Short Communication

Improved Health After Intervention in a School with Moisture Problems

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Abstract In a school with floor moisture problems, the personnel had complaints consistent with the sick-building syndrome (SBS). Interventive measures including the laying of a ventilated floor were undertaken to eliminate the emissions. To examine if the intervention resulted in positive health effects, 34 personnel and 336 pupils were interviewed just before the intervention and also 7 months after. Also were interviewed 21 personnel and 224 pupils at an adjacent school serving as a control. Compared with the control school, the problem school showed more complaints, more general symptoms and more symptoms from the eyes, airways and skin, both among the personnel and the pupils. In the post-intervention examinations, the excess of symptoms among the personnel had almost disappeared. Among the pupils, the frequency of eye irritation was reduced but a general improvement of the other symptoms was not as obvious. However, after adjustment for a recent common cold, atopy and stress among the pupils, only one symptom ("stuffy nose") remained significantly elevated. In conclusion, the intervention was followed by positive health effects, supporting the hypothesis that emissions from building material had contributed to the excess of symptoms. A recent common cold was highly related to the symptoms and should be considered in future SBS studies.

Key words Sick building syndrome; Symptoms; School environment; Intervention; Emissions; Moisture problems.

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Background

In the 1990s, various complaints were reported with increasing frequency by the personnel of a Stockholm suburban school. Several examinations carried out by the Occupational Health Service by means of questionnaires confirmed a high occurrence of tiredness, headache and symptoms from the eyes, nose, throat and skin, all being related to work at school. Also reported was a case of allergic alveolitis, possibly caused by mould exposure in the school (Thörn et al., 1996).

The school was built in 1980. It was founded on a concrete slab with flooring of linoleum. The building was mechanically ventilated and equipped with a rotary air-to-air heat exchanger. Initially, the measured air exchange rates were somewhat low but were acceptable after rebuilding in 1990. The original roof was flat. In 1992, after repeated episodes of water leakage, it was replaced by a tilting one. During the reconstruction period there was still more leakage, and the low parts of the interior walls were moistened. In some of the interior walls the moisture was a cause of microbial contamination.

Most parts of the concrete slab were moist. In 1995, the relative air humidity (RH) in the slab was measured at several places and was found to vary between 70–90% RH. There were different sources of the moisture. Probably the most important one was diffusion and capillary suction from the underlying ground. Laboratory analysis confirmed that the self-leveling mortar compound contained protein. High concentrations of ammonia, 4–170 ppm, were measured at different places under the linoleum carpets, indicating mortar break-down processes in progress. Volatile organic compounds (VOC) in the indoor air were measured with standard methods at several places in the building. No excess concentrations were found.

From November 1995 to the summer months of 1996 an intervention programme was realised. In order to

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minimise emissions from the flooring, a ventilated floor was installed. On the old linoleum carpets a profiled plastic sheeting was laid and on top a new oak parquet floor. The profiled sheeting formed a ventilated air space over the old flooring. In this air space a negative pressure was created by small fans. The negative pressure minimised the possibility of leakage of contaminated air into the classrooms. Also, as a part of the intervention programme, the water damaged wall boards were exchanged.

**Objectives**
The main objective of the present study was to evaluate, by interviews, if the intervention resulted in positive health effects. Hypothetically, longstanding moisture in a building material, in this case mainly the floors, will generate break-down processes leading to gas emissions and impaired indoor air quality which in turn, partly by unknown mechanisms, will cause an excess of mental and irritative symptoms from mucus membranes, airways and from the skin. If this hypothetical chain of causes is true and the intervention would really result in the cessation of the emissions and in an improved indoor air quality, then the health problems would cease or at least decrease.

**Material and Methods**
All personnel and pupils in the problem school (School A, n=55 and n=469, respectively) as well as in the adjacent school, (School B, n=34 and n=323, respectively) serving as control, were selected for the study. These two schools were the only compulsory schools in this suburb, which had an even distribution of social factors, such as gender, immigrants and type of dwellings. There were no known indoor air problems at school B except complaints of too low temperature. After examination it was stated that casein-containing mortar had not been used there. No changes were made at school B between the two interviews, except improvement of the temperature regulation.

The pre-intervention interviews were performed in November 1995, immediately before and in the beginning of the rebuilding work. In February 1997, approximately 7 months after the reconstruction was finished, a second (post-intervention) examination was performed using the same interview questionnaire (see below). The post-intervention interviews were made with all persons having participated in the pre-intervention interviews provided that they still were attending the school. Not included were new classes and classes having left for a neighbouring high school. The four interview groups consisted of 34 personnel and 337 pupils at school A and 21 personnel and 224 pupils at school B. In a comparison between the two schools, there was no significant difference in the distribution of sex, atopics, smokers, “passive” smokers at home, persons riding or and having pets at home (Table 1).

The interviews were based on the Örebro questionnaire MM040 NA, frequently in use in Sweden and in several other countries for surveys of SBS problems (Andersson et al., 1998; Hill et al., 1992; Schulz et al., 1990). However, the question form was modified in

| Table 1 Pre-intervention demographic data for personnel and pupils at schools A and B |
|----------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                        | Personnel       |                 |                 |                 |                 |                 |                 |                 |
|                                        | School A        | School B        | School A        | School B        | School A        | School B        | School A        | School B        |
| Base population                        |                 |                 |                 |                 |                 |                 |                 |                 |
| Subjects                               | n               | 55              | 34              | 469             | 323             |                 |                 |                 |
| Primary drop out                       | n (%)           | 11 (20%)        | 5 (15%)         | 9 (2%)          | 22 (7%)         |                 |                 |                 |
| Subjects interviewed                   | n               | 44              | 29              | 460             | 301             |                 |                 |                 |
| Intervention group (participating in both the pre- and post-intervention interviews) |                 |                 |                 |                 |                 |                 |                 |                 |
| Secondary drop out                     | n (%)           | 10 (23%)        | 8 (28%)         | 123 (27%)       | 77 (26%)        |                 |                 |                 |
| Subjects interviewed                   | n               | 34              | 21              | 337             | 224             |                 |                 |                 |
| Females                                | %               | 88              | 81              | 48              | 47              |                 |                 |                 |
| Age                                    | mean (range)    | 46 (32–60)      | 44 (28–62)      | 9 (7–11)        | 10 (7–11)       |                 |                 |                 |
| Years at school                        | mean (range)    | 8 (0.2–14)      | 5 (0.2–16)      | 2 (0.2–4)       | 2 (0.2–4)       |                 |                 |                 |
| Current smokers                        | %               | 18              | 10              |                 |                 |                 |                 |                 |
| “Passive smoking”                      | %               | 9               | 14              |                 |                 |                 |                 |                 |
| Pets at home                           | %               | 32              | 43              |                 |                 |                 |                 |                 |
| Riding                                 | %               | 0               | 0               |                 |                 |                 |                 |                 |
| Any atopic disease                     | %               | 56              | 48              |                 |                 |                 |                 |                 |
| – eczema                               | %               | 29              | 24              |                 |                 |                 |                 |                 |
| – hay fever                            | %               | 29              | 29              |                 |                 |                 |                 |                 |
| – asthmatic symptoms                   | %               | 21              | 5               |                 |                 |                 |                 |                 |
| – asthma (doctors’ diagnosis)          | %               | 9               | 5               |                 |                 |                 |                 |                 |

*P<0.05 (chi²-test) compared with school B

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some aspects. For example, questions about the degree of symptoms were asked for in terms of “severe” or “weak” instead of “yes, often” and “yes, sometimes” as in the MM040 NA questionnaire. It was also adapted to be easier understood by the pupils. Instead of asking for symptoms during “the last three months” we asked for “the last one or two weeks” which is better brought in line with school children’s idea of time. Questions about complaints of the physical and psycho-social school environment were simplified to be answered by “yes” or “no”.

One physician and three nurses performed the interviews. The physician interviewed all personnel both times. Regarding the pupils, 11 out of 15 classes at school A and 4 out of 11 classes at school B were interviewed by the same nurse both times. The other classes were interviewed by different nurses.

Statistics
The Fisher exact test was used in a comparison between the schools regarding the distribution of demographic data, complaints of school environment factors (psycho-social effects and general physical complaints, Figure 1) and “severe” symptoms (Figure 2). Multiple logistic regression was used to analyse the relation between symptoms and school. Prevalence odds ratios (POR) were adjusted for atopy (defined as a history of atopic eczema, hay fever or asthma), a recent common cold and experienced stress. Among the personnel, experienced stress was defined as a positive response to the question of “stress” and among the pupils as “unrest in the class”.

Results
The intervention group, i.e. those persons who participated in both the pre- and post-intervention interviews, did not differ significantly from the total pre-intervention study group with respect to distribution of gender, riding, furred animals or passive smoking at home. Nor did they differ in symptom frequencies. In the following, only the intervention group results are reported.

Pre-intervention results
Personnel
Regarding school environment parameters, the only significant difference between the two schools was that

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Fig. 1 Pre- and post-intervention physical and psycho-social school-environment parameters (percent complaints) among the personnel (A and B) and pupils (C and D)

*p<0.05, **p<0.01 and ***p<0.001 versus school B (Fisher’s exact test)
the personnel at school B stated more complaints of too low temperature at school (Figure 1A).

26% of the personnel at school A and 48% at school B stated a common cold during the last one or two weeks before the interview. Compared with school B, the personnel at school A had in general more symptoms. The frequency of dry throat and hoarseness was significantly elevated, and there was a tendency to more eye irritation, cough, dyspnea, headache and fatigue (P<0.10, Figure 2A).

**Pupils**

Generally, the pupils stated less complaints than the personnel. In a comparison of the two schools, there were more complaints of too high room temperature, noise and unpleasant odours at school A (Figure 1C). 47% of the pupils at school A and 50% at school B stated a common cold during the last one or two weeks before the interview. The frequency of eye irritation, stuffy nose, and fatigue was significantly elevated at school A (Figure 2C). Using multiple logistic regression of the symptoms versus school with adjustment for a recent common cold, atopy and “unrest in the class”, significantly elevated POR remained for these symptoms (eye irritation POR 3.9; 95% confidence interval 1.1–13.6, stuffy nose 3.4; 1.7–6.5 and fatigue 2.0; 1.1–3.4).

**Post-intervention results**

**Personnel**

When the pre- and post-intervention results were compared, the personnel at school A experienced a slightly better school environment after the intervention. However, the only significant improvement was the normalisation of the complaints of too low temperature at school B (Figure 1A, B). 35% of the personnel at school A and 24% at school B stated a common cold during the last one or two weeks before the interview. Regarding symptoms, most of them had diminished and, compared with school B, were no longer significantly elevated, except for skin irritation in the face (Figure 2A, B).

**Pupils**

Also among the pupils, the significant differences in the experienced school environment parameters had disappeared in the post-intervention interviews (Figure 1D).

50% of the pupils at school A and 44% at school B stated a common cold during the last one or two weeks before the interview.

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**Fig. 2 Pre- and post-intervention frequency of symptoms (percent complaints of “severe” symptoms) among the personnel (A and B) and pupils (C and D)**

(*)p<0.10, **p<0.05, ***p<0.01 and ****p<0.001 versus school B (Fisher’s exact test)
before the interview. A slight decrease of symptoms was also noted among the pupils, and the occurrence of eye irritation was significantly reduced (Figure 2C, D). However, in comparison with school B there were still elevated frequencies of several symptoms at school A. Using multiple logistic regression of symptoms versus school with adjustment for atopy, a recent common cold and “unrest in the class” significantly elevated POR only remained for “stuffy nose” (3.1; 1.3–7.3) at school A.

The pre- and post-intervention complaints were evenly distributed in the school A building and no evident cluster of high frequency of symptoms was located to any special area.

Discussion

Many studies have shown a relation between damp and/or mouldy buildings on the one hand and, on the other, unspecified symptoms consistent with the “sick building syndrome” (SBS) as well as more specific diagnostoses, such as rhinitis, bronchitis, asthma and allergies (Peat et al., 1998; Taskinen et al., 1997; Williamson et al., 1997; Maier et al., 1997; Husman, 1996; Brunekreef, 1992; Göthe et al., 1992; Waegemaekers et al., 1989). However, only a few studies have been published concerning interventions in such problem buildings (Andersson et al., 1993; Sudakin, 1998; Stridh and Andersson, 1995). In the latter studies, the interventions resulted in positive health effects.

In this study, the results from the pre-intervention interview confirmed the previously known health problems among the personnel at school A. Moreover and to some extent, it also revealed health problems among the pupils at school A. This was partly unexpected because earlier there had been no general spontaneous complaints from the pupils. On the other hand, it could be expected that if there really existed indoor climate factors generating symptoms, these symptoms should also, at least to some extent, occur among the pupils.

We found a post-intervention decrease of the symptoms, especially among the personnel. Among the pupils there was a significant decrease of eye irritation. Otherwise, there was no general pattern of improvement in the crude analyses, but after control for a recent common cold, atopy and experienced stress, we found that only one symptom remained significantly elevated. This indicated that the intervention was followed by positive health effects. Altogether, the improvement among the personnel and the pupils indirectly supports the hypothesis that emissions from damp building material had contributed to the excess of symptoms at school A. The fact that the complaints were evenly distributed in the building speaks for a relationship to the general problem with damp flooring in the whole school building. Mouldy walls may also have contributed to the symptoms.

A statistical analysis showed that a common cold during the last two weeks before the interviews was highly related to many of the different symptoms. This is hardly surprising since many of the symptoms are common during an upper-airway infection. It could be argued that a bad indoor climate might promote such infections. However, before the intervention, the occurrence of a recent common cold was less in school A than in school B. Therefore, this presumed effect could not have been a large one. The common-cold factor is seldom noted but should, in our opinion, be included in future SBS studies, at least when short recall periods are used.

Besides the common-cold factor, there are some facts that could explain why, among the pupils, there was no general reduction of the post-intervention symptoms at school A. Firstly, even the pre-intervention symptom frequencies were not high and much lower than among the personnel, implying that adults may be more sensitive to indoor air pollutants than children. School children usually report few symptoms and seldom relate symptoms to specific environments. Secondly, an explanation may be the possibility of remaining mucous membrane sensitivity caused by bad indoor air before the intervention. A remaining nasal hyper-reactivity has previously been reported in subjects after removal from a SBS domestic area (Ohm et al., 1995; Ohm et al., 1997). A third – speculative – possibility may be that the intervention did not result in a full elimination of emissions causing the symptoms. After installation of a ventilated floor it is important that there is always enough under-pressure under the floor. Lastly, although a standardised questionnaire was used, different interviewers, as in the case of the pupils, may to some extent imply a risk of systematic bias. In this study and for practical reasons, it was not possible for all pupils to be interviewed by the same person on both occasions.

In conclusion, we found positive health effects following the intervention at school A. The findings support the hypothesis that moisture-related emissions did contribute to the excess of symptoms before the intervention.

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