Identification of Mold and Dampness-Associated Respiratory Morbidity in 2 Schools: Comparison of Questionnaire Survey Responses to National Data

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ABSTRACT

BACKGROUND: Dampness and mold problems are frequently encountered in schools. Approximately one third of US public schools require extensive repairs or need at least 1 building replaced. This study illustrates how national data can be used to identify building-related health risks in school employees and students.

METHODS: School employees (n = 309) in 2 elementary schools (schools A and B) with dampness and mold problems completed standardized questionnaires. Responses were compared with participant responses from the 3rd National Health and Nutrition Examination Survey and were indirectly standardized for gender, age, smoking status, and (for school B) race. Uncontrolled comparisons were made to responses from a study of office workers, as well as between responses from school employees in different sections of the school buildings designated by decade of construction.

RESULTS: Employees from both schools had excess work-related throat and lower respiratory symptoms, as well as eye, nasal, sinus, and wheezing symptoms. School B employees also had excess physician-diagnosed asthma and work-related fatigue, headache, and skin irritation. Employees in sections of the school buildings that were categorized as having greater dampness and mold contamination had more frequent upper and lower respiratory symptoms than employees working in other building sections.

CONCLUSIONS: This noncostly type of analysis of indoor air quality complaints can be used to motivate and prioritize building remediation in public schools where funds for building remediation are usually limited.

Keywords: public health; environmental health; chronic diseases.

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A random survey of 10,000 public schools completed by the US General Accounting Office in 1994 indicated that one third of schools had at least 1 entire building in need of extensive repair or replacement.[1] The mean among states for inadequate roofs was 27% of schools (range 15-67%); for inadequate heating, ventilating, and air-conditioning systems was 37% (16-66%); for inadequate ventilation was 28% (7-52%); and for poor indoor air quality was 21% (6-50%). Children are more susceptible than adults to some environmental pollutants due to breathing higher volumes of air relative to their body weights and their active growth, making the indoor air quality exposures that may result from school building insufficiencies particularly troublesome.

Epidemiological studies have demonstrated associations between building dampness or mold and upper respiratory symptoms,[2,3] cough,[4,5] wheeze,[4,6] shortness of breath,[7,8] asthma symptoms in people with asthma,[3,6] development of asthma,[9,10] fatigue,[2,11] headache,[11] eye irritation,[11] and skin irritation.[2,11] The Institute of Medicine of the National Academies recently completed a comprehensive review of the scientific literature and concluded that there was sufficient evidence for an association between mold or dampness in indoor environments and upper respiratory tract symptoms, wheeze, cough, asthma symptoms in sensitized persons, and hypersensitivity pneumonitis in susceptible persons; and limited or suggestive evidence for an association between dampness in indoor environments and lower respiratory illness in otherwise healthy children and the development of asthma.[12]

Despite a well-established association between building dampness and a variety of symptoms, the actual causative agents are not known. Proposed agents include fungi, bacteria, microbial spores or fragments, mite and cockroach allergens, microbial volatile organic chemicals, and chemical emissions from water-damaged building materials. Damp indoor environments are commonly assessed by measuring airborne levels of microbial agents. Limitations of this approach include large analytical errors and a prohibitive number of samples (and associated cost) required to reliably measure exposures. Typical studies of indoor environments with limited numbers of air samples often fail to demonstrate associations between environmental measurements and adverse health effects.

This study demonstrates a means of generating data that can motivate remediation of damp school buildings and assist with prioritization of expenditures, which are usually limited in public schools. Our approach is inexpensive and can be performed without costly environmental sampling.

METHODS

Subjects

During February 2003 and June 2004, the National Institute for Occupational Safety and Health (NIOSH) responded to 2 requests to investigate suspected building-related health hazards in elementary schools. The 2 schools, located in South Carolina (school A) and Connecticut (school B), historically had problems with water incursion and musty odors. Employees at these schools had reported asthma and numerous respiratory and other symptoms that they thought were related to indoor air quality.

Instrument

The questionnaire consisted of sections on demographics; symptoms (upper and lower respiratory, systemic, headache, and skin irritation) in the last 4 weeks and 12 months, and in relation to being in the school building; physician-diagnosed asthma; job category; and work location. Work-related symptoms were defined as symptoms that occurred at least 1 day per week in the preceding month and that improved when away from work. Most survey questions were extracted from 2 national surveys: the Building Assessment Survey and Evaluation (BASE) study,[13] a 1994-1998 Environmental Protection Agency survey of office employees at office buildings with no known or perceived problems in large US cities, and the 3rd National Health and Nutrition Examination Survey (NHANES III),[14] a 1988-1994 survey of the US civilian, noninstitutionalized population.

Procedure

All school employees were invited to participate; students were not included in the study due to restrictions of the NIOSH federal mandate to study occupational health hazards. The questionnaire was administered to small groups of employees at a time, using schedules prepared by the management of the 2 schools. During each session, NIOSH staff described the purpose of the survey and the consent process. Participants were informed that by completing the questionnaire, they were indicating their consent to participate in the survey. Information from independent environmental consultant reports was used to categorize building sections by relative degree of dampness and mold contamination. The study was approved by the NIOSH Human Subjects Review Board as part of the NIOSH Health Hazard Evaluation program.

Data Analysis

Survey data were entered using a double-key method to ensure data accuracy. Data were analyzed

using SAS software version 9.0 (SAS Institute Inc., Cary, NC). The prevalences of work-related symptoms among employees at schools A and B were compared with employees at 41 office buildings in the BASE study[15] using unadjusted prevalence ratios. Prevalences of respiratory symptoms and self-reported asthma among employees were compared with prevalence rates observed in US adults collected in NHANES III.[14] Data collected at school A were compared with NHANES III using indirect standardization for age (17-39 and 40-69 years), gender, and smoking status (current, former, and never). Data collected at school B were compared with NHANES III using indirect standardization for age (17-39 and 40-69), gender, smoking status (current, former, and never), and race. Unadjusted prevalence ratios were used to compare symptom and asthma prevalences among employees working in building sections categorized as having greater dampness or mold contamination to prevalences of employees working in other school sections. Poisson distributions were assumed in the calculation of the 95% confidence intervals of all prevalence ratios,[16] and probability values less than .05 were used to determine statistical significance.

RESULTS

Environmental Consultant Reports

School A consisted of 3 sections constructed, respectively, in the 1970s, 1980s, and 1990s. Water incursion had occurred through roof leaks, courtyard doors (due to outside flooding), concrete slab cracks, and an exterior wall (due to a clogged rain gutter). Other water problems included clogged drain lines for individual room air conditioners that caused persistent dripping of water onto the carpet, standing water in central air-handling units, and water that was not thoroughly extracted from carpets after cleaning. Bowed ceiling tiles and musty odor of library books provided indirect evidence of chronic high indoor relative humidity. Most dampness problems had occurred in the building sections constructed in the 1970s and 1980s.

School B was originally built in the 1930s, with 2 newer sections added on in the 1970s and 1980s, respectively. Water incursion had occurred through roof leaks and flooding outside courtyard doors. Although all building sections had experienced water incursion, visible mold was noted to be present in the plenum (above the ceiling tiles) in multiple areas of the building sections constructed in the 1930s and 1980s.

NIOSH Health Survey

Among 293 school A employees, 210 (72%) participated in our survey. Ever and current physician-diagnosed asthma prevalences were 13.0% and 7.3%, respectively. Demographics for employees are summarized in Table 1. Compared with participants in the BASE study, school employees had statistically significant 1.9- to 2.6-fold excesses of work-related sore throat, chest tightness, shortness of breath, and cough. Compared with NHANES III examinees, school employees had statistically significant 1.3- to 2.3-fold excesses of eye and nasal symptoms, sinusitis, and wheezing (Table 2). Employees working in the (1970s and 1980s) building sections with the greater dampness problems had statistically significant excesses of nasal and wheezing symptoms and work-related sore throat, compared with those who worked in the other (1990s) building section (Table 3).

Among 108 school B employees, 99 (92%) participated in our survey. Demographics for employees are summarized in Table 1. Ever and current physician-diagnosed asthma prevalences were 17.2% and

Table 1. **Demographics of Employees Working by School and Different Building Sections Designated by Decade of Construction**

	School A			School B		
Characteristic	**All Employees (N = 210)***	**1970s and 1980s Sections (N = 144)**	**1990s Section (N = 51)**	**All Employees (N = 99)***	**1930s and 1980s Sections (N = 44)**	**1970s Section (N = 35)**
Age (years), mean ± SD	45.5 ± 10.6	44.7 ± 10.8	47.4 ± 9.6	44.6 ± 11.6	43.1 ± 11.8	46.6 ± 11.8
Gender (% female)	93.6	92.9	95.9	88.9	97.7	85.7
Building tenure (years), mean ± SD	6.5 ± 7.2	5.8 ± 6.0	7.9 ± 8.8	5.7 ± 6.4	4.7 ± 4.4	7.1 ± 7.3
Smoking status						
Current smoker (%)	9.2	9.2	8.0	4.1	4.6	5.9
Former smoker (%)	26.1	26.1	28.0	30.6	22.7	32.4
Never smoker (%)	64.7	64.8	64.0	65.3	72.7	61.8
Job category						
Teachers/assistants (%)	74.5	82.4	54.9	71.7	81.8	60.0
Clerical/administration (%)	8.2	6.3	13.7	7.1	0.0	20.0
Other (%)	17.3	11.3	31.4	21.2	18.2	20.0

*The number of participants in the 2 building sections do not sum to the total number since those employees who worked in both building sections or portable building units were not included in the analysis.

Table 2. **Symptom and Self-Reported Asthma Prevalences by School and Prevalence Ratios Based on Comparisons With BASE and NHANES III Study Participants***

Survey Questions	School A†			School B‡		
	Prevalence (%)	Prevalence Ratio	95% Confidence Interval	Prevalence (%)	Prevalence Ratio	95% Confidence Interval
BASE: Have you had any of the following symptoms 1 or more days per week in the last 4 weeks with symptoms getting better away from work (eg, holidays and weekends)?						
Sore or dry throat	18.5	**2.6**	**1.88-3.60**	26.3	**3.7**	**2.52-5.42**
Chest tightness	5.5	**2.3**	**1.28-4.10**	10.1	**4.2**	**2.28-7.74**
Shortness of breath	4.6	**2.2**	**1.15-4.15**	10.2	**4.9**	**2.64-8.94**
Cough	10.2	**1.9**	**1.22-2.85**	17.2	**3.1**	**1.95-5.00**
Wheezing	4.4	1.8	0.97-3.49	10.1	**4.2**	**2.28-7.74**
Unusual tiredness, fatigue, or drowsiness	13.6	0.8	0.58-1.22	36.4	**2.2**	**1.62-3.11**
Headache	15.2	0.9	0.64-1.30	34.3	**2.1**	**1.47-2.87**
Dry or itchy skin	6.6	1.3	0.74-2.17	10.1	**1.9**	**1.05-3.57**
NHANES III: Have you had any of the following symptoms any time in the last 12 months?						
Watery or itchy eyes	64.4	**1.3**	**1.11-1.60**	58.6	**1.3**	**1.00-1.68**
Stuffy, itchy, or runny nose	72.9	**1.3**	**1.05-1.47**	83.8	**1.4**	**1.12-1.72**
Sinusitis or sinus problems	65.9	**1.6**	**1.34-1.91**	67.7	**1.6**	**1.26-2.05**
Wheezing or whistling in the chest	33.3	**2.3**	**1.76-2.88**	49.5	**3.5**	**2.64-4.63**
NHANES III						
Has a doctor ever told you that you have asthma?	13.0	1.5	0.97-2.18	17.2	**2.2**	**1.37-3.51**
Do you still have asthma?	7.3	1.4	0.81-2.29	12.1	**2.3**	**1.32-4.03**

*Bold font indicates statistically significant results, $p < .05$.

†NHANES III prevalence ratios and 95% confidence intervals adjusted for age, gender, and smoking status.

‡NHANES III prevalence ratios and 95% confidence intervals adjusted for age, race, gender, and smoking status.

12.1%, respectively. Compared with participants in the BASE study, school employees had statistically significant 1.9- to 4.9-fold excesses of all work-related symptoms. Compared with NHANES III examinees, school employees had statistically significant 1.3- to 3.5-fold excesses of eye and respiratory symptoms and more than 2-fold statistically significant excesses of ever and current physician-diagnosed asthma (Table 2). Employees working in the 1930s and 1980s building sections where mold had been found in the ceiling plenum had statistically significant excesses of work-related headache, as well as wheezing and shortness of breath, compared with those who worked in the other (1970s) building section (Table 3).

DISCUSSION

The results of these 2 questionnaire surveys carried out by NIOSH investigators indicate that employees from both schools had excess work-related throat and lower respiratory symptoms, as well as eye, nasal, sinus, and wheezing symptoms. School B employees also had excess physician-diagnosed asthma and work-related fatigue, headache, and skin irritation. Our findings are consistent with scientific literature reviews that have identified sufficient evidence for causal associations between dampness or the presence of mold and respiratory health effects.[12,17]

Renovation and remediation had occurred in both schools mostly during school breaks and summer recesses over a period of several years prior to our surveys. Subsequent to our surveys, a new heating ventilation and air-conditioning system was installed (in the 1980s building section) and carpeting was replaced by vinyl flooring (in the 1970s and 1980s building sections) in school A; and teachers and students in the 1930s and 1980s building sections of school B were relocated to another building. Although no follow-up is available for our study, intervention studies among teachers and students in mold-damaged schools have documented improvement in respiratory health (nasal symptoms, sore throat, cough, bronchitis, symptoms of allergic rhinitis, and number of episodes of respiratory infections) and eye symptoms, fatigue, and headache following remediation.[18,19]

The findings of this study are subject to the following limitations. First, the analyses were based on self-reported diagnosed asthma and symptoms. However, NIOSH investigators have substantiated the validity of self-reported asthma and symptoms in an investigation of office workers in a damp building where the majority of those meeting an asthma case definition (based on self-reported asthma and symptoms) had objective physiologic abnormalities and/or used prescription asthma medication.[20] Validation studies of self-reported asthma using nonspecific bronchial challenge as the gold standard have yielded sensitivities (the likelihood of identifying asthmatic subjects based on self-reported asthma) ranging from 7% to 80% and specificities (the likelihood of identifying nonasthmatic subjects based on the lack of self-reported asthma)

Table 3. **Symptom and Self-Reported Asthma Prevalence Ratios for Internal Comparisons of Employees Working in Different Building Sections Designated by Decade of Construction***

Survey Questions	School A		School B†	
	Prevalence Ratio (1970s and 1980s Compared With 1990s Building Sections)	95% Confidence Interval	Prevalence Ratio (1930s and 1980s Compared With 1970s Building Sections)	95% Confidence Interval
Have you had any of the following symptoms 1 or more days per week in the last 4 weeks with symptoms getting better away from work (eg, holidays and weekends)?				
Sore throat	**2.9**	**1.06-7.71**	1.5	0.66-3.30
Chest tightness	1.5	0.32-6.64	1.3	0.34-5.17
Shortness of breath	2.6	0.32-20.3	7.2	0.95-53.9
Cough	2.1	0.66-6.97	0.7	0.25-1.85
Wheeze	3.1‡	0.40-23.9	5.6	0.72-43.2
Unusual fatigue	1.5	0.61-3.82	1.7	0.91-3.07
Headache	1.0	0.45-1.99	**1.9**	**1.03-3.67**
Dry or itchy skin	2.1	0.47-9.00	1.0	0.29-3.43
Have you had any of the following symptoms any time in the last 12 months?				
Watery or itchy eyes	1.2	0.93-1.61	1.2	0.80-1.85
Stuffy, itchy, or runny nose	**1.3**	**1.05-1.72**	1.1	0.90-1.39
Sinusitis or sinus problems	1.1	0.88-1.47	1.3	0.94-1.83
Wheezing or whistling in the chest	**1.9**	**1.03-3.37**	**2.1**	**1.23-3.58**
Chest tightness	1.5	0.89-2.61	1.4	0.88-2.30
Shortness of breath	1.5	0.79-2.69	**2.7**	**1.40-5.15**
Cough	1.4	0.98-1.88	1.2	0.84-1.64
Has a doctor ever told you that you have asthma?	0.7	0.32-1.42	1.4	0.53-3.89
Do you still have asthma?	0.6	0.21-1.47	1.4	0.44-4.38

*Bold font indicates statistically significant results, $p < .05$.

†Four employees who worked in a modular unit and 1 of the building sections were included.

‡No employees working in the 1990s building section reported this symptom; because calculation of a prevalence ratio is not possible with a zero denominator, 1 employee working in this building section was assigned the indicated symptom.

ranging from 74% to 100%.[21] Second, employees who perceive problems with their work area may differentially report health concerns. Third, selection bias may have been present, especially in school A, which had a lower participation rate. Fourth, the external BASE comparisons and internal comparisons were not controlled for possible confounders, such as age, gender, tenure, and smoking status. However, employees who worked in different building sections in each of the schools were generally comparable for these characteristics, suggesting that the internal comparisons were not confounded by these factors (Table 1). Fifth, our ability to categorize building sections by relative degree of dampness and mold contamination was limited by the amount of information available from independent consultant indoor air quality evaluations, which did not allow us to use a systematic approach, or to stratify exposure level as others have done.[22] Finally, although many of the questions in our questionnaires have been used by other researchers, the questionnaire as a whole has not been assessed for validity and reliability.

CONCLUSIONS

The 2 case studies presented here demonstrate simple analytic approaches for investigation of indoor air quality complaints in schools. NIOSH has used this approach in investigations of damp buildings to motivate remediation when excess symptoms or asthma were demonstrated. In buildings with building sections with evident water damage or mold contamination, internal comparisons can buttress evidence for building-related health effects and can assist in prioritizing preventive interventions. These analytical approaches do not depend upon costly environmental measurements, such as bioaerosol sampling that are inappropriate for nonresearch applications in indoor settings. The questionnaire and analytic approaches illustrated by these 2 school investigations may be useful to school boards and public health agencies dealing with indoor air quality complaints in schools. While these 2 investigations focused on school employees, similar investigations could allay parental concerns or provide evidence to motivate appropriate preventive interventions where school dampness is suspected as causing or exacerbating asthma among students. NIOSH investigators have developed semiquantitative indices (based on the presence of visible water stains, visible mold, mold odor, and moisture) that assess building dampness on a room by room basis.[23] NIOSH continues to field-test these observational damp/mold indices in schools to further develop a practical, low-cost, standardized approach to assessing building dampness that may allow remediation efforts to be more effectively targeted to problem areas of school buildings.

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