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Occurrence of moisture problems in schools in three countries from different climatic regions of Europe based on questionnaires and building inspections – the HITEA study

Abstract The aim of this study was to assess occurrence of dampness and mold in school buildings in three European countries (the Netherlands, Spain, and Finland), representing different climatic regions. An assessment was performed utilizing both questionnaires and on-site building investigations, and the agreement between these two methods was evaluated for validation purposes. On the basis of questionnaire data from a representative sample of schools, different types of moisture problems were reported in 24–47% of all school buildings at the time of the study. Most commonly reported was dampness in the Netherlands, moisture/water damage in Spain, and mold odor in Finland. Subsequently, 20–24 schools per country were selected for on-site inspections by trained staff. The overall agreement between the questionnaire and inspection data was good (kappa-value 0.62), however, with large differences (0.39–0.91) between countries. Extrapolating from the inspection data, the minimum estimates for prevalence of moisture problems in school buildings are 20% in the Netherlands, 41% in Spain, and 24% in Finland. In conclusion, moisture problems (such as moisture damage, dampness, and mold) are relatively common in schools. The occurrence and severity may vary across geographical areas, which can be partly explained by building characteristics.

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Practical Implications

On the basis of this study, the prevalence of verified moisture problems in school buildings was highest in Spain, but lower and similar in Finland and the Netherlands. Questionnaire-based surveys can be used to assess moisture problems in school buildings, but because of large variation in agreement with inspection data, the questionnaire needs to be validated by on-site inspections in a subsample of the surveyed buildings.

Introduction

Biological pollution because of indoor dampness, moisture, or water damage is a challenging environmental health issue. Association between these moisture problems and related mold growth and human health has been extensively documented. In many cross-sectional studies looking at the effects of 'dampness and mold' on occupants' health, respiratory symptoms such as cough, rhinitis, hoarseness and wheezing have usually been the most commonly documented (IOM, 2004, WHO, 2009). Dampness and mold have also been associated with asthma; both with exacerbation of symptoms of previous asthma (IOM, 2004) and with onset of new asthma (Jaakkola et al., 2005; Pekkanen et al., 2007).

In the school environment, dampness and mold have also been associated with respiratory symptoms and asthma among school children (Kim et al., 2007; Meklin et al., 2002; Smedje and Norbäck, 2003). Intervention studies in schools showing a positive effect of remediation, that is removal of the source of moisture problems on the occupants' health, have strengthened the assumption of the causal link between moisture problems and associated health effects (Meklin et al., 2005). They also show that part of the health outcomes are short-term and reversible, although there are also individuals whose symptoms are more persistent and fail to disappear after the exposure has been ceased (Haverinen-Shaughnessy et al., 2004).

Whereas moisture problems are recognized risk factors for a number of short-term and long-term health effects, there is limited knowledge on exposures to these problems in school environments and their health effects across the different climate zones in Europe. These data are urgently needed as increasingly more students, parents, teachers, and school staff express concerns about the indoor air quality in schools. The significance of the school indoor environment to the students' and teachers' health should be better evaluated, leading to adequate risk assessment in the future. More comprehensive data about the condition of the school buildings will facilitate the policy development for improved indoor air quality and maintenance of school buildings.

The 'Health Effects of Indoor Pollutants: Integrating Microbial, Toxicological and Epidemiological Approaches (HITEA)' study is designed to explore associations between poor indoor air quality in schools and short-term health effects among students and teachers. Such short-term effects may potentially lead to long-term effects. The study was motivated by need for comparable data related to occurrence of moisture problems and their potential health impacts on occupants in schools across Europe. This study deals with the early phase of the study laying the groundwork for detailed exposure and health impact assessments.

The aims of this study were to assess occurrence of moisture problems in schools in three European countries with different climates (Spain, the Netherlands, and Finland), and to validate the prevalence estimates based on questionnaire with estimates based on on-site building inspections by the trained staff. We also aimed to study building factors that may contribute to dampness and mold-related exposures in different climates or regions and create a consistent case–control setting for a subsequent, large-scale epidemiological study among pupils and teachers related to exposure to dampness and mold in schools in the course of the HITEA study.

Materials and methods

A minimum of 48 schools in Spain, the Netherlands, and Finland were targeted for health impact assessments. To obtain the desired sample of suitable schools for this case–control setting, a larger sample of over 700 schools was invited to respond to an initial screening questionnaire. In addition, existing data sources were used as described below. Questionnaire responses were gathered from a total of 193 schools, corresponding to 85 (18%) school buildings from Spain, and 92 buildings (35%) from the Netherlands, whereas in Finland, data were obtained from 59 school buildings via phone interviews. The study flowchart is presented in Figure 1.

The questionnaire was first developed in English and translated into Spanish, Catalan, Dutch, and Finnish, using an Internet-based platform. It included ten questions on current and past dampness, moisture, and mold observations; seven questions on general information (e.g. type and size of the building, number of building occupants); ten questions on background information (e.g. recent and planned renovations, most pertinent building and ventilation characteristics); and ten optional questions on additional information (e.g. building materials and cleaning activities). The questionnaire was addressed to the principals of the schools; where needed, support for answering the questions was asked from the personnel responsible for school building maintenance.

In Spain, a total of 379 elementary schools from four municipalities in Barcelona area were invited to respond to the questionnaire via the Internet. Additional 60 schools from another district had been screened by a postal questionnaire earlier. The total of 439 schools represents all elementary schools in these five districts. In the Netherlands, a random sample consisted of 263 elementary schools that were invited to participate in the study. The sample corresponded to approximately 60% of all the schools in the province of Utrecht. The schools in the Netherlands could either respond to the Internet questionnaire or fill in a printed version of the questionnaire and mail it to the research personnel, who would then enter the responses in the Internet-based system. In Finland, a large Internet-based questionnaire study including the same or similar questions had recently been conducted (Haverinen-Shaughnessy et al., 2012), including all Finnish elementary schools, with response rate of 42% (N = 1152). The information gathered from these school buildings was complemented by a phone interview targeting large (more than 200 pupils)

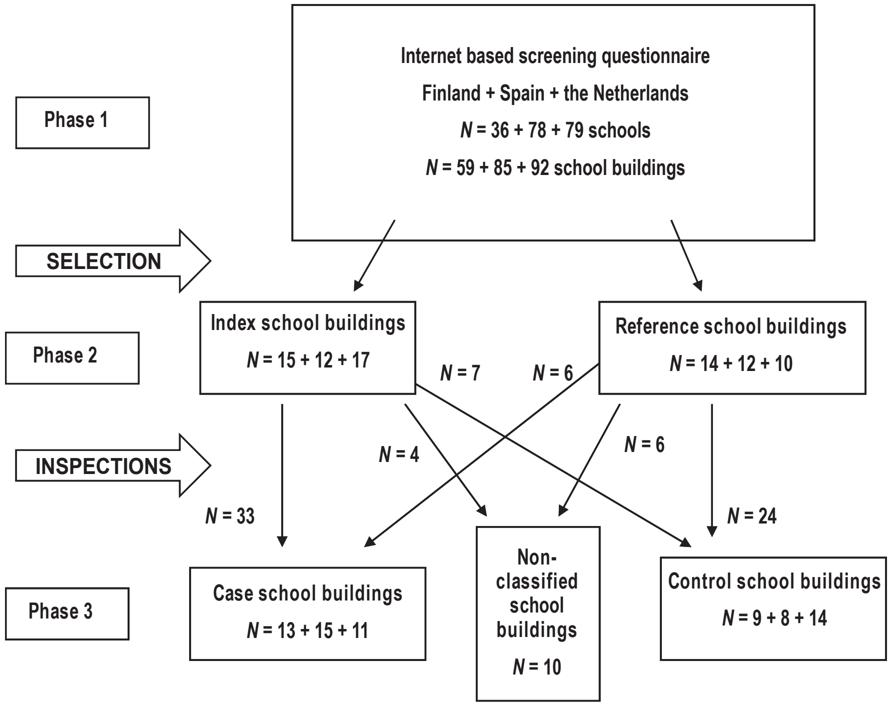

Fig. 1 Study flowchart: from the index/reference school building classification (based on the screening questionnaire) to the case/control school building classification (based on the school inspections)

elementary schools ($N = 59$) that did not respond to the national survey and were located in a convenient geographical proximity to the conducting study center in Kuopio, Finland. The data from the phone interviews were also entered into the common database. The data from the Finnish national survey will be reported elsewhere in detail, but some results are presented here to supplement information collected via phone interviews.

Of schools that participated in the screening phase, between 20 and 24 schools (24 and 29 buildings) per country were selected for on-site inspections. They were schools that were willing to participate, had more than 200 pupils, and had not planned major repairs or renovations in the next 2 years. Approximately half of the schools inspected represented schools that reportedly did not have any signs of dampness problems, moisture or water damage, or mold growth in the building nor a history with such problems ('reference schools'). The other half represented schools with such problems that were either widespread, and/or affected several classrooms, and/or there were observations of mold within the past 12 months ('index schools').

The inspections included walkthroughs utilizing predesigned checklists and non-destructive measurements by trained research personnel. The research personnel was centrally trained by senior members of the research group with extensive experience in building investigations. The training methods included (i) completion of recommended reading material, (ii) web-based teaching sessions, and (iii) on-site training. Field personnel from all countries participated in the training that gave elementary background information on indoor environmental research (specifically moisture problems), relevant information about building types and dynamics, special features related to schools, investigation and measurement techniques, and examples of typical problems illustrated by photographs. The training went into assessment of moisture problems, and measuring instruments selected to be used in the field investigations. Measuring instruments included hand-held moisture detectors, relative humidity, temperature and CO_2 monitoring devices, and simple airflow detection instruments (smoke puffers). Finally, on-site training was conducted in the three countries involving investigations according to the study protocol in a minimum of two school buildings.

Consistency of assessment of observed moisture problems was considered critical for the overall outcomes of the study. Hence, field personnel were instructed to take detailed notes and photographs of all locations with suspected problems that they could not assess or were uncertain of. The senior members would then help to complete the assessment.

Both screening and inspection data from the three countries were analyzed collectively using SPSS version 15.0.1 and STATA statistical software version 10.1. The analysis techniques used included descriptive statistics (distributions, frequencies, mean and median values), cross tabulation (categorical variables), and calculating means/medians (continuous variables) by country. Symmetric measures were assessed for agreement between the screening and inspection data. In addition, association between selected building characteristics and signs of moisture problems reported in the questionnaires were assessed using multivariable logistic regression analyses. On the basis of the inspection data, minimum estimates for prevalence of moisture problems in school buildings were extrapolated by calculating a sum of true cases and a portion of non-inspected schools relative to false-negative controls.

Results

Table 1 shows general information about schools based on the screening questionnaire data. In Finland, the school buildings were older: average year of construction was 1967 for the interviewed schools (relating to 1955 among the national sample), whereas in Spain, it was 1971, and in the Netherlands 1979. Median floor area was largest in Finland, whereas the number of students was smallest, indicating relatively smaller occupant density. Renovation activity in the past had been highest in Finnish schools, but there were no substantial differences between the three countries in the planned renovations for the following 2-year period.

By country, the school buildings in Finland were more likely detached from any other buildings, whereas the proportion of portable and/or temporal school buildings was similar in all countries (Table 1). The schools in the Netherlands were most commonly one storey buildings, whereas in Finland, two storey buildings were most prevalent, and in Spain, the schools most often had more than two storeys. Most prevalent window types were triple glass in Finland (64%), double glass in the Netherlands (49%), and single glass in Spain (64%). Observations of condensation on the windowpanes were reported in 5% of schools in Finland, 50% in the Netherlands, and 27% in Spain.

Predominant characteristics of Finnish school buildings were basement, concrete frame (also relatively high proportion of schools with timber frame), ridge roof, and ventilation system with mechanical exhaust and support air. Predominant characteristics in Spanish school buildings were slab on the ground foundation, no basement, concrete frame, flat roof, and natural ventilation (i.e. no mechanical exhaust or support air). School buildings in the Netherlands most commonly had crawl space foundation, no basement, had concrete or masonry frame (also relatively high proportion of schools with steel frame), flat roof, and natural ventilation.

Table 2 shows the main results related to signs of moisture problems, which were also used for the initial designation into index and reference schools. Some 29% of the school buildings in the Netherlands reported current (i.e. at the time of the study) signs of dampness problems (i.e. condensation on cold surfaces, windows, etc.), whereas the corresponding numbers were 18% in Spain and 5% in Finland. The school buildings in Spain reported highest percentage, 38%, of current water or moisture damage (i.e. plumbing leaks, roof leaks, etc.), while school buildings in the Netherlands and Finland reported 25% and 22% correspondingly. Mold damage (i.e. visible mold growth on building surface or structure inside the building) was reported in 7–15% of school buildings. None of the previously described problems were reported in 53% of school buildings in Spain, 57% in the Netherlands, and 76% in Finland.

Moisture problems were located in classrooms in 37% of school buildings in the Netherlands, 17% in Finland, and 16% in Spain (Table 2). In addition, the schools in the Netherlands most commonly reported several classrooms affected. The most common cause of problems identified was water from outside sources in all three countries. Rising damp was suggested the second common cause in Finland and Spain, whereas water/moisture from inside sources was suggested the second most common cause in the Netherlands.

Previous water damage (1–5 years ago, >5 years ago) was most often reported in the Finnish schools, whereas signs of dampness problems in the last 12 months were most often reported in the Netherlands (27%). Current and past mold odor was most often observed in Finnish school buildings (15–27%).

Table 3 shows the associations between selected building characteristics and reported signs of current dampness, moisture, or mold damage, adjusted for country. For example, buildings constructed before 1970 have a higher risk of having moisture problems compared with a newer buildings (OR 1.4, CI 95% 0.7–2.8). Statistically significant ($P < 0.05$) or almost significant ($P < 0.1$) associations were observed between any signs of dampness, moisture or mold damage and main frame structure material [masonry OR 1.9 (0.9–3.8)], and the type of windowpane [single pane 5.2 (1.3–21)]. However, the associations were not statistically significant when both frame material and windowpane were included in the same model.

Criteria for selection of index/reference schools and case/control schools are presented in Table 4. School inspections were performed in a total of 80 school buildings. On the basis of the inspections, ten school buildings could not be classified into either cases or controls. Out of 70 remaining school buildings, reference status matched with control status in 24 school buildings, and index status matched with case status in 33 school buildings (Table 5). The overall agreement of building status based on screening (reference vs. index) and inspection (control vs. case) data was 81%, and the corresponding kappa-value was 0.622, indicating moderate or good agreement. There were a total of 6

Table 1 School building characteristics from a random sample of primary schools in three European countries

	Finland	Spain	The Netherlands
School buildings/Schools	*N* = 59/36	*N* = 85/78	*N* = 92/79
School consists of more than one building, *N* (%)	20 (56)	25 (32)	24 (30)
Year of construction, *N* (%)			
≥1990	13 (22)	21 (26)	35 (39)
1970–1989	16 (27)	33 (40)	35 (39)
<1970	30 (51)	28 (34)	20 (22)
Age of the building[b]	44 (29)	40 (28)	32 (24)
Year of construction[b]	1967 (29)	1971 (28)	1979 (24)
Floor area of the building m^2 [d]	2000 (1000–2676)	800 (500–1500)	1120 (800–1500)
Number of classrooms[d]	13 (6–21)	20 (14–25)	9 (8–11)
Number of students[d]	200 (80–300)	322 (205–450)	201 (150–260)
Crowdedness index[d]*	16 (13–18)	17 (13–20)	22 (19–25)
Type of the building, *N* (%)			
Detached from any other building	52 (90)	60 (72)	63 (70)
Attached to one or more buildings	2 (3)	20 (24)	21 (23)
Portable, temporal building	4 (7)	3 (4)	6 (7)
Number of storeys in the building, *N* (%)			
One	17 (29)	16 (19)	50 (54)
Two	28 (47)	15 (18)	34 (37)
Three or more	14 (24)	54 (63)	8 (9)
Type of windowpanes in the classrooms, *N* (%)			
Single	0 (0)	53 (64)	36 (39)
Double	17 (29)	26 (32)	45 (49)
Triple	38 (64)	0 (0)	0 (0)
Other	4 (7)	4 (4)	11 (12)
Condensation on the windowpanes, *N* (%)	3 (5)	22 (27)	46 (50)
Type of foundation/ground floor structure, *N* (%)			
Ground slab	N/A	34 (64)	10 (12)
Crawl space	N/A	1 (2)	57 (69)
Other/Not known	N/A	18 (34)	15 (18)
Building has a basement, *N* (%)	32 (54)	30 (36)	10 (11)
Main frame structure material, *N* (%)			
Concrete	22 (37)	43 (52)	24 (26)
Masonry	13 (22)	24 (29)	21 (23)
Timber	9 (15)	1 (1)	5 (6)
Steel	0	3 (4)	16 (17)
Other/Not known	15 (25)	12 (14)	26 (28)
Type of the roof, *N* (%)			
Flat	12 (20)	47 (57)	51 (55)
Ridge	38 (65)	27 (32)	19 (21)
Other	9 (15)	9 (11)	22 (24)
Ventilation, air conditioning and air systems/equipment employed in the building, *N* (%)			
Mechanical exhaust	58 (98)	24 (30)	42 (47)
Mechanical support of outdoor air	51 (86)	6 (8)	18 (20)
Central air conditioning system	13 (22)	3 (4)	2 (2)
Single-room air conditioning units	8 (14)	6 (7)	1 (1)
Regularly used humidifiers	2 (3)	0	0
Regularly used dehumidifiers	0	3 (4)	1 (1)
Regularly used air purifiers	2 (3)	2 (3)	2 (2)
School building undergone large repairs or renovations, *N* (%)			
Currently	2 (3)	4 (5)	3 (3)
In the past 12 months	5 (8)	17 (20)	11 (12)
1–5 years ago	21 (36)	16 (19)	24 (26)
More than 5 years ago	24 (41)	16 (19)	9 (10)
Major repairs or renovations planned within the next two years, *N* (%)	13 (22)	22 (26)	21 (23)

[b]Mean (s.d.).
[d]Median (P25–P75).
*Crowdedness index defined as number students/number classrooms.
N/A: data not available.

false-negative cases (i.e. cases that were originally classified as references based on the absence of reported moisture problems). Out of these, four cases were from Spain, whereas there was one case both from Finland and the Netherlands. There also were a total of seven false-positive controls (i.e. buildings with reported

Table 2 Current moisture problems in school buildings: status, location and causes

	Finland	Spain	The Netherlands
School buildings/Schools	*N* = 59/36	*N* = 85/78	*N* = 92/79
Any sign of damp/mold, *N* (%)	14 (24)	39 (47)	40 (43)
Dampness	3 (5)	15 (18)	27 (29)
Water/moisture damage	13 (22)	32 (38)	23 (25)
Mold damage	5 (9)	6 (7)	14 (15)
Mold odor, *N* (%)	10 (17)	3 (4)	6 (7)
Location of the problems, *N* (%)			
Regular classrooms	10 (17)	14 (16)	34 (37)
Teachers lounge/room	1 (2)	2 (2)	6 (7)
Rooms occupied only occasionally*	2 (3)	13 (15)	7 (8)
Hallways	6 (10)	16 (19)	21 (23)
Bathrooms/toilets	2 (3)	11 (13)	5 (5)
Any other rooms	6 (10)	18 (21)	3 (3)
Number of regular classrooms affected, *N* (%)			
Only one regular classroom affected	2 (12)	3 (8)	5 (12)
Several regular classrooms affected	8 (50)	11 (31)	29 (71)
Suggested causes of the problems, *N* (%)			
Water from outside	13 (22)	9 (34)	19 (21)
Rising damp from the ground	4 (7)	4 (16)	4 (4)
Water/moisture from inside sources	2 (3)	11 (13)	10 (11)
Other	0	9 (10)	9 (10)
Last 12 months, *N* (%)			
Any signs of damp/mold	10 (30)	22 (52)	34 (49)
Signs of dampness	0	7 (8)	25 (27)
Water/moisture damage	9 (15)	20 (24)	21 (23)
Mold damage	3 (5)	3 (4)	7 (8)
Mold odor	9 (15)	6 (7)	9 (10)
1–5 years ago, *N* (%)			
Any signs of damp/mold	27 (60)	25 (64)	24 (45)
Signs dampness	3 (5)	5 (6)	6 (7)
Water/moisture damage	26 (44)	25 (29)	19 (21)
Mold damage	3 (5)	1 (1)	10 (11)
Mold odor	16 (27)	9 (11)	8 (9)
More than 5 years ago, *N* (%)			
Any signs of damp/mold	22 (54)	15 (43)	12 (26)
Signs of dampness	4 (7)	7 (8)	8 (9)
Water/moisture damage	20 (34)	11 (13)	3 (3)
Mold damage	7 (12)	4 (5)	3 (3)
Mold odor	9 (15)	8 (9)	3 (3)

*Cafeteria, gym, etc.

moisture problems that could not be confirmed by the inspections), and all of them were from the Netherlands. Extrapolating from the inspection data, the minimum estimates for prevalence of moisture problems in school buildings are 41% in Spain, 24% in Finland, and 20% in the Netherlands.

Discussion

In this study, some differences were observed in the school building characteristics between the countries. These differences were seen in both age and types of the buildings, which may have various effects on the condition of the buildings and possibly the occurrence of moisture problems. The school buildings in Finland were older than the school buildings in the Netherlands or Spain, which could explain the observed higher renovation activity in the past 5 years. This could imply that the school buildings were commonly updated, also addressing issues related to dampness and ventilation. Past moisture problems were more commonly reported in Finnish schools than current problems, supporting this hypothesis. Smaller occupant density could relate to ventilation adequacy together with the common use of mechanical ventilation systems and explain the relatively small number of dampness and condensation observations. However, ventilation by opening windows is used less frequently in Finnish schools during the lengthy heating season because of energy conservation and comfort issues. Given these premises, it may be challenging to provide sufficient ventilation even with mechanical ventilation systems (Palonen et al., 2009). Both current and past mold odor were relatively commonly reported in Finnish schools, which could be attributed to (hidden) microbial growth in parts of the buildings.

The school buildings in Spain reported moderate levels of current dampness problems, but had relatively high prevalence of current moisture or water damage. Common causes of problems identified were water from outside sources and rising damp. Predominant building characteristics included flat roof and slab-on ground, which could explain some of the issues related to rising damp. However, concrete/masonry structures and the common usage of ceramic tile flooring are typically protective against such problems. Most buildings had no mechanical ventilation, and only a small proportion of schools had air conditioning; however, thermal conditions were not addressed in the questionnaire.

In the Netherlands, the schools commonly reported signs of dampness, both at the time of the questionnaire and in the past 12 months. Unlike Finnish and Spanish school buildings, moisture problems were commonly located in the classrooms. However, mold odor was reported less often. Condensation on windows was commonly observed, which could be attributed to the type of the windows as well as insufficient ventilation and modified by the relatively high occupancy observed in schools in the Netherlands.

On the basis of logistic regression analyses, some building characteristics were associated with current moisture problems, when adjusted only for country. However, when these building characteristics were included in a multivariate model, the associations did not remain statistically significant. While it is plausible that building characteristics, such as frame material and type of windows, are associated with occurrence of moisture problems, our sample size may not have been sufficiently large to verify these associations.

The Internet-based method used allowed a relatively fast distribution and collection of the questionnaires,

Table 3 Associations between selected building characteristics and reported signs of dampness, moisture or mold damage at the time of the study (N = 236)

	Any sign currently N (%)	Adjusted only for country OR (95% CI)	Adjusted OR (95%)[a]
Country			
Finland	14 (24)	1	1
Spain	39 (47)	2.8 (1.3–5.8)*	1.2 (0.3–4.8)
The Netherlands	40 (43)	2.4 (1.2–5)*	1.3 (0.3–4.9)
Number of students >200			
No	31 (35)	1	–
Yes	62 (43)	1.3 (0.7–2.3)	
Year of construction			
≥1990	28 (38)	1	–
1970–1989	33 (39)	1 (0.5–2)	
<1970	32 (42)	1.4 (0.7–2.8)	
Type of roof			
Ridge	31 (37)	1	–
Flat	47 (43)	0.9 (0.5–1.8)	
Type building			
Detached	68 (39)	1	–
Attached	22 (52)	1.4 (0.7–2.8)	
Number of storeys			
≤2	60 (38)	1	–
>2	33 (45)	1.2 (0.6–2.4)	
Building has a basement			
No	63 (39)	1	–
Yes	28 (40)	1.3 (0.7–2.5)	
Main frame structure material			
Concrete	29 (33)	1	1
Masonry	28 (48)	1.9 (0.9–3.8)*#	1.6 (0.7–3.3)
Timber or steel	13 (38)	1.3 (0.5–3.1)	1.3 (0.5–3.2)
Type of windowpane			
Triple	9 (24)	1	1
Double	27 (31)	1.8 (0.5–6)	1.1 (0.2–4.6)
Single	49 (56)	5.2 (1.3–21)*	2.7 (0.5–14)
Mechanical exhaust			
Yes	39 (32)	1	–
No	49 (48)	1.4 (0.7–2.6)	
Mechanical support of outdoor air			
Yes	22 (30)	1	–
No	66 (44)	1.1 (0.5–2.5)	

*$P < 0.05$, #$P < 01$.

[a]Adjusted ORs based on a multivariable model including country, type of window, and main frame structure material as independent variables.

and different language options were inbuilt in the service. Also the data management was less time consuming as the Internet responses were readily in an electronic format. However, many survey factors have to be carefully considered with respect to the Internet-based questionnaires, such as accessibility to the Internet, structure of the questionnaire, and confidentiality. As concerns the practical application of the Internet questionnaire, the study centers in the three countries opted for different supplementary options, that is use of a paper version and phone interviews, based on the previous experiences and expectations on response behavior of school officials.

Among the other survey factors, translation of the questionnaire into several languages naturally provides challenges. Certain technical terminology might not be applicable in different countries and is difficult to translate verbatim, considering both lingual and cultural differences. These issues need to be considered when attempting to explain the observed differences between the countries.

In Finland, a national survey using an Internet-based questionnaire had recently been conducted (response rate 41% of all Finnish elementary schools) providing same or similar data from school buildings. However, there was a number of non-respondents within a convenient geographical proximity to the conducting study center, which were sufficiently large (over 200 pupils) to be potentially included in the next phases of the HITEA study (i.e. detailed exposure and health impact assessments). Because of the non-response to the previous questionnaire survey and aiming at maximizing participation, it was decided to conduct a phone interview among these schools. The interviewed schools were, on average, larger and newer buildings located in more urban areas. These characteristics are related to criterion of having more than 200 pupils, and such schools typically represent newer buildings in growing urban areas. However, the other pertinent building characteristics and reported moisture problems appeared to be comparable to the larger sample collected from the national survey. For example, no moisture problems were reported in 76% of the interviewed schools, whereas a similar percentage of the schools (73%) reported no such problems based on the national survey (data not shown).

Because of self-reporting, the screening questionnaire results should be interpreted with caution. Some of the questions included in the questionnaire are relatively simple to answer and readily known by school personnel, who in most cases also have the most long-term knowledge of their school and its condition. However, some of the questions are more difficult to answer, requiring personal judgment to some degree. Such questions include the existence of moisture problems, their location, and extent. A part of the problems may be hidden, that is not visible, and their discovery is therefore dependent on the other types of manifestations, for example odor. In any case, these responses are always somewhat subjective, and variation can be expected even between trained personnel, depending on their background and experience (Haverinen-Shaughnessy et al., 2005).

The agreement between dichotomous rating of school buildings based on dampness, moisture, and mold observations drawn from questionnaire and inspection data was relatively good (kappa 0.62). However, it should be mentioned that the variation in agreement between questionnaire and inspector data between countries was large (0.39–0.91). It could be speculated that the variation is related to each individual inspector's judgment on moisture problems, or to differences in awareness of the responding school personnel.

Table 4 Selection criteria for index/reference and case/control schools

Selection criteria for index/reference
Index schools
1) Current signs of dampness problems, moisture or water damage and/or mold in the building
2) Larger extent of damage (widespread and/or large)
3) Priority given to schools with location of the damage in the classrooms and a bigger number of regular classrooms affected
Reference schools
1) No current signs of dampness problems, moisture or water damage or mold in the building
2) No previous dampness/mold/moisture damage in the last 12 months
3) Priority given to schools with previous problems or repairs more than 5 years ago
Selection criteria for case/control
Gradient classification based on the number of damage sites in the classrooms, their extent and severity
*Extent estimated in square meters.
*Severity based on 6-point scale
0 = No damage observed
1 = Minor damage such as coloured stains on interior coverings that are caused by faulty appliances (e.g. washing and dishwashing machines) or pipe leaks and no further consequences is anticipated
2 = Deteriorated interior finish or covering, which needs drying, re-gluing, or fixing
3 = Damaged interior structural component that needed opening, drying and renewal or minor repair
4 = A functional element that needs partial or total renewal
5 = The building is unsuitable for use, beyond repair

Comparing to the relatively good overall agreement between questionnaire and inspection assessment in our study, a previous study in Finnish residential buildings (Haverinen-Shaughnessy et al., 2005) concluded that the overall agreement between an inspector and occupants was poor (average kappa 0.23), whereas the agreement between two inspectors was higher (average kappa 0.41). In a study conducted in Bulgarian residences, kappa-values between parents' and inspectors' reported dampness and mold indicators varied between 0.21–0.47 (Naydenov et al., 2008). Possible explanations for the better agreement obtained in this study involving school buildings include questionnaire respondents being all school principals and therefore presumably a more homogenous group than occupants of residential buildings. School principals may also have sought help from the school technical personnel, who typically has profound knowledge on technical matters and condition of the schools. It is also possible that when selecting schools for the on-site inspections, the research personnel became aware of the problems reported by the personnel, which subsequently may have influenced their observations and ratings in the course of the actual inspections. However, the primary purpose of the on-site inspections was to discern false-negative and false-positive cases or controls among the 'index' and 'reference' schools selected based on the questionnaire study. Being that a total of 13 of 70 schools inspected were discovered with false status, it appears that the inspections could overcome the potential bias and provide as objective results as reasonably possible.

False-negative schools are schools with moisture problems that were originally classified with a reference status. This could be related to the school personnel being unaware of the potential dampness and mold-related issues. Four of six false-negative cases were from Spain. Five of the buildings had a basement, and four of them had slab-on-ground foundation and ridge roof. Three of the buildings were from the 1960s; two were from 1975 to 1980 and one from 2007. Two had reported major water intrusion, but none of them reported complaints related to dampness or mold. However, two schools had reported indoor air quality complaints. With respect to exposure and health impact assessment, inclusion of these false-negative cases could have led to biased results.

Conversely biased results could have been obtained by inclusion of false-positive controls. These referring to schools classified as cases where moisture problems could not be confirmed in the on-site inspections. Being that all seven false controls came from the Netherlands, it could be speculated that the awareness of dampness and mold issues may be high because of recent media attention, and therefore, the school personnel could be sensitive in reporting such signs. Naturally, there are also other possible explanations. Six of the seven school buildings had a crawl space, and five of them had a flat roof. However, these were typical school building characteristics in the Netherlands. Two reported major water intrusion and complaints of dampness or mold, whereas three school buildings reported complaints related to indoor air quality, so in this sense, these buildings did not differ much from the false-negative cases. Interestingly, four of these seven buildings were newer constructions built in 2004–2008. It is not apparent why these newer buildings had reported moisture problems in the screening

Table 5 Comparison of exposure status of school buildings assessed by screening questionnaire only (stage 2: reference vs. index) and assessed by both questionnaire and inspection data (stage 3: control vs. case), per country and combined

	Index case (True +)	Index control (False +)	Reference control (True −)	Reference case (False −)	*K* (*P*)	Sensitivity (%)	Specificity (%)
Finland	12 (54.5%)	0	9 (41%)	1 (4.5%)	0.91 (0.000)	92	100
The Netherlands	10 (40%)	7 (28%)	7 (28%)	1 (4%)	0.39 (0.030)	91	50
Spain	11 (48%)	0	8 (35%)	4 (17%)	0.66 (0.001)	73	100
Combined	33 (47%)	7 (10%)	24 (34%)	6 (9%)	0.62 (0.000)	85	77

questionnaire, but it may at least partly explain why visible signs of dampness and mold were not observed in the inspections. Also newer buildings may still experience some off-gassing from buildings materials resulting odors and possibly indoor air quality complaints, not always easily distinguished from dampness and mold issues.

It should be pointed out that our intention was not to generalize the study findings to the three climatic regions but to study occurrence of dampness and mold in schools in three countries representing three climatic regions. There are numerous possible explanations with respect to differences observed between different countries. In any case, as best possible, we were trying to obtain data that would be comparable. To our knowledge, this is the first study of this nature in school environments (many international studies have been conducted related to home environments).

In addition to providing comparable data related to occurrence of moisture problems in schools in three European countries, this study aimed to create a consistent case–control setting for subsequent health impact assessment related to exposure to dampness and mold in schools in the course of the HITEA study. The inspections of the school buildings following the initial screening questionnaire assessment were performed to confirm, objectify, standardize, and further expand the assessment on moisture problems in the study schools. It appears that both country-specific analyses and pooled analyses based on the case–control status of selected buildings should be feasible after adjusting for relevant confounding factors including the data source, that is country of origin.

Conclusions

On the basis of the results and analyses of the data collected by questionnaire from school principals and on-site investigations by trained staff, the minimum estimates for prevalence of moisture problems in school buildings are 41% in Spain, 24% in Finland, and 20% in the Netherlands. The overall agreement between dichotomous rating of school buildings based on dampness, moisture and mold observations drawn from questionnaire and inspection data was relatively good (kappa 0.62), but the variation in agreement between countries was large (kappa 0.39–0.91). Thus, questionnaire based surveys can be used to assess moisture problems in school buildings, but because of large variation in validity, the questionnaire needs to be validated by on-site inspections in a subsample of the surveyed buildings.

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Appendix: The HITEA study group

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