

# Irritants and Allergens at School in Relation to Furnishings and Cleaning

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**Abstract** In order to study the influence of furnishings and cleaning on the indoor air quality at school, 181 randomly chosen classrooms were investigated. The amounts of open shelves, textiles and other fittings were noted, data were gathered on cleaning routines, and a number of pollutants were measured in the classrooms. In classrooms with more fabrics there was more settled dust and the concentration of formaldehyde was higher. Classrooms with more open shelves had more formaldehyde, and more pet allergens in settled dust, and classrooms with a white board, instead of a chalk board, were less dusty. Classrooms mainly cleaned through wet mopping had more airborne viable bacteria but less settled dust than classrooms mainly cleaned by dry methods. In rooms where the desks and curtains were more often cleaned, the concentrations of cat and dog allergen in settled dust were lower. It is concluded that furnishings and textiles in the classroom act as significant reservoirs of irritants and allergens and have an impact on the indoor air quality at school.

**Key words** Cat allergen; Classrooms; Dog allergen; Dust; Formaldehyde; Micro-organisms

## Practical Implications

Furnishings and textiles act as reservoirs of irritants and allergens and are of importance for the indoor air quality at school. The amount of such fittings should be minimised. Cleaning could be helpful in reducing the concentration of allergen. In schools without textile flooring, it would seem important to improve the cleaning of furniture and fabrics.

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## Introduction

In recent years the prevalence of allergies and asthma in the industrialised world has increased, especially in children and young persons. As a consequence, increasing interest has been paid to exposure to allergens

and irritants in the indoor environment. Apart from the home, school is the most important indoor environment for children and there is increasing concern about the school environment and its impact on health. Several studies have shown that in school buildings the air exchange rate is often low, the concentration of carbon dioxide (CO<sub>2</sub>) high and the ventilation standards not fulfilled (Ruotsalainen et al., 1995; Smedje et al., 1997a; Willers et al., 1996). Furthermore, the concentrations of dust and airborne and dust-bound micro-organisms are often elevated (Dybendal and Elsayed, 1994; Levetin et al., 1995). Recently, the presence of pet dander has gained increased attention, and several studies have been focused on the transfer route and identification of the fittings in which the particles are deposited (Patchett et al., 1997; Berge et al., 1998; Perzanowski et al., 1999; Almqvist et al. 1999). It has been shown that indoor dust contains different allergens and irritants (Gyntelberg et al., 1994), and that fabrics, in carpets, curtains and upholstered seats, constitute reservoirs and sinks for such particles and compounds (Custovic et al., 1996; van der Wal et al., 1998). The classroom fittings could act both as direct and indirect sources of different particles and compounds. In an earlier study we found that among secondary school children, asthma was more common in those attending schools with more open shelves in the classrooms (Smedje et al., 1997b). Further, in a study on school employees, more nasal obstruction was found in those working in schools with more settled dust; and the nasal patency was lower and the levels of inflammatory biomarkers in nasal lavage fluid higher in persons working in schools with a lower frequency of cleaning (Wållinder et al., 1999). Despite the recent focus on the indoor environment in schools, information is sparse concerning the relationships between furnishings and cleaning in

schools, and the exposure levels of different pollutants, including allergens.

Within the frame of the Swedish School Environment Project, we have studied 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 the concentrations of irritants and allergens measured in classrooms, in relation to some possible indoor sources. The aims of the study were:

- to measure the concentrations of formaldehyde, volatile organic compounds (VOC), micro-organisms, dust, and cat and dog allergens in classrooms, and
- to relate these pollutants to the furnishings and the cleaning routines.

As a working hypothesis it was assumed that the concentrations of pollutants would be higher in classrooms with more open shelves and fabrics, and lower in classrooms more often cleaned.

## Material and Methods

### The School Buildings

In 1992 we randomly selected 39 out of the approximately 130 primary schools and lower secondary schools in the county of Uppsala in the center of Sweden, and investigated a total of 98 classrooms during March–May 1993. The following year, we also chose all nine upper secondary schools in the county and in these, 33 classrooms were investigated during January–March. Finally, in 1995 we investigated an additional 50 classrooms in the 39 primary and lower secondary schools during January–March. In total, 181 randomly chosen classrooms, situated in 57 buildings in 48 schools, were investigated. Depending on the size of the school, 2–5 classrooms were randomly chosen in each school. Each classroom was investigated once, during one school day. The schools varied in respect to factors such as year of construction, type of construction, and size.

Occupational hygienists, experienced in building related problems and indoor air quality, inspected the buildings and noted details of their construction, building materials, equipment such as type of ventilation system, presence of open shelves, fabrics and potted plants, smells, and signs of dampness in the construction. In accordance with the procedure introduced in the Danish Town Hall study (Skov et al., 1990) we calculated the shelf factor (length of open shelves in relation to room volume) and fleece factor ( $\text{m}^2$  of fabrics in relation to room volume). The cleaning staff were asked about the cleaning routines. The air exchange rate was measured with a tracer gas decay method, using acetone as the tracer gas (Anundi et al., 1992).

Data on pet ownership were obtained through a questionnaire study, which was conducted in parallel with this study, and in which 2,410 (85%) randomly selected pupils participated.

### Measurements of Pollutants

Room temperature, relative humidity, and the concentrations of respirable dust,  $\text{CO}_2$ , formaldehyde and other VOC, moulds and bacteria were measured in each classroom. In 1993 and 1994 we also measured cat and dog allergens in settled dust.

Room temperature and air humidity were recorded by an Assman psychrometer (Sato Keiryoki MFG. Co. Ltd, Japan). Respirable dust and  $\text{CO}_2$  were recorded by direct reading instruments (Sibata P-5H2, Sibata Scientific Technology Ltd., Tokyo, Japan and Riken RI 411-A, Riken Keiki Co. Ltd, Tokyo, Japan, respectively). The Sibata was calibrated at the factory and the Riken at our department. Temperature, air humidity and respirable dust were measured twice in each classroom; the dust and  $\text{CO}_2$  measured as average values during the last 15 min of the lessons, and the mean of the two measurements was calculated.

Formaldehyde was measured with glass fibre filters impregnated with 2,4-dinitro-phenylhydrazine, at a sampling rate of 0.2 l/min, for 4 h. The filters were analysed by liquid chromatography. Other 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 1 ml of carbon disulphide, and analysed on a gas chromatograph (Hewlett Packard 5880A) equipped with a packed non-polar column and a flame ionisation detector (FID) (Norbäck et al., 1990). The total concentration of VOC between the peaks of benzene ( $\text{C}_6$ ) and n-dodecane ( $\text{C}_{12}$ ) was calculated, assuming the same response rate as for n-decane (decane equivalents) for all compounds. Airborne micro-organisms were sampled on 25-mm nucleopore filters with a pore size of 0.4  $\mu\text{m}$  for 4 h at a sampling rate of 1.5 l/min. The total concentrations of airborne moulds and bacteria were determined by the CAMNEA method (Palmgren et al., 1986). Viable moulds and bacteria were identified and their amounts determined by incubation on two different media. The detection limit of viable organisms was 30 colony forming units (cfu) per  $\text{m}^3$  of air.

Settled dust was collected by a 400-W vacuum cleaner provided with a special dust collector from ALK Laboratories (Copenhagen, Denmark) containing a Millipore filter (pore size 6  $\mu\text{m}$ ). Each classroom was vacuumed for 4 min, equally divided between desks, chairs and floor. After the dust had passed through a sieve containing a filter with a porosity of 300  $\mu\text{m}$ , the amount of fine dust was determined by weighing the filters. Cat (Fel d 1) and dog (Can f 1) allergens were quantified through sandwich ELISA, using monoclonal antibodies (Munir et al., 1993).

For each day of measurement, the season (winter, spring or summer) was recorded on the basis of the outdoor temperature, presence of snow on the ground and day of the year. Winter was defined as a temperature below  $0^\circ\text{C}$  and snow on the ground, spring as a temperature above  $0^\circ\text{C}$  but not  $10^\circ\text{C}$  and no snow, and summer as a temperature above  $10^\circ\text{C}$ . Single days diverging from the characteristics of the period were recorded as being in the same season as adjacent days.

### Statistical Analysis

Possible relations between the pollutants and the season, air exchange rate, fittings in the classroom, and cleaning routines were analysed by bivariate statistical methods and multiple regression. Bivariate analyses of differences between groups were performed using the Mann Whitney

U test. For analyses of differences between factors having at least ordinal scales, the nonparametric Kendall's  $\tau$  correlation test was used.

Season and air exchange rate were found to be important predictors of measured pollutants, and relations between the independent variables (furnishings and cleaning routines) and the pollutants were also analysed through multiple linear regression, with adjustment for these factors. When analysing relations to dog and cat allergens, we also took into account the percentages of dog and cat owners among the pupils. Relations between pollutants and cleaning of floors, desks and fabrics, were first analysed for one such cleaning factor at a time, and finally with all three cleaning factors in the statistical model. Logarithmic values of cat and dog allergens were used to obtain normally distributed residuals in the regression models.

In all analyses, two-tailed tests and a significance level of 5% were used.

## Results

### Characteristics of the Buildings and Classrooms

Data on building and classroom characteristics are given in Table 1. More than half of the buildings were constructed between 1940 and 1974; these usually had 2–3 storeys, and a basement and were built of stone materials. Eighteen per cent of the buildings had an "old style" and were built before 1940. These buildings were also 2–3 storeys high, and had a basement, and most of them were of stone materials, but there were also a few wooden buildings. Originally, these buildings had had a natural ventilation system, but in several cases a mechanical ventilation system had been installed later. A total of 28% of the buildings were constructed after 1975 and in accordance with "new" energy saving standards. These buildings usually had one storey and no basement, and were built mainly of wood.

Of the classrooms, 80% had mechanical and 20% had natural ventilation. The mean air flow rate was 5.7 l/s person, with a range from 0.2–34 l/s p. The mean concentration of CO<sub>2</sub> was below 1,000 ppm, but the Swedish ventilation standard demanding a supply air flow of approximately 8 l/s per person and a concentration of CO<sub>2</sub> below 1,000 ppm (AFS, 1993) was not fulfilled in 40% of the classrooms.

**Table 1** Building characteristics and fittings of the 181 classrooms

|                                                 | geometric<br>mean | gsd <sup>†</sup> | min–max   |
|-------------------------------------------------|-------------------|------------------|-----------|
| Year of construction                            | 1959              | 1.0              | 1848–1992 |
| Classroom area (m <sup>2</sup> )                | 59                | 1.2              | 36–193    |
| Classroom volume (m <sup>3</sup> )              | 178               | 1.2              | 114–440   |
| Air exchange rate (ac/h) <sup>‡</sup>           | 2.6               | 2.9              | 0.1–9.8   |
| Fleece factor (m <sup>2</sup> /m <sup>3</sup> ) | 0.05              | 2.0              | 0–0.24    |
| Shelf factor (m/m <sup>3</sup> )                | 0.03              | 2.0              | 0–0.14    |

<sup>†</sup>gsd: geometric standard deviation

<sup>‡</sup>ac/h: air changes per hour

**Table 2** Cleaning routines in the 181 classrooms

|                                             | % of classrooms |
|---------------------------------------------|-----------------|
| Cleaning of floors                          |                 |
| every weekday                               | 72              |
| every second weekday                        | 28              |
| Only dry mopping of floors                  | 48              |
| Mainly dry mopping of floors                | 21              |
| Only wet mopping of floors                  | 18              |
| Mainly wet mopping of floors                | 0               |
| Equally often dry and wet mopping of floors | 13              |
| Wiping furniture                            |                 |
| every weekday                               | 19              |
| every second weekday                        | 19              |
| once a week                                 | 54              |
| never                                       | 8               |
| Washing curtains                            |                 |
| never                                       | 60              |
| once a year                                 | 38              |
| >once a year                                | 2               |

In 52% of the classrooms the floors were covered with carpets of PVC, and in 45% with linoleum. The rest had wooden floors. There were no textile wall-to-wall carpets in any classroom. In the lower forms the indoor environment was more "cosy", with more potted plants and higher shelf and fleece factors than were found in the secondary schools. There was a traditional dark board for chalk in 81% of the classrooms, but in 16% there was a white board for pens. In 3% there was no board at all. In all the schools with a white board, special pens emitting only small amounts of VOC were used.

Data on cleaning routines are given in Table 2. Dry or only slightly moist mopping of floors was more common than wet mopping. Desks, shelves and other furniture were usually wiped once a week, but there was a range from never to every weekday. In more than half of the schools there were no routines for cleaning curtains and other fabrics.

### Pollutants in the Classrooms

Data on pollutants in the classrooms are given in Table 3. The most common micro-organisms in the classrooms were *Cladosporium spp.* and *Penicillium spp.*, which were found in 42 and 36% of the classrooms, respectively. Yeast, *Pseudomonas sp.*, *Streptomyces sp.* and *Aspergillus spp.* were found in 14, 11, 9 and 8% of the classrooms. Dog allergen was found in all schools but two, as was cat allergen. In one of the 48 schools, neither dog nor cat allergen was found. The mean proportions of pupils keeping a dog or cat at home were 23 and 32%, respectively. In schools where a higher percentage of the pupils kept a cat at home, the amount of cat allergen at school was higher. In schools where more than 32% were cat owners, the geometric mean of the amount of cat allergen in settled dust was

173 ng/g, compared to 140 ng/g in schools with few cat owners. Multiple linear regression analysis yielded a partial regression correlation coefficient (b) of 25 ng/g per 20% increase in the percentage of cat owners ( $P=0.006$ ). There was no significant relation between percentage of dog owners and concentration of dog allergen in settled dust at school.

### Pollutants in Relation to Classroom Fittings

Through the bivariate analyses, we found that in classrooms with more open shelves or more textiles, the concentration of formaldehyde was higher and in classrooms with more fabrics there was also more settled dust (Table 4). Although the concentration of formaldehyde was low in most classrooms, it was about 1.5 times more common not to have any detectable formaldehyde among the classrooms with a shelf or fleece factor below, compared to above, the median (Table 5). In classrooms with a low fleece factor the geometric mean amount of settled dust was 72% of that in classrooms with more fabrics. Classrooms equipped with a white board had less settled dust as well as less respirable airborne dust than those equipped with a board for chalk ( $P=0.006$

and  $P=0.002$ , respectively). The geometric mean of amount of settled dust in classrooms with a white board was 50 mg/sample, compared to 85 mg/sample in classrooms with a chalk board. The corresponding concentrations of respirable dust were 12 and 15  $\mu\text{g}/\text{m}^3$ . There was no significant difference in the concentration of VOC in classrooms in relation to the type of board (geometric mean white board 20  $\mu\text{g}/\text{m}^3$ , chalk board 24  $\mu\text{g}/\text{m}^3$ ).

After adjustments for season and air exchange rate and, when relevant, pet ownership, the significant relations between classroom fittings and pollutants found in the bivariate analyses persisted (Table 6). In addition, we found that in classrooms with more open shelves the concentrations of cat and dog allergens in settled dust were higher. As seen from the partial correlation coefficient (b), an increase, for example, in the fleece factor by 0.1  $\text{m}^2/\text{m}^3$  was related to an increase in settled dust by 26 mg/sample, and in formaldehyde by 4  $\mu\text{g}/\text{m}^3$ .

### Pollutants in Relation to Cleaning Routines

In the bivariate analyses (Table 4), we found that in classrooms where dry mopping of floors was mainly

**Table 3** Pollutants in the 181 classrooms

|                                                                      | geometric mean | gsd <sup>†</sup> | min-max       |
|----------------------------------------------------------------------|----------------|------------------|---------------|
| Respirable dust ( $\mu\text{g}/\text{m}^3$ )                         | 15             | 1.5              | 6–45          |
| Viable bacteria (cfu/ $\text{m}^3$ )                                 | 360            | 2.8              | 50–18,000     |
| Total bacteria (no./ $\text{m}^3$ )                                  | 22,800         | 2.8              | 2,500–734,000 |
| Viable moulds (cfu/ $\text{m}^3$ )                                   | 200            | 2.4              | 30–4 500      |
| Total moulds (no./ $\text{m}^3$ )                                    | 17,600         | 2.3              | 2,500–360,000 |
| Formaldehyde ( $\mu\text{g}/\text{m}^3$ )                            | 3              | 3.5              | <3–72         |
| Volatile organic compounds ( $\mu\text{g}/\text{m}^3$ ) <sup>‡</sup> | 54             | 2.5              | 7–646         |
| Settled dust (mg/sample)                                             | 73             | 1.9              | 13–205        |
| Dog allergen (ng/g dust)                                             | 375            | 4.1              | <100–3,990    |
| Cat allergen (ng/g dust)                                             | 108            | 3.1              | <15–391       |

<sup>†</sup>gsd: geometric standard deviation

<sup>‡</sup>Total concentration of volatile organic compounds  $\text{C}_6\text{--C}_{12}$

**Table 4** Classroom fittings and cleaning in relation to pollutants<sup>†</sup>

|                                           | Pollutants                                    | Correlation coefficient | P-value |
|-------------------------------------------|-----------------------------------------------|-------------------------|---------|
| Fittings                                  |                                               |                         |         |
| Fleece factor ( $\text{m}^2/\text{m}^3$ ) | Settled dust (mg/sample)                      | 0.104                   | 0.048   |
| Fleece factor ( $\text{m}^2/\text{m}^3$ ) | Formaldehyde ( $\mu\text{g}/\text{m}^3$ )     | 0.230                   | <0.001  |
| Shelf factor ( $\text{m}/\text{m}^3$ )    | Formaldehyde ( $\mu\text{g}/\text{m}^3$ )     | 0.248                   | <0.001  |
| Cleaning routines                         |                                               |                         |         |
| Dry mopping (times/week)                  | Settled dust (mg/sample)                      | 0.218                   | 0.008   |
| Wet mopping (times/week)                  | VOC ( $\mu\text{g}/\text{m}^3$ ) <sup>‡</sup> | 0.116                   | 0.050   |
| Wet mopping (times/week)                  | Viable bacteria (cfu/ $\text{m}^3$ )          | 0.239                   | <0.001  |
| Wet mopping (times/week)                  | Cat allergen (ng/g dust)                      | –0.389                  | <0.001  |
| Wet mopping (times/week)                  | Dog allergen (ng/g dust)                      | –0.313                  | <0.001  |
| Curtain washing (times/year)              | Cat allergen (ng/g dust)                      | –0.325                  | <0.001  |
| Curtain washing (times/year)              | Dog allergen (ng/g dust)                      | –0.296                  | 0.001   |

<sup>†</sup>Analysed by Kendall's  $\tau$  correlation

<sup>‡</sup>Total concentration of volatile organic compounds  $\text{C}_6\text{--C}_{12}$

**Table 5** Settled dust and formaldehyde in classrooms with a high and low fleece or shelf factor<sup>†</sup>

| Fitting                                         | Settled dust (mg/sample)  |         | Formaldehyde (µg/m <sup>3</sup> ) |         |
|-------------------------------------------------|---------------------------|---------|-----------------------------------|---------|
|                                                 | GM <sup>‡</sup> (min-max) | P-value | GM <sup>‡</sup> (min-max)         | P-value |
| Fleece factor (m <sup>2</sup> /m <sup>3</sup> ) | >0.06                     | 0.006   | 6 (0–72)                          | 0.002   |
|                                                 | ≤0.06                     |         | 0 (0–28)                          |         |
| Shelf factor (m/m <sup>3</sup> )                | >0.04                     | 0.386   | 7 (0–72)                          | 0.008   |
|                                                 | ≤0.04                     |         | 0 (0–32)                          |         |

<sup>†</sup>Differences between the groups analysed by the Mann Whitney U test

<sup>‡</sup> GM: geometric mean

**Table 6** Classroom fittings and cleaning routines in relation to pollutants in the 181 classrooms

|                                                 | Pollutants                                         | b      | Confidence interval | p value |
|-------------------------------------------------|----------------------------------------------------|--------|---------------------|---------|
| <b>Fittings</b>                                 |                                                    |        |                     |         |
| White board (yes/no)                            | Settled dust (mg/sample) <sup>†</sup>              | –34    | –57––10             | 0.005   |
| White board (yes/no)                            | Respirable dust (µg/m <sup>3</sup> ) <sup>†</sup>  | –3     | –5––0.1             | 0.044   |
| Fleece factor (m <sup>2</sup> /m <sup>3</sup> ) | Settled dust (mg/sample) <sup>†</sup>              | 258    | 29–487              | 0.029   |
| Fleece factor (m <sup>2</sup> /m <sup>3</sup> ) | Formaldehyde (µg/m <sup>3</sup> ) <sup>†</sup>     | 42     | 9–75                | 0.013   |
| Shelf factor (m/m <sup>3</sup> )                | Formaldehyde (µg/m <sup>3</sup> ) <sup>†</sup>     | 84     | 39–130              | <0.001  |
| Shelf factor (m/m <sup>3</sup> )                | 10log cat allergen (ng/g dust) <sup>‡</sup>        | 4      | 1–8                 | 0.010   |
| Shelf factor (m/m <sup>3</sup> )                | 10log dog allergen (ng/g dust) <sup>‡</sup>        | 6      | 1–11                | 0.024   |
| <b>Cleaning routines</b>                        |                                                    |        |                     |         |
| Dry mopping (times/week)                        | Settled dust (mg/sample) <sup>†</sup>              | 17     | 5–30                | 0.010   |
| Wet mopping (times/week)                        | VOC (µg/m <sup>3</sup> ) <sup>†</sup>              | 6      | 1–10                | 0.020   |
| Wet mopping (times/week)                        | Viable bacteria (cfu/m <sup>3</sup> ) <sup>†</sup> | 92     | 21–163              | 0.013   |
| Desk wiping (times/week)                        | 10log cat allergen (ng/g dust) <sup>‡</sup>        | –0.104 | –0.176––0.032       | 0.006   |
| Desk wiping (times/week)                        | 10log dog allergen (ng/g dust) <sup>‡</sup>        | –0.153 | –0.251––0.056       | 0.003   |
| Curtain washing (times/year)                    | 10log cat allergen (ng/g dust) <sup>‡</sup>        | –0.326 | –0.550––0.108       | 0.006   |
| Curtain washing (times/year)                    | 10 log dog allergen (ng/g dust) <sup>‡</sup>       | –0.438 | –0.725––0.151       | 0.004   |

<sup>†</sup>Analysed by multiple linear regression and with adjustments for season and air exchange rate.

<sup>‡</sup>Analysed by multiple linear regression and with adjustments for season, air exchange rate and percentage of cat or dog owners

applied, there was more settled dust. Wet mopping of floors, on the other hand, was related to an increase in VOC and viable bacteria in the classroom air, but to a lower concentration of cat and dog allergens in settled dust. The concentrations of pet allergens were also lower in classrooms where the curtains were washed at least once a year. The geometric mean amounts of cat allergen in classrooms where the curtains were washed at least once a year and in those in which they were washed more seldom were 56 and 142 ng/g, respectively, and for dog allergen the corresponding figures were 214 and 556 ng/g. Thus, the differences were at least 2.5-fold.

In the regressions (Table 6) and keeping all the three cleaning factors (cleaning of floor, desks and curtains) in the model, the significant relationship between wet mopping and allergen disappeared. Instead, a relationship between more frequent desk wiping and less cat and dog allergen was found. The other significant relationships persisted. We found no significant relationship between frequency of floor mopping (regardless of method) and any of the pollutants studied.

## Discussion

The classrooms were randomly chosen, and thus there should be no selection bias as to the characteristics of the investigated classrooms. In each classroom, the measurements were performed during only one day. For several of the pollutants there is a considerable day-to-day, as well as seasonal, variation. In 1993 the measurements were conducted during March–May and in 1994 and 1995 during January–March. This should have introduced some variations in the measured pollutants that were not due to consistent differences between the classrooms. These problems were dealt with by making allowances for season in the statistical analyses. This may be a rather rough correction. However, in the subset of classrooms investigated 1994 and 1995 respirable dust and micro-organisms were measured also outdoors, and for dust and viable moulds outdoor and indoor concentrations were related. When including, for this subgroup, the outdoor measurements in the statistical models, similar significant relationships were found as for the total set of classrooms. In addition, significant relations were also

found between respirable dust and shelf factor and viable bacteria and fleece factor. Furthermore, since the measurements were performed in randomly chosen classrooms on randomly chosen days, the day-to-day variation would most probably lead to a non-differential misclassification which would, of course, result in less significant relations between measured pollutants and the independent variables. So the relations found should not be attributable to such potential variations in the pollutants. By performing many statistical analyses, a risk of mass significance is introduced. However, the relations found seem biologically and technically reasonable, or are in accordance with results from other studies. In conclusion, we do not consider that the results are seriously biased.

We found that in classrooms with more fabrics and open shelves the concentration of formaldehyde was higher and there were more pet allergens. It has been shown previously that pet allergens accumulate in carpeted floors and curtains at school (Patchett et al., 1997; Berge et al., 1998). Volatile compounds can be adsorbed by indoor surfaces and re-emitted to the indoor environment (van der Wal et al., 1998), but a relation between the furnishings and the concentration of formaldehyde, a well known irritant, has not been demonstrated before in the school environment. These findings stress the importance of limiting the amount of fleece or large surface materials in order to keep the total concentration of pollutants low. We also observed that there was more airborne respirable dust and more settled dust in classrooms equipped with a traditional board for chalk than in those with a white board. This may have been expected, but to our knowledge this observation has not been published before.

Our results imply that washing the curtains at least once a year may substantially reduce the amount of pet allergens in the classroom. This result was consistent through all the different statistical analyses. The regressions including both the frequency of cleaning of the floor, and of furniture and curtains in the model demonstrated a relation between more frequent desk cleaning and less pet allergen. In another study, in which nasal symptoms were analysed in school employees (Wålinder et al., 1999), we found that those who worked in schools with more frequent desk cleaning showed higher nasal patency and fewer signs

of inflammation in the nose. It has been shown previously that the concentrations of cat and dog allergens are higher on the chairs than on the floor (Munir et al., 1993; Perzanowski et al., 1999). However, cleaning in schools is primarily aimed at the floor, and the furnishings receive much less attention. The present results suggest that more frequent cleaning of the furniture and fabrics could be a significant measure in attempts to reduce the amounts of pet allergens at school. We found consistent indications that wet mopping of floors increases the airborne concentrations of viable bacteria and VOC, a finding in accordance with previous results (Andersen et al., 1997). Equally consistent was the observation that dry mopping was related to more settled dust. Again, this result is in conformity with those of Andersen et al., but others have found that some dry mopping methods could be the most effective in reducing the amount of dust (Schneider et al., 1994). However, those studies were not performed in schools and there may also be large differences between various mops. The efficacy of different cleaning methods on the allergen content in the dust has only been sparsely studied before. We found that wet mopping could be more effective in collecting allergen, but this finding was not consistent through all the analyses, and this matter needs to be investigated further.

In conclusion, furnishings and textiles in the classroom act as significant reservoirs of irritants and allergens and are of importance for the indoor air quality at school. The amount of such fittings should be minimised. Despite the constant influx of pet allergen through the occupants, cleaning could be helpful in reducing the concentration of allergen. In schools without textile flooring, it would seem important to improve the cleaning of furniture and fabrics.

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