Asthma among secondary schoolchildren in relation to the school environment

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Summary

Background Poor indoor air quality has been suggested to be related to the increase in the prevalence of asthma that has occurred in the western world, especially among children and young persons. Apart from the home, school is the most important indoor environment for children.

Objectives The aims were to study the prevalence of current asthma among secondary pupils and its relationship to the school environment, but also to personal factors and domestic exposures.

Methods Data on asthmatic symptoms, other health aspects, and domestic exposures were gathered using a questionnaire which was sent to 762 pupils in the seventh form (13–14 years old) in 11 randomly chosen schools in the county of Uppsala in Sweden. Pupils answering 'yes' to having had asthma diagnosed by a physician, and having had recent asthma attacks, or who used asthma medication were defined as having current asthma. Data on exposures at school were gathered by measurements in 28 classrooms. The relationship between asthma and exposures was analysed by multiple logistic regression.

Results The questionnaire was completed by 627 (82%). Current asthma was found among 40 pupils (6.4%). Current asthma was more common in those who had an atopic disposition, or food allergy, or who had attended a day care centre for several years. Controlling for these factors, current asthma was related to several factors in the school environment. There were more pupils with current asthma in schools that were larger, had more open shelves, lower room temperature, higher relative air humidity, higher concentrations of formaldehyde or other volatile organic compounds, viable moulds or bacteria or more cat allergen in the settled dust.

Conclusions Although the pupils attended school for a minor part of their time, our study indicates that the quality of the school environment is of importance and may affect asthmatic symptoms.

Keywords: asthma, secondary school pupils, school environment, shelf factor, micro-organisms, cat allergen

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Introduction

In the last few decades the prevalence of asthma has increased in the western world, especially among children and young persons [1,2]. A number of causes have been proposed for this increase including changes in the standard of living, fewer infections during early childhood, exposure to cigarette smoke and other irritants and allergens outdoors and indoors [1,3–6], damp housing and the presence of moulds in the home [7]. Despite this, the aetiology of asthma is still not sufficiently well understood.

Apart from the home, school is the most important indoor environment for children aged 6–16 and there is growing concern in Sweden about the impact on health of the school environment. Poor indoor air quality in schools may be

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related to the increase in allergic conditions [8] but few studies have been published on this subject. Although pets are not supposed to be present at school, pet owners carry pet dander in their hair and clothes and it has been shown that the amount of pet allergen in Swedish schools is high enough to cause symptoms in children with asthma [9]. Pulmonary function was impaired and lower respiratory symptoms exacerbated among personnel working in a school in which micro-organisms were found to be growing [10]. Other studies have shown that the air exchange rate is low, resulting in high concentrations of carbon dioxide (CO_2) and that the concentrations of both airborne and dustbound fungi are higher in classrooms than in offices [11,12]. Pollution from materials in the classroom and from the ventilation system, in mechanically ventilated schools, contributed more to the perceived pollution level than the occupants [13]. Finally, exposure to volatile organic compounds and fleecy materials in classrooms was related to an increase in complaints about health and poor indoor air quality among school personnel [14,15].

Most studies on the school environment do not deal with asthmatic symptoms, however, and most studies relating asthmatic symptoms to the environment deal with the domestic environment, not that of schools.

In the Swedish School Environment Project we have undertaken a number of studies of asthmatic and sick building symptoms among school personnel and pupils and have related these to the school environment. In this paper we present results concerning asthmatic symptoms among secondary schoolchildren in the seventh form (13–14 years old). The aims of the study were: to study the prevalence of asthmatic symptoms among 7th form pupils; and to relate these symptoms to the school environment, personal factors and domestic exposures.

As a working hypothesis it was assumed that asthmatic symptoms were related to different characteristics of the school building, the fittings and furniture, pollutants in the classroom air, psychosocial factors in the school environment and personal factors and exposures in the home.

Material and methods

The study population

In Sweden there are nine forms in the compulsory school system and the vast majority of Swedish children attend state schools. In the county of Uppsala in 1992 there were ≈ 130 such schools of which 39 were randomly chosen for our studies. Of these 39, 11 were secondary schools (i.e. comprising the three highest forms). The headmasters of the secondary schools were asked if they wished their school to participate and all agreed to do so. Two of the schools were in Uppsala (117 000 inhabitants), one in the town of Enköping (19 000 inhabitants) and the others in minor communities; each school had between 350 and 600 pupils. For each school, three classes in the seventh form were randomly chosen, except for one where there only were two classes in this form.

Information from the pupils

Recording of symptoms was made by means of a standardized self-administered questionnaire mailed in January/February 1993 to the 762 pupils in the chosen classes at their home address.

The questionnaire contained a number of questions relating to asthmatic symptoms slightly amended from those in the questionnaire used in the European Community Respiratory health survey [16]. Thus, questions concerning persistent cough, wheeze or shortness of breath during the past 12 months were replaced by those asking about recurrent symptoms. For our analysis, however, it was important to identify those pupils who currently had asthma and exclude those with past symptoms only. We defined current asthma in a pupil if he or she reported that they had ever had asthma diagnosed by a physician, and also gave a positive response to at least one of the questions concerning the current use of asthmatic drugs, having had asthmatic attacks, attacks of shortness of breath at night or after exercise during the past 12 months, or recurrent symptoms during the time that they had attended the present school.

The questionnaire also requested information on concurrent diseases and symptoms, including number of respiratory infections during the past 3 months, on the composition of the family, smoking habits, and included some questions about domestic exposures such as environmental tobacco smoke and dampness in the home as well as day-care centre attendance during early childhood. There were also questions on three different aspects of the psychosocial environment at school; general satisfaction, stress, and degree of co-operation. Each of these questions consisted of an analogue rating scale of 10 cm length, measuring from 0 (minimum of the psychosocial condition) to 1 (maximum), where the subjects could freely mark their answer at will. These scales had been used previously [14].

Assessment of exposure

During the spring of 1993 exposure measurements were performed in the schools. In each school we chose 2–3 classrooms used frequently by the selected classes and located in the different buildings; a total of 28 classrooms was investigated. Trained occupational hygienists inspected the buildings and noted details of their construction, building materials, equipment such as type of ventilation system, room size and presence of open shelves and fabrics, smells and signs of damp in the structure. As in the Danish Town Hall study [17], we calculated the shelf factor (length of open shelves in relation to room volume) and fleece factor (m^2 of fabrics in relation to room volume) and the cleaning staff were asked about the cleaning routines.

In each classroom we measured the air exchange rate, the temperature, relative humidity and the levels of respirable dust, CO_2, formaldehyde, the sum of volatile organic compounds (VOC), moulds, bacteria, nitrogen dioxide (NO_2) in the air, and the concentrations of endotoxin and cat, dog and mite allergens in the settled dust.

Room temperature and air humidity were recorded with an Assman psychrometer. Respirable dust and CO_2 were recorded by direct reading instruments (Sibata P-5H2 and Riken RI 411-A), respectively. The Sibata was calibrated at the factory (Sibata Scientific Technology Ltd) and the Riken in our department. Temperature, humidity, dust and CO_2 were measured twice in each classroom, the dust and CO_2 as average values during the last 15 min of the lessons.

Formaldehyde concentrations were measured with glass fibre filters impregnated with 2,4-dinitro-phenylhydrazine using a pump and a sampling rate of 0.2 L/min for 4 h. The filters were analysed by liquid chromatography. VOC were sampled on beaded charcoal sorbent tubes (SKC Anasorb 747) with the same sampling rate and time as for formaldehyde. The charcoal tubes were desorbed with one ml of carbon disulphide and analysed by gas chromatography and mass spectrometry. Fourteen common VOC were identified and quantified using external standard techniques and selective ion monitoring (SIM). VOC were also sampled by a charcoal diffusion sampler (ORSA 5) placed in the classroom for 6–7 days. The charcoal was desorbed with two mL of carbon disulphide and then analysed in the same way as the pumped samples. Airborne micro-organisms were sampled on 25 mm nucleopore filters with a pore size of 0.4 μm and a sampling rate of 1.5 L/min for 4 h. The total concentration of airborne micro-organisms was determined through epifluorescence microscopy [18]. Viable moulds and bacteria were determined by incubation on two different media. The detection limit of viable organisms was 30 colony forming units (cfu) per m^3 of air. The sampling was stationary with the tubes and filters placed at about 0.9 m above the floor. NO_2 was sampled with a passive sampling badge obtained from Toyo Roshi Kaisha Ltd, Tokyo, Japan, also placed in the classroom for 6–7 days and then analysed by liquid chromatography using an overall mass transfer coefficient of 0.10 cm/s [19].

Settled dust was collected from desks, chairs and floor by a 400 W vacuum cleaner provided with a special dust collector from ALK Laboratories, Copenhagen, containing a Millipore filter (pore size 6 μm). After passing through a sieve containing a filter with a porosity of 300 μm, the amount of fine dust was determined by weighing the filters. Cat (Fel d 1) and dog (Can f 1) allergens were quantified with an enzyme-linked immunosorbent assay using monoclonal antibodies [9]. The content of the major mite allergens in the dust was also determined by enzyme immunoassay [20] and by the semiquantative Acarex test [21]. Endotoxin was analysed using the Limulus Amebocyte Lysate test [22].

General and local air exchange rates were measured by a tracer gas decay method using acetone as the tracer gas [23]. Based on the air exchange rate and the room volume the supply air rate was calculated.

The measurements were made during normal schooldays and under representative conditions. If the windows were usually kept open during lessons, they were also kept open when these measurements were made. When measuring the rate of air exchange, however, the windows and doors were all closed.

Statistical methods

Analysis of the relationships between asthmatic symptoms, questionnaire data and measured exposures were undertaken with multivariate methods. Multiple logistic regression analysis was performed in several steps using the SPIDA statistical package [24]. Regression diagnostics available in the SPIDA package were used to test for collinearity.

As a first step, all the questionnaire data were forced into the model. Non-significant factors were excluded in the second step and in the third, all the school exposure variables were forced into the model one by one. For the total number of moulds and bacteria logarithmic transformations of the raw data were used. All significant school exposure factors were continuous variables so the estimated odds ratios depended on how the exposures were entered into the model and the units of these variables. This should be handled by choosing any reasonable value that give a clear indication of how the risk of the outcome changes with the variable [25]. We chose to calculate the odds ratios for changes of the exposure variables by multiples of 1, 10, 100 or 1000, dependent on the range of the measured values. For instance, the range of the measured levels of viable moulds in the different schools was 100–4500 cfu/m^3, and we chose to calculate the odds ratio for each increase of viable moulds by 1000 cfu/m^3. The range of the relative humidity was 22–61%, and we calculated the odds ratio for each increase of the relative humidity by 10%.

In order to detect non-linear exposure–response relationships, the relation to current asthma was analysed for each degree of room temperature and litre of supply air/person.

Relations between different exposure variables were analysed by linear regression. In all the statistical analyses, two tailed tests and a significance level of 5% were used.

Table 1. Personal factors, domestic exposures and other characteristics of 627 pupils aged 13–14 years

	n	%
Gender, girls	327	52
boys	300	48
Atopy*	212	34
Hay fever	61	10
Pet allergy	60	10
Childhood eczema	159	25
Food allergy	37	6
Smoker	17	3
Size of household, 2–3 persons	131	22
4 persons	222	37
5 persons	166	28
6–8 persons	79	13
Day care centre attendance, never	367	59
< 1 year	23	4
1–3 year	90	14
> 3 year	140	23
Home built after 1974	310	50
Detached/semi detached domestic house	483	77
Wall to wall carpet at home	192	31
Repainting indoors past year	179	29
Damp at home	76	12
Environmental tobacco smoke at home	253	41
Furry pets or cage birds	399	64

* Having hay fever, pet allergy and/or childhood eczema.

Table 2. Prevalence of asthmatic symptoms among 627 secondary school pupils aged 13–14 years

	n	%
Recurrent episodes with persistent cough	60	9.6
Recurrent episodes with persistent wheeze	28	4.5
Recurrent episodes with shortness of breath	38	6.1
Ever had asthma	50	8.0
Ever had asthma diagnosed by a physician	48	7.7
Asthmatic attack during the past 12 months	19	3.0
Current use of asthma medication	25	4.0
Shortness of breath after excercise during the past 12 months	33	5.3
Nocturnal shortness of breath during the past 12 months	11	1.8
Current asthma*	40	6.4

* Ever had asthma diagnosed by a physician plus current use of asthma medication or having had recent asthmatic symptoms.

Results

Questionnaire data

Of the 762 subjects, 627 (82%) completed and returned the questionnaires; the response rate was higher among girls than boys, 86 vs 79%.

Data on personal factors and domestic exposures are given in Table 1. Atopy, defined as a positive response to having had childhood eczema, hay fever or pet allergy, was reported by 34% of the subjects. Eczema alone was reported by 18%. The most common food allergies were to oranges, tomatoes, shrimps, nuts, eggs and chocolate. Mean number of respiratory infections during the past 3 months was 1, with 9% of the pupils reporting at least three infections. Almost all of the 3% who were smokers smoked one to seven cigarettes daily. About 40% of the subjects had older siblings. Cats were the most common pets, followed by dogs, while different kinds of rodent and cage birds were kept by a small number of subjects. Among those having signs of damp in the home, leaks of water were the most common cause. Mould in the home was reported by 5%. On the analogue rating scale concerning psychosocial work environment at school, general satisfaction with school was rated as 0.73, stress at school as 0.37 and the degree of co-operation as 0.68.

The answers to the different questions on asthmatic symptoms are given in Table 2. Having ever had asthma diagnosed by a physician was reported by 48 (7.7%) of subjects. Of these, eight had had no symptoms since they started at their present school and did not use medication so we regarded them as having past symptoms only. Current asthma was thus considered to be reported by 40 pupils (6.4%). About half of these had their first asthma attack after they had started school. There was no difference in the prevalence of asthma as between boys and girls; among those with current asthma 19 were boys and 21 were girls.

Building characteristics

The mean age of the school buildings was 30 years; the oldest was built in 1925 and the newest in 1981. The number of employees was used as a measure of the size of the school; the mean being 75 with a range from 50 to 99. All the schools were built of stone with two or three storeys; half had a cellar. Mechanical supply and exhaust air systems, without air cooling or humidification, were found in 20 classrooms, while four had a mechanical exhaust system only and four had natural ventilation. The mean air exchange rate in the classrooms was 6.9 L/s p, with a range from 0.1 to 19.0 L/s p. The lowest air exchange rate was in buildings with natural ventilation, but several of the mechanically ventilated rooms also had a low air exchange rate. All the classrooms had hard floor coverings, mostly of PVC or linoleum. In four classrooms there were visible

Table 3. Exposures in 28 secondary school classrooms

Exposure factor	Arithmetic mean	Minimum –Maximum
Temperature (°C)	24.0	21.0–27.5
Relative humidity (%)	37	22–61
Carbon dioxide (ppm)	910	550–1725
Formaldehyde ($\mu g/m^3$)	<5	<5–10.
VOC, sampled by pump ($\mu g/m^3$)*	23	5–60
VOC, sampled by diffusion ($\mu g/m^3$)*	26	4–93
Nitrogen dioxide ($\mu g/m^3$)	5	2–9
Respirable dust ($\mu g/m^3$)	14	6–29
Total number of bacteria ($10^3/m^3$)	38	8–110
Number of viable bacteria ($10^3/m^3$)	0.3	0.1–1.1
Total number of moulds ($10^3/m^3$)	33	8–170
Number of viable moulds ($10^3/m^3$)	0.4	0.1–4.5
Settled dust (mg/classroom)	66	18–107
Cat allergen (ng/g fine dust)	131	<16–391
Dog allergen (ng/g fine dust)	921	<60–3990
Endotoxin (ng/g) dust)	3	2–5

* Sum of 14 identified VOC.

signs of damp. None of the schools had kerosene heating or any other sources of indoor combustion. The mean shelf factor was 0.03, and the mean fleece factor, 0.05. In about 70% of the schools the floors were cleaned once a day with a moistened mop, while 30% were cleaned every second day. The desks were usually wiped once a week. In nearly half the schools there were no routines for washing the curtains, while in the others they were usually washed once a year.

Exposure measurements

The data relating to the various exposures at the schools are given in Table 3. The mean room temperature was 24.0°C and in aproximately a quarter of the measurements the temperature was 25°C or more. The concentration of CO_2 was above 1000 ppm in 29% of the measurements. In two-thirds of the classrooms the concentration of formaldehyde was below the detection limit of 5 $\mu g/m^3$. By both sampling methods toluene, *n*-decane and *n*-undecane were among the VOC with the highest concentrations. Among the compounds with the highest concentration also were limonene, when sampled by pump, and xylene and δ-carene, when sampled by diffusion. The highest concentrations of NO_2 were found in schools in the city of Uppsala. The most common micro-organisms were *Cladosporium*, and *Penicillium* which were found in 68 and 54% of the classrooms, respectively, but a large proportion of the moulds could not be identified. Allergens (Der p 1 and Der f 1) from house dust mites were not found in any of the schools using monoclonal antibodies, but the Acarex method showed the presence of mites in three classrooms. Cat and dog allergens were found in all the schools but one.

Table 4. Personal factors significantly related to current asthma among 627 secondary school pupils. Multiple logistic regression

Factor	Odds Ratio	CI (95%)	*P*-value
Atopy*	3.5	1.6–7.4	0.001
Food allergy	5.3	2.2–12.7	<0.001
Day-care centre >3 years	1.4	1.1–1.9	0.006

* Having hay fever, pet allergy and/or childhood eczema. CI, confidence intervals.

Current asthma in relation to personal factors and domestic exposure

Current asthma was more common among pupils who had an atopic disposition, food allergy or who had attended a day care centre for more than 3 years during childhood (Table 4). There were no significant relations between current asthma and gender, allergy towards nickel, number of recent respiratory infections, proneness to infection as a child, number of persons in the home, number of older siblings, smoking habits, type or age of domestic house, passive smoking in the home, having pets, recent repainting, signs of damp or wall-to-wall carpets at home, or psychosocial environment at school.

Current asthma in relation to the school environment

Current asthma was more common among pupils who attended larger schools or were in classrooms with a higher shelf factor, lower room temperature, higher relative humidity or higher concentrations in the classroom air of formaldehyde, VOC sampled by diffusion, viable bacteria or moulds or more cat allergen in settled dust (Table 5). Using the collinearity diagnostics in the SPIDA package it was detected that several of the factors were correlated to each other and it was not possible to keep all these factors in the statistical model at the same time. Thus, for most exposures it was not possible to control for size of the school, except for viable moulds and bacteria where we then found a borderline significance (*P*-values 0.06 and 0.07, respectively). The shelf factor always remained significant when tested with the other exposure factors one at a time. No significant relations were found between current asthma and age of the school building, type of ventilation system, air exchange rate, CO_2, visible signs of building dampness, fleece factor, respirable dust, settled dust, total moulds, total

Table 5. School exposures significantly related to current asthma among 627 secondary school pupils. Multiple logistic regression, controlling for personal factors

Factor	Odds Ratio	CI (95%)	*P*-value
Size of school	1.6*	1.2–2.1	0.001
Shelf factor	1.4	1.2–1.6	<0.001
Room temperature	0.6	0.4–0.8	0.003
Relative humidity	1.8†	1.1–2.8	0.014
Formaldehyde	1.1	1.01–1.2	0.042
Volatile organic compounds	1.3‡	1.1–1.5	<0.001
Viable bacteria	1.4§	1.1–1.8	0.010
Viable moulds	1.5‖	1.2–1.9	<0.001
Cat allergen	1.8¶	1.3–2.4	0.001

* Odds ratio expressed as change of coefficient per 10 employees; † Odds ratio expressed as change of coefficient per 10%; ‡ Odds ratio expressed as change of coefficient per 10 $\mu g/m^3$; § Odds ratio expressed as change of coefficient per 100 organisms/m^3; ‖ Odds ratio expressed as change of coefficient per 1000 organisms/m^3; ¶ Odds ratio expressed as change of coefficient per 100 ng/g fine dust.

bacteria, VOC sampled by pump, NO_2, endotoxin or dog allergen.

Discussion

We found that current asthma among secondary school children was related to several characteristics, and exposures in the school environment.

In this study the subjects attended randomly chosen classes in randomly selected schools and the response rate was 82% but there were more boys among the non-reponders. Asthma has been reported to be more common among boys [26], but this may be true only for pre-school children and may not apply to teenage children [27]. If the boys had responsed at the same rate as the girls, 21 more would have answered the questionnaire but this would not have affected the results of the study in any decisive way.

The occurrence of asthmatic symptoms was determined from the responses to a questionnaire sent directly to the pupils' home and addressed to the pupils. We do not know if the pupils have responded all by themselves or the extent of the parents' contribution. However, considering the characters of Swedish teenagers, we think that the possible influence of the parents would not affect the answers in a uniform way. Symptom questionnaires have previously been validated in children of the same age group as in our study. A postal questionnare plus a video tape displaying the different symptoms resulted in a lower prevalence of asthmatic symptoms compared with questionnaire only [28] suggesting that there may have been some overreporting of symptoms in our study. However, by restricting the definition of the outcome variable not only to having had recent symptoms, but also to a diagnosis of asthma by a physician, we have increased the specificity. The exposure measurements were all carried out by professional occupational hygienists after the questionnaires had been answered. Thus, there should be no serious recall bias regarding symptom reporting or exposure.

When performing a number of statistical tests, there is the risk of mass significance. However, we analysed the exposure variables with different definitions of the outcome variable, and all gave similar results, except for pupils reporting shortness of breath after exercise only. (In the study comparing postal questionnaires with and without video tapes, the greatest discrepancy between the answers concerned exercise induced shortness of breath [28].) Thus, we consider that the study has sufficient internal validity and that the results are not seriously biased.

Current asthma was related to reported atopy (hay fever, pet allergy and childhood eczema) and food allergy as reported in other studies [29]. Current asthma was also related to having attended a day care centre for several years. More lower respiratory tract disease or wheezing bronchitis has been reported in children who attend day care centres [30] but we have no reports to suggest that this may result in asthma during adolescence. In our study none of the socioeconomic factors that were related to day care centre attendance were related to current asthma but since only 16 pupils with current asthma had attended day care centres for several years, the relationship between current asthma and day care may be a chance effect.

Exposure to tobacco smoke in the home was not related to current asthma but since we do not know the prevalence of exposure when the subjects were small, it is possible that passive smoking may have had an impact on the development of asthma in some children. Current asthma was not related to damp in the home. Most studies reporting a relation between asthma and damp in the home have dealt with a constantly high air humididy resulting in the growth of mould and the occurrence of mites. In this study, only 5% of the subjects reported the presence of mould, and the air humidity and prevalence of mites are low at our northern latitude so these factors may not be equally important as in many other countries.

Current asthma was related to several factors in the school environment. Many of these were interrelated but each significant exposure factor seems to have some biological relevance for the proposed effect. In Table 5 odds ratios for the significant exposures are given for specified values of change of the exposure variable, but other changes of the size of the exposure variable would result in other odds ratios. If we calculate the odds ratios of having current asthma if attending the school with the highest exposure compared to the lowest, the odds ratios would, e.g. be 20 for viable bacteria, 11 for the shelf factor and 10 for cat allergen. This indicates that there is also a dose–response relationship between current asthma and the signifiant school exposures.

Pupils with current asthma were more prevalent in larger schools. The number of contacts with other people should be higher in a larger school. In this study, reported number of recent respiratory infections was not significantly related to the size of the school, in contrast to the levels of pet allergen and pollution. One explanation could be that in a larger school there are more people bringing pet allergen to the school. The size of the school may thus not be regarded as a causative factor, but the results reflect that there were different exposure patterns in schools of different sizes. There were more open shelves in the larger schools. Open shelves were strongly related to higher concentrations of VOC, viable moulds and cat allergen. Thus, our results support the assumption that open shelves act as reservoirs for dust which may contain different kinds of allergens and pollution [31]. There were more pupils with current asthma in schools with lower room temperature or higher relative humidity and asthmatics have been shown to be impaired in cold and humid conditions [32].

Current asthma was more frequent among pupils exposed to higher levels of formaldehyde or diffusion sampled volatile organic compounds in school. Low concentrations of VOC can influence lung function and may act as bronchial irritants [33]. In a study relating formaldehyde concentration in the home to daily measurements of peak expiratory flow rate (PEF), the variability of PEF were higher among children living in houses with higher levels of formaldehyde [34]. Moreover, asthmatic symptoms were more common among subjects living in homes with higher concentrations of formaldehyde or VOC [35]. Although the levels of formaldehyde and VOC in the schools were low, it seems that sensitive individuals may still be affected. Only VOC sampled by diffusion, and not VOC sampled by a pump, were related to current asthma. In this study diffusion sampling gave the average concentration of VOC during 1 week, while active sampling was performed during 4 h of a school-day. These two methods measure somewhat different emissions. VOC sampled by pump during the school-day more reflect the emissions from the subjects, while diffusion sampled VOC are more related to exposures from the building, since the subjects are present for only a minor part of the sampling time. The significant relation between diffusion sampled VOC and current asthma thus stresses the importance of the building.

We found higher concentrations of viable bacteria or moulds in schools where more pupils reported current asthma and exposure to dampness and indoor moulds may be a risk factor for respiratory symptoms. The biological mechanisms that have been proposed include type 1 allergy, and inflammatory reactions involving endotoxin and glucans [36]. In a Swedish study, fungal allergy was found among 41% of asthmatic children, and of all children with fungal allergy 86% had asthma [37]. Moreover, concentrations of moulds and bacteria were found to be higher in the homes of adults with asthma-related symptoms [38]. In schools indoor microorganisms come from both indoor and outdoor sources.

Current asthma was more common among pupils attending schools with higher levels of cat allergen. It has previously been shown that the amount of cat allergen is high enough to cause asthmatic symptoms in children sensitized to cats [9]. Since there was more cat allergen in schools with a greater number of open shelves and since normal cleaning has little effect on the amount of cat allergen [39], measures to prevent asthma in school children should include minimizing the amount of fittings and fixtures which attract and retain dust.

We found no significant association between current asthma and the level of nitrogen dioxide, type of ventilation system or air exhange rate in school. In Sweden, exposure to NO_2 is low since there are seldom any indoor combustion sources. Also, earlier studies have concerned exposure to NO_2 at home or outdoors. The Swedish ventilation standards of 1000 ppm CO_2 and 7 L/s p supply air were not reached in 64% of the classrooms. Further analysis of the different exposures that had a significant relationship with asthma showed that these exposures were often associated with different ventilation characteristics. The aetiological relationship between current asthma and exposures in the school environment is not readily apparent, and is probably related to a number of different factors in the different kinds of school.

Conclusions

Although children attend school only a minor part of their time, asthma symptoms are enhanced by the school environment. The school that should be recommended to sensitive individuals should be small, the classrooms should be furnished so that dust-binding fittings are minimized, the air exchange rate should be according to standards, and the school must be maintained and cleaned so that moisture damage is avoided and allergen burden minimized.

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