THE REMEDIATION OF MOLD DAMAGED SCHOOL - A THREE-YEAR FOLLOW-UP STUDY ON TEACHERS' HEALTH

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SUMMARY

The health effects in teachers of a mold-damaged school before and during an extensive remediation process were assessed. Health data were collected with self-administered questionnaires from teachers (n=31) working in a moisture and mold damaged school and from the reference group of teachers (n=13) working in a non-damaged school. The questionnaire study was repeated three times. Spirometry was measured in 33 individuals in the spring 1997 and repeated in the spring 1999 and 2000.

In the damaged school, a cluster of eight asthma cases was identified, the prevalence of asthma being 26%. Before the remediation, the number of sinusitis episodes was higher (p=0.040) and the mean duration of sick leaves longer (p=0.015) among the study group than in the reference group. A higher prevalence of hoarseness and perceived poor quality of indoor air were reported. During the follow-up, no new asthma cases appeared. After the remediation, bronchitis, conjunctivitis, symptoms of allergic rhinitis and the sum of respiratory infection episodes decreased significantly. Some of the asthmatics had low values in the spirometry, but no changes in the lung function were observed at the group level.

The remediation of the mold damage had beneficial effects on teachers' health.

Key words: indoor air, adults, moisture damage, spirometry, asthma

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INTRODUCTION

Indoor environment in moisture and mold damaged buildings is a risk factor for the respiratory health of the occupants (1). This seems to be a concern in all kinds of modern buildings, i.e. residences (2-9), offices (10) and schools (11, 12). The indoor air quality of school buildings is an important part of healthy work environment for the teachers.

Building-related mold is predominantly associated with respiratory health effects, such as respiratory symptoms and infections, but also with general symptoms, such as tiredness, headache and difficulties in concentration among adults in moldy homes (2-9) or with mold exposure in their workplaces (10-14). Asthma has been associated with damp housing (15) and there appears to be a dose--response relationship (7). Preliminary reports have suggested that repair measures decrease the symptoms of the occupants (16), which speaks for a causal connection between exposure and symptoms. In spite of the strong association between building dampness and adverse health effects, little is known about the long-term health effects of prolonged microbial indoor exposure. In many cases, there is a need and public pressure for repairs to be initiated, i.e. the health problems are a trigger for repairs to be undertaken, but there is little documentation about the success of such repair process.

In this study, a cluster of asthma cases among the teachers in a mold-damaged school was identified along with complaints on symptoms and poor indoor air quality. A number of evident visible signs of moisture and mold damage were observed. Due to the complexity of mold associated health issues (17) and the need to document the damage and its remediation, a study of the health of the whole school personnel was initiated.

The aim of the study was to assess the health status of the teachers of a mold-damaged school compared that of a non-damaged school, and the effect of extensive mold remediation process on their health. We studied the health of the teachers in the two schools with a symptom questionnaire and clinical measurements including spirometry. Simultaneously, an interdisciplinary intervention study was made in order to focus on the health effects of mold remediation. Technical and microbial investigations as well as subsequent planning and monitoring of the repair process were included in the study (17).

MATERIAL AND METHODS

The school center under study is situated in a town in central Finland. The three buildings of the school center were inspected

Abbreviations: FVC - forced vital capacity; FEV1 - forced expiratory volume in one second; FEV% - FEV1/FVCx100; MEF_{50} - maximal expiratory flow at 50% of vital capacity; MEF_{25} - maximal expiratory flow at 25% of vital capacity.

visually, recording the visible signs of moisture and mold combined with surface moisture measurements. The exposure assessment was continued with microbial sampling of the indoor environment. The investigations and the process of risk assessment and risk communication have been described previously in detail (17).

The repair process was based on the findings in these investigations, and the main remediation was completed within a year from its onset. All damaged materials were replaced and the moisture function of the structures was improved.

Health data were collected from the teachers working in the complex of three school buildings (N=44), with self-administered questionnaires. The questionnaire was later repeated two times, first after 12 months and then after three years from the first study. The questionnaire included 70 questions and was based on the Örebro-questionnaire (MM40) (18) and the Tuohilampi questionnaire (19). Clinical data on the cases with asthma were collected from the case records of the local central hospital.

The first questionnaire was sent before the technical investigations were started in spring 1996. The response rate was 93%. After the repairs had been completed (spring 1997), a similar questionnaire was sent to the personnel as a follow-up; this was repeated again two years later (spring 1999). The second and third questionnaires, identical to each other, were based on the first questionnaire with a few added questions to evaluate the change associated with the repair. The response rate for the second questionnaire was 85% and for the third 83%.

The respondents were divided into two groups, an index group (n=31) who were working in the two damaged buildings of the school center, which were the subject to the remediation, and a reference group (n=13) that worked in a reference school building within the same building complex. At the beginning of the study, no major differences between index and reference groups were found in the distributions of gender, mean age, smoking, pets indoors, moisture problems at home, working years at school or regular medication. The occurrence of the respiratory symptoms as well as the number of respiratory infections were summed up and the symptom score was analysed as an ordinal scale variable in the comparison between the index and the reference groups.

A clinical study among 33 volunteers out of 44 teachers was carried out in the spring 1997. Of the group participating in the clinical study, 23 persons came from the damaged schools (index group) and 10 from the reference school, respectively (reference group). Spirometry was performed on each subject with computerised flow volume spirometer (M905 Medikro Oy, Kuopio, Finland). The spirometer was calibrated daily. During the measurement, the studied subject was seated and wore a nose clip. Three acceptable forced maximal expirations were performed according to the standards of the American Thoracic Society (20). From the maximum expiratory flow volume curves, the highest forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and flow rates at the highest forced vital capacity (MEF_{50}, MEF_{25}) were read. All of the values were expressed as percentages of individual predicted values for Finnish population adjusted for gender, age and height (21). The follow-up measurements were made two and three years after the completion of the repairs with the same spirometer and the same experienced nurse perfomed all the measurements throughout the study.

A complete series of the three measurements was obtained from 23 individuals, of whom 17 were from the exposed group and 6 from the reference group. After the first questionnaire, two of the eight asthma cases moved away, and one of the asthma cases was not willing to take part in lung function measurements.

The data were analysed with the SPSS statistical package by using χ^2-test, Fisher's exact test, Kruskal-Wallis test, Friedman's test and ANOVA (22). Poisson regression was used to examine the differences in the risk of infection episodes between the questionnaires. A linear regression for repeated measurements and the MIXED procedure were used to examine the levels of lung function measurements at the end of the remediation and two years later (23).

RESULTS

There were eight cases of doctor diagnosed asthma among the 31 teachers in the index school; thus the prevalence of asthma was 26%. Out of the eight asthma cases reported, three had been diagnosed as an occupational disease caused by the mold exposure. There were no asthmatic teachers in the reference school. The age distribution, gender, years at school, smoking habits, the number of sick leave days during the previous 12 months, the year of asthma diagnosis and the number of infection episodes of the asthmatic teachers are described in Table 1. The use of medication of the asthma patients at the start of the study and during the three-year follow-up is shown in Table 2.

During the follow-up period of three years, no new asthma cases appeared. All except two of the asthmatic teachers had

Table 1. *Characteristics of the asthmatic teachers*

Case No	Age	Gender	Years at school	Smoking	The year of asthma diagnosis	The number of sick leave days 1996[1]	The number of infection episodes[2]
1	45	female	6	never	1996	0	0
2	52	male	23	never	childhood	0	0
3	49	female	17	never	1995	4	1
4	52	female	14	never	1996	0	0
5	50	female	18	never	1995	0	0
6	31	female	3	never	1996	19	1
7	31	female	6	never	childhood	120	9
8	62	female	37	never	childhood	0	0

[1] During the previous 12 months

[2] Including tonsillitis, infection of the middle ear, sinusitis, bronchitis and pneumonia

Table 2. *Medication of asthma and allergy of the asthmatic teachers during the three-year follow-up*

Case No.	1	3	4	5	6	7
Inhaled cort.[1]	oy	xo	xoy		xoy	xoy
Inhaled β-agonist	oy	xoy	xoy	xo		xo
Inhaled nedocromil	y					o
Intranasal cort.[1]	o	x	x	xoy	oy	xoy
Intranasal c.s.[2]	o				y	
Ophthalmic c.s.[2]	o			xoy	y	
Antihistamine per os	oy		oy	xoy	xoy	xy
Cort.[1] per os						o

[1] Corticosteroid

[2] Cromolyn sodium

Case numbers 2 and 8 did not have any medication at the beginning and within a year they had moved away.

x = the year 1996, o = the year 1997 and y = the year 1999

Table 3. *Results of the lung function measurements of the asthmatic teachers during the three-year follow-up*

Case No.	FVC 1997 (% of predicted[1])	FVC 2000 (% of predicted[1])	FEV1 1997 (% of predicted[1])	FEV1 2000 (% of predicted[1])
1	2.97 (76%)	2.51 (66%)	2.36 (74%)	2.20 (71%)
2[2]	-	-	-	-
3	3.10 (75%)	2.59 (72%)	2.22 (65%)	2.24 (81%)
4	2.84 (88%)	2.82 (91%)	2.26 (86%)	2.12 (84%)
5	-	-	-	-
6	4.13 (91%)	3.76 (83%)	3.16 (82%)	3.05 (80%)
7	3.77 (87%)	3.57 (84%)	3.00 (81%)	3.11 (87%)
8[2]	-	-	-	-

[1] Reference values were those presented by Viljanen et al. 1982

[2] Cases number two and eight moved away before the first measurements of the lung function

[3] Case number five was not willing to participate in the measurements of the lung function

regular medication and they could not give up medication after the remediation. The results of the lung function measurements of the asthmatic teachers are shown in Table 3. In the first lung function measurements, lung functions were at the normal level in three of the individuals and decreased in two of the cases in spite of the medication. In the follow-up, the situation remained the same.

The health status of all the teachers was also monitored. In the beginning of the study, sinusitis episodes were more prevalent in the index school. The mean number of the sinusitis episodes was 3.29 per teacher in the index school while in the reference school, it was 1.25 (p=0.040) although the number of respondents that had had sinusitis during past 12 months was equal in both groups. There was no difference in the numbers of sick leave periods but the mean duration of sick leaves was longer in the index than in the reference group; 22.43 days in index school vs. 2.25 in reference school (p=0.015). The occurrence of common colds was higher in the control group. Hoarseness was more common among the index than reference group (p=0.038). A similar trend was found in asthmatic symptoms; altogether six persons (26%) in the index group had wheezing symptoms while none of the reference group, similarly 10 (40%) had dyspnea vs. only one in the reference group. In other self-reported respiratory symptoms or skin and general symptoms there were no major differences. All the teachers in both groups complained of excessive fatigue. The index group had more complaints about the quality of indoor air (p=0.005); mold odour (p=0.017), cellar like odour (p=0.034), unpleasant odours (p=0.007), stuffy air (p=0.052) and dust (p=0.058) (data not shown).

Comparison of self-reported allergic symptoms, infections, respiratory, skin and general symptoms at the beginning of the study and during the follow-up among the index group are shown in Table 4. In the follow-up, the incidence of self-reported bronchitis and conjunctivitis decreased in the index group and a similar trend was observed in the occurrence of sinusitis. Symptoms of allergic rhinitis were less frequent at the one-year follow-up. In the follow-up among the reference group, there were no changes in self-reported infections and allergic symptoms (data not shown).

At the end of the three-year follow-up study, fever and cough with phlegm were more common than before the repairs in both groups (Table 4). Otherwise, with respect to respiratory symptoms, there were no differences during the three-year follow-up study. Fatigue decreased in both groups during the study.

Table 4. *Self-reported health status of the index school teachers at the beginning of the study and during the three year follow-up study*

	Before mold remediation, spring 1996 (n=27) n (%)	After mold remediation, one year follow-up, spring 1997 (n=26) n (%)	Three years' follow-up spring 1999 (n=22) n (%)	p
1. Allergy symptoms (1 difference between first and second questionnaire during the follow-up period)				
Allergic rhinitis	19 (70)	11 (42)	12 (55)	0.123 0.039[1]
Asthma	8 (31)	6 (23)	6 (27)	0.945
Atopic eczema	5 (19)	5 (19)	6 (27)	0.775
Family atopy	9 (39)	6 (23)	8 (36)	0.652
2. Infections				
Common cold	13 (48)	10 (42)	10 (45)	0.956
Sinusitis	7 (26)	2 (8)	1 (5)	0.083
Bronchitis	5 (19)	-	1 (5)	0.034
Pneumonia	1 (4)	1 (4)	-	1.000
Conjunctivitis	11 (41)	3 (12)	4 (18)	0.017
Sick leaves	7 (26)	6 (23)	6 (27)	0.587
3. Respiratory symptoms				
Fever	7 (26)	14 (53)	10 (45)	0.053
Cough with phlegm	8 (30)	20 (77)	20 (91)	0.000
Wheezing	6 (22)	8 (31)	7 (32)	0.848
Dyspnea	10 (37)	10 (38)	8 (36)	1.000
Nasal bleeding	7 (26)	5 (19)	7 (32)	0.525
Rhinitis	20 (74)	21 (81)	19 (86)	0.724
Sore throat	20 (74)	19 (73)	17 (77)	0.941
Hoarseness	25 (93)	19 (73)	20 (91)	0.172
4. Other symptoms				
Facial eczema	14 (52)	11 (42)	11 (50)	0.837
Hand eczema	13 (48)	11 (42)	12 (55)	0.642
Eye irritation	16 (59)	17 (65)	15 (68)	1.000
Headache	22 (82)	17 (68)	16 (73)	0.552
Fatigue	27 (100)	24 (92)	18 (82)	0.022
Difficulties in concentration	19 (70)	15 (58)	13 (59)	0.860

[1] The difference between first and second questionnaire

Table 5. *The sum of grouped symptoms before and after the mold remediation. The number of the teachers in the index school before mold remediation was 27, after mold remediation 26 and in the three years' follow-up 22 and the numbers for the reference school were 12, 11 and 9, respectively.*

	Before mold remediation mean	After mold remediation, one year follow-up mean	Three years' follow-up mean	p
Index school				
General symptoms	6.67	5.88	5.81	0.081
Lower respiratory symptoms	3.67	4.48	4.60	0.005
Irritative symptoms	9.96	10.3	11.6	0.047
Reference school				
General symptoms	6.75	5.27	5.50	0.043
Lower respiratory symptoms	3.17	4.36	4.50	0.004
Irritative symptoms	9.58	10.5	11.9	0.056

Table 6. *Spirometry results in the end of the mold repair spring 1997*

	Index group spring 1997 (n=23)	Reference group spring 1997 (n=10)	p
FEV1			
mean±SD	3.20±0.80	3.44±0.62	0.256
% of predicted[1]	92.3	98.1	
FVC			
mean±SD	3.92±0.89	4.21±0.75	0.240
% of predicted[1]	92.5	98.1	
FEV%			
mean±SD	81.4±5.3	81.7±6.7	0.784
% of predicted[1]	99.8	99.8	
MEF_{50}			
mean±SD	3.88±1.34	4.35±0.25	0.357
% of predicted[1]	81.8	90.7	
MEF_{25}			
mean±SD	1.42±0.70	1.47±0.37	0.505
% of predicted[1]	96.2	100	

[1] Reference values were those of presented by Viljanen et al., 1982

When all the infection episodes were summed up, the risk of respiratory infections including tonsillitis, sinusitis, infection of the middle ear, bronchitis and pneumonia was lower both at the one and three-year follow-up (RR= 0.24, 95% CI = 0.11 - 0.55 and RR= 0.29, 95% CI = 0.13 - 0.65) than before the repair (RR=1) among the index school teachers but there was no such change among reference teachers. The sum of general symptoms (headache, fatigue and difficulties in concentration) decreased in the reference group and the same tendency was observed in the index group. The sum of lower respiratory symptoms (cough with phlegm, dyspnoea and wheezing) as well as the sum of irritative symptoms (nasal bleeding, rhinitis, sore throat, hoarseness, cough and eye irritation) increased both in the index group and in the reference group (Table 5). The complaints of high temperatures and dust or dirt indoors decreased among the index group but the complaints of odour remained the same (data not shown).

The results from the lung function measurements in the whole study group are shown in Table 6. The baseline levels of the lung function measurements did not differ between the index and reference groups. During the three-year follow-up, no changes in lung function measurements were found among the index school teachers as shown in Table 7.

DISCUSSION

In the first phase of the study, a cross-sectional investigation was made on teachers' health in a mold-damaged school and a reference school. As the second part of the study, the effects of mold remediation on the teachers' health were monitored with repeated questionnaires and lung function measurements.

A cluster of asthmatic individuals along with complaints of other respiratory problems was identified in a school center with clear evidence of moisture and mold damage. The prevalence of asthma was as high as 26%, which was more than 4-fold compared with the prevalence in general adult population (6%) (24). Regular and intensive asthma medication was used by most of these subjects. An increased prevalence of asthma was also found among the pupils of the same school (17). Increased risk of asthma has been previously reported in association with moisture and mold exposure (7). However, the causal relationship remains unclear as immunoglobulin E-mediated allergy is not usually found in moisture damage-associated asthma cases (25). Among these cases three patients had shown a causal relationship on individual level, i.e. bronchial provocation with a mold extract.

During the follow-up period after the remediation, and the elimination of the exposure, no new asthma cases appeared. The need for the asthma medication as well as allergy medication of the asthmatic teachers was still obvious even three years after the completion of the repairs. Although there was some decrease observed in the symptoms as a result of the remediation, the clinical condition of the asthmatic individuals did not markedly improve. In addition, two of the cases continued to have impaired pulmonary function even though they were adequately medicated. The slowness of recovery from nasal mucosal hyperreactivity resulting from exposure to indoor mold has been reported previously among Swedish school teachers (26).

The symptom prevalence among the teachers was high before the repair. At the beginning of the study, the teachers of the index schools had high symptom rates and were subjectively irritated and annoyed by many indoor air factors in their working environment. The symptoms and subjective annoyance were similar to those described by Alexandersson and Hedenstierna (27). The number of episodes of sinusitis was high, supporting previous reports of increased occurrence of sinusitis associated

Table 7. *Spirometry results from the three-year follow-up study from the same index school teachers that participated in all the measurements*

	At the completion of the mold repair, spring 1997 (n=17) mean±SD	Two-year follow-up spring 1999 (n=17) mean±SD	Three-year follow-up spring 2000 (n=17) mean±SD	p
FVC	4.00±1.00	4.00±0.93	3.81±0.90	0.981
FEV1	3.26±0.88	3.24±0.86	3.15±0.76	0.738
FEV%	81.3±5.21	80.6±5.34	82.8±4.79	0.584
$MEFF_{50}$	3.89±1.41	4.10±1.66	3.93±1.27	0.522
$MEFF_{25}$	1.46±0.76	1.31±0.50	1.40±0.60	0.126

with moisture and mold damage has been reported in the adult population (6, 8). The mean length of sick leaves was high in the exposed subjects at the beginning of the study. This is a new finding among adults exposed to indoor mold. A similar finding, i.e. a higher number of sick leaves, was observed in children attending a moisture-damaged day-care center (8). The length of sick leave periods has not been addressed much in previous studies, but it may deserve attention as a measure of the seriousness of perceived symptoms or prolongation of infection episodes, although these health outcomes are non--specific by their nature. Subjective observations of annoyance due to indoor air factors in the working environment were on a high level, especially concerning odours. Mold odour has also been an important determinant of irritation symptoms in other studies (13, 29).

The effect of the intervention, i.e. remediation of mold damage on the teachers' health was studied as a long-term follow--up study. Health data were collected twice after the buildings underwent an extensive mold remediation procedure. During the follow-up, a significant improvement of the health status occurred in the index group, i.e. there was a decrease of respiratory infections. Bronchitis and conjunctivitis were decreased and the sum of infection episodes went down to the level of the reference group. An association between sum of infection episodes and observed moisture damages has also been reported in an adult population based study concerning residential buildings (28). Hence, exposure to indoor moisture and mold seems to associate with a variety of infections in the airways. The decrease in the infections after elimination of the exposure is evidence in favour of a causal connection, although the etiological aspects remain to be clarified.

Mold odour has also been an important determinant of irritation symptoms in other studies (13, 29). According to repeated questionnaires, the feelings of annoyance due to poor indoor quality decreased in the index group at the end of the follow-up period compared to their assessments at the beginning of the study.

It was presumed that if chronic changes in the lungs had taken place there would have been a detectable difference in the lung function between the exposed group and the control group. In spite of the many clinically verified asthma cases in the index group, there were no significant differences in the mean values of measurements of spirometry between the index and the reference groups. During the three-year follow up study, the lung function of the index school teachers remained at the same level. It has been shown earlier that short term, reversible functional changes occur in spirometry (27). In our study, the follow-up was started immediately after the repair and no permanent changes were found in the lung function of the exposed teachers. This indicates that either no functional changes occurred or spirometry is not sensitive enough to detect minor changes in the pulmonary function of nonasthmatic workers in a mold-damaged school.

In our study, most of the repair work was done during the summer vacation and special techniques were used to prevent the contamination of adjacent rooms. Thus the remediation process did probably not cause any additional microbial exposure of the teachers. Structural and microbiological investigations one and three years later after the remediation showed that the exposure, measured by microbiological and building-physical methods had been diminished both quantitatively and qualitatively after the repair. Furthermore the presence of damage-indicating microbes had decreased to the background level, as reported in detail by Haverinen et al. (30).

The reference school building represented a "normal" school building built in the 1950. In the health status of the reference teachers, no significant changes were found in the follow-up study except for the incidence of fever and cough with phlegm which had increased at the end of the study. It can be assumed that these symptoms, reported also by the index group, were caused by a respiratory infection epidemic which affected the area during the survey.

CONCLUSION

In conclusion, a cluster of asthma cases was identified in a mold-damaged school, together with an increased prevalence of respiratory symptoms and infections compared with the reference group. This suggests a causal relationship between the onset of asthma and indoor mold exposure. The intervention, i.e., the thorough remediation of the moisture damage had a beneficial effect on the health of the exposed personnel, seen as a decrease of conjunctivitis, bronchitis and sinusitis. No changes in the lung function at the group level could be shown, which indicates the reversibility of most adverse health effects with the exception of occupational asthma.

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