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Toxigenic Fungi in a Water-Damaged Building: An Intervention Study

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In an investigation of health complaints among employees of a water-damaged office building, the environment showed evidence of fungal contamination with the isolation of Stachybotrys chartarum *in one of five bulk samples tested for fungal growth. In response, a public health official recommended that employees be relocated from the building. Employees were subsequently moved to a different environment. A focused environmental investigation of microbial growth within the building followed, revealing moderate to high levels of fungi* (Penicillium, Aspergillus versicolor) *and bacteria in bulk and surface samples.* S. chartarum *was identified in one of 19 (5%) environmental samples using Czapek agar. A health survey of building occupants revealed a high prevalence of multiple symptoms, with a predominance of neurobehavioral and upper respiratory tract complaints. The majority of symptoms were significantly less prevalent after relocation from the water-damaged environment. The initial hypothesis that exposure to toxigenic fungi was responsible for the high prevalence of reported symptoms is difficult to investigate and confirm given the current limits of epidemiological knowledge regarding exposure to these organisms and building-related illness. Future interventions where mycotoxin exposure is suspected should emphasize the importance of risk assessment and risk communication.* Am. J. Ind. Med. 34:183–190, 1998. © *1998 Wiley-Liss, Inc.*

KEY WORDS: building-related illness;* Stachybotrys chartarum*; mycotoxin; trichothecene; risk assessment; epidemiology

INTRODUCTION

Although the allergenic potential of fungal organisms has been well-described [Horner et al., 1995; Patterson et al., 1997], recent indoor air quality investigations have evaluated the role that mycotoxins produced by certain fungi may play in the etiology of building-related illness [Johanning et al., 1996]. The toxic effects of some mycotoxins, such as aflatoxins produced by certain *Aspergillus* species, have been well-studied in animal models and are known to be potent human hepatocarcinogens [Stoloff, 1977]. Much of what is currently known about mycotoxins has emerged from veterinary science [Hintikka, 1977]. Pathogenic effects of trichothecene mycotoxins produced by *Stachybotrys chartarum* have been described in animals since the 1920s, when veterinary researchers reported disease in cattle and horses that ingested hay contaminated with toxigenic strains of this mold. Case descriptions included observations of severe skin and mucous membrane irritation, bleeding disorders, low-grade fever, conjunctivitis, and upper and lower respiratory disorders. The mechanism of trichothecene toxicity appears to be related to the potent ability to inhibit DNA, RNA, and protein synthesis [Ueno, 1980]. Trichothecene mycotoxins have been well-studied in animal models because of concerns about their potential misuse as agents of biological warfare [Pang et al., 1988; Creasia and Lambert, 1989].

Human health effects from environmental exposure to *S. chartarum* have been reported in case studies [Croft et al., 1986] and case-control studies [Johanning et al., 1996], with

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broad symptom complexes, including generalized fatigue, headaches, dermatitis, and upper and lower respiratory complaints. More recently, a case-control study of infants occupying water-damaged building environments associated exposure to toxigenic fungi with the development of pulmonary hemosiderosis and hemorrhage [Dearborn et al., 1997]. This is the first report of a specific and uncommon diagnosis where *S. chartarum* has been implicated in association with mortality in humans.

Water damage in buildings as a result of flooding or plumbing leaks is not uncommon, particularly in environments that have high yearly rainfall. In the summer of 1996, an office building in the Pacific Northwest was investigated because of health complaints among building occupants that had been documented for several years. Symptoms included recurrent upper and lower respiratory tract infections, fatigue, headache, depression, and difficulty concentrating. An industrial hygiene survey conducted 6 years earlier had identified an elevation in carbon dioxide levels (1,000 parts per million), a high level of particulates, and hot and cold regions within the building. Levels of nitrogen dioxide, ozone, and volatile aromatic hydrocarbons were not found to be elevated. The ventilation system was cleaned, and in an attempt to improve the air handling system, the fresh air intake was moved from the ground to the roof of the building.

As symptoms among building occupants persisted, a public health official was consulted to conduct a walk-through evaluation of the three-level structure. Their report documented evidence of moisture incursion throughout the building. Roof scuppers were blocked, resulting in standing water and leakage into the building walls. Inadequate foundation drainage was also noted. Mold odors were detected and several areas were identified where mold growth was suspected. *S. chartarum* was isolated from the baseboard of an interior wall in one of five environmental samples tested for fungal growth. The summary report concluded that the toxigenic mold was likely to be present within all the wet walls of the building, and that symptoms reported by building occupants were consistent with toxigenic mold exposure. The report concluded by strongly recommending that building occupants be removed from exposure and relocated to a dry building. Recommendations were made that legal consultation be considered regarding any potential liability issues relating to the continued use, remediation, or sale of the building. After reviewing the report, employee union representatives served an "unsafe condition notification." All employees were subsequently moved to a different work environment.

A high level of concern arose from individuals who had occupied the building. Many sought medical care for an evaluation of their symptoms. The National Institute for Occupational Safety and Health (NIOSH) was consulted to conduct a Health Hazard Evaluation [Boudreau and Perkner, 1997]. An evaluation of environmental conditions within the building and health symptoms among building occupants was conducted. This article discusses the methodology and the results of the evaluation.

METHODS

Two independent industrial hygiene consultants performed an assessment of environmental conditions within the building after it had been vacated. The heating, ventilation, and air conditioning (HVAC) system was still functioning as it had been previously. The first industrial hygiene evaluation was conducted within 1 month after the building was vacated. The survey included an inspection of the ventilation system, collection of bulk and surface samples from sources suspected of fungal and bacterial contamination, and air sampling for fungal and bacterial bioaerosols.

Standard sampling and isolation techniques were used for bulk, surface, and air samples. Surfaces were sampled with a sterile swab, and transported to a laboratory the same day in sterile transport agar. A 1 to 10 dilution was made using sterile phosphate buffer. One milliliter of the suspension was used to make a pour plate, using malt extract agar (MEA) for molds and aerobic plate count agar for bacteria. Aerobic plates were incubated at 35°C for 2 days before total colonies were counted and identified by type and species. Bulk samples for fungi were cultured at 24°C for 5 days, then counted for total colonies. Fungal colonies were identified after 7 and 14 days for selected samples based on high total counts. Bulk samples of solid materials were cut and returned to the laboratory using sterile containers. They were placed in a sterile phosphate buffer to make a 1 to 10 dilution, plated on MEA and aerobic plate agar medium, and read in the same manner as swab samples. Liquid samples were plated directly by placing 1 ml on a petri dish and a pour plate method using MEA and aerobic plate count agar.

Air samples were collected using an RCS Plus® sampler with flexible agar strips for molds and aerobic plate counts for bacteria. Fifty liters of air were drawn per minute. Two-minute samples were taken at 15 indoor locations, and a double set was taken outdoors for reference. Typical indoor sample locations were on tables or other hard furniture several feet above floor level. The strips were returned to the laboratory for incubation, culture, and identification using the same methods as the swab samples.

A second industrial hygiene consultant conducted a microbial survey of the building 2 months after the building was vacated. The sampling method sought building materials that had sustained water damage and areas where mold growth was suspected. For control purposes, building materials with no evidence of water damage or mold growth were sampled. The HVAC condensate pan residue and unit filter were sampled. Nineteen sites were sampled in total. Samples were plated on both MEA and Czapek (cellulose) agar, and

concentration of fungi on individual media were measured using colony forming units, listing the genera of fungi in descending order of occurrence. A chemical analysis for mycotoxin production by isolated fungi was not conducted, and air sampling was not conducted in this survey.

The Health Hazard Evaluation conducted by NIOSH consisted of a questionnaire administered to current and former employees who had occupied the building. NIOSH personnel conducted private medical interviews over a 2-day period, 5 months after the building had been vacated. Demographic data (age, sex, duration of employment), concurrent diagnoses, environmental observations while working in the building, and information on health effects (current symptoms and symptoms experienced while working in the building) were obtained by self-report from participants. Twenty-five symptoms evaluating multiple organ systems were investigated using dichotomous outcomes (yes/no). The McNemar chi-square test was used to compare differences in the proportion of employees reporting symptoms before and after being relocated from the building. Employee satisfaction with the employer was measured. Employees were asked whether they had read reports about environmental conditions within the building. An overall assessment of health since vacating the building was measured using an ordinal scale. Data were recorded using EpiInfo, version 6.04b.

RESULTS

Table I lists the gross counts for the aerobic plates (bacteria) and molds plated on malt extract agar, obtained by the first industrial hygiene consultant. Elevated mold counts were observed in several locations, including a filter from a return air duct, a sample from the main HVAC unit, a carpet sample, and a second-floor window sill. High aerobic plate counts were measured in areas of water leakage on the first and second floors of the building. Very high aerobic plate counts were measured from stained ceiling tiles and carpeting samples.

Table II lists the location and identification of samples with high aerobic plate counts or fungal growth on malt extract agar. Where fungal levels were highest, there was a predominance of *Penicillium* and *Phoma* species. *S. chartarum* was not identified in any of the bulk, swab, or liquid samples cultured on MEA. Where high aerobic plate counts were encountered, the organisms were predominantly Gram-negative rods (not coliform, with the exception of an area of ceiling tile where *Enterobacter cloacae* was identified).

Table III summarizes the ranges of gross airborne concentrations measured from bioaerosol sampling for fungi and bacteria. Airborne mold levels inside the building were less than outside air. Aerobic plate counts were consistently elevated throughout the building compared to outdoor air,

TABLE I. Results of Bulk (Material), Swab (Surface), and Liquid Microbiological Sampling of First Industrial Hygiene Consultant

Location (sample number)	Molds colony-forming units/gram, square inch, or mL	Aerobic plate counts colony-forming units/gram, square inch, or mL
Second floor, window sill (3183)	952,000	2,280
Main HVAC unit drip pan (3178)	70,000	20
Second floor, outdoor window ledge (3184)	54,000	<10
First floor, carpeting (3174)	35,000	10,416,000
Return air duct, dirty filter (3181)	33,000	1,000
Second floor, wet ceiling tile (3175)	15,000	4,312,000
First floor, stained ceiling tile (3173)	8,000	372,000
First floor, janitors station water leak (3186)	7,000	103,000
Second floor, water leak down wall (3176)	6,000	14,140
Inside duct of outside air intake (3190)	2,170	270
Return air duct, dust (3180)	250	760
Roof, water beside outside air intake (3189)	170	6,720
First floor, inside supply duct (3187)	70	150
Second floor, return air duct (3188)	60	40
Second floor water leak (3177)	33	3,584
Second floor, top of ceiling tile (3182)	20	<10
First floor ceiling tile (3185)	<10	526,000

Gross counts for the aerobic plates and molds (using malt extract agar) are listed. Water-damaged building, Pacific Northwest 1996.

with the predominant organisms identified as Gram-positive cocci in clusters. *Staphylococcus aureus* was not identified.

The locations of samples with the highest airborne mold levels are identified and reported in Table IV. The predominant airborne fungus identified within the building was *Penicillium*. *S. chartarum* was not identified in any of the air samples in this survey. The summary report recommended that the building be sold or demolished, as the building appeared to be in need of extensive repair and updating.

The second industrial hygiene survey identified moderate to high levels of fungi present in the building at 8 of 19 (42%) sampling locations. Most sample locations with moderate to high counts were associated with building materials which showed signs of water damage. The analysis

TABLE II. Location and Identification of Bulk, Swab, and Liquid Samples with High Aerobic Plate (Bacteria) and Fungal Counts; Water-Damaged Building Pacific Northwest 1996

Location (sample number)	Bacteria	Fungi	Number of fungal colonies
Second floor, window sill (3183)		*Cladosporium*	148
		Phoma	20
		Ulocladium	1
Main HVAC unit, drip pan (3178)		unidentified yeast	28
		Phoma	28
		Penicillium	26
		Alternaria	2
		Mucor	2
		Paecilomyces	1
First floor, carpeting (3174)	*Leclerla adecarboc-ylata*	*Phoma*	25
		Penicillium	19
		Aspergillus	2
		Mucor	1
Return air duct, dirty filter (3181)	*Bacillus*	*Penicillium*	405
		Cladosporium	69
		Rhizopus	25
		Mucor	10
		Aspergillus niger	8
		Epicoccum purpura-scens	6
		Alternaria	6
		Botrytis	2
		Curyalaria	1
Second floor, wet ceiling tile (3175)	Gram-negative rods (not coliform)	*Phoma*	2
		Penicillium	1
First floor, stained ceiling tile (3173)	*Enterobacter cloacae*	*Phoma*	24
	Bacillus	*Penicillium*	1
First floor, water leak (3186)	Gram-negative rods (not coliform)		
Second floor wall, water leak (3176)	Gram-negative rods (not coliform)	*Phoma*	4
		Penicillium	1
		unidentified yeast	26
Inside duct of out-side air intake (3190)		*Penicillium*	30
		Phoma	15
		Ascomycetes	6
		Ulocladium	3
		Aspergillus	2
		Alternaria	2
		Epicoccum purpura-scens	1
		Mucor	1
Roof water near air intake (3189)	Gram-negative rods (not coliform)		

TABLE III. Ranges of Airborne Fungal and Bacterial Concentrations, Measured in Colony-Forming Units/Cubic Meter, Collected From Multiple Locations; Water-Damaged Building, Pacific Northwest 1996

Location	Airborne mold levels (CFU/m³)	Aerobic plates (bacteria) (CFU/m³)
Outside—North exit doorway	340–360	10–30
Basement—HVAC room	120	150
First floor	20–120	0–310
Second floor	20–50	10–140

TABLE IV. Location and Identification of Air Samples With the Highest Airborne Fungal Levels

Location	Fungus	Number of colonies	Percentage
Outdoors at building exit	*Cladosporium*	16	64
	Penicillium	6	24
	Aspergillus	3	12
Basement, HVAC room	*Penicillium*	7	58
	Cladosporium	3	25
	Aspergillus nidulans	1	8
	Aspergillus sp.	1	8
Office, first floor	*Penicillium*	7	64
	Phoma	2	18
	Paecilomyces	1	9
	Cladosporium	1	9
Main reception area	*Penicillium*	12	86
	Paecilomyces	1	7
	Cladosporium	1	7

of building materials which had no visible water damage showed low microbial counts. Fungal growth in the HVAC condensate pan was described as low (4×10^2 CFU/mL on Czapek agar, 9.0×10^2 CFU/mL on MEA), with moderate growth on filter fabric from inside the HVAC unit (1.0×10^4 CFU/g on Czapek Agar, 1.2×10^4 CFU/g on MEA). A summary of fungal growth on Czapek agar for samples with moderate to high fungal levels is shown in Table V. Where concentrations of fungi were highest, *Aspergillus versicolor* and *Penicillium* were the predominant fungi. *S. chartarum* was not identified in any of the samples plated on malt extract agar. One of 19 (5%) samples cultured on Czapek agar were found to contain *S. chartarum*. This sample was taken from paint at the roof line at a major structural crack on the second floor of the building. The summary report of this industrial hygiene survey recommended remediation of the building prior to reoccupation.

TABLE V. Location and Identification of Building Samples With Moderate to High Fungal Growth on Czapek Agar; Water-Damaged Building, Pacific Northwest 1996

Location (description)	Concentration (colony forming units per swab, mL, or gram of sample)	Genera	Taxon count
First floor (patched area on wall measuring 8" × 10")	3.0×10^6	*Aspergillus versicolor*	61/61
First floor (discolored ceiling tile)	1.1×10^6	*Mycelia sterilia*	10/11
		Acremonium	1/11
Second floor (mushroom sample at ceiling line)	5.1×10^4	*Penicillium*	51/51
First floor (blistered paint)	2.0×10^4	*Aspergillus versicolor*	15/15
First floor (water damage beneath window)	1.6×10^4	*Aspergillus versicolor*	178/179
		Mycelia sterilia	1/179
Second floor (paint from roof line at major structural crack)	1.3×10^4	*Aspergillus versicolor*	8/15
		Mycelia sterilia	4/15
		Stachybotrys chartarum	2/15
		Penicillium	1/15
HVAC filter	1.0×10^4	*Penicillium*	42/53
		Aspergillus versicolor	4/53
		Ulocladium	4/53
		Cladosporium	1/53
		Rhizopus	1/53
		Mycelia sterilia	1/53
First floor (water damage beneath window)	2.6×10^3	*Aspergillus versicolor*	23/44
		Acremonium	12/44
		Mycelia sterilia	5/44
		Fusarium	2/44
		Penicillium	1/44
		Tritirachium	1/44

NIOSH investigators interviewed 37 individuals. Twenty-nine of 31 (94%) current employees and 8 of 18 (44%) former employees participated in medical interviews and responded to the symptom questionnaire. Thirty-three of the 37 individuals interviewed (89%) agreed to release the questionnaire data from NIOSH to this investigator. The mean age was 48.7 (range 34–67); 25 of 33 (76%) were female; mean duration of employment was 7.8 years (range 1–17). Study participants reported exposure to heat (61%), cold (58%), moisture (45%), odors (79%), and visible mold growth (82%) while working in the building. There was a high prevalence of mold allergies (27%), asthma (21%), and bronchitis (30%) among participants by self-report.

TABLE VI. Proportion of 33 Participants Reporting Symptoms Before and After Relocation From a Water-Damaged Building, Pacific Northwest 1996

Symptom	Before relocation	After relocation	*P*-value*
CNS/constitutional			
Fatigue	81.8	27.3	.001
Headache	69.7	27.3	.001
Difficulty concentrating	69.7	30.3	.002
Anxiety	60.6	24.2	.003
Recurrent infections	57.6	21.2	.001
Dizziness	48.5	15.2	.018
Depression	45.5	21.2	.045
Fever, chills, sweats	33.3	6.1	.007
Respiratory			
Cough	39.4	15.2	.013
Shortness of breath	36.4	12.1	.013
Wheezing	24.2	6.1	.041
Hemoptysis	3.0	0	$P > .05$
Ear, Nose, Throat			
Sinus congestion	69.7	33.3	.001
Water eyes	60.6	24.2	.001
Runny nose	54.5	27.3	.015
Odors	48.5	12.1	.007
Sore throat	48.5	6.1	.001
Bloody nose	27.3	6.1	.023
Gastrointestinal			
Diarrhea	39.4	21.2	.041
Nausea	24.2	12.1	$P > .05$
Bloody stool	15.2	3.0	$P > .05$
Vomiting	3.0	0	$P > .05$
Musculoskeletal			
Myalgias	45.5	33.3	$P > .05$
Dermatologic			
Rash	36.4	18.2	.041
Flushing	33.3	6.1	.007

*McNemar's chi-square, 1 df.

The proportion of participants reporting symptoms before and after relocation from the building are shown in Table VI. The symptoms with highest prevalence reported while occupying the building were fatigue (81.8%), headache (69.7%), difficulty concentrating (69.7%), and sinus congestion (69.7%). The average number of symptoms reported while occupying the building decreased significantly after relocation (mean difference = −6.25, t = 5.894,

$P < .0001$). Overall, every symptom evaluated on the questionnaire was less prevalent after the intervention, although symptoms of nausea, bloody stool, vomiting, hemoptysis, and myalgias failed to achieve statistical significance. The majority of the participants (70%) described their overall health as "better" since being relocated. Equal proportions (15%) described their overall health as "same" and "worse." Most (88%) had read the report about environmental conditions within the building. More than half (52%) described themselves as being dissatisfied with their employer. Participants who were dissatisfied with their employer did not report more symptoms while occupying the building ($F = 0.22$, $P = .64$), or after relocation ($F = 1.09$, $P = .30$), when compared to participants who described themselves as satisfied.

DISCUSSION

This case report describes an intervention that was associated with a significant reduction in the prevalence of multiple health complaints among individuals exposed to a water-damaged building environment. Evidence of fungal and bacterial growth throughout the study environment was clearly demonstrated. The working hypothesis that *S. chartarum* was growing in abundance in the building was not confirmed despite the use of methods which would favor its isolation in bulk and surface samples, an observation which exemplifies one of many difficulties encountered in investigating the risks associated with exposure to this organism.

S. chartarum does not compete well with other molds or bacteria and is easily overgrown in a sample unless cellulose-based agar (Czapek agar) is used [Jarvis, 1990]. Measurement of airborne *Stachybotrys* spores may inaccurately measure true exposure since nonviable spores, which under dry conditions may become airborne, can contain a high concentration of mycotoxins [Sorenson et al., 1987]. A significant limitation in exposure assessment is that mycotoxin production by *S. chartarum* is dependent on the specific isolate and the environmental conditions of its growth [Nikulin et al., 1994]. The isolation of a toxigenic fungus from a building environment does not necessarily indicate that exposure to mycotoxins has taken place [Jarvis, 1994].

In this investigation, fungi known to be associated with human health effects were measured at levels which have been associated with building-related illness in previous studies [Harrison et al., 1992]. *Penicillium* are ubiquitous fungi, although they are often measured at higher levels indoors than outdoors in buildings with water damage [Flannigan and Miller, 1994]. Although *Penicillium* has been associated with occupational allergies, asthma, and hypersensitivity pneumonitis [Rose, 1994], other investigators have reported nonspecific respiratory symptoms among exposed individuals [Bernstein et al., 1983]. Some *Penicillium* species have been identified as mycotoxin producers [Mislivec, 1977]. An analysis for mycotoxin production by the fungi isolated in the current investigation was not conducted, and this limits the ability to assess the role of mycotoxins in the prevalence of building-related symptoms.

A. versicolor was identified in many bulk samples, which is consistent with studies demonstrating its high prevalence in water-damaged buildings and indoor environments with high humidity [Lewis et al., 1994]. *A. versicolor* can produce sterigmatocystin mycotoxins, which are related in structure to aflatoxins [Smith and Moss, 1985]. Compared to what is known about the hepatotoxic and genotoxic properties of aflatoxins, relatively little information is available about the acute and chronic effects of sterigmatocystin in humans. Sterigmatocystin mycotoxins are considered a potential carcinogenic risk to humans, owing largely to the widespread contamination of food with these compounds [McConnell and Garner, 1994].

The building-related symptoms with the highest prevalence in this study (fatigue, headache, difficulty concentrating) were neurobehavioral. Investigators who have reported behavioral changes in animals associated with exposure to trichothecenes produced by *Fusarium* species have proposed that these mycotoxins may cause hyperaminoacidemia as a result of inhibited protein synthesis, with elevations of brain tryptophan and serotonin levels leading to behavioral effects [Smith, 1992]. The degree to which this hypothesis may be applicable to humans is unknown, and is difficult to assess given the current lack of reliable biomarkers of exposure to trichothecenes in humans.

Other environmental risk factors were identified in the study environment, including high levels of bacteria in bulk and liquid samples and elevations of airborne bacterial levels compared to outdoor air. Previous studies have identified an association between airborne concentrations of Gram-negative bacteria and building-related illness, and have proposed that endotoxin may have a significant role in the development of symptoms [Teeuw et al., 1994]. The airborne bacteria observed in the current study were Gram-positive cocci in clusters (not *S. aureus*), and unlikely to be of clinical significance, although the consistent finding of elevations of viable airborne bacteria in buildings with water damage and a high prevalence of symptoms among building occupants [Li et al., 1997] is an interesting finding that warrants further evaluation.

An analysis of demographic and other factors relating to the study participants reveals characteristics which have been demonstrated in previous studies to be positively associated with building-related illness, including female sex [Bourbeau et al., 1996], a history of atopy and asthma [Skov et al., 1989], mold allergies [Linz et al., 1998], and psychosocial factors (dissatisfaction with the employer) [Stenberg et al., 1994]. In addition to exposure to fungi, other environmental risk factors which have been positively

associated with building-related illness were not measured as part of the focus of this investigation. These include temperature [Jaakkola et al., 1989] and exposure to dust and particulates [Menzies et al., 1996], both of which had been identified as problems within the building in previous evaluations. The inability to control for these potential confounders is a limitation in identifying a causal factor to explain the prevalence of building-related symptoms.

Weaknesses to the health effects data include the subjective nature of symptom reporting and the delay between relocation from the building and the collection of health effects data. The majority of participants had read reports about microbial contamination within their work environment and the reported adverse health effects of exposure to toxigenic fungi. Because the reporting of building-related health complaints is influenced not only by environmental factors, but by an individual's perception of their environment [Ooi and Goh, 1997], the role of risk communication and the events leading to the closure of the building may have contributed to significant error in the measurement of the prevalence of building-related health complaints.

The current body of scientific knowledge regarding exposure to *S. chartarum* is limited, and a causal role in human morbidity and mortality remains poorly defined. The biological plausibility of pulmonary effects of *S. chartarum* exposure has been demonstrated in recent experimental animal studies [Nikulin et al., 1996], and is consistent with a recent report of an association with pulmonary hemosiderosis in infants [Dearborn et al., 1996]. In that report, the associations were weak (odds ratio 1.6) compared to other environmental risk factors (including exposure to environmental cigarette smoke (odds ratio 7.9)), with confidence intervals including the possibility that there was no association. Other studies which have reported significant differences in chronic fatigue, constitutional, and upper airway symptoms among individuals with varying levels of exposure to *S. chartarum* have not identified significant abnormalities in immune function or specific antibodies directed against the hypothesized causal factor [Johanning et al., 1996]. The limited ability to control for confounding host and environmental factors in such observational studies remains an ongoing problem in their interpretation.

As public awareness of the health effects associated with water-damaged environments increases [Marwick, 1997], the role of toxigenic fungi in building-related illness will continue to confront risk managers, including physicians, industrial hygienists, and public health officials. Interventions involving the relocation of an affected population from a building environment have been proposed by some authors as a method to investigate and mitigate building-related illness, but have not been previously studied using a rigorous study design [Menzies, 1997]. This case study demonstrates some of the pitfalls that may be encountered under circumstances where a specific causal factor is proposed to justify the need for the intervention, yet the hypothesis cannot be confirmed. Given the amount of uncertainty regarding toxigenic fungi and their role in building-related illness, future interventions should place greater emphasis on a careful analysis of the weight and quality of scientific evidence, examine risk in its full context, and characterize risk with information that is useful to all affected individuals. Such an approach is likely to result in more successful management and an improved understanding of this emerging issue in environmental health.

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