

Social factors, allergen, endotoxin, and dust mass in mattress

Abstract Indoor environment has been associated with allergic disease. Further, it has been observed that the prevalences of allergic sensitization are different in different social groups. We therefore investigated the association between socioeconomic status (SES) and indoor bio-contaminants. House dust samples were collected from parents' and infants' mattress from 2166 families in Munich (62.2%) and Leipzig (37.8%), Germany. Major mite allergen Der p 1 and Der f 1, cat allergen Fel d 1, and endotoxin were extracted and quantified. Parental educational level and family equivalent income were used independently as socioeconomic indicators. Indoor endotoxin, mite allergen Der p 1, and the amount of sampled dust were not associated with the social factors. Mite allergen Der f 1 was slightly associated by family SES but without a consistent pattern. In families who are not cat owners, however, a negative association between the amount of cat allergen and family SES were observed. The observed negative association between cat allergen loads and concentrations in mattress and family SES in non-cat owners' homes indicated that community is an important source of cat allergen exposure.

**C.-M. Chen^{1,2}, A. Mielck¹,
B. Fahlbusch³, W. Bischof⁴,
O. Herbarth⁵, M. Borte^{6,7},
H.-E. Wichmann^{1,2}, J. Heinrich¹**

¹GSF – National Research Centre for Environment and Health, Institute of Epidemiology, Neuherberg, Germany, ²Ludwig-Maximilians University of Munich, Institute of Medical Data Management, Biometrics and Epidemiology, Munich, Germany, ³Friedrich-Schiller-University of Jena, Institute of Clinical Immunology, Jena, Germany, ⁴Department of Indoor Climatology (ark), Institute of Occupational, Social and Environmental Medicine, Friedrich-Schiller-University of Jena, Jena, Germany, ⁵Department of Human Exposure Research and Epidemiology, UFZ-Centre for Environmental Research Leipzig, Leipzig, Germany, ⁶Klinik für Kinder- und Jugendmedizin, Städt. Klinikum "St.Georg" Leipzig, Akademisches Lehrkrankenhaus der Universität Leipzig, Leipzig, Germany, ⁷Department of Pediatrics, University of Leipzig, Leipzig, Germany

Key words: Allergic; Cat allergen; Endotoxin; Indoor; Mite allergen; Socioeconomic status.

Dr. Joachim Heinrich
GSF – National Research Centre for Environment and Health
Institute of Epidemiology
Ingolstaedter Landstrasse 1
D-85764 Neuherberg, Germany
Tel.: (49) 89 3187 4150
Fax: (49) 89 3187-3380
e-mail: joachim.heinrich@gsf.de

Received for review 23 August 2006. Accepted for publication 10 May 2007.
© Indoor Air (2007)

Practical Implications

The study indicated that community is a major source of cat allergen exposure especially in communities of low SES.

Introduction

Differences in prevalence of allergic sensitization between social groups have been reported (Almqvist et al., 2005; Bergmann et al., 2000; Heinrich et al., 1998; Lewis et al., 2001). Although the patterns of the association were not consistent between different study populations, the results indicate that environmental

factors which are highly associated with socioeconomic status (SES) have a strong effect on the development of allergic sensitization. On the other hand, indoor environmental exposure to bio-contaminants in settled house dust has been considered associated with allergic sensitization. For example, several cohort studies have shown that cat allergen exposure is a risk factor for the development of cat allergen specific sensitization in very

young children (Brussee et al., 2005; Lau et al., 2000). Cross-sectional studies have suggested that very high dose of cat allergen exposure protects children from allergic sensitization because it may induce modified immune responses (Hesselmar et al., 2003; Platts-Mills et al., 2001). Indoor endotoxin exposure in early life has been suggested to provide protection against the development of allergic sensitization (Williams et al., 2005). Finally, the amount of settled house dust was found to be associated with the quantity of endotoxin concentrations (Gehring et al., 2004a) and fungal components (Gehring et al., 2001), both of which were considered to be associated with allergic sensitization.

Studies have shown several determinants of the amount of indoor bio-contaminants. House dust mite allergen appear to vary by geographic locations and housing characteristics (Simpson et al., 2001). Cat allergen, however, is ubiquitous and persistently airborne (Almqvist et al., 1999; Bollinger et al., 1996; Ichikawa et al., 1999). Contact with pets, cleaning habits, and the number of persons living in the house are considered to be associated with the amount of indoor endotoxin (Bischof et al., 2002; Gehring et al., 2004b; Park et al., 2000). Socioeconomic conditions are also considered to affect the amount of some indoor bio-contaminants. Home characteristics, housing stock, cleaning habits, and pet ownership, which highly influence the amount of indoor allergen, are considered to vary between families in different socioeconomic categories. A recent study conducted in the greater Boston area in the USA showed that in the homes of asthmatic or allergic people, having mite allergen Der p 1 and Der f 1 concentration $< 10 \mu\text{g/g}$ was associated with low family income, less maternal education, and race/ethnicity (black or Hispanic vs. white). The study also showed that high amount of domestic cat allergen was associated with living in homes located in the low- or mid-poverty regions of a large metropolitan area (Kitch et al., 2000). In this particular article, we investigated the association between socioeconomic conditions and indoor bio-contaminants.

Method

Study population

The Influences of Lifestyle-related Factors on the Immune System and the Development of Allergies in Childhood Study is an on-going birth cohort study. The details of the study is provided elsewhere (Zutavern et al., 2006). Briefly, parents of neonates admitted in one of the six obstetrical clinics in Munich and all four obstetrical clinics in Leipzig Germany were contacted. A total of 2443 neonates who were born between December 1997 and December 1999 were recruited in the study. The study was approved by the

ethics committees of Bavarian General Medical Council and the University of Leipzig.

Questionnaire data

Information on parental educational level, housing characteristics, and family history of allergic disease were collected using self-administered questionnaires at birth and at 3 months of age of the cohort. Information on family equivalent income was collected when the children were 2-year old using self-administered questionnaires. The parental educational level and the family equivalent income were used independently as socioeconomic indicators in this paper. The parental educational level was categorized based on the German educational system, which takes both the highest completed grade in school and vocational training into account (Appendix) (Ahrens et al., 1998). In the analysis, the parental education level was defined as the higher education level from either parent. The family equivalent income was calculated by dividing the net household income per month, which was reported on an 11-point scale ranging from $< \text{€}500$ to more than $\text{€}3000$, by the equivalence scale that considers family size. The equivalence scale gives a weight of 1.0 to the first adult in the family, 0.5 to any other family members above 15, and 0.3 to family members below 14. The calculation was based on the new Organization for Economic Cooperation and Development (OECD) guidelines (Hauser, 1988). The families were categorized into tertiles based on their family equivalent income.

Collection and analysis of house dust

A total of 2166 (89%) families participated in the house dust collection when the cohort was 3-month old. Trained field workers carried out dust sampling based on a standardized operating procedure. Dust samples were taken from mothers' and infants' mattress by vacuuming 1 m^2 of the mattress surface for 2 min using vacuum cleaners equipped with special nozzles (ALK allergen mouthpiece, Hørsholm, Denmark). The samples were stored at -20°C until extraction to kill the mites and prevent bacteria growth. Major mite allergens Der p 1 and Der f 1 and cat allergen Fel d 1 were extracted using ELISA allergen assay. Endotoxin was quantified using the kinetic Limulus Amebocyte Lysate assay (BioWhittaker, Walkersville, MD, USA). The detection limits were 10 ng/g dust for mite allergens, 15 ng/g dust for cat allergen, and $50 \text{ endotoxin unit (EU)/g}$ dust for endotoxin. Samples with bio-contaminants below the detection limit were assigned half of the lower detection limit and the surface loads were calculated as the assigned values multiplying the amount of total dust mass sampled. The amounts of allergen and the endotoxin were expressed in both unit/gram dust and unit/ m^2 surface area.

Statistical analysis

The distribution of dust and bio-contaminants loads and concentrations were highly skewed, therefore, the amount of indoor dust, allergens, and endotoxin were described using median and quartiles. Non-parametric Spearman correlation coefficients were used to assess the correlations between different allergens, endotoxin, dust mass, and bio-contaminants from parents' and infants' bed. Non-parametric Kruskal–Wallis test was used to test if the amount of dust, allergens, and endotoxin vary between families of different SES. In the dust samples from infants' mattress, however, only 37% contained mite allergen Der p 1 loads and concentrations above the detection limit. Therefore, the amount of Der p 1 from infants' mattresses were categorized as detectable and non-detectable, and chi-squared test was performed to test the associations between the amount of allergen and family SES. To estimate the association between family SES and the amount of indoor dust and bio-contaminant, observed dust and bio-contaminant loads and concentrations were categorized into tertiles and ordinal logistic regression models adjusting for confounders were fitted. Potential confounders were selected based on literatures including season of sampling, study center, characteristics of the house, floor and mattress type, dampness of the house, heating system, crowdedness in children's room, pet, cleaning habit, and ventilation of the house. Confounders adjusted in the model were identified from the potential confounders using chi-squared tests. Variables, which were associated with both dependent and independent variables, were selected. Confounders adjusted for mite allergen (Der p 1 and Der f 1) models included season, study center, current signs of mold, parental history of allergic disease, and anti-allergen mattress cover. For cat allergen (Fel d 1) models, season, study center, cat ownership, and previous cat in the house were adjusted. Season, study center, current signs of mold, parental history of allergic disease, and previous cat in the house were adjusted for endotoxin models and season and study center were adjusted for dust models. The results were presented as odds ratios with 95% confidence intervals for each socioeconomic category.

The analyses were performed with SAS version 8 (SAS Institute Inc., Cary, North Carolina, USA).

Results

Dust samples from 2118 (98%) mothers' mattress and 2098 (97%) infants' mattress were available. For those infants who slept occasionally on their mother's bed or on their own bed, only the mattress the infants had very frequent contact with was sampled. Forty-seven percent ($n = 1001$) of the mother's mattresses had mite allergen Der p 1 below the detection limit, of which 68% were sampled in Munich and 32% in Leipzig. In each study center, there were more than 60% of the infants' mattresses had undetectable mite allergen Der p 1. The amounts of dust collected from the infants' mattresses were very low. The median load of the infants' mattresses dust samples was a quarter of the median dust load collected from the mothers' mattresses (Table 1). In general, there were no significant differences in the amounts of allergens in infants' mattress between the two study centers and the amount of endotoxin was slightly higher in the homes in Leipzig. For mother's mattress, there were higher amount of mite and cat allergens in both concentrations and surface loads in Leipzig (data not shown).

The correlation between bio-contaminant loads measured from mothers' and infants' mattresses were not strong, especially for mite allergens (Figure 1). The correlation coefficients between allergen concentrations from mothers' and infants' mattresses were almost identical to the correlation coefficients between allergen loads from mothers' and infants' mattresses reported in the figure ($r = 0.4$ for Der p 1, $r = 0.4$ for Der f 1, $r = 0.6$ for Fel d 1, and $r = 0.4$ for endotoxin). There were also no strong correlations between different bio-contaminants loads and generally very weak correlations between different bio-contaminants concentrations (Table 2). However, different bio-contaminant loads and concentrations in the dust collected from infants' mattresses were generally better correlated compared with those collected from mothers' mattresses.

Table 3 shows the distribution of socioeconomic groups of the study population. Comparing the two study centers, families in Munich generally had higher

Table 1 The amount of domestic allergen and endotoxin measured from mothers' and infants' mattress (median (25th and 75th percentile))

Sampling site	Der p 1 (nanogram)	Der f 1 (nanogram)	Fel d 1 (nanogram)	Endotoxin (endotoxin unit)	Total dust mass (mg/m ²)
Mothers' mattress					
Unit/gram dust	97.7 (5, 608.3)	634.1 (125.4, 3601.8)	180.2 (68.6, 820.5)	3008 (1045.5, 7913)	738.5 (453.0, 1166.0)
Unit/m ² dust	84.2 (3.4, 487.6)	428.8 (91.5, 2853.5)	130.9 (50.9, 696)	2071 (594.5, 6916)	
N (detectable %)	52.6%	79.6%	88.5%	100%	N = 2118
Infants' mattress					
Unit/gram dust	5.0 (5.0, 642.9)	525.1 (5.0, 2324.7)	326.0 (84.7, 1322.5)	5866 (2336, 14669)	188.0 (120.0, 289.0)
Unit/m ² dust	1.3 (0.7, 138.8)	106.8 (0.9, 509.6)	65.6 (16.6, 333.1)	1015 (330, 3022)	
N (detectable %)	37.1%	63.6%	77.5%	100%	N = 2098

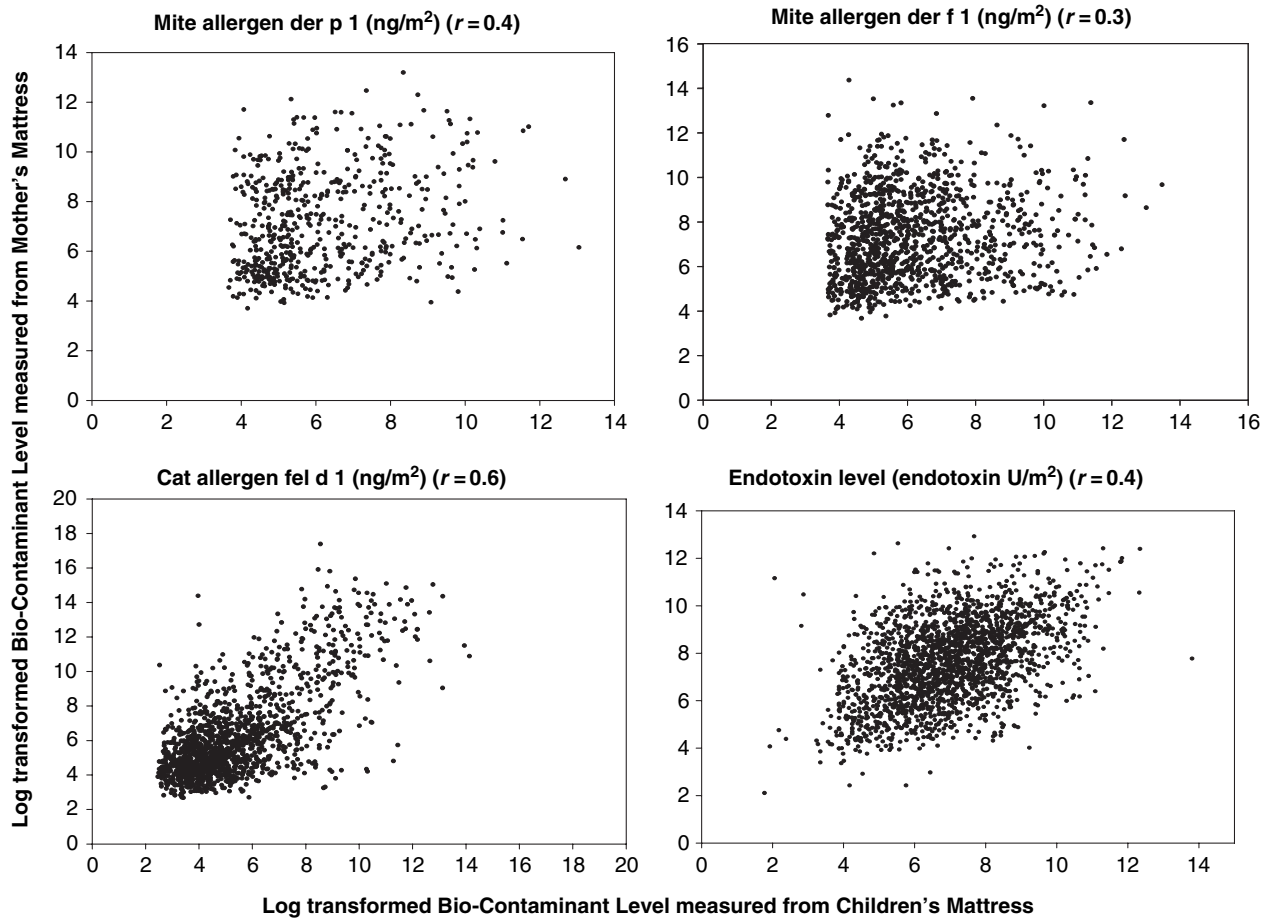


Fig. 1 Correlation between the log-transformed domestic bio-contaminants collected from mothers' and infants' mattress

Table 2 The correlation between the amount of bio-contaminants collected from both mothers' and infants' mattress

	Der p 1 (ng/m ²)	Der f 1 (ng/m ²)	Fel d 1 (ng/m ²)	Endotoxin (EU/m ²)	Total dust mass (mg/m ²)
Der p 1 (ng/m ²)		<i>0.62</i>	<i>0.41</i>	<i>0.46</i>	<i>0.70</i>
Der f 1 (ng/m ²)	0.45		<i>0.39</i>	<i>0.46</i>	<i>0.58</i>
Fel d1 (ng/m ²)	0.29	0.24		<i>0.36</i>	<i>0.48</i>
Endotoxin (EU/m ²)	0.37	0.34	0.35		<i>0.58</i>
Total dust mass (mg/m ²)	0.45	0.41	0.41	0.54	
	Der p 1 (ng/g)	Der f 1 (ng/g)	Fel d 1 (ng/g)	Endotoxin (EU/g)	Total dust mass (mg/g)
Der p 1 (ng/g)		<i>0.43</i>	<i>0.18</i>	<i>0.16</i>	<i>0.30</i>
Der f 1 (ng/g)	0.35		<i>0.20</i>	<i>0.23</i>	<i>0.33</i>
Fel d1 (ng/g)	0.13	0.11		<i>0.14</i>	<i>0.23</i>
Endotoxin (EU/g)	0.17	0.17	0.16		<i>0.19</i>
Total dust mass (mg/g)	0.12	0.16	0.11	0.16	

The numbers in italic format are correlation between the amount of bio-contaminants collected from infants' mattress and the numbers in normal format are correlation between the amount of bio-contaminants collected from mothers' mattress.

percentages of highly educated parents and higher income; however, the cost of living in Munich is also higher. Table 4 shows the housing characteristics and the family history of allergic disease of the study population. We stratified the data by study center and chi-squared test ($\alpha = 0.05$) showed that in Leipzig, higher percentages of the recruited families lived in flats, and the families were more likely to have a dog.

In Munich, higher percentages of the recruited families were using anti-allergen mattress cover, used to have a cat in their house and reported signs of mold. We also recruited fewer parents with a history of allergic disease in Leipzig than in Munich center. Comparisons between dust, allergen, and endotoxin loads and concentrations measured from families in different socioeconomic groups are listed in Table 5. It showed

Table 3 The socioeconomic level of the study population

	Munich <i>n</i> (%)	Leipzig <i>n</i> (%)	Total <i>n</i> (%)
Parental education level			
Very high	903 (67.0%)	356 (44.5%)	1259 (58.1%)
High	217 (16.1%)	168 (21.5%)	385 (18.8%)
Median	162 (12.0%)	237 (29.0%)	399 (18.4%)
Low	53 (4.9%)	43 (5.3%)	96 (4.4%)
Family equivalent income			
High	502 (37.2%)	86 (11.5%)	588 (27.1%)
Median	402 (30.8%)	173 (21.1%)	575 (27.5%)
Low	226 (17.8%)	383 (47.8%)	609 (28.1%)

that there was a steady decrease of the amount of cat allergen Fel d 1 on the mattress from families with lower SES to families with higher SES. After adjusting for confounders, the amount of cat allergen in both mothers' and infants' mattress dust were significantly negatively associated with the two independent socioeconomic indicators. For example, in homes of parents with very high education, the odds of having high cat allergen load (over 66th percentile of the overall cat allergen load from the study population) on their mattresses was 0.44 times smaller than having middle and low cat allergen load (<66th percentile of the overall cat allergen load from the study population).

Likewise, in homes of parents with very high education, the odds of having median and high cat allergen load (over 33rd percentile of the overall cat allergen load from the study population) on their mattresses vs. low cat allergen load (<33rd percentile of the overall cat allergen load from the study population) was 0.44 times smaller. Mite allergen Der f 1 on mothers' mattresses was also associated with family SES. However, the pattern of the association was not clear. The amount of endotoxin, mite allergen Der p 1, and dust sampled in both mothers' and infant's mattress dust had no associations with social factors (Table 6). Because of the unequal distributions of socioeconomic groups of the recruited families in Munich and Leipzig and the differences of the amount of allergens between the two centers, stratified analysis was performed. In each stratified group, there were no associations between family SES and mite allergen, endotoxin and dust mass loads and concentrations in mattresses. However, the effect estimates of the associations between the amount of mite allergen Der p 1 and family SES were slightly different. The effect estimates in the Munich subgroup were very close to unity, while the estimates in the Leipzig subgroup were tend to be bigger than one. The negative associations between the amount of cat allergen and family SES was detected in

Table 4 The housing characteristics and the family history of allergic disease of the study population

	<i>n/N</i> (%)		
	Munich, <i>N</i> = 1348 (62.2%)	Leipzig, <i>N</i> = 818 (37.8%)	Total, <i>N</i> = 2166
^a Number of people sharing children's room			
1	144/1348 (11%)	70/818 (9%)	214/2096 (10.2%)
≥ 2	812/1348 (60%)	591/818 (72%)	1403/2096 (66.9%)
^a Parents or siblings have a history of atopic disease	856/1348 (64%)	378/818 (46%)	1234/1560 (79.1%)
Season of sampling			
Spring (March–May)	327/1348 (24%)	182/818 (22%)	509/2164 (23.5%)
Summer (June–August)	308/1348 (23%)	229/818 (28%)	537/2164 (24.8%)
Autumn (September–November)	368/1348 (27%)	216/818 (26%)	584/2164 (27.0%)
Winter (December–February)	344/1348 (26%)	190/818 (23%)	534/2164 (24.7%)
^a House type			
Alone-standing house	280/1348 (21%)	66/818 (8%)	346/2151 (16.1%)
Not alone-standing one family house	210/1348 (16%)	39/818 (5%)	249/2151 (11.6%)
Flat	749/1348 (56%)	666/818 (81%)	1415/2151 (65.8%)
Multi-storage house	106/1348 (8%)	35/818 (4%)	141/2151 (6.5%)
^a Story of dwelling			
Ground floor	585/1348 (43%)	173/818 (21%)	758/2135 (35.5%)
First floor	321/1348 (24%)	170/818 (21%)	491/2135 (23.0%)
Second floor and higher	425/1348 (32%)	461/818 (56%)	886/2135 (41.5%)
^a Having a dog currently in the house	73/1348 (5%)	71/818 (9%)	144/2145 (6.71%)
Having a cat currently in the house	124/1348 (9%)	83/818 (10%)	207/2145 (9.65%)
^a Used to have a cat in the house	139/1348 (10%)	55/818 (7%)	194/2087 (9.3%)
^a Mattress cover against allergen	71/1348 (5%)	26/818 (3%)	97/2151 (4.5%)
Current signs of dampness	82/1348 (6%)	50/818 (6%)	132/2151 (6.1%)
^a Current signs of mold	408/1348 (30%)	189/818 (23%)	597/2151 (27.8%)
Water damage (past 12 months)	121/1348 (9%)	60/818 (7%)	181/2151 (8.4%)
^a Heating system			
Heating in the flat	169/1348 (13%)	118/818 (14%)	287/2151 (13.3%)
Central heating	1042/1348 (77%)	649/818 (79%)	1691/2151 (78.6%)
Both	135/1348 (10%)	38/818 (5%)	173/2151 (8.0%)

^aThe characteristic is statistically significantly different between the two study centers ($\alpha = 0.05$).

Table 5 The amount of domestic biocontaminants [median (25th and 75th percentile)] measured from mothers' and infants' mattress by family's socioeconomic levels, Kruskal–Wallis test/chi-squared test

Allergen	Sampling site (mattress) (unit)	Parental educational level				Family equivalent income			
		Low	Median	High	Very high	P-value	Low	Median	High
Der p 1	Mothers (ng/g)	5 (5, 295)	160 (5, 1175)	42 (5, 553)	96 (5, 547)	0.03	112 (5, 608)	146 (5, 857)	5 (5, 416)
	Mothers (ng/m ²)	13 (4, 301)	144 (3.4, 788)	46 (3, 427)	80 (3, 471)	0.14	116 (3, 485)	105 (4, 635)	9 (3, 299)
	Children (<i>n</i> detectable %)	34 (36.6%)	139 (35.6%)	125 (33.7%)	471 (38.8%)	0.30	228 (38.5%)	223 (40.3%)	193 (34.2%)
Der f 1	Mothers (ng/g)	387 (5, 2389)	492 (5, 3782)	513 (98, 2630)	819 (167, 3797)	<0.01	687 (126, 4050)	791 (171, 4281)	520 (101, 2831)
	Mothers (ng/m ²)	316 (13, 2495)	291 (9, 2583)	315 (68, 2260)	543 (122, 3081)	<0.01	434 (95, 3013)	512 (100, 3177)	401 (90, 2272)
	Children (ng/g)	436 (5, 2337)	362 (5, 2226)	457 (5, 2434)	610 (5, 2325)	0.07	546 (5, 2434)	613 (5, 2698)	478 (5, 1814)
	Children (ng/m ²)	115 (1, 399)	79 (1, 419)	95 (1, 471)	125 (1, 531)	0.08	105 (0.9, 510)	127 (1, 614)	102 (1, 398)
Fel d 1	Mothers (ng/g)	589 (144, 7566)	280 (95, 2203)	232 (77, 1522)	148 (59, 463)	<0.01	238 (80, 1571)	174 (72, 705)	131 (51, 441)
	Mothers (ng/m ²)	424 (86, 11280)	193 (63, 1663)	171 (60, 1048)	107 (46, 465)	<0.01	193 (593, 1467)	127 (49, 852)	101 (43, 445)
	Children (ng/g)	918 (239, 5363)	452 (116, 2883)	350 (52, 1640)	271 (64, 909)	<0.01	447 (92, 1639.9)	273 (58, 1134)	270 (91, 959)
	Children (ng/m ²)	174 (51, 1998)	89 (25, 573)	65 (15, 396)	56 (15, 221)	<0.01	79 (20, 410)	52 (13, 276)	60 (19, 239)
Endotoxin	Mothers (EU/g)	2841 (929, 6253)	2838 (1031, 7708)	2478 (926, 7531)	3151 (1110, 8591)	0.23	3090 (1032, 8332)	2970 (1041, 7293)	2797 (1020, 7563)
	Mothers (EU/m ²)	2096 (792, 7402)	1818 (623, 6393)	1715 (514, 6306)	2324 (594, 7368)	0.22	2016 (629, 7103)	1896 (585, 6522)	2070 (568, 6978)
	Children (EU/g)	5846 (2153, 15515)	6100 (2663, 13473)	5552 (2369, 14413)	5850 (2035, 15094)	0.83	6063 (2588, 14532)	5021 (1878, 12990)	5746 (1983, 15143)
	Children (EU/m ²)	1272 (345, 2959)	1010 (409, 3434)	1038 (318, 2821)	1023 (325, 3394)	0.85	1201 (357, 3573)	861 (320, 2713)	1043 (307, 3581)
Dust mass	Mothers (mg/m ²)	813 (503, 1185)	701 (450, 1108)	706 (427, 1171)	759 (460, 1172)	0.31	732 (464, 1192)	720 (428, 1094)	792 (471, 1166)
	Children (mg/m ²)	191 (109, 296)	190 (121, 290)	178 (115, 266)	190 (120, 301)	0.36	181 (122, 289)	187 (120, 285)	197 (118, 303)

both centers. However, because only 38% of the recruited families were from Leipzig, the power of detecting differences of the amount of allergen between socioeconomic groups is lower in this subgroup. The magnitudes of the effect estimates, however, were similar (data not shown).

In our study population, families of lower parental education were more likely to keep cats (20% in low parental educational families and 6% in high parental educational families). Further, sensitivity analysis showed that the observed negative associations between family SES and domestic cat allergen loads and concentrations were restricted to the families who are not current cat owners (Table 7). For the families who were cat owners at the time of dust sampling and those who used to have a cat in their house, we re-categorized the cat allergen loads and the concentrations based on the amount of cat allergen in each subgroup and performed the logistic regression analysis for each subgroup. The results showed that for those who used to have a cat in their house, the negative associations were less pronounced. In homes of current cat owners, the associations between the amount of cat allergen and families SES were not consistent.

Discussion

This study compared the amount of indoor bio-contaminants of families with different SES in Leipzig and Munich in Germany. We confirmed the negative association between the amount of indoor cat allergen and family SES, particularly in families who are not cat owners. We also found that mite allergen Der f 1 loads and concentrations vary between social categories but without a clear trend. The total amount of dust, endotoxin, and Der p 1 loads and concentrations in mattresses, however, do not vary between families of different social classes.

A few studies have explored the association between family socioeconomic conditions and the amount of domestic bio-contaminants, and the observed associations are not consistent. Recent US studies suggested that high group 1 mite allergen concentration (Der p 1 and Der f 1) is associated with homes in the low poverty area, with higher maternal education and higher household income (Kitch et al., 2000; Leaderer et al., 2002). The German Multicenter Allergy Study (MAS) Research Group observed that in their study population high mite allergen concentration in carpet dust is significantly more common in homes of low SES (Bergmann et al., 2000). However, the two smaller German studies, which have analyzed mite allergen Der p 1 and Der f 1 concentrations in mattress dust independently, have stated that there is a positive association between parental education level and Der f 1 but not Der p 1 concentration (Kramer et al., 2006;

Table 6 The associations between the amount of domestic allergen and the endotoxin measured from mothers' and infants' mattress and the family socioeconomic levels

Allergen	Sampling site	Unit	Parental education level [OR (CI) ^a]				Family equivalent income [OR (CI) ^a]		
			Low	Median	High	Very high	Low	Median	High
Der p 1	Mothers' mattress	ng/g	1.0	1.43 (0.83, 2.52)	1.17 (0.68, 2.04)	1.38 (0.83, 2.33)	1.0	1.22 (0.94, 1.59)	1.01 (0.76, 1.34)
		ng/m ²	1.0	1.36 (0.79, 2.39)	1.15 (0.66, 2.01)	1.36 (0.82, 2.3)	1.0	1.17 (0.9, 1.52)	1.02 (0.77, 1.36)
	Infants' mattress	ng/g	1.0	0.74 (0.42, 1.32)	0.79 (0.45, 1.41)	0.9 (0.54, 1.54)	1.0	1.01 (0.76, 1.33)	0.71 (0.53, 0.96)
		ng/m ²	1.0	0.74 (0.42, 1.32)	0.74 (0.42, 1.32)	0.86 (0.51, 1.47)	1.0	0.98 (0.74, 1.29)	0.7 (0.52, 0.95)
Der f 1	Mothers' mattress	ng/g	1.0	1.03 (0.61, 1.71)	0.95 (0.57, 1.58)	1.63 (1.02, 2.62)	1.0	1.29 (1, 1.67)	1.08 (0.83, 1.42)
		ng/m ²	1.0	0.85 (0.51, 1.44)	0.88 (0.52, 1.47)	1.51 (0.93, 2.44)	1.0	1.34 (1.03, 1.73)	1.28 (0.98, 1.68)
	Infants' mattress	ng/g	1.0	0.9 (0.53, 1.55)	1.04 (0.61, 1.78)	1.21 (0.74, 2)	1.0	1.06 (0.82, 1.38)	0.91 (0.69, 1.19)
		ng/m ²	1.0	0.93 (0.55, 1.58)	1.04 (0.62, 1.76)	1.21 (0.75, 1.99)	1.0	1.1 (0.85, 1.42)	0.93 (0.71, 1.22)
Fel d 1 ^b	Mothers' mattress	ng/g	1.0	0.56 (0.3, 1.03)	0.51 (0.27, 0.92)	0.38 (0.21, 0.67)	1.0	0.87 (0.66, 1.15)	0.6 (0.45, 0.81)
		ng/m ²	1.0	0.61 (0.33, 1.13)	0.58 (0.31, 1.05)	0.44 (0.25, 0.78)	1.0	0.77 (0.58, 1.01)	0.63 (0.47, 0.84)
	Infants' mattress	ng/g	1.0	0.66 (0.37, 1.17)	0.5 (0.28, 0.88)	0.44 (0.26, 0.75)	1.0	0.83 (0.63, 1.09)	0.81 (0.61, 1.08)
		ng/m ²	1.0	0.65 (0.36, 1.16)	0.51 (0.28, 0.9)	0.47 (0.27, 0.81)	1.0	0.83 (0.63, 1.09)	0.88 (0.66, 1.17)
Endotoxin ^c	Mothers' mattress	EU/g	1.0	1.24 (0.81, 1.9)	1.09 (0.71, 1.67)	1.27 (0.85, 1.91)	1.0	1.01 (0.81, 1.27)	0.94 (0.74, 1.19)
		EU/m ²	1.0	0.86 (0.56, 1.31)	0.82 (0.54, 1.26)	0.98 (0.66, 1.45)	1.0	0.9 (0.72, 1.13)	0.94 (0.74, 1.19)
	Infants' mattress	EU/g	1.0	0.97 (0.64, 1.49)	0.98 (0.64, 1.51)	1.00 (0.67, 1.50)	1.0	0.84 (0.67, 1.05)	0.97 (0.76, 1.23)
		EU/m ²	1.0	0.9 (0.6, 1.4)	0.8 (0.6, 1.3)	0.9 (0.6, 1.3)	1.0	0.91 (0.73, 1.13)	1.04 (0.82, 1.31)
Dust mass ^d	Mothers' mattress	mg/g	1.0	0.8 (0.52, 1.22)	0.8 (0.52, 1.22)	0.92 (0.62, 1.36)	1.0	0.95 (0.76, 1.18)	1.19 (0.94, 1.5)
		mg/m ²	1.0	1.17 (0.77, 1.76)	0.97 (0.64, 1.46)	1.13 (0.77, 1.66)	1.0	0.96 (0.77, 1.21)	1.07 (0.85, 1.36)

^aConfounders adjusted for mite allergen (Der p 1 and Der f 1) model: season, study center, current signs of mold, family history of allergic disease, and anti-allergen mattress cover.

^bConfounders adjusted for cat allergen (Fel d 1) model: season, study center, current cat owners, family history of allergic disease, and previous cat in the house.

^cConfounders adjusted for endotoxin model: season, study center, current signs of mold, and previous cat in the house.

^dConfounders adjusted for dust model: season and study center.

Table 7 The association between the amount of domestic cat allergen measured in mothers' and infants' mattress dust and the family socioeconomic levels stratified by the family cat ownership

Cat ownership	Sampling site	unit	Parental education level [OR (CI) ^a]				Family equivalent income [OR (CI) ^a]		
			Low	Median	High	Very high	Low	Median	High
Never ^b	Mothers' mattress	ng/g	1.0	0.56(0.29, 1.07)	0.53 (0.28, 1)	0.4 (0.22, 0.73)	1.0	0.98 (0.74, 1.31)	0.65 (0.48, 0.88)
		ng/m ²	1.0	0.64 (0.33, 1.22)	0.61 (0.32, 1.15)	0.49 (0.26, 0.89)	1.0	0.85 (0.64, 1.13)	0.68 (0.5, 0.91)
	Infants' mattress	ng/g	1.0	0.74 (0.4, 1.37)	0.54 (0.3, 1)	0.49 (0.28, 0.87)	1.0	0.9 (0.68, 1.19)	0.86 (0.64, 1.17)
		ng/m ²	1.0	0.78 (0.41, 1.45)	0.56 (0.3, 1.05)	0.54 (0.3, 0.97)	1.0	0.88 (0.66, 1.17)	0.9 (0.67, 1.21)
Current ^c	Mothers' mattress	ng/g	1.0	0.62 (0.17, 2.16)	0.75 (0.2, 2.74)	0.53 (0.16, 1.74)	1.0	1.42 (0.59, 3.46)	0.5 (0.2, 1.26)
		ng/m ²	1.0	0.37 (0.1, 1.35)	0.53 (0.13, 2.01)	0.51 (0.15, 1.73)	1.0	2.21 (0.91, 5.48)	1.25 (0.5, 3.15)
	Infants' mattress	ng/g	1.0	0.74 (0.19, 2.85)	1.46 (0.38, 5.67)	1.2 (0.34, 4.31)	1.0	1.43 (0.56, 3.66)	0.64 (0.24, 1.64)
		ng/m ²	1.0	0.68 (0.17, 2.68)	1.1 (0.27, 4.5)	0.85 (0.22, 3.16)	1.0	2.07 (0.8, 5.46)	0.51 (0.2, 1.29)
Used to have a cat in the house (not necessarily cat owners) ^c	Mothers' mattress	ng/g	1.0	0.18 (0.01, 1.7)	0.19 (0.01, 1.9)	0.09 (0, 0.72)	1.0	0.21 (0.07, 0.66)	0.22 (0.06, 0.72)
		ng/m ²	1.0	0.26 (0.01, 2.45)	0.2 (0.01, 2.04)	0.1 (0.01, 0.85)	1.0	0.13 (0.04, 0.42)	0.22 (0.06, 0.73)
	Infants' mattress	ng/g	1.0	0.16 (0.01, 1.57)	0.08 (0, 0.78)	0.07 (0, 0.57)	1.0	0.16 (0.05, 0.49)	0.25 (0.07, 0.81)
		ng/m ²	1.0	0.32 (0.03, 2.41)	0.26 (0.03, 2.03)	0.23 (0.03, 1.4)	1.0	0.29 (0.09, 0.84)	0.45 (0.14, 1.4)

^aConfounders adjusted: season, study center, and family history of allergic disease.

^bFamilies had no cat at the time of dust sampling and had no cat previously in their house.

^cBecause of the amount of cat allergen in the homes of current and past cat owners homes are generally very high. We could not perform the analysis using the original tertile categorization of the amount of allergen from the whole population. We therefore performed the analysis in the two subgroups with cat allergen loads and concentrations re-categorized into the tertiles based on the amount of allergen in each subgroup.

Kuehr et al., 1994). Elevated domestic cat allergen, on the other hand, is associated with white families in the US studies (Kitch et al., 2000; Leaderer et al., 2002), and low SES in the German MAS study and the Swedish cohort study in Stockholm and Uppsala (Almqvist et al., 2003; Bergmann et al., 2000). Finally, it was observed that the house dust endotoxin concentrations in homes of public health professionals and their neighbors are lower than samples from homes of low-income families in Denver, Colorado, USA (Gereda et al., 2001).

Similar to the recently published study in southern Germany (Kramer et al., 2006), we found no significant difference between mite allergen Der p 1 loads and concentrations in the mattress dust of families with different socioeconomic conditions, but higher Der f 1 loads and concentrations were found in families of a high educational level. A small number of studies have investigated the determinants of the amount of indoor Der f 1, and the observed potential risk factors are not consistent (Gross et al., 2000; Wickens et al., 2004). The report on the distribution and determinants of

house dust mite allergens in Europe suggested that families who are house occupants, who have bedrooms on the ground floor, never open windows in the winter, and who use old mattresses are in higher risk of high mattress Der f 1 exposure (Zock et al., 2006). In our study, higher proportions of highly educated, high-income families were house occupants with bedrooms on the ground floor. There were also significant associations between families of high SES and older age of mothers' mattress in our data (data not shown). Another study in the Asia-Pacific region suggested that the material of the mattress is a potential determinant of mite allergen Der f 1 concentration (Wickens et al., 2004). However, no information about the mattress material was collected in our study.

We confirmed that the amount of domestic cat allergen is lower in the socially advantaged families, which is in line with the observations described in other European studies (Almqvist et al., 2003; Bergmann et al., 2000). In our study population, families of lower parental education were more likely to keep cats. The analysis, however, showed that the families who are not cat owners mainly contributed to the negative association between the amount of indoor cat allergen and family SES. Cat allergen is ubiquitous and constantly airborne. Exposure to cat allergen is passive. The allergen can attach to the clothes of those people who have regular contact with cats, which facilitates it to be transferred to public places such as offices and schools (Almqvist et al., 1999; Bollinger et al., 1996; Ichikawa et al., 1999). There, through direct contact with cat owners or by catching cat allergen in the air, the clothes of those who do not have cats at home are contaminated, and cat allergen is spread in homes without cats. Living in a district of communities with high numbers of cat owners can therefore increase the amount of cat allergen at home.

Our study population was selected from Munich and Leipzig with very high percentages of families with highly educated parents. Furthermore, it is common for epidemiological studies that only a few families of extremely high- or low-social classes agree to participate. Therefore, the study was under representative to the true difference of the amount of domestic bio-contaminants and dust across families of different SES. The recruitment process and using self-administered questionnaires for collecting baseline information may have also caused higher refusal rate from the families of extreme socioeconomic conditions.

The impacts of the two socioeconomic factors are likely to vary across the populations with time. In our study population, the minimum age of the fathers was 19 years old, 26% of the families of both parents under 30 years old. It should be taken into account that these younger parents in our study population may still in the process of education or professional training, which indicates high educational but low or median income

level. Our study investigated the association between SES conditions and the amount of domestic bio-contaminants and dust only at one point in time. It cannot be considered as the reflection of lifelong impact of SES on the environmental influence on health.

In the study population, 47% ($n = 1001$) of the mother's mattresses dust samples had mite allergen Der p 1 concentration below the detection limit, of which 68% were sampled in Munich and 32% in Leipzig. Two-third of the non-detectable samples were from Munich. This might be due to the very low temperature in winter in Munich which makes it more difficult for mite allergen Der p 1 to survive (Gehring et al., 2005; Zock et al., 2006). The mean temperatures in January and February 1997 in Munich were -4.3°C and 3.5°C respectively comparing with -2.7°C and 4.5°C in Leipzig. The mean temperatures in January and February 1998 in Munich were 0.7°C and 2.7°C respectively comparing with 3.1°C and 5.2°C in Leipzig [<http://www.dwd.de> (accessed 9 November, 2006)]. Furthermore, in our study, we have mainly recruited young families, who have just moved in with new mattresses. It has been reported by the European Community Respiratory Health Survey (ECRHS) that mattress age is positively associated with the amount of mite allergen in the mattress dust (Zock et al., 2006). We compared the age of the mattresses between our study in Leipzig and ECRHS in Erfurt. In our study, 24% of the mothers' mattresses were < 1 year old and only 7% were over 9 years old. In the ECRHS Erfurt samples, only 7% of the mattresses were < 1 year old and 37% were over 9 years old. On the other hand, in the Munich study population, 19% of the parents' mattresses were < 1 year old and 44% were between 2 and 5 years old. Therefore, we could conclude that because of the young families we have recruited in our study who have relatively new mattresses, we had higher percentages of non-detectable mite allergen Der p 1 in the mattress dust even with a relatively low detection limit.

In our study, the amount of bio-contaminant and dust were measured only from mothers' and infants' mattresses, which cannot represent the overall domestic allergen exposure. As indoor bio-contaminants are often ubiquitously distributed throughout accommodations, reservoirs of mite allergens includes carpet and soft furnishings (Tovey et al., 1981). Cat allergen and endotoxin, on the other hand, is consistently airborne (Murray et al., 2001). Therefore, there may be wider differences between the amounts of bio-contaminant in families with different SES levels than observed in our study.

The advantage of this study was that the dust samples were collected from both mothers' and child's mattress. The analysis showed that the correlations between bio-contaminant from the two sampling sites were poor. Infants' mattresses appeared to contain less amount of

dust and the amounts of bio-contaminant in the dust were very low. This implied that when measuring childhood indoor bio-contaminants exposure, it is necessary to collect settled house dust samples from both mother and child's mattress. We also individually analyzed mite allergens Der p 1 and Der f 1 and found different associations between the two mite allergens and social class while most of the studies used the sum of Der p 1 and Der f 1 as Der 1 group for analysis (Bergmann et al., 2000; Kitch et al., 2000; Smith and Hart, 1998).

In conclusion, the study shows that mite allergen Der f 1 loads and concentrations vary between social

categories but without a clear trend, domestic cat allergen levels were higher in the homes of lower socioeconomic groups, particularly for those families who are not cat owners. Total amount of dust, endotoxin, and Der p 1 loads and concentrations were similarly distributed between families of different social classes. However, further investigations on the effect of unequally distributed cat allergen between different socioeconomic groups on the prevalence of allergic sensitization are in need.

References

- Ahrens, W., Bellach, B.M. and Joeckel, K.H. (1998) *Messung soziodemographischer Merkmale in der Epidemiologie*. RKI-Schriften. MMV Medizin Verlag, Munich.
- Almqvist, C., Egmar, A.C., Hage-Hamsten, M., Berglund, N., Pershagen, G., Nordvall, S.L., Svartengren, M., Hedlin, G. and Wickman, M. (2003) Heredity, pet ownership, and confounding control in a population-based birth cohort, *J. Allergy Clin. Immunol.*, **111**, 800–806.
- Almqvist, C., Larsson, P.H., Egmar, A.C., Hedren, M., Malmberg, P. and Wickman, M. (1999) School as a risk environment for children allergic to cats and a site for transfer of cat allergen to homes, *J. Allergy Clin. Immunol.*, **103**, 1012–1017.
- Almqvist, C., Pershagen, G. and Wickman, M. (2005) Low socioeconomic status as a risk factor for asthma, rhinitis and sensitization at 4 years in a birth cohort, *Clin. Exp. Allergy*, **35**, 612–618.
- Bergmann, R.L., Edenharter, G., Bergmann, K.E., Lau, S. and Wahn, U. (2000) Socioeconomic status is a risk factor for allergy in parents but not in their children, *Clin. Exp. Allergy*, **30**, 1740–1745.
- Bischof, W., Koch, A., Gehring, U., Fahlbusch, B., Wichmann, H.E. and Heinrich, J. (2002) Predictors of high endotoxin concentrations in the settled dust of German homes, *Indoor Air*, **12**, 2–9.
- Bollinger, M.E., Eggleston, P.A., Flanagan, E. and Wood, R.A. (1996) Cat antigen in homes with and without cats may induce allergic symptoms, *J. Allergy Clin. Immunol.*, **97**, 907–914.
- Brussee, J.E., Smit, H.A., Van Strien, R.T., Corver, K., Kerkhof, M., Wijga, A.H., Aalberse, R.C., Postma, D., Gerritsen, J., Grobbee, D.E., de Jongste, J.C. and Brunekreef, B. (2005) Allergen exposure in infancy and the development of sensitization, wheeze, and asthma at 4 years, *J. Allergy Clin. Immunol.*, **115**, 946–952.
- Gehring, U., Douwes, J., Doekes, G., Koch, A., Bischof, W., Fahlbusch, B., Richter, K., Wichmann, H.E. and Heinrich, J. (2001) Beta(1-3)-glucan in house dust of German homes: housing characteristics, occupant behavior, and relations with endotoxins, allergens, and molds, *Environ. Health Perspect.*, **109**, 139–144.
- Gehring, U., Bischof, W., Borte, M., Herbarth, O., Wichmann, H.E. and Heinrich, J. (2004a) Levels and predictors of endotoxin in mattress dust samples from East and West German homes, *Indoor Air*, **14**, 284–292.
- Gehring, U., Bischof, W., Borte, M., Herbarth, O., Wichmann, H.E. and Heinrich, J. (2004b) Levels and predictors of endotoxin in mattress dust samples from East and West German homes, *Indoor Air*, **14**, 284–292.
- Gehring, U., Brunekreef, B., Fahlbusch, B., Wichmann, H.E. and Heinrich, J. (2005) Are house dust mite allergen levels influenced by cold winter weather?, *Allergy*, **60**, 1079–1082.
- Gereda, J.E., Klinnert, M.D., Price, M.R., Leung, D.Y. and Liu, A.H. (2001) Metropolitan home living conditions associated with indoor endotoxin levels, *J. Allergy Clin. Immunol.*, **107**, 790–796.
- Gross, I., Heinrich, J., Fahlbusch, B., Jäger, L., Bischof, W. and Wichmann, H.E. (2000) Indoor determinants of Der p 1 and Der f 1 concentrations in house dust are different, *Clin. Exp. Allergy*, **30**, 376–382.
- Hauser R. (1988) *Adequacy and Poverty Among the Retired*, Organization for Economic Cooperation and Development, Paris.
- Heinrich, J., Popescu, M.A., Wjst, M., Goldstein, I.F. and Wichmann, H.E. (1998) Atopy in children and parental social class, *Am. J. Public Health*, **88**, 1319–1324.
- Hesselmar, B., Aberg, B., Eriksson, B., Björkstén, B. and Aberg, N. (2003) High-dose exposure to cat is associated with clinical tolerance – a modified Th2 immune response?, *Clin. Exp. Allergy*, **33**, 1681–1685.
- Ichikawa, K., Iwasaki, E., Baba, M. and Chapman, M.D. (1999) High prevalence of sensitization to cat allergen among Japanese children with asthma, living without cats, *Clin. Exp. Allergy*, **29**, 754–761.
- Kitch, B.T., Chew, G., Burge, H.A., Muihlenberg, M.L., Weiss, S.T., Platts-Mills, T.A., O'Connor, G. and Gold, D.R. (2000) Socioeconomic predictors of high allergen levels in homes in the greater Boston area, *Environ. Health Perspect.*, **108**, 301–307.
- Kramer, U., Lemmen, C., Bartusel, C., Link, E., Ring, J., Behrendt, H., (2006) Current eczema in children is related to Der f 1 exposure but not to Der p 1 exposure, *Br. J. Dermatol.*, **154**, 99–105.
- Kuehr, J., Frischer, T., Karmaus, W., Meinert, R., Barth, R., Schraub, S., Daschner, A., Urbanek, R. and Forster, J. (1994) Natural variation in mite antigen density in house dust and relationship to residential factors, *Clin. Exp. Allergy*, **24**, 229–237.
- Lau, S., Illi, S., Sommerfeld, C., Niggemann, B., Bergmann, R., von Mutius, E. and Wahn, U. (2000) Early exposure to house-dust mite and cat allergens and development of childhood asthma: a cohort study. Multicentre Allergy Study Group, *Lancet*, **356**, 1392–1397.
- Leaderer, B.P., Belanger, K., Triche, E., Holford, T., Gold, D.R., Kim, Y., Jankun, T., Ren, P., McSharry, J.E., Platts-Mills, T.A., Chapman, M.D. and Bracken, M.B. (2002) Dust mite, cockroach, cat, and dog allergen concentrations in homes of asthmatic children in the northeastern United States: impact of socioeconomic factors and population density, *Environ. Health Perspect.*, **110**, 419–425.
- Lewis, S.A., Weiss, S.T., Platts-Mills, T.A., Syring, M. and Gold, D.R. (2001) Association of specific allergen sensitization with socioeconomic factors and allergic disease in a population of Boston women, *J. Allergy Clin. Immunol.*, **107**, 615–622.

- Murray, C.S., Woodcock, A. and Custovic, A. (2001) The role of indoor allergen exposure in the development of sensitization and asthma, *Curr. Opin. Allergy Clin. Immunol.*, **1**, 407–412.
- Park, J.H., Spiegelman, D.L., Burge, H.A., Gold, D.R., Chew, G.L. and Milton, D.K. (2000) Longitudinal study of dust and airborne endotoxin in the home, *Environ. Health Perspect.*, **108**, 1023–1028.
- Platts-Mills, T., Vaughan, J., Squillace, S., Woodfolk, J. and Sporik, R. (2001) Sensitisation, asthma, and a modified Th2 response in children exposed to cat allergen: a population-based cross-sectional study, *Lancet*, **357**, 752–756.
- Simpson, A., Woodcock, A. and Custovic, A. (2001) Housing characteristics and mite allergen levels: to humidity and beyond, *Clin. Exp. Allergy*, **31**, 803–805.
- Smith, G.D. and Hart, C. (1998) Socioeconomic factors and determinants of mortality, *JAMA*, **280**, 1744–1745.
- Tovey, E.R., Chapman, M.D., Wells, C.W. and Platts-Mills, T.A. (1981) The distribution of dust mite allergen in the houses of patients with asthma, *Am. Rev. Respir. Dis.*, **124**, 630–635.
- Wickens, K., de Bruyne, J., Calvo, M., Choon-Kook, S., Jayaraj, G., Lai, C.K., Lane, J., Maheshwari, R., Mallol, J., Nishima, S., Purdie, G., Siebers, R., Sukumaran, T., Trakultivakorn, M. and Crane, J. (2004) The determinants of dust mite allergen and its relationship to the prevalence of symptoms of asthma in the Asia-Pacific region, *Pediatr. Allergy Immunol.*, **15**, 55–61.
- Williams, L.K., Ownby, D.R., Maliarik, M.J. and Johnson, C.C. (2005) The role of endotoxin and its receptors in allergic disease, *Ann. Allergy Asthma Immunol.*, **94**, 323–332.
- Zock, J.P., Heinrich, J., Verlato, G., Norbaeck, D., Plana, E., Sunyer, J., Chinn, S., Olivieri, M., Soon, A., Villani, S., Ponzio, M., Dahlman-Hoglund, A., Svanes, C. and Luczynska, C. (2006) Distribution and determinants of house dust mite allergens in Europe: The European Community Respiratory Health Survey II, *J. Allergy Clin. Immunol.*, **118**, 682–690.
- Zutavern, A., Brockow, I., Schaaf, B., Bolte, G., von Berg, A., Diez, U., Borte, M., Herbarth, O., Wichmann, H.E. and Heinrich, J. (2006) Timing of solid food introduction in relation to atopic dermatitis and atopic sensitization: results from a prospective birth cohort study, *Pediatrics*, **117**, 401–411.

Appendix

Table 1 Index of the parental educational level based on the German education and vocational training system

Vocational training	School education				
	No graduation (kein Abschluss)	Primary (Hauptschule)	Secondary (Mittlere Reife)	Tertiary: low (FH-Reife)	Tertiary: high (Abitur)
No graduation [(noch) kein Abschluss]	1	2	3	5	6
Graduation at the worksite (beruflich-betrieblich)	3	3	4	5	6
Graduation at a basic school (beruflich-schulisch)	3	3	4	5	6
Graduation at a master school (Meisterschule)	4	4	5	6	6
Graduation at a college (Fachhochschule)	–	7	7	7	7
Graduation at a university (Universität)	–	8	8	8	8
Other graduation (anderer Abschluss)	3	3	4	5	7

Categories of parental education level are: (i) very high index 7 or 8; (ii) high index 5 or 6; (iii) middle index 4; and (iv) low index 1–3.