased prevalence rate of rhinitis ($p < 0.05$). It is interesting to find that air-conditioning system was associated with less dampness problems. This indicates that there must be other potential risks that may overcome the benefits of less dampness problems in houses with air-conditioning systems. The negative association between air-conditioning system and health outcomes is consistent with prior findings in homes and/or offices. In two large-scale studies in Europe and America on housing characteristics and health, it was reported that air-conditioning was associated with an increment of lower respiratory symptoms (relative risk 1.14) [28] and asthma outcomes (AOR 1.0–1.5) [31]. Seppänen and Fisk [32] summarized that air-conditioning in offices, relative to natural ventilation, is associated with a statistically significant increase in the prevalence of one or more SBS symptoms, by approximately 30–200%. Mendell et al. [33] identified that poor drainage in air-conditioning drip pans might increase adverse respiratory effects (AOR 2.6, 95% CI 1.3–5.2), particularly among asthmatics. Menzies et al. [34] demonstrated that installation of ultraviolet germicidal irradiation (UVGI) of drip pans and cooling coils within ventilation systems of office buildings would reduce microbial contamination, and thus occupants' work-related symptoms.

The present study did not find significant associations between PVC floor covering and health outcomes. This is probably due to the limited sample size (122 (4.4%) families had PVC flooring). It can also be due to the fact that, with the increased health concern about plasticizers,

manufactures have changed the composition of PVC products. In the European studies, di-2-ethylhexyl phthalate (DEHP) and butyl benzyl phthalate (BBzP) were associated with asthma and allergies [9,10]. These plasticizers are today not used in, e.g. PVC flooring, in Europe and USA. Carpet is a common flooring material in Northeast Texas. Carpets with less-frequent cleaning can be a breeding ground for mites and a reservoir of dust. In the present study, carpet was significantly associated with an increment of rhinitis in children, which is in agreement with a previous case-control study among adults [11]. Laminated wall panel is an emerging decoration technique. This is a resin-based decorative layer pressed on high-density fiberboard. It was found that lower respiratory tract symptoms – wheeze and asthma – were associated with the presence of such panels. However, only 58 families had laminated panel as wall covering. Further studies are needed to verify this result.

Conclusions

In Northeast Texas, flat roof and pier/beam foundation are the type of constructions related to dampness problems. Living in trailers was related to diagnosed asthma and diagnosed hay fever of children. Central air-conditioning systems were associated with an increment trend of allergic symptoms among children, especially with rhinitis. These findings indicate that housing characteristics and its related problems (e.g. dampness) have substantial impact on children's health. Housing maintenance and inspections are needed to identify and resolve risk factors in housing environmental exposures.

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References

- 1 Pearce N, Ait-Khaled N, Beasley R, Mallol J, Keil U, Mitchell AE, Robertson C: Worldwide trends in the prevalence of asthma symptoms: phase three of the International Study of Asthma and Allergies in Childhood (ISAAC): Thorax 2007;62:758–766.
- 2 Copper PJ, Rodrigues LC, Cruz AA, Barreto ML: Asthma in Latin America: a public health challenge and research opportunity: Allergy 2009;64(1):5–17.
- 3 Bloom B, Cohen RA: Summary health statistics for U.S. children: National Health Interview Survey, 2006. National Center for Health Statistics: Vital Health Stat 2007;10(234).
- 4 National Center for Health Statistics (NCHS): Current estimates from the National Health Interview Survey, 1990: Vital Health Stat 1997;10(194).
- 5 National Heart, Lung, and Blood Institute (NHLBI): Data Fact Sheet, Asthma Statistics, National Institutes of Health, Public Health Service (PHS), 1999.
- 6 D'Amato G, Liccardi G, D'Amato M, Cazzola M: Respiratory allergic diseases induced by outdoor air pollution in urban areas: Monaldi Arch Chest Dis 2002;57(3–4):161–163.
- 7 Sivertsen B, Clench-Aas J: Exposure to environmental chemicals relevant for respiratory hypersensitivity: European aspects: Toxicol Lett 1996;86(2–3):143–153.
- 8 Jacobs DE, Wilson J, Dixon S, Smith J, Evens A: The relationship of housing and population health: a 30-year retrospective analysis: Environ Health Persp 2009;117(4):597–604.
- 9 Bornehag CG, Sundell J, Weschler CJ, Sigsgaard T, Lundgren B, Hasselgren M,

- Hägerhed-Engman L: The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study: *Environ Health Persp* 2004;112(14):1393–1397.
- 10 Kolarik B, Naydenov K, Larsson M, Bornehag CG, Sundell J: The association between phthalates in dust and allergic diseases among Bulgarian children: *Environ Health Persp* 2008;116(1):98–103.
- 11 Jaakkola JJK, Leromnimon A, Jaakkola MS: Interior surface materials and asthma in adults: a population-based incident case-control study: *Am J Epidemiol* 2006;164:742–749.
- 12 Sun YX, Sundell J: Life style and home environment are associated with racial disparities of asthma and allergy in Northeast Texas children: *Sci Total Environ* 2011;409:4229–4234.
- 13 Asher MI, Keil U, Anderson HR, Beasley R, Crane J, Martinez F, Mitchell EA, Pearce N, Sibbald B, Stewart AW: International Study of Asthma and Allergies in Childhood (ISAAC): rationale and methods: *Eur Respir J* 1995;8:483–491.
- 14 Naydenov K, Melikov A, Markov D, Stankov P, Bornehag CG, Sundell J: A comparison between occupants' and inspectors' reports on home dampness and their association with the health of children: the ALLHOME study: *Build Environ* 2008;43(11):1840–1849.
- 15 Bornehag CG, Sundell J, Hagerhed-Engman L, Sigsgaard T: Association between ventilation rates in 390 Swedish homes and allergic symptoms in children: *Indoor Air* 2005;15:275–280.
- 16 Hagerhed-Engman L, Bornehag CG, Sundell J: How valid are parents' questionnaire responses regarding building characteristics, moldy odor, and signs of moisture problems in Swedish homes? *Scand J Public Health* 2007;35:125–132.
- 17 Sun Y, Sundell J, Zhang Y: Validity of building characteristics and dorm dampness obtained in a self-administrated questionnaire: *Sci Total Environ* 2007;387:276–282.
- 18 Mak H, Johnston P, Abbey H, Talamo RC: Prevalence of asthma and health service utilization of asthmatic children in an inner city: *J Allergy Clin Immunol* 1982;70(5):367–372.
- 19 Speight AN, Lee DA, Hey EN: Underdiagnosis and undertreatment of asthma in childhood: *Br Med J* 1983;286:1253–1256.
- 20 Maier CW, Arrighi HM, Morray B, Llewellyn C, Redding JG: Indoor risk factors for asthma and wheezing among Seattle school children: *Environ Health Persp* 1997;105(2):208–214.
- 21 Stark PC, Burge HA, Ryan LM, Milton DK, Gold DR: Fungal levels in the home and lower respiratory tract illnesses in the first year of life: *Am J Respir Crit Care Med* 2003;168:232–237.
- 22 Bornehag CG, Blomquist G, Gynzelberg F, Jarvholm B, Malmberg P, Nordvall L, Nielsen A, Pershagen G, Sundell J: Dampness in buildings and health. Nordic interdisciplinary review of the scientific evidence on associations between exposure to "dampness" in buildings and health effects (NORDDAMP): *Indoor Air* 2001;11:72–86.
- 23 Bornehag CG, Sundell J, Hagerhed-Engman L, Sigsgaard T, Janson S, Aberg N, DBH Study Group: 'Dampness' at home and its association with airway, nose, and skin symptoms among 10,851 preschool children in Sweden: a cross-sectional study: *Indoor Air* 2005;15(Suppl 10):48–55.
- 24 Larsson M, Hagerhad-Engman L, Moniruzzaman S, Janson S, Sundell J, Bornehag CG: Can we trust cross-sectional studies when studying the risk of moisture related problems indoor for asthma in children? *Int J Environ Health Res* 2011;21(4):237–247.
- 25 Roaf S: *Ecohouse*, 3rd edn. Oxford, Architectural Press, 2007.
- 26 Hagerhed-Engman L, Bornehag CG, Sundell J: Building characteristics associated with moisture related problems in 8918 Swedish dwellings: *Int J Environ Heal R* 2009;19(4):251–265.
- 27 Nevalainen A, Partanen P, Jaaskelainen E, Hyvarinen A, Koskinen O, Meklin T, Vahteristo M, Koivisto J, Husman T: Prevalence of moisture in Finnish houses: *Indoor Air* 1998;4:45–49.
- 28 Spengler J, Neas L, Nakai S, Dockery D, Speizer F, Ware J, Raizenne M: Respiratory symptoms and housing characteristics: *Indoor Air* 1994;4(2):72–82.
- 29 Sun Y, Zhang Y, Sundell J, Fan Z, Bao L: Dampness at dorm and its associations with allergy and airways infection among college students in China: a cross-sectional study: *Indoor Air* 2009;19(2):174–182.
- 30 Sun Y, Zhang Y, Bao L, Fan Z, Sundell J: Ventilation and dampness in dorms and their associations with allergy among college students in China: a case-control study: *Indoor Air* 2011;21(4):277–283.
- 31 Zock JP, Jarvis D, Luczynska C, Sunyer J, Burney P: Housing characteristics, reported mold exposure, and asthma in the European Community Respiratory Health Survey: *J Allergy Clin Immunol* 2002;110:285–292.
- 32 Seppänen O, Fisk WJ: Association of ventilation system type with SBS symptoms in office workers: *Indoor Air* 2002;12(2):98–112.
- 33 Mendell MJ, Naco GM, Wilcox TG, Sieber WK: Environmental risk factors and work-related lower respiratory symptoms in 80 office buildings: an exploratory analysis of NIOSH data: *Am J Ind Med* 2003;43(6):630–641.
- 34 Menzies D, Popa J, Hanley JA, Rand T, Milton DK: Effect of ultraviolet germicidal lights installed in office ventilation systems on workers' health and wellbeing: double-blind multiple crossover trial: *Lancet* 2003;362:1785–1791.