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# Transferring from moisture damaged school building to clean facilities – The avoidance of mold exposure induces a decline in symptoms and improvement in lung function among personnel

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ABSTRACT

Working in a moisture-damaged building can cause different symptoms and effects on lung functions. Moving to a clean environment, it is believed to reduce symptoms and alleviate potential adverse health effects. This case study monitors the health effects of personnel in one school building before and after all school activities were transferred from a moisture-damaged school building to clean premises.

The whole school staff was invited to attend this follow-up study. All participants ($N = 45$) were interviewed, and pulmonary functions were measured by spirometry and exhaled nitric oxide testing ($FE_{NO}$) before transferring the school activities to a new building and the control measurements were performed twice; three months and six months after the transfer.

After transferring to temporary facilities, 82% of participants felt that their symptoms were improved or resolved and the pulmonary functions were improved; 50% of those who had decreased pulmonary functions at the beginning, their pulmonary function values returned to normal after three months. Over the next six months, the perceived symptoms continued to reduce so that 93% of the respondents felt fully asymptomatic with respect to indoor air, and the spirometry results improved further.

Transferring workers from the damaged building to healthy environment provided beneficial health effects on pulmonary functions and to perceived symptoms even in a relatively short time period. Based on this study, and from the perspective of promoting and protecting the health and well-being of personnel, transferring school activities from a moisture damaged building to clean facilities brought considerable advantages, despite the possible cost and difficulties of finding replacement facilities.

## CRediT author statement

**Liisa Vilén:** Conceptualization, Writing - Original Draft, Investigation, Formal analysis. **Marja Päivinen:** Conceptualization, Investigation, Writing - Review & Editing, Formal analysis. **Janne Atosuo:** Conceptualization, Writing - Review & Editing, Visualization. **Tuula Putus:** Conceptualization, Writing - Review & Editing, Supervision.

## 1. Introduction

A considerable proportion of buildings suffers from excessive moisture at some stage in their life cycle though the risk factors vary between building types, geographic areas, and climates (IOM, 2011). Untreated excessive moisture in a building structure leads to the growth of microbes such as fungi, yeast, and bacteria, causing adverse health risk to the building users (Heseltine and Rosen, 2009; Seguel et al., 2017). In addition, excess moisture may also lead to the emission of chemicals from damaged building materials and furnishings (Bernstein et al., 2008; Heseltine and Rosen, 2009). It has been estimated that up to 20–40% of the buildings in northern Europe are mold contaminated (Verdier et al., 2014).

Moisture damaged buildings with increased mold and bacterial growth are considered a potential health risk, even though the causal relationship between individual mold species and health problems has not yet been established (Hurraβ et al., 2017; Wiesmüller et al., 2017). Nevertheless, there is sufficient evidence for associations between

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moisture indicator microbes and the health effects on allergic respiratory disease, asthma, allergic rhinitis, hypersensitivity pneumonitis and an increased occurrence of common respiratory infections (Wiesmüller et al., 2017). The most frequently observed effects are, however, irritation of the mucous membranes in the eyes and the respiratory tract (Heseltine and Rosen, 2009; Hurraβ et al., 2017). Patients have also reported multiple general symptoms, such as fatigue, muscle pain, headaches, insomnia, dizziness, balance disturbance or gastrointestinal problems (Hope, 2013). In most cases, indoor health hazards are short-lived and reversible when the exposure is short-term. If the exposure continues, adverse health effects may become more severe or even permanent (Johanning et al., 2014); for example, the risk of developing asthma has been found to be more than four-fold with prolonged exposure (Heseltine and Rosen, 2009; Karvala et al., 2011).

The health and comfort hazards caused by indoor air problems are quite common in Finnish schools; according to a study by the University of Turku and The Trade Union of Education in Finland (OAJ) more than half of the teachers experience weekly or daily problems with stuffiness and inadequate ventilation, and a fifth with mold, cellar, or sewer odors (Putus et al., 2017). The prevalence of moisture and mold damage in school buildings has been the subject of many estimates during last decade; the range varying from 12 to 18% (Reijula et al., 2012; Soimakallio et al., 2017) and possibly up to 70% of the school building in Finland (RIL 250-2011, 2011).

In a large school in southern Finland, which had had persistent indoor air problems, all the school activities were transferred to temporary premises for the duration of the remediation. The purpose of this follow-up study was to determine how the move to healthy facilities would affect both the perceived symptoms and the measured pulmonary functions of the personnel. In addition, the success of the renovation will be monitored in the future after the remediation is completed and the personnel have returned to their former facilities.

## 2. Materials and methods

A large school in southern Finland, originally built in 1954, has had indoor air problems for several years; people working in the building have experienced symptoms suggestive of indoor air problems and the perceived indoor air has been poor. The school building is a two-to three-story building, which has been extended several times: in the 1980s, the 1990s and the 2000s. The exterior walls of the building are mainly plastered bricks and the roofs are of tin. In addition to the expansions, the building has been renovated several times in the past, but the indoor air problems have not decreased. An extensive survey was commissioned on the building to determine the factors that may occur in the structures and affect the indoor air quality. The external experts trained in construction engineering, found both moisture damage and abundant microbial growth (including typical moisture indicator microbes, such as *Aspergillus versicolor* and actinobacteria) as well as faults in the ventilation system and structural problems. All the information on the building structures and materials, the history of the building and together with the discovered ventilation problems, structural defects and moisture damage has been obtained from the school principal as well as from the reports of the external experts. All these were public documents.

In the fall of 2018, all the school activities were relocated to replacement facilities for the duration of the remediation. The whole school staff, including other occupational groups like cooks, cleaners, etc. In addition to the teachers, were all invited to participate in this follow-up study. All the participants were interviewed, and pulmonary function tests were performed before the school was transferred to the replacement facilities (Phase I). The follow-ups were performed three months after the transfer (Phase II) and half-year after that (Phase III). The final Phase IV will be conducted after the remediation process has been completed and the staff have returned to their former premises.

Health information and perceived indoor air related symptoms were collected through interviews. All the interviews were conducted and analyzed by one person. In the analysis, the health effects were categorized into four categories according to the severity of the symptoms: severely symptomatic, chronically symptomatic, irritation - and general symptoms and no symptoms (Table 1). We looked mainly for perceived symptoms and not diseases; for example, when asthma was not under control nor the treatment in balance, the case was categorized as 'severely symptomatic', but once a balance in the treatment (= asymptomatic and normal lung function) has been attained, it was categorized as 'no symptoms'.

### 2.1. Pulmonary function tests

Pulmonary function was measured by spirometry testing and exhaled nitric oxide measurements ($FE_{NO}$). Spirometry describes the efficiency of the pulmonary function by providing information about air flows and lung capacity. $FE_{NO}$ measures the content of nitric oxide in the exhaled air. Previous studies have shown that inflammation in the airways increases the content of nitric oxide in exhaled air. This method is reported to be suitable for studying environmental effects on airways from indoor or outdoor air (Bernard et al., 2005; Sandrini et al., 2010).

The spirometry was measured with a Spiro Star 2000 spirometer (Medikro, Kuopio, Finland) according to the ATS and ERS guidelines (Miller et al., 2005; Pedersen et al., 2005). The spirometry results were expressed as a percentage of participant's age, size and gender matched predicted values (Kainu et al., 2016) according to the most recent ATS and ERS criteria. Forced vital capacity (FVC) and forced expiratory volume in 1 s ($FEV_1$) and their ratio ($FEV_1$/FVC), peak expiratory flow (PEF) and mean mid expiratory flow (MMEF) were also analyzed. In addition, maximum expiratory flow rates at 75%, 50% and 25% of vital capacity, (MEF75, MEF50 and MEF25) were obtained.

The exhaled nitric oxide measurements $FE_{NO}$ were performed with a Niox Vero (Aerocrine, Sweden) analyzer. The results are expressed as parts of a billion (ppb). The exclusion criteria for the pulmonary function tests were those participants who suffer from acute breathing problems and/or had had an acute respiratory infection during the previous two weeks.

### 2.2. Data analysis

Data were analyzed by descriptive statistical methods using an SPSS25 (IBM Corporation, Armonk, New York, United States). To examine the significance of the incidence of symptoms at different times, the Wilcoxon signed-rank test was used. A repeated linear test (repeated measures proc mixed) was used to study the effect of transferring into the healthy environment on FVC, $FEV_1$ and FVC/$FEV_1$. The $FE_{NO}$ results were not normally distributed so the Friedman's test was used to study whether the changes were significant. Statistical models were used for testing which of the factors most affected the changes.

## 3. Results

### 3.1. Participants

Int the first phase of the study, there were 45 participants; 30 women

**Table 1**
Categorization of symptoms.

| Severity of symptoms | Including: |
|---|---|
| Severely symptomatic | Recurrent asthma attacks, severe breathing difficulties/ shortness of breath |
| Chronically symptomatic | Allergic rhinitis, infectious diseases such as sinusitis, acute and chronic bronchitis |
| Irritation - and general symptoms | Nasal congestion, itchy eyes, itchy skin, hoarseness, fatigue, headache |
| No symptoms | – |

and 15 men, with the average age of 44.5 years (range: 26–63 years). In Phase II, there were 32 participants and in Phase III, 28 participants. Three participants had an asthma-diagnosis (7%) and one was currently being investigated for the possibility of having asthma. Four of the participants smoked (9%).

### 3.2. Symptoms

In the first phase, the majority (n = 38/85%) of the staff had a varied severity of symptoms; from headaches and other irritations - and general symptoms, even up to the asthma attacks, which have required hospitalization. There were no statistically significant differences between either the gender or smoking habits and the severity of the symptoms. A total of seven participants had changed jobs or retired during the follow-up period; two severely symptomatic, three chronically symptomatic, and two with irritation - and general symptoms. The prevalence and the changes in the prevalence of symptoms are presented in Table 2.

By the first follow-up (Phase II), 82% of the patients reported that their symptoms had diminished (n = 12) or completely disappeared (n = 11). Compared with the beginning of the follow-up, all the participants felt that their symptoms had either disappeared (n = 22) or been reduced (n = 2) by Phase III. There were no participants with severe or chronic symptoms in the follow-up phases. The reduction in perceived symptoms at Phases II and - III were both statistically significant ($p < 0.001$).

### 3.3. Pulmonary function tests

In the first phase 42 subjects performed the spirometry testing. The results showed normal findings in 24, mild airway obstruction in 14 and severe obstruction in 2 out of the 41 subjects. Two subjects were not able to perform the spirometry testing due to breathing problems or coughs.

Exhaled nitric oxide measurements showed normal findings in 30 participants, normal/elevated in 10 and elevated findings in 4 of the 44 study subjects. One subject could not perform the test in an appropriate way.

The second phase showed clear improvement in the pulmonary function tests. At the group level, the mean results of the spirometry findings as a percentage of the age, size and gender matched the predicted values. The spirometry findings at the group level as a percentage of the predicted normal values are presented in Table 3, while Table 4 presents the findings at the personal level.

The increase in FVC -values were found significant between the timepoints ($p < 0.05$). Paired test between the first measurement and last follow up showed significant change ($p < 0.01$). Statistical models were used to study which factors affected the change. Analysis showed that the age and effect of the combination of age and time affected the change the most ($p < 0.05$) and ($p < 0.05$) respectively.

The improvement in $FEV_1$ were found significant at each timepoints ($p < 0.001$). Paired tests between the first measurement and the first follow up showed significant change ($p < 0.05$), and between the first measurement and the second follow up there was also significant change ($p < 0.001$) and finally, there was significant change between the first and the second follow up ($p < 0.05$). Statistical modelling showed that the effect of the combination of both age and time and gender and time were significant ($p < 0.01$) and ($p < 0.05$).

The changes in $FVC/FEV_1$ were found significant at each of the timepoints ($p < 0.05$). Paired test between the first measurement and the first follow up showed significant change ($p < 0.05$) and between the first and the second follow up the change was also significant ($p < 0.05$). Statistical modelling showed that the effect of the combination of age and time was significant ($p < 0.01$).

The second phase also showed improvement in the $FE_{NO}$ results also. In Phase I $FE_{NO}$ had a mean of 17 ppb and in Phase II 13 ppb. However, the change in $FE_{NO}$ between the different timepoints was not significant ($p = 0.4$). $FE_{NO}$ findings at the group-level are presented in Table 5.

In Phase III the number of normal spirometry findings for 21 the participants remained the same.

Four participants showed an airway obstruction finding and three subjects could not participate due to a recent bout of flu during the previous two-weeks period. $FE_{NO}$ findings remained close to the level of the Phase II findings. Symptoms, $FE_{NO}$ and spirometry findings in different phases are summarized in Fig. 1.

In conclusion, the transition to a healthy environment improved the pulmonary function findings for the school workers after a three months-period and the improvement was still observable after 6 months. The follow-up of the study group will continue.

**Table 2**
The prevalence and the changes of symptoms at the various phases of follow-up (n (%) of respondents).

| Symptoms | Phase I N = 45 | Phase I → Phase II N = 32 | | Phase I → Phase III N = 28 | |
|---|---|---|---|---|---|
| Severely symptomatic | 4 (9) | 2 (6) | – | 1 (4) | – |
| Chronically symptomatic | 17 (38) | 14 (44) | – | 12 (43) | – |
| Irritation - and general symptoms | 17 (38) | 12 (38) | 16 (50) | 11 (39) | 2 (7) |
| No symptoms | 7 (15) | 4 (12) | 16 (50) | 4 (14) | 26 (93) |

## 4. Discussion

Indoor air problems are often caused by an accumulation of many individual contaminants and even though there are different reference values for indoor air pollutants, in practice they do not take into account the interactions between different pollutants or the sensitivity of individuals and are therefore an unreliable assessment for a in the health impact appraisal. Consequently, international experts recommend avoiding or at least minimizing exposures (Johanning et al., 2014).

The indoor air problems that have troubled schools for a long time have led to a search for various solutions to guarantee a healthy and safe working environment for both staff and students. In several municipalities and towns, schools have begun to work in temporary premises during the remediation or construction of a new school building. Moving to evacuation facilities is often the last option when the minor or superficial renovations have not produced sufficient results and the majority of staff and students continue to report different kind of symptoms. At this stage, indoor air problems have often already caused both direct and indirect costs, such as increasing work absence, reduced working efficiency, medical expenses, as well as the costs of property repairs.

In this case study, even in the relatively short period of time, the transition of school staff to clean temporary facilities had a significant impact on both perceived and measured health. After three months, 82% of participants felt that their symptoms were improved or resolved and half a year after the first measurement, 93% of respondents felt that they were fully asymptomatic with respect to indoor air. The lung function measurements performed also supported the perceived health, by both at the group and individual level. Results showed that the mild obstruction findings were reversible. However, the moderate or severe obstruction findings did not change after the transition to a healthy environment and may indicate irreversible changes in lung function. A clear improvement was shown also in the exhaled nitric oxide findings, suggesting reduction in the inflammatory process in the lungs of the study participants. Similar findings were recently published by Tischer and coworkers (Tischer et al., 2021).

Several studies have been conducted in the past on the success of renovations and their impact on indoor air and symptoms for both teachers and students, suggesting that repairing moisture damage to a school buildings has a positive effect on health, including a reduction in

**Table 3**
Spirometry results in group-level in three different measurements as absolute values, age, size, and gender predicted values and in percent of age, size, gender predicted values for Finnish population of Kainu et al. (2016). Phase I the baseline measurement in damaged building. Phase II three months after transferring to a healthy building. Phase III nine months after transferring to a healthy building.

| | Phase I N = 42 | | | Phase II N = 30 | | | Phase III N = 28 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Measured value | Age, size sex matched predicted value | % of age, size sex predicted | Measured value | Age, size sex matched predicted value | % of age, size sex predicted | Measured value | Age, size sex matched predicted value | % of age, size sex predicted |
| FVC | 3.91 | 4.42 | 88.25 | 4.31 | 4.62 | 90 | 4.19 | 4.48 | 94 |
| $FEV_1$ | 3.18 | 3.59 | 88.3 | 3.37 | 3.64 | 92 | 3.35 | 3.51 | 95 |
| $FEV_1$/FVC | 81.47 | 81.37 | 100.25 | 80.8 | 77.4 | 102 | 0.80 | 0.79 | 102 |
| PEF | 8.74 | 8.57 | 81.78 | 7.75 | 8.89 | 88 | 7.94 | 8.69 | 91 |

**Table 4**
Spirometry findings at the personal level in Phases I and II (n (%) of.

| First and second phase spirometry findings | N = 30 |
|---|---|
| I Phase normal – II Phase normal finding | 14 (47) |
| I Phase mild obstruction – II Phase normal finding | 6 (20) |
| I Phase mild obstruction – II Phase mild obstruction finding | 5 (17) |
| I Phase moderate obstruction – II Phase moderate obstruction | 2 (7) |
| I Phase not able to perform spirometry- II Phase normal finding | 2 (7) |
| I Phase normal - II Phase moderate obstruction | 1 (3) |

**Table 5**
FENO findings at the group-level for the three different measurements. Phase I baseline measurement in damaged building. Phase II three months after transferring to healthy building. Phase III nine months after transferring to a healthy building.

| | Phase I N = 44 | Phase II N = 30 | Phase III N = 28 |
|---|---|---|---|
| FENO ppb | 17 | 13 | 15 |
| Normal <20 ppb | 30/44 | 26/30 | 22/28 |
| Normal or slightly elevated 20–30 ppb | 10/44 | 3/30 | 5/28 |
| Elevated >30 | 4/44 | 1/30 | 1/28 |

general symptoms and respiratory infections (Haverinen-Shaughnessy et al., 2004; Immonen et al., 2004; Lignell et al., 2007; Meklin et al., 2007; Patovirta et al., 2004; Sauni et al., 2013; Savilahti et al., 2000). The health effects of transferring to temporary facilities during renovations have only been published as regards children (Koskinen et al., 1999). Even though the symptoms caused by exposure appear to be largely reversible (Johanning et al., 2014; Patovirta et al., 2004), it may take several years for the situation to return to normal after a renovation (Haverinen-Shaughnessy et al., 2004; Meklin et al., 2007). However, the prolonged symptoms in previous cases have been explained by e.g. post-renovation dust or microbial dust in the premises as well as in the ventilation ducts and furniture (Johanning et al., 2014; Meklin et al., 2007). In addition, emissions of volatile organic compounds (VOCs) from building materials and surface treatments used in repairs will be at their highest, and these new levels and can also cause various symptoms such as irritation symptoms or even asthma (Herbarth and Matysik 2010; Holøs et al., 2019; Johanning et al., 2014; Meklin et al., 2007; Zhou et al., 2011). Therefore, due to the above-mentioned factors, a direct comparison with past results cannot be made in a reliable way. However, the results in previous studies are very similar, although in these the relief of symptoms has not been as rapid as in our study.

The main problem with follow-up research has often been the large number of participants withdrawing from the study and this is particularly highlighted in small samples, like ours. Even though only 71% of the initial number of participants participated in Phase II and 62% in Phase III, the relative number of symptoms (severely symptomatic/chronically symptomatic/irritation - and general symptoms/no symptoms) remained at a reasonable level, and therefore the results can be considered reliable.

The strength of our study is that the exposure was well-documented prior to the clinical study. Additionally, the same individuals participated at each three time-points and the effect of the changes in exposure were documented with objective lung function measurements and not only with questionnaires of symptoms.

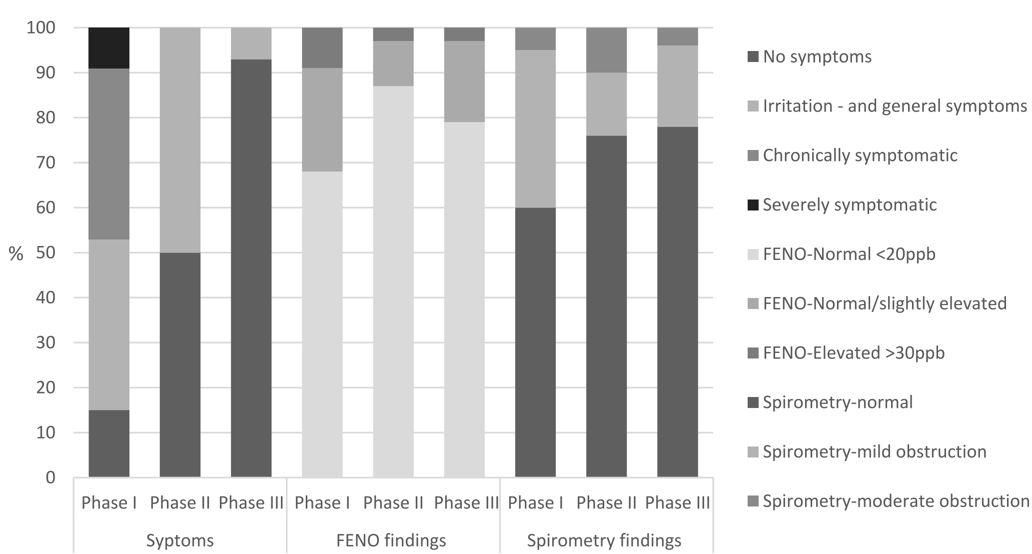


**Fig. 1.** Symptoms, $FE_{NO}$ and spirometry findings in different phases of the study (percent of respondents).

## 5. Conclusions

Although relocating all the school activities to replacement facilities for the duration of the renovation is often considered too cumbersome and costly, its health benefits are significant, according to this case study. Even in a relatively short time, moving the school personnel to clean alternative facilities had a significant impact on both the perceived and measured health.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

Bernard, A., Carbonnelle, S., Nickmilder, M., de Burbure, C., 2005. Non-invasive biomarkers of pulmonary damage and inflammation: application to children exposed to ozone and trichloramine. Toxicol. Appl. Pharmacol. 206 (2), 185–190. https://doi.org/10.1016/j.taap.2004.10.022.
Bernstein, J., Alexis, N., Bacchus, H., Bernstein, I.L., Fritz, P., Horner, E., et al., 2008. The health effects of nonindustrial indoor air pollution. J. Allergy Clin. Immunol. 121 (3), 585–591. https://doi.org/10.1016/j.jaci.2007.10.045.
Haverinen-Shaughnessy, U., Pekkanen, J., Nevalainen, A., Moschandreas, D., Husman, T., 2004. Estimating effects of moisture damage repairs on students' health-a long-term intervention study. J. Expo. Anal. Environ. Epidemiol. 14 (S1), S58–S64. https://doi.org/10.1038/sj.jea.7500359.
Herbarth, O., Matysik, S., 2010. Decreasing concentrations of volatile organic compounds (VOC) emitted following home renovations. Indoor Air 20 (2), 141–146. https://doi.org/10.1111/j.1600-0668.2009.00631.x.
Heseltine, E., Rosen, J. (Eds.), 2009. WHO Guidelines for Indoor Air Quality: Dampness and Mould. The Regional Office for Europe of the World Health Organization, Denmark.
Holøs, S.B., Yang, A., Lind, M., Thunshelle, K., Schild, P., Mysen, M., 2019. VOC emission rates in newly built and renovated buildings, and the influence of ventilation – a review and meta-analysis. Int. J. Vent. 18 (3), 153–166. https://doi.org/10.1080/14733315.2018.1435026.
Hope, J., 2013. A review of the mechanism of injury and treatment approaches for illness resulting from exposure to water-damaged buildings, mold, and mycotoxins. TheScientificWorldJOURNAL 2013, 767482. https://doi.org/10.1155/2013/767482, 20.
Hurraß, J., Heinzow, B., Aurbach, U., Bergmann, K., Bufe, A., Buzina, W., et al., 2017. Medical diagnostics for indoor mold exposure. Int. J. Hyg Environ. Health 220 (2, Part B), 305–328, 2048/10.1016/j.ijheh.2016.11.012.
Immonen, J., Taskinen, T., Pekkanen, J., Korppi, M., 2004. Bronchial reactivity in students from moisture and mold-damaged schools: changes in relation to changes in exposure. Pediatr. Asthma Allergy Immunol. 17 (2), 116–125. https://doi.org/10.1089/0883187041269878.
IOM, 2011. Climate Change, the Indoor Environment, and Health. National Academies Press, Washington, D.C.
Johanning, E., Auger, P., Morey, P., Yang, C., Olmsted, E., 2014. Review of health hazards and prevention measures for response and recovery workers and volunteers after natural disasters, flooding, and water damage: mold and dampness. Environ. Health Prev. Med. 19 (2), 93–99. https://doi.org/10.1007/s12199-013-0368-0.
Kainu, A., Timonen, K.L., Toikka, J., Qaiser, B., Pitkäniemi, J., Kotaniemi, J.T., et al., 2016. Reference values of spirometry for Finnish adults. Clin. Physiol. Funct. Imag. 36 (5), 346–358. https://doi.org/10.1111/cpf.12237.
Karvala, K., Toskala, E., Luukkonen, R., Uitti, J., Lappalainen, S., Nordman, H., 2011. Prolonged exposure to damp and moldy workplaces and new-onset asthma. Int. Arch. Occup. Environ. Health 84 (7), 713–721. https://doi.org/10.1007/s00420-011-0677-9.
Koskinen, O.M., Husman, T.M., Meclin, T.M., Nevalainen, A.I., 1999. The relationship between moisture or mould observations in houses and the state of health of their occupants. Eur. Respir. J. 14 (6), 1363–1367. https://doi.org/10.1183/09031936.99.14613639.
Lignell, U., Meklin, T., Putus, T., Rintala, H., Vepsaelaeinen, A., Kalliokoski, P., et al., 2007. Effects of moisture damage and renovation on microbial conditions and pupils' health in two schools–a longitudinal analysis of five years. J. Environ. Monit. 9 (3), 225–233. https://doi.org/10.1039/b615459j.
Meklin, T., Putus, T., Hyvärinen, A., Haverinen-Shaughnessy, U., Lignell, U., Nevalainen, A., 2007. Koulurakennusten Kosteus- Ja Homevauriot, Opas Ongelmien Selvittämiseen. National Public Health Institute.
Miller, M.R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., et al., 2005. Standardisation of spirometry. Eur. Respir. J. 26 (2), 319–338. https://doi.org/10.1183/09031936.05.00034805.
Patovirta, R.L., Meklin, T., Nevalainen, A., Husman, T., 2004. Effects of mould remediation on school teachers' health. Int. J. Environ. Health Res. 14 (6), 415–427. https://doi.org/10.1080/09603120400012876.
Pedersen, O.F., Pellegrino, R., Viegi, G., Wanger, J., 2005. Standardisation of spirometry. Eur. Respir. J. 26 (2), 319–338.
Putus, T., Länsikallio, R., Ilves, V., 2017. Koulutus-, Kasvatus- Ja Tutkimusalan Sisäilmatutkimus 2017. Available at: https://www.oaj.fi/globalassets/julkaisut/2017/sisailmatutkimus_3010_final_sivut.pdf. (Accessed 15 December 2019).
Reijula, K., Ahonen, G., Alenius, H., Holopainen, R., Lappalainen, S., Palomäki, E., et al., 2012. Rakennusten Kosteus- Ja Homeongelmat. 1. Espoo:Eduskunnan Tarkastusvaliokunnan Julkaisu 1/2012.
RIL 250-2011, 2011. Kosteudenhallinta Ja Homevaurioiden Estäminen. Saarijärven Offset Oy:Suomen Rakennusinsinöörien Liitto RIL ry.
Sandrini, A., Taylor, D.R., Thomas, P.S., Yates, D.H., 2010. Fractional exhaled nitric oxide in asthma: an update. Respirology 15 (1), 57–70. https://doi.org/10.1111/j.1440-1843.2009.01616.x.
Sauni, R., Uitti, J., Jauhiainen, M., Kreiss, K., Sigsgaard, T., Verbeek, J.H., 2013. Remediating buildings damaged by dampness and mould for preventing or reducing respiratory tract symptoms, infections and asthma (review). Evid. Base Child Health: Cochrane Rev. J. 8 (3), 944–1000. https://doi.org/10.1002/ebch.1914.
Savilahti, R., Uitti, J., Laippala, P., Husman, T., Roto, P., 2000. Respiratory Morbidity Among Children Following Renovation of a Water-Damaged School. Taylor & Francis Ltd.
Seguel, J.M., Merrill, R., Seguel, D., Campagna, A.C., 2017. Indoor air quality. Am. J. Lifestyle Med. 11 (4), 284–295. https://doi.org/10.1177/1559827616653343.
Soimakallio, S., Hildén, M., Lanki, T., Eskelinen, H., Karvosenoja, N., Kuusipalo, H., et al., 2017. Energia- Ja Ilmastostrategian Ja Keskipitkän aikavälin Ilmastopolitiikan suunnitelman ympäristövaikutusten arviointi. Available at: http://julkaisut.valtioneuvosto.fi/handle/10024/80289. (Accessed 15 December 2019).
Tischer, C., Karvonen, A.M., Kirjavainen, P.V., Flexeder, C., Roponen, M., Hyvärinen, A., et al., 2021. Early age exposure to moisture and mould is related to FeNO at the age of 6 years. Pediatr. Allergy Immunol. https://doi.org/10.1111/pai.13526.
Verdier, T., Coutand, M., Bertron, A., Roques, C., 2014. A review of indoor microbial growth across building materials and sampling and analysis methods. Build. Environ. 80, 136–149. https://doi.org/10.1016/j.buildenv.2014.05.030.
Wiesmüller, G., Heinzow, B., Aurbach, U., Bergmann, K., Bufe, A., Buzina, W., et al., 2017. Abridged version of the AWMF guideline for the medical clinical diagnostics of indoor mould exposure. Allergo J. Int. 26 (5), 168–193. https://doi.org/10.1007/s40629-017-0013-3.
Zhou, J., You, Y., Bai, Z., Hu, Y., Zhang, J., Zhang, N., 2011. Health risk assessment of personal inhalation exposure to volatile organic compounds in Tianjin, China. Sci. Total Environ. 409 (3), 452–459. https://doi.org/10.1016/j.scitotenv.2010.10.022.