

EFFECTS OF MOISTURE DAMAGE REPAIR ON MICROBIAL EXPOSURE AND HEALTH EFFECTS IN SCHOOLS

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ABSTRACT

This intervention study was designed to show the effects of the renovation of moisture and mold damaged school building on the schoolchildren's health and exposure. Microbial sampling from indoor air of the school and a health questionnaire study were performed before and after renovation. The results were compared to those from non-damaged reference school. The effect of a thorough renovation in the damaged school was seen as decreased concentrations of airborne fungi and decreased diversity of mycoflora. There was a significant decrease in the prevalence of the respiratory symptoms among schoolchildren after the renovation. The results show that the symptoms are associated with the moisture damage and that the increased symptom levels can be normalized with proper repair measures.

INDEX TERMS

Moisture damage, Schools, Renovation, Indoor air microbes, Symptoms, Children

INTRODUCTION

Respiratory symptoms and other adverse health effects are common among schoolchildren in moisture damaged schools (Haverinen *et al.* 1999, Meklin *et al.* 2002). Remarkable resources are put on the repair measures, but little documented data is so far available about the effects of the renovations on the users' health and thus on the cost effectiveness of the repairs. This intervention study was designed to show the effects of the renovation on the schoolchildren's health and exposure. The aim was to find out whether the moisture and mould repairs of the school buildings have an effect on the exposure to indoor air microbes, and on the prevalence of respiratory symptoms of the schoolchildren.

METHODS

The study consisted of two primary schools locating in central Finland. Both schools had main frame construction of concrete. The school buildings were technically investigated for moisture damage at the beginning of the study and classified as moisture damaged (school A) and a non-damaged reference school (school B) based on the observations made in the technical survey. During the five-year follow-up period the damaged school was extensively renovated for all identified faults. The study was conducted with health questionnaires and by environmental sampling of the indoor air microbes before the renovation and after the repair measures were completed. The reference school was sampled with a similar protocol.

First, the technical investigations for moisture and mold damage in both school buildings were made by a trained civil engineer of our group according to an established protocol. The procedure for these investigations has been developed and described earlier (Nevalainen *et al.* 1998) and it includes a checklist recording various types of visible moisture signs, e.g. visible mold, moisture stains, detaching of surface materials, changes in material color and moldy or stuffy odor. Surface moisture recorders were used to assess the moisture level of surface

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materials, and the relative humidity and temperature of indoor air were recorded. Types and obvious reasons for the damage as well as the extent of the damage were recorded when possible without opening or dismantling the structures. During the study, school A was totally renovated covering all the facilities of the building. Damaged structures were opened and renewed and all the coating materials were renewed. Also alteration from natural ventilation to mechanical exhaust and air supply and a thorough cleaning of the school was performed.

Air sampling

Indoor air microbes were sampled by using a six-stage impactor (Andersen 10-800). Two media were used in sampling for viable fungi; 2% malt extract agar (MEA) and dichloran 18% glycerol agar (DG18). Samples for bacteria were taken on tryptone glucose yeast agar (TGY). Samples were taken mostly from classrooms and hall facilities and from personnel rooms so that total numbers were 19 and 20 for damaged and non-damaged schools, respectively. Sampling was repeated in the same rooms both before and after the intervention and total numbers of air samples were 38 and 40 for the schools. Samples were taken during snow cover on the ground to minimize the effect of outdoor air spore load. Sampling times were from 7 to 15 minutes and detection limits (DL) varied from 2 to 5 cfu/m³ depending on the sampling time. Fungi were incubated for 7 days at 25°C. Bacteria were incubated for up to 14 days at room temperature (about 20°C). The total number of viable bacteria was counted after 5 days of incubation and the number of actinobacteria after 14 days of incubation. The colonies were counted as colony forming units (cfu/m³) using positive hole correction (Andersen 1958) and the fungi were identified morphologically by genus using an optical microscope. Actinobacteria detection was based on the dry, actinobacteria-type appearance of the colonies.

Follow-up of respiratory symptoms

Information on the respiratory symptoms and health of participating children was collected with questionnaires as a cross-sectional study. Children aged from 7 to 13 years participated in the study before and after the intervention, respectively. Numbers of participating children at the beginning/at the end of the study were 414/408 and 431/296 in damaged and non-damaged schools, respectively. The questionnaire used was a modified version of those used in other Finnish studies on respiratory symptoms and diseases (Susitaival and Husman 1996). The questionnaire comprised of 32 questions concerning among others personal characteristics, home environment, perceived indoor air quality characteristics and occurrence of respiratory symptoms. Symptom manifestations during fall and spring terms were asked separately. Questionnaires were delivered to schools, where teachers administered them to the pupils and parents were asked to fill in the questionnaire together with the child. The teachers collected the questionnaires.

Statistical analysis

Concentrations of airborne microbes were not normally distributed and normality could not be obtained by standard transformations. Non-parametric tests were used for data analysis. Total concentrations of viable airborne fungi and bacteria and concentrations of most common fungi before and after intervention within a school were compared with Wilcoxon Rank-Sum test and those between the damaged and reference schools with Mann Whitney's U-test. Differences in frequencies of concentration categories between the schools were tested with χ^2 - test as well as frequencies of different microbial groups. McNemar test was used to test differences in occurrence of microbial groups before and after intervention within a school.

Differences in symptom prevalence before and after intervention within a school and between the schools were analyzed after cross-tabulations with χ^2 – test. Associations between the symptoms and moisture damage repair in the damaged school were verified using logistic regression models adjusting for gender, age, moisture observations at home, atopy and smoking. All the differences were tested using exact p-values. SPSS statistical package, version 10 was used for all analyses.

RESULTS

Airborne microbes

After a thorough renovation in the intervention school, a significant decrease in mean concentrations of viable airborne fungi ($p=0.002$) was seen. Difference found before the repairs compared to its reference school disappeared. GMs of total concentration of airborne fungi before and after renovation were 22.6 cfu/m³ and 6.3 cfu/m³, respectively. The corresponding values for the reference school were 6.1 cfu/m³ and 7.9 cfu/m³. Percentage of samples with low fungal levels (<20 cfu/m³) increased from 28 % to 70 % after the renovation. Also a lower number of different microbial genera or species was found after the repairs; the number of microbial genera came down from 25 to 16 and thus was on the level found in the reference school. The most common fungi occurring in indoor air of studied schools were *Penicillium*, *Cladosporium*, *Aspergillus*, yeasts and non-sporing isolates.

The effect of renovation in the intervention school A was seen as decrease of the total concentration of airborne viable bacteria ($p=0.006$). GMs were 888 cfu/m³ and 210 cfu/m³ before and after repairs. The GM for the reference school B was 239 cfu/m³ at the end of the study. The range of actinobacteria concentrations narrowed from 0 - 10 cfu/m³ (GM=0.6 cfu/m³) to 0 - 4 cfu/m³ (GM=0.2 cfu/m³) (N.S).

Symptoms of schoolchildren

Before renovation of the damaged school, differences in symptom prevalence between the schoolchildren attending the damaged school and children attending the reference school were significant for all the other symptoms except for nasal bleeding, cough with phlegm (fall term) and for difficulties in concentration. After the thorough renovation, a significant decrease in all other symptoms but in general symptoms was seen (Figure 1). The differences in prevalence of symptoms between the intervention school A and reference school B disappeared. Numbers of participated children were 414 and 408 before and after renovation, respectively. The symptom prevalence in the reference school C varied from 7 to 44%, mostly without significant difference between the initial and final surveys.

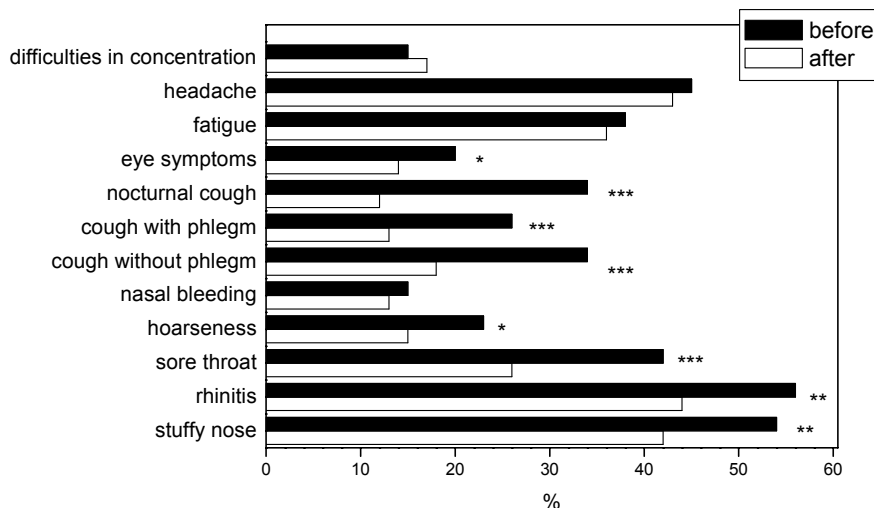


Figure 1. The proportions of schoolchildren with respiratory and other symptoms in the intervention school before and after thorough repairs.

DISCUSSION

The effect of renovation in a moisture damaged school building was studied by monitoring the microbial quality of the indoor air and conducting a health questionnaire study among the schoolchildren before and after renovation. The results were compared to those from a non-damaged reference school.

Although the adverse health effects of “moisture damaged, damp or moldy” indoor environment have been addressed in a number of studies, the exact causative agents and mechanisms by which symptoms and diseases will develop are still mostly unclear. It is well known that moisture damaged indoor environment acts as a source of a number of pollutants, and the microbial loads and diversity of the air exceeds that of normal school environment (Rand 1999, Lappalainen *et al.* 2001, Meklin *et al.* 2002). The monitoring of viable microbes in the air can be used as a marker of the microbial status of the indoor environment. In this study, the effect of a thorough renovation in the damaged school was seen as a significant decrease in mean concentrations of viable airborne fungi ($p=0.002$), as the higher frequency of samples showing low levels (<20 cfu/m³) of fungal concentration and as a lower number of different microbial genera found in the repaired school. Also a significant decrease of the total concentration of airborne viable bacteria was found after repairs.

Before the renovation, there was a higher prevalence of symptoms in the moisture-damaged school compared to the reference school. This showed an association between the damage of the building and adverse health effects in schoolchildren, found also in previous studies (Taskinen *et al.* 1997, Haverinen *et al.* 1999, Meklin *et al.* 2002). Significant decrease in the prevalence of the respiratory symptoms among schoolchildren in the moisture-damaged school was reported after the renovation of the building. Findings are consistent with the reports of Savilahti *et al.* (2000) and Åhman *et al.* (2000). Our findings establish the beneficial effects of the repairs. The decrease of symptoms after the renovation emphasizes the causal connection between the damage-associated exposure and the adverse health effects.

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