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October 22, 2009

Paul Krell, President
Administrative and Residual Employees Union Local 4200
705 North Mountain Road, Suite A211
Newington, Connecticut 06111

Dear Mr. Krell:

Please find attached the Interim Report X which provides updates on the NIOSH medical and environmental surveys at 25 Sigourney Street, Hartford, Connecticut. The interim report is based on results of cross-sectional data analyses of the last health and environmental survey conducted in August 2007, as well as some data analyses of the multiple cross-sectional surveys conducted in 2001/2002, 2004, 2005, and 2007. Much of the information in this report was included in presentations by NIOSH staff at the stakeholders meeting held on June 18, 2008 at the Sigourney Street building or was addressed in the response letter dated September 15, 2008 to the 17 questions asked by the Department of Public Works Commissioner, Connecticut. This report also contains analyses examining associations between environmental and health data from the 2007 surveys.

If you have any questions regarding the information provided in this interim report, please do not hesitate to contact us at 1-800-232-2114.

Sincerely,

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Interim Report X
Questionnaire and Environmental Surveys
At 25 Sigourney Street, Hartford, CT
HETA 2001-0445
October 2009

INTRODUCTION

This interim report pertains to the health hazard evaluation which was requested in 2001 from the Administrative and Residual Employees Union Local 4200 representing office workers at 25 Sigourney Street in Hartford, Connecticut in relation to respiratory health and water damage. This report contains results from the cross-sectional analyses of the health questionnaire and environmental survey conducted in August 2007, as well as longitudinal analyses of employee health and environmental measurements based on the four surveys conducted in 2001/2002, 2004, 2005, and 2007. This report extends the information presented at the stakeholders meeting held on June 18, 2008 at the Sigourney Street building, and addressed in the response letter dated September 15, 2008 to the 17 questions asked by the Connecticut Department of Public Works Commissioner. The report also presents analyses linking environmental and health data from the 2007 surveys.

METHODS

Questionnaire survey in 2007

We invited all employees currently working in the Sigourney Street building, as well as current employees working in other locations who had both previously worked in the building and taken part in one or more of the past NIOSH surveys, to take part in a web-based questionnaire survey. The survey was open from August 27, 2007 to October 5, 2007 and run from a secure site at the Centers for Disease Control and Prevention in Atlanta. Each employee was e-mailed a unique identity code and temporary password to access the questionnaire. Before beginning the questionnaire the participant was prompted to create a new password. After a completed questionnaire was submitted, the link to the questionnaire was disabled. During the first week of the survey, NIOSH personnel were on-site at the Sigourney Street building to assist employees in completing the web-based questionnaire. We called all employees and attempted to speak with each of them individually to explain the purpose of the survey and to encourage them to participate. If the person was not available, we left a voice mail explaining the purpose of the survey and to contact us if they had any difficulty accessing it. Sixty-two employees did not have the capability to receive e-mail or complete the questionnaire on-line or we did not have a correct e-mail address for them. We mailed these employees paper versions of the questionnaire.

Environmental survey in 2007

In August 2007, we collected dust samples from carpeted floors of 150 workstations on the 15 occupied floors in the building. We selected the 150 sampling locations for this survey. We included all previously defined case-comparison workstations and then made up the remainder with locations randomly selected by floor from the 297 sampling locations of the 2005 survey. Shortly before the survey, we received current seating plans from the agencies and compared the employee names we had from the previous survey for the selected locations. If a selected

employee had changed workstations, we changed our sample to the new location. For each sampling location, a two square meter (m^2) carpeted floor area around the worker's seating area was vacuumed for five minutes using a L'il Hummer™ backpack vacuum. If there was a chair mat at the workstation, we took the sample around the chair mat within the workstation. The dust was collected onto a polyethylene filter sock inserted into the end of the vacuum extension rod using a pre-cleaned crevice tool. Between samples we cleaned the end of the vacuum extension rod with an isopropyl alcohol wipe.

After dust collection, the filter socks were sealed in plastic bags and transported to the laboratory. We removed hair, fluff, gravel, and other large objects from each dust sample using sterile kitchen sink screens. Then each dust sample was placed into a 50 ml pyrogen-free conical tube and homogenized by rotation on a 360-degree rotary arm shaker at 65 rpm for two hours. The dust samples were then weighed, partitioned, and sent for analyses of culturable fungi, culturable bacteria, endotoxin, ergosterol, glucan, actinomycetes, and allergens from cat, dog, cockroach, and dust mite.

Data analysis

We compared lower and upper respiratory symptoms and physician-diagnosed asthma to data from the US adult population, based on the third National Health and Nutrition Examination Survey (NHANES III). We also compared asthma prevalences to the adult population in Connecticut, based on data from the 2007 Behavioral Risk Factor Surveillance System (BRFSS). Finally, we compared the prevalence of work-related symptoms occurring weekly in the past month to US office workers in buildings without known indoor air quality problems (EPA BASE study).

We compared the prevalence of symptoms among persons starting at the Sigourney Street building in January 2004 or later (shorter-term employees) with persons occupying the building before that date (longer-term employees). We chose 2004 to define shorter-term employees since major building remediations were completed by then.

Since participants may have reported different dates of diagnoses, dates of birth, and building occupancy dates in different questionnaires, the dates used for our analyses were set taking into account all dates reported. The date reported most frequently in the questionnaires was the one used. If there was not one date reported most frequently, we used the date given in the earliest questionnaire completed.

We randomly selected 200 non-participants from the Department of Revenue Services (DRS) ($n=100$) and the Department of Social Services (DSS) ($n=100$), along with the 8 non-participants in Department of Emergency Management and Homeland Security (DEMHS), to take part in a short health questionnaire after the initial survey was completed. The questionnaire was mailed along with a postage-paid return envelope to these non-participants in November 2007. The non-participant survey was conducted to determine if there were differences in asthma and symptoms reported between the non-participants and participants in the 2007 survey. The survey consisted of questions on lower respiratory symptoms in the last 12 months, if they ever had been diagnosed with asthma, and if they felt they had symptoms related to the building. We used a

chi-square test to compare the differences between the non-participant and 2007 health questionnaire responses.

We examined physician diagnosis dates of post-occupancy asthma, hypersensitivity pneumonitis, and sarcoidosis using the 1,487 people that participated in one or more NIOSH surveys in 2001/2002, 2004, 2005, and 2007 to evaluate the distribution of new-onset diseases at the building by year since 1994. We also analyzed these respiratory disease cases for multiple diagnoses.

For the 2007 data, we used logistic regression models adjusted for age, gender, smoking status, and building tenure to examine the association between exposure to individual or multiple microbial agents and selected health outcomes. For each of the 15 floors, we calculated geometric means (GM) per meter squared area of carpet for individual microbial agents in the dust samples. Based on rank order of these floor-specific GMs for each of these agents, the 15 floors were categorized into three exposure groups: low (first tertile), medium (second tertile) or high (third tertile). We assigned participants into tertile exposure groups based on the floor they occupied. The health outcomes used in the models included: individual work-related symptoms experienced in the last 12 months, post-occupancy physician-diagnosed asthma, and epidemiologically defined asthma and respiratory cases. Our epidemiologic definitions follow.

We defined a respiratory case group as those participants who reported one or more of the following: three or more of five asthma symptoms (wheeze, chest tightness, shortness of breath, coughing, and awakened by an attack of breathing difficulty) occurring weekly in the last 4 weeks; two or more of hypersensitivity pneumonitis symptoms (fever and chills, flu-like achiness or achy joints, and shortness of breath hurrying on the level or walking up a slight incline) occurring weekly in the last 4 weeks; current physician-diagnosed asthma occurring after building occupancy; or physician-diagnosed hypersensitivity pneumonitis (HP) or sarcoidosis. We defined the comparison group as having none of the symptoms listed above in the last year, nor any of the specified diagnoses. We defined a fewer symptoms group as those participants who reported lower respiratory or systemic symptoms in the last 12 months but did not meet the respiratory case group definition.

We also defined two asthma-like symptom groups as those who reported having three or more of five lower respiratory symptoms (wheeze, chest tightness, shortness of breath, coughing, and awakened by an attack of breathing difficulty) occurring weekly in the last 4 weeks (asthma-like symptoms in 4 weeks) or occurring in the last 12 months (asthma-like symptoms in 12 months). Epidemiologically defined asthma (epi-asthma) included those who reported current physician-diagnosed asthma with post-occupancy onset or asthma-like symptoms in the last 4 weeks. Work-related symptoms were defined as those improving when away from the building.

RESULTS AND DISCUSSION

Questionnaire

Demographics and participation

Participation in the 2007 questionnaire was 60% (762/1278), as compared to the 64% to 67% participation in previous NIOSH questionnaire surveys in the building. Of the 762 participants,

31 (4%) partially completed the questionnaire. Respondents were primarily female (57%) and white (80%), and had been in the building, on average, for 9.4 years (see Table 1). Nearly two-thirds of participants had never smoked. These demographics were similar to those reported in the 2001, 2004, and 2005 surveys.

Table 1. Demographics of participants (August 2007)

Age (Mean \pm SD)	48.6 \pm 8.4
Gender (% Female)	437/762 (57%)
Building tenure (Mean \pm SD)	9.4 \pm 4.6
Race	
White	591/737 (80%)
Black	123/737 (17%)
Other	23/737 (3%)
Ethnicity	
Hispanic	54/760 (7%)
Smoking status	
Current	69/738 (9%)
Former	205/738 (28%)
Never	464/737 (63%)

Prevalence of symptoms

The prevalence of overall and work-related symptoms occurring in the last 12 months is shown in Table 2. Among symptoms, stuffy, itchy, or runny nose, sneezing, and headaches were reported most frequently among participants. Between 32% and 57% of participants with symptoms in the last 12 months reported that their symptoms were better away from their work environments. Among the work-related symptoms, sneezing and a stuffy, itchy or runny nose were reported most frequently, along with drowsiness or concentration difficulty. The percentage of participants reporting symptoms occurring at least once a week in the last four weeks was much lower, although the prevalence of symptoms that improved when away from work was similar (33%-62%) (Table 3). One hundred sixty-six participants (22%) reported physician-diagnosed asthma, and 53 of them (32%) had current post-occupancy onset asthma (Table 4). Thirteen and six of the participants reported physician-diagnosed hypersensitivity pneumonitis and sarcoidosis, respectively.

Table 2. Prevalence of symptoms in the last 12 months for all participants (August 2007)

Symptoms present in the last 12 months	Prevalence of symptoms	Prevalence of work-related symptoms
Lower Respiratory Symptoms		
Wheeze or whistling in chest	273/762 (36%)	145/759 (19%)
Chest tightness	249/758 (33%)	129/757 (17%)
Shortness of breath	225/756 (30%)	125/755 (17%)
Shortness of breath while hurrying on level	300/751 (40%)	112/749 (15%)
Coughing attack	313/755 (41%)	177/751 (24%)
Cough with phlegm	352/750 (47%)	112/749 (15%)
Awakened by an attack of breathing difficulty	106/752 (14%)	41/752 (5%)
Upper Respiratory Symptoms		
Stuffy, itchy or runny nose	509/746 (68%)	221/746 (30%)
Watery, itchy eyes	392/746 (53%)	205/746 (27%)
Sneezing	467/746 (63%)	232/746 (31%)
Sinusitis or sinus problems	346/746 (46%)	154/745 (21%)
Hoarseness or a dry, sore, or burning throat	278/746 (37%)	130/746 (17%)
Non-Respiratory Symptoms		
Episodes of fever and chills	209/748 (28%)	53/746 (7%)
Flu-like achiness or achy joints	357/747 (48%)	95/747 (13%)
Excessive fatigue	333/746 (45%)	149/746 (20%)
Headache	443/746 (59%)	183/746 (25%)
Drowsiness, memory, or concentration difficulty	390/746 (52%)	214/745 (29%)
Dizziness or lightheadedness	239/746 (32%)	119/745 (16%)
Rash or itchy skin	236/746 (32%)	84/746 (11%)

Table 3. Prevalence of symptoms in the last 4 weeks (August 2007)

Symptoms present in the last 4 weeks	Prevalence of symptoms	Prevalence of work-related symptoms
Lower Respiratory Symptoms		
Wheeze or whistling in chest	138/759 (18%)	85/759 (11%)
Chest tightness	127/757 (17%)	73/757 (10%)
Shortness of breath	130/755 (17%)	75/755 (10%)
Shortness of breath while hurrying on level	210/750 (28%)	81/749 (11%)
Coughing attack	165/752 (22%)	104/752 (14%)
Cough with phlegm	174/749 (23%)	58/749 (8%)
Awakened by an attack of breathing difficulty	50/752 (7%)	20/752 (3%)
Upper Respiratory Symptoms		
Stuffy, itchy or runny nose	348/746 (47%)	168/746 (23%)
Watery, itchy eyes	299/746 (40%)	165/746 (22%)
Sneezing	371/746 (50%)	198/746 (27%)
Sinusitis or sinus problems	213/746 (29%)	103/746 (14%)
Hoarseness or a dry, sore, or burning throat	179/746 (24%)	95/746 (13%)
Non-Respiratory Symptoms		
Episodes of fever and chills	47/747 (6%)	22/747 (3%)
Flu-like achiness or achy joints	185/747 (25%)	51/747 (7%)
Excessive fatigue	269/746 (36%)	125/746 (17%)
Headache	280/746 (38%)	131/746 (18%)
Drowsiness, memory, or concentration difficulty	315/745 (42%)	179/745 (24%)
Dizziness or lightheadedness	137/745 (18%)	73/745 (10%)
Rash or itchy skin	167/746 (22%)	59/746 (8%)

Table 4. Prevalences of physician-diagnosed conditions (August 2007)

Condition	Prevalence
Asthma	166/745 (22%)
Current asthma	119/745 (16%)
Post-occupancy asthma	69/725 (10%)
Post-occupancy, current asthma	53/731 (7%)
Hypersensitivity pneumonitis	13/744 (2%)
Sarcoidosis	6/745 (1%)

Comparison of prevalences of symptoms and asthma between participants and non-participants in the 2007 survey

Forty-six percent (95/208) of the invited original survey non-participants returned a completed questionnaire. Symptom prevalences were somewhat higher in the participants than in the non-participants. Participants were also significantly more likely to report that they had symptoms which they believed were worse in the Sigourney Street building when compared to non-participants ($p < 0.01$) (Table 5).

The non-participant survey results indicate that the prevalences estimated from the 762 participants in the original survey would tend to overestimate the full building population prevalences. To account for this, we estimated the percentage of symptoms and asthma in the building population. To estimate the prevalence numerator, we subtracted the number of participants from the total building population ($N=1278$) and then multiplied this number by the percentage reported by non-participants for a particular condition. We then added this number to the number of participants reporting the condition in the August 2007 survey to come up with an estimate for the entire building. For example, for wheeze, we subtracted 762 from 1278 to come up with 516 non-participants. We then multiplied this number by 0.26 to estimate that 134 non-participants had wheeze or whistling in the chest. When we added this to 273, we arrived at an estimate of 407 persons who reported wheeze, which is 32% of the building population. Using this approach, it is seen that the adjusted prevalences were not very much lower than the prevalences reported by the participants (Table 5).

Table 5. Prevalences of asthma and symptoms in participants and non-participants (August 2007)

Symptom	Participants	Non-participants	Adjusted estimate for total population
Wheeze or whistling in chest*	273/762 (36%)	24/91 (26%)	407/1278 (32%)
Chest tightness	249/758 (33%)	22/92 (24%)	374/1278 (29%)
Shortness of breath	225/756 (30%)	20/92 (22%)	340/1278 (27%)
Cough	313/755 (41%)	32/95 (34%)	491/1278 (38%)
Awakened by an attack of breathing difficulty	106/752 (14%)	11/93 (12%)	169/1278 (13%)
Ever diagnosed with asthma	166/745 (22%)	16/93 (17%)	257/1278 (20%)
Building-related symptoms**	410/737 (56%)	28/92 (30%)	572/1278 (45%)

** $p < 0.01$, the difference between participants and non-participants, using a chi-square test

* $p < 0.10$, the difference between participants and non-participants using a chi-square test

Comparison of 2007 prevalences to national and state data

As compared to the U.S population, we found that lower and upper respiratory symptoms among the 762 participants were 1.3-3.1 times higher than expected (Table 6). If we use the adjusted estimates provided in Table 5 for this comparison, asthma and wheeze still remained significantly higher than the US population (Odds ratio (OR): 2.5 and 1.8, respectively). However, we were not able to adjust for gender, age, smoking status, or race, since we did not have this information on the entire building population. We were also only able to compare wheeze and asthma to the US population, since we did not ask the other health symptoms in the non-participant survey. Although the comparison to the state population (BRFSS) gave lower prevalence ratios than those from the US population comparison (NHANES III), participants were still significantly more likely to have ever been diagnosed with asthma or have current asthma (OR: 1.8 and 1.9, respectively, $p < 0.05$) (Table 7). Using the adjusted estimate for the total building population, the rate of asthma diagnosis was still 1.4 higher than the state population and was statistically significant at $p = 0.05$. When comparing the rate of work-related symptoms occurring at least once a week in the last 4 weeks to the BASE study, lower respiratory symptoms (wheeze, chest tightness, shortness of breath, and cough) were significantly higher among study participants (OR: 2.7-6.2, $p < 0.05$). Sneezing, sore or dry throat, and dry or itchy skin were also more prevalent among participants when compared to BASE, although not as high as lower respiratory symptoms. Headaches and unusual tiredness, fatigue, or drowsiness were not significantly higher (Table 8).

Table 6. Comparison of selected health outcomes for 25 Sigourney Street with NHANES III (August 2007)

Condition	Number observed	Prevalence Ratio (95% CI)*
Ever diagnosed with asthma	159	2.8 (2.4-3.3)
Current asthma	115	3.1 (2.6-3.7)
Wheezing or whistling in your chest in the last 12 months	257	2.6 (2.3-3.0)
Shortness of breath when hurrying on the level or walking up a slight incline in the last 12 months [†]	286	1.8 (1.6-2.0)
Sinusitis or sinus problems in the last 12 months	335	1.3 (1.1-1.4)
Stuffy, itchy or runny nose in the last 12 months	489	1.3 (1.2-1.4)
Watery, itchy eyes in the last 12 months	372	1.3 (1.2-1.4)

* These prevalence ratios were adjusted for age, gender, race, and smoking status.

[†] NHANES III does not specify in the last 12 months

Table 7. Comparison of asthma for 25 Sigourney Street with 2005 BRFSS for the state of Connecticut (August 2007)

Condition	Number observed	Prevalence Ratio (95% CI)*
Ever diagnosed with asthma	166	1.8 (1.6-2.1)
Current asthma	119	1.9 (1.6-2.3)

* The prevalence ratios were adjusted for gender.

Table 8. Comparison of selected health outcomes for 25 Sigourney Street with BASE Study (August 2007)

Symptom: At least once a week in the last 4 weeks and better away from work	Number observed	Prevalence Ratio (95% CI)
Wheeze	85	6.2 (5.0-7.7)
Chest tightness	73	4.4 (3.5-5.5)
Shortness of breath	75	5.5 (4.4-6.9)
Cough	104	2.7 (2.2-3.3)
Sneezing	198	2.3 (2.0-2.7)
Sore or dry throat	95	1.9 (1.6-2.4)
Headache	131	1.2 (1.0-1.4)
Excessive fatigue	125	1.1 (0.9-1.3)
Dry or itchy skin	59	1.6 (1.2-2.0)

Difference in symptom status between those occupying the building prior to 2004 and 2004 or later

We identified 592 participants who occupied the building prior to 2004 and 154 participants who occupied the building in 2004 or later among the participants of the 2007 survey. In general, the prevalence of symptoms among shorter-term employees was lower than longer-term employees (Figures 1 to 4). This difference was greater when comparing work-related symptoms. This pattern is consistent with an improvement in building indoor environmental quality after major building remediation in 2004, at least in regards to health effects for employees starting work in the building after major remediation in 2004.

Figure 1. Prevalences of symptoms in last 12 months, by occupancy period (August 2007)

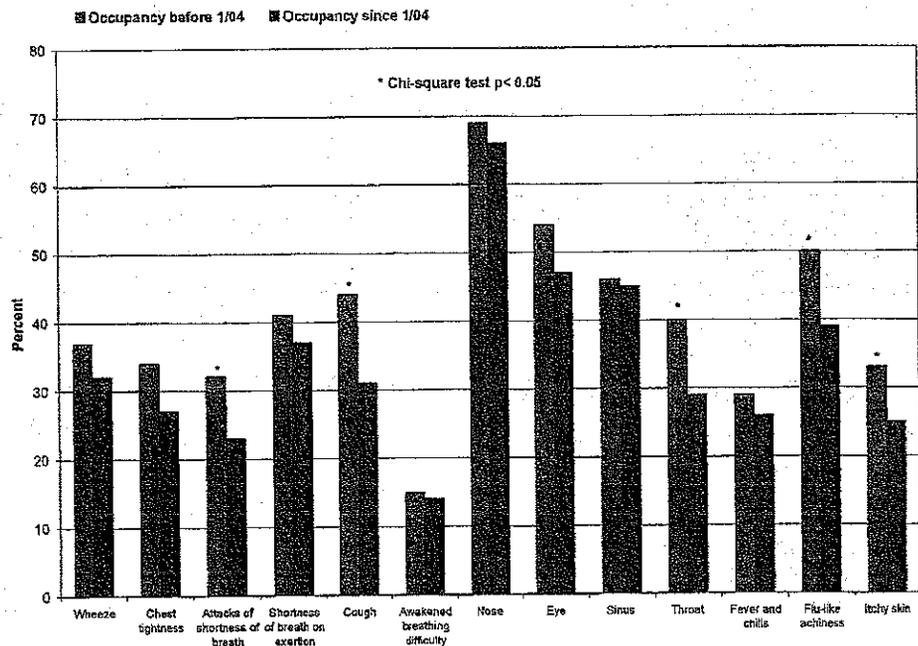


Figure 2. Prevalences of work-related symptoms in the last 12 months, by occupancy period (August 2007)

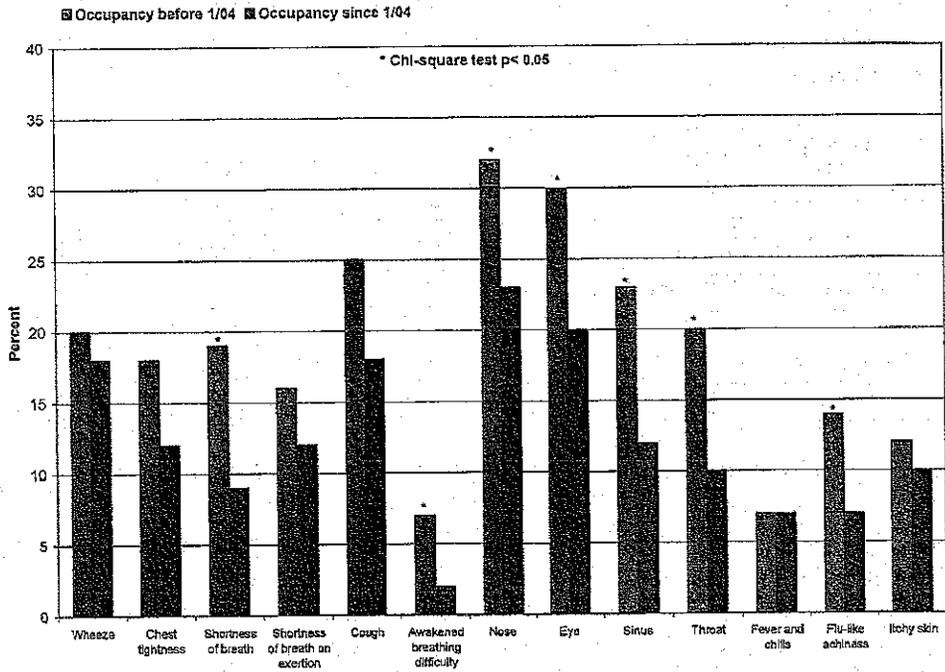


Figure 3. Prevalences of symptoms occurring at least once a week in the last 4 weeks, by occupancy period (August 2007)

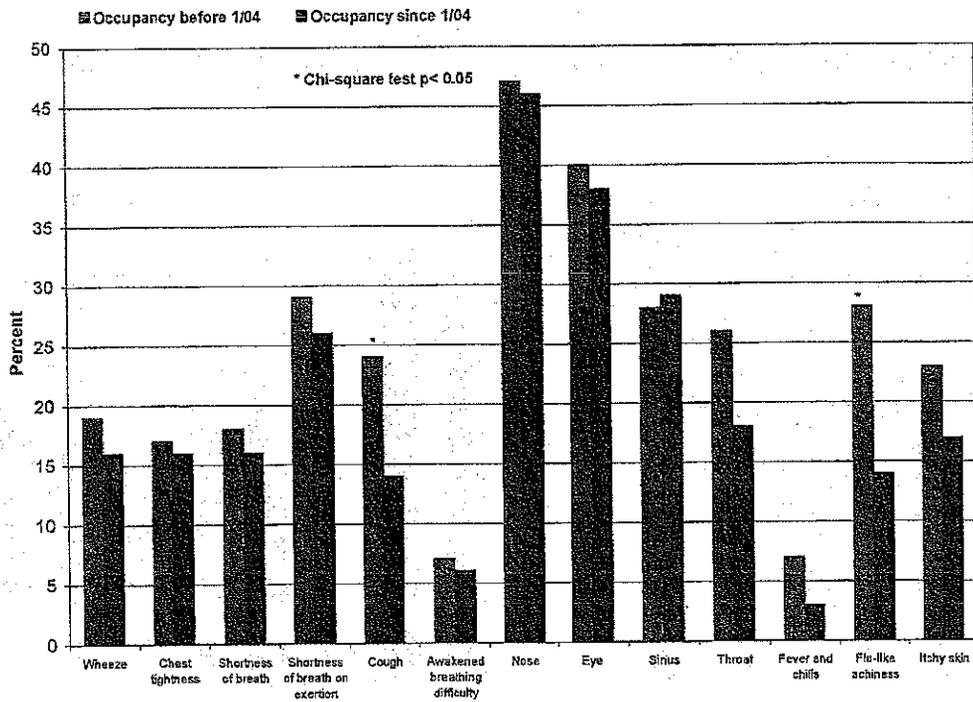
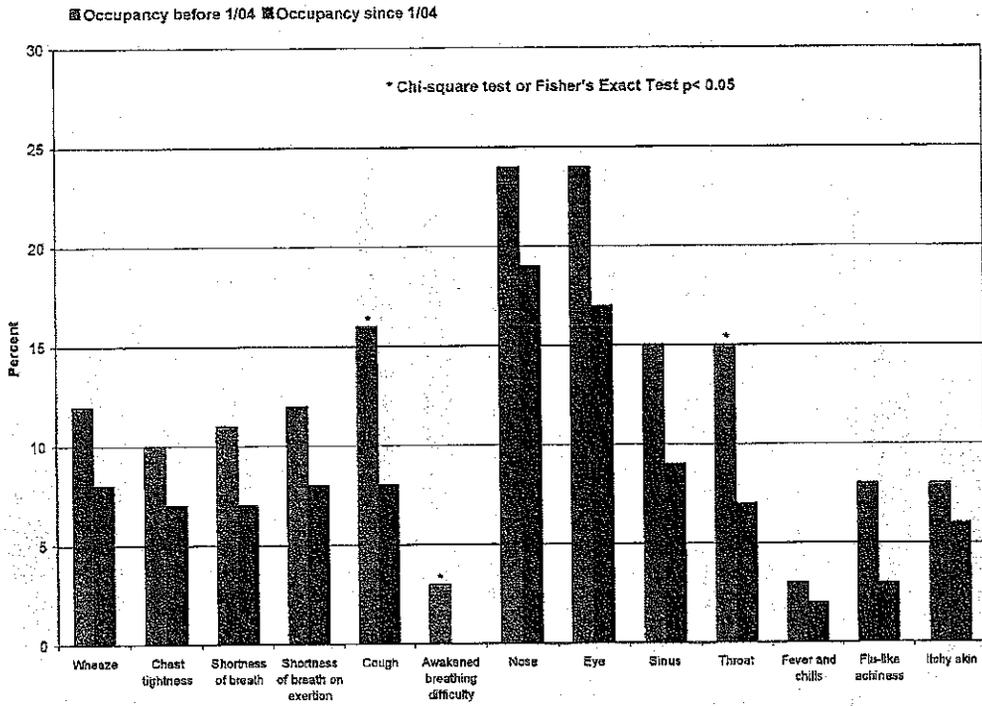


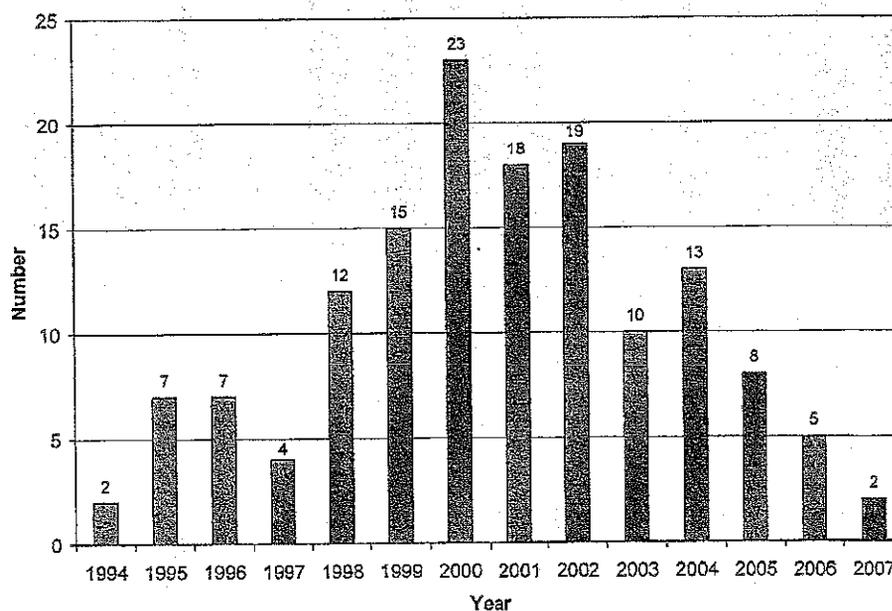
Figure 4. Prevalences of work-related symptoms occurring at least once a week in the last 4 weeks, by occupancy period (August 2007)



Post-occupancy onset of physician-diagnosed asthma, hypersensitivity pneumonitis, and sarcoidosis in participants surveyed from 2001 to 2007

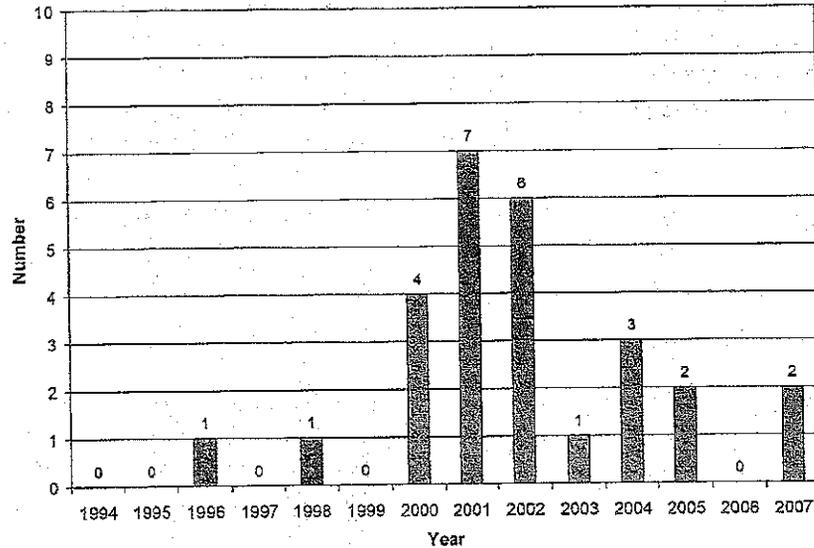
Out of the 1,494 individuals who participated in at least one of the NIOSH surveys, we identified 145 post-occupancy physician-diagnosed asthma cases. Figure 5 shows the distribution of their reported diagnosis dates. There were 28 reported post-occupancy asthma cases diagnosed in 2004 or later. Of these, 25 cases occupied the building before 2004 (longer-term employees), and only 2 cases reported that they occupied the building in 2004 or later (shorter-term employees). One case provided no occupancy date. Of the 25 new cases among longer-term employees, 18 reported at least one lower respiratory symptom before 2004, 4 reported symptoms after 2004, and 3 provided no information on symptoms. Both of the two new cases in shorter-term employees reported that their lower respiratory symptoms occurred after 2004.

Figure 5. Diagnosis dates of 145 post-occupancy asthma cases among 2001-2007 participants



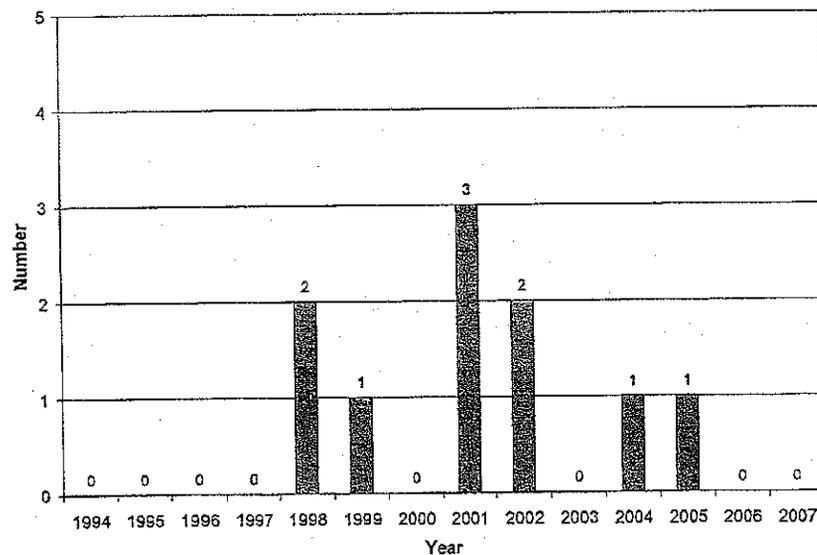
We identified 27 post-occupancy HP cases among the 1,494 participants and their diagnosis dates are shown in Figure 6. Of these 27, there were 7 post-occupancy HP cases diagnosed in 2004 or later. Among these, 6 cases reported that they developed lower respiratory or HP-like symptoms before 2004, and only one case reported that the symptom onset was after 2004.

Figure 6. Diagnosis dates of 27 post-occupancy HP cases among 2001-2007 participants



There were 10 identified sarcoidosis cases among the 1,494 participants. Of these, two new post-occupancy sarcoidosis cases were reported in 2004 or later (Figure 7). Both cases occupied the building prior to 2004 and reported lower respiratory or HP like-symptoms that began prior to 2004.

Figure 7. Diagnosis dates of 10 post-occupancy sarcoidosis cases among 2001-2007 participants

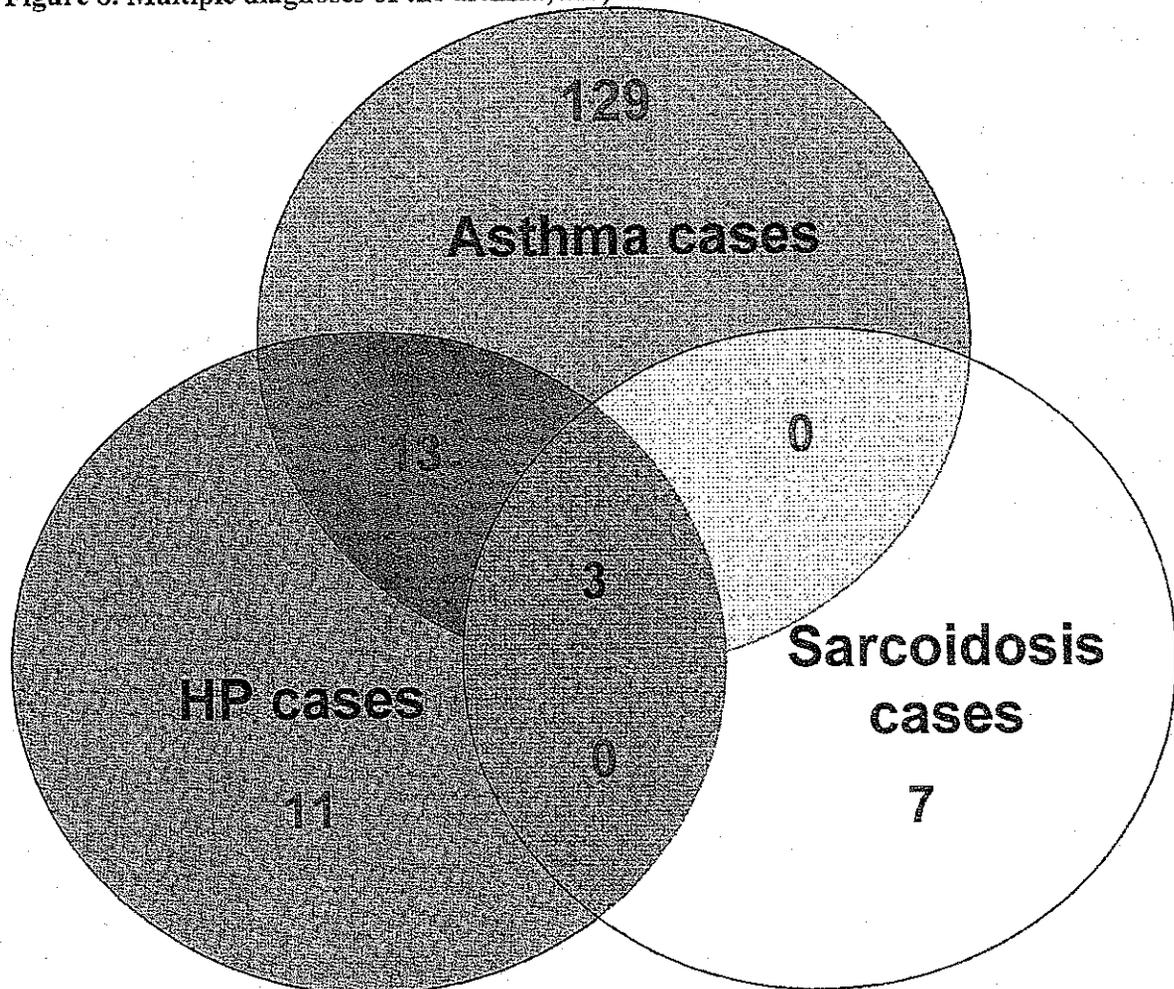


These data (Figures 5-7) indicate that new-onsets of asthma, HP, or sarcoidosis seem to have been declining since 2000 or 2001 and the majority of new diagnoses in 2004 or later were in people who occupied the building before 2004 (longer-term employees).

Multiple diagnoses of post-occupancy respiratory diseases

We examined multiple diagnoses of the above 145 post-occupancy asthma cases (Figure 5), 27 HP cases (Figure 6), and 10 sarcoidosis cases (Figure 7). Of the 145 asthma cases, 16 people also reported a HP diagnosis, and 3 of these 16 cases also reported a sarcoidosis diagnosis (Figure 8).

Figure 8. Multiple diagnoses of the asthma, HP, and sarcoidosis cases



In summary, from the health questionnaire results we found:

1. Work-related symptoms were still high in 2007, but lower in people who occupied the building in 2004 or later.
2. Incidence of post-occupancy asthma diagnoses seemed to be declining.
3. The majority of asthma/HP/sarcoidosis diagnosed in 2004 or later was in people who occupied the building before 2004.
4. There were some asthma and HP cases with both diagnosis and symptoms onset in 2004 or later.

**Environmental
2007 Survey Results**

Dust

The number of dust samples and the average (GM) amount of dust collected per square meter by floor is shown in Table 9. The floors with the highest average amount of dust were the 7th and 14th floors (0.75 and 0.72, respectively).

Table 9. Number of samples and amount of dust collected per square meter of carpet by floor of the building (August 2007)

Floor	No. of Samples	GM \pm GSD	Minimum	Maximum
All	150	0.41 \pm 2.02	0.02	2.38
5	4	0.30 \pm 1.54	0.19	0.47
6	10	0.40 \pm 1.45	0.29	0.73
7	11	0.75 \pm 1.28	0.52	1.25
8	11	0.47 \pm 1.56	0.20	0.89
9	12	0.45 \pm 1.89	0.12	1.15
10	10	0.52 \pm 1.40	0.25	0.82
11	11	0.32 \pm 1.99	0.10	1.01
12	10	0.26 \pm 1.52	0.14	0.47
14	10	0.72 \pm 1.86	0.22	1.84
15	10	0.52 \pm 2.02	0.16	1.21
16	10	0.30 \pm 1.78	0.13	0.69
17	14	0.23 \pm 1.61	0.14	0.67
18	12	0.40 \pm 4.11	0.02	2.38
19	12	0.42 \pm 1.86	0.16	1.06
20	3	0.38 \pm 1.36	0.27	0.50

Fungi

Table 10 shows the average (GM) levels of total culturable fungi per gram of dust by floor of the building. In general, the levels of total culturable fungi (colony forming unit per gram dust: CFU/g) tended to be higher on the upper floors (15, 16, 17, 19, 20th floors) of the building, with the highest levels occurring on the 20th and 17th floors.

Table 10. The average (GM) levels of total culturable fungi in dust (CFU/g) by floor (August 2007)

Floor	No. of Samples	GM \pm GSD	Minimum	Maximum
All	150	$7.84 \times 10^4 \pm 3.86$	1.08×10^3	1.19×10^6
5	4	$8.03 \times 10^4 \pm 1.48$	5.65×10^4	1.36×10^5
6	10	$5.52 \times 10^4 \pm 2.84$	1.47×10^4	2.13×10^5
7	11	$5.12 \times 10^4 \pm 3.85$	1.07×10^4	8.62×10^5
8	11	$1.18 \times 10^5 \pm 3.61$	2.08×10^4	6.77×10^5
9	12	$3.81 \times 10^4 \pm 2.09$	4.80×10^3	1.01×10^5
10	10	$2.26 \times 10^4 \pm 2.84$	5.59×10^3	1.72×10^5
11	11	$4.17 \times 10^4 \pm 2.68$	1.12×10^4	2.08×10^5
12	10	$4.83 \times 10^4 \pm 3.21$	1.08×10^4	3.54×10^5
14	10	$5.55 \times 10^4 \pm 2.55$	1.35×10^4	1.56×10^5
15	10	$1.86 \times 10^5 \pm 2.69$	3.38×10^4	1.19×10^6
16	10	$1.24 \times 10^5 \pm 2.54$	3.00×10^4	5.81×10^5
17	14	$2.71 \times 10^5 \pm 5.88$	1.08×10^5	9.79×10^5
18	12	$4.44 \times 10^4 \pm 4.19$	6.28×10^3	3.23×10^5
19	12	$1.95 \times 10^5 \pm 2.78$	3.12×10^4	1.03×10^6
20	3	$4.31 \times 10^5 \pm 2.49$	1.67×10^5	1.03×10^6

The fungal profile of the 150 samples was diverse, with 26 genera and 45 species identified (Table 11). The most frequently found species from dust samples were as follows: *Phoma herbarum*, which was identified in 87% of samples, followed by *Epicoccum nigrum* (71%) and *Cladosporium cladosporioides* (67%). Unidentified yeasts were also prevalent in 73% of the samples. We identified *Stachybotrys chartarum* from one dust sample and *Aspergillus fumigatus* from 12 samples (8%).

Table 11. Prevalence of fungal species found in floor dust (August 2007)

Fungal Species	N	%
<i>Acremonium strictum</i>	1	1%
<i>Acrodontium simplex</i>	0	0%
<i>Alternaria alternata</i>	36	24%
<i>Aspergillus flavus</i>	2	1%
<i>Aspergillus fumigatus</i>	12	8%
<i>Aspergillus glaucus</i>	6	4%
<i>Aspergillus nidulans</i>	2	1%
<i>Aspergillus niger</i>	29	19%
<i>Aspergillus ustus</i>	10	7%
<i>Aspergillus versicolor</i>	7	5%
<i>Aureobasidium pullulans</i>	86	57%
<i>Blakeslea trispora</i>	2	1%
<i>Botrytis cinerea</i>	1	1%
<i>Chaetomium globosum</i>	10	7%
<i>Cladosporium cladosporioides*</i>	101	67%
<i>Cladosporium sphaerospermum</i>	0	0%
<i>Curvularia lunata</i>	31	21%
<i>Epicoccum nigrum*</i>	106	71%
<i>Fusarium oxysporum</i>	22	15%
<i>Mucor plumbeus</i>	15	10%
<i>Nigrospora sphaerica</i>	14	9%
Non-sporulating fungi	9	6%
<i>Paecilomyces variotii</i>	8	5%
<i>Penicillium aurantiogriseum</i>	1	1%
<i>Penicillium brevicompactum</i>	11	7%
<i>Penicillium chrysogenum</i>	35	23%
<i>Penicillium citrinum</i>	1	1%
<i>Penicillium corylophilum</i>	2	1%
<i>Penicillium decumbens</i>	0	0%
<i>Penicillium glabrum</i>	2	1%
<i>Penicillium oxalicum</i>	18	12%
<i>Penicillium paxilli</i>	2	1%
<i>Penicillium purpurogenum</i>	13	9%
<i>Penicillium species</i>	10	7%
<i>Penicillium variabile</i>	2	1%
<i>Phoma coelomycetes</i>	1	1%
<i>Phoma glomerata</i>	11	7%
<i>Phoma herbarum*</i>	130	87%
<i>Phoma species</i>	22	15%
<i>Pithomyces chartarum</i>	59	39%
<i>Rhizopus stolonifer</i>	7	5%
<i>Scopulariopsis brevicaulis</i>	1	1%
<i>Stachybotrys chartarum</i>	1	1%
<i>Thamnidium elegans</i>	2	1%
<i>Trichoderma harzianum</i>	18	12%
<i>Ulocladium chartarum</i>	18	12%
<i>Wallemia sebi</i>	4	3%
Yeasts, other	109	73%
<i>Yeasts sporobolomyces</i>	14	9%

*Top three dominant species

Ergosterol

Ergosterol, a principal sterol found in the fungal membrane, was measured as an index of total fungal biomass including fungal fragments as well as both viable and nonviable spores. The average (GM) levels of ergosterol were also generally high on the upper floors (16, 17, and 19th floors) although the highest average (GM) level was found from a sample taken on the 5th floor (Table 12).

Table 12. The average (GM) level of ergosterol in dust (nanogram/gram dust) by floor (August 2007)

Floor	No. of Samples	GM \pm GSD	Minimum	Maximum
All	143	706.33 \pm 1.94	122	3584
5	4	1566.52 \pm 1.90	845	3584
6	10	648.91 \pm 1.94	274	2052
7	11	453.24 \pm 1.58	270	1098
8	10	574.62 \pm 1.81	214	1692
9	11	688.52 \pm 1.82	324	1931
10	10	543.30 \pm 1.86	122	1253
11	11	739.66 \pm 1.83	268	2479
12	10	791.32 \pm 2.25	250	2977
14	10	791.45 \pm 2.03	329	2759
15	10	488.48 \pm 1.64	229	1062
16	9	941.87 \pm 2.02	404	2909
17	11	1009.68 \pm 1.80	313	2315
18	11	566.72 \pm 1.90	237	2354
19	12	1063.88 \pm 1.84	422	2898
20	3	579.32 \pm 1.31	424	699

Glucan

Glucan, a cell wall component of fungi, was measured as an index of total fungal biomass and a pro-inflammatory substance. The average (GM) levels of glucan were highest on the 9th, 10th, 12th, 16th, 17th, and 19th floors (Table 13).

Table 13. The average (GM) level of glucan in dust (picogram/gram dust) by floor (August 2007)

Floor	No. of Samples	GM \pm GSD	Minimum	Maximum
All	142	$5.99 \times 10^4 \pm 1.69$	9.82×10^3	4.00×10^5
5	4	$5.90 \times 10^4 \pm 2.01$	2.93×10^4	1.36×10^5
6	10	$4.88 \times 10^4 \pm 2.13$	1.59×10^4	1.50×10^5
7	11	$4.18 \times 10^4 \pm 1.41$	2.42×10^4	6.69×10^4
8	11	$4.79 \times 10^4 \pm 1.60$	2.23×10^4	9.21×10^4
9	11	$7.12 \times 10^4 \pm 1.54$	3.29×10^4	1.38×10^5
10	10	$7.94 \times 10^4 \pm 1.38$	5.20×10^4	1.45×10^5
11	11	$4.94 \times 10^4 \pm 1.51$	2.21×10^4	8.09×10^4
12	10	$7.47 \times 10^4 \pm 1.30$	5.51×10^4	1.33×10^5
14	10	$6.49 \times 10^4 \pm 1.61$	3.32×10^4	1.30×10^5
15	10	$6.37 \times 10^4 \pm 1.42$	3.23×10^4	1.21×10^5
16	8	$8.84 \times 10^4 \pm 1.30$	6.19×10^4	1.37×10^5
17	11	$8.00 \times 10^4 \pm 1.83$	4.59×10^4	4.00×10^5
18	10	$4.12 \times 10^4 \pm 1.32$	2.61×10^4	6.21×10^4
19	12	$7.09 \times 10^4 \pm 1.66$	3.02×10^4	1.71×10^5
20	3	$2.76 \times 10^4 \pm 2.90$	9.82×10^3	8.23×10^4

Endotoxin and Bacteria

The level of endotoxin, a component of the outer membrane of gram negative bacteria, by floor is shown in Table 14. Endotoxin was measured as an index of gram negative bacteria biomass and also as an inflammatory substance. The average (GM) level of endotoxin was highest on the 5th, 8th, 14th, and 19th floors. The average (GM) levels of culturable gram negative bacteria were higher from the 11th floor upwards, except for the 18th floor (Table 15). Total bacterial counts (which includes both gram positive and gram negative bacteria) were highest for the 14th, 16th, and 17th floors.

Table 14. The average (GM) level of endotoxin in dust (Endotoxin Unit/gram dust: EU/g) by floor (August 2007)

Floor	No. of samples	GM \pm GSD	Minimum	Maximum
All	142	$2.70 \times 10^4 \pm 2.35$	5.23×10^3	5.37×10^5
5	4	$3.76 \times 10^4 \pm 2.53$	1.28×10^4	1.23×10^5
6	10	$2.89 \times 10^4 \pm 1.73$	1.38×10^4	6.26×10^4
7	11	$2.06 \times 10^4 \pm 1.70$	9.84×10^3	5.94×10^4
8	11	$6.08 \times 10^4 \pm 4.01$	9.63×10^3	5.37×10^5
9	11	$2.37 \times 10^4 \pm 1.70$	1.23×10^4	7.15×10^4
10	10	$1.72 \times 10^4 \pm 1.66$	5.35×10^3	3.16×10^4
11	11	$1.91 \times 10^4 \pm 2.25$	7.78×10^3	7.05×10^4
12	10	$2.81 \times 10^4 \pm 2.32$	9.63×10^3	1.35×10^5
14	10	$3.23 \times 10^4 \pm 1.98$	1.33×10^4	1.26×10^5
15	10	$2.12 \times 10^4 \pm 2.48$	6.26×10^3	8.47×10^4
16	8	$2.81 \times 10^4 \pm 2.40$	1.21×10^4	1.68×10^5
17	11	$2.66 \times 10^4 \pm 2.01$	5.23×10^3	6.58×10^4
18	10	$2.10 \times 10^4 \pm 2.08$	1.10×10^4	1.24×10^5
19	12	$4.68 \times 10^4 \pm 2.73$	1.20×10^4	2.20×10^5
20	3	$1.24 \times 10^4 \pm 2.02$	5.68×10^3	2.23×10^4

Table 15. The average (GM) level of bacteria in dust (CFU/g dust) by floor (August 2007)

Floor	No. of Samples	Total bacteria GM \pm GSD	Gram-Negative GM \pm GSD	Gram-Positive GM \pm GSD
All	148	$1.86 \times 10^6 \pm 24.16$	$4.15 \times 10^4 \pm 152.20$	$4.61 \times 10^5 \pm 30.02$
5	4	$5.47 \times 10^6 \pm 6.90$	$8.62 \times 10^3 \pm 3.38$	$4.42 \times 10^6 \pm 5.51$
6	10	$6.57 \times 10^5 \pm 8.65$	$2.87 \times 10^3 \pm 28.82$	$3.39 \times 10^4 \pm 358.38$
7	11	$1.02 \times 10^5 \pm 14.11$	$4.31 \times 10^3 \pm 3.58$	$3.68 \times 10^4 \pm 18.07$
8	11	$6.82 \times 10^5 \pm 3.91$	$7.10 \times 10^3 \pm 6.27$	$4.61 \times 10^5 \pm 4.66$
9	12	$5.99 \times 10^5 \pm 6.16$	$2.01 \times 10^3 \pm 122.29$	$3.71 \times 10^5 \pm 7.01$
10	10	$2.77 \times 10^5 \pm 15.56$	$1.29 \times 10^3 \pm 82.50$	$1.44 \times 10^5 \pm 19.66$
11	11	$2.09 \times 10^6 \pm 7.49$	$9.78 \times 10^3 \pm 110.25$	$1.07 \times 10^6 \pm 8.32$
12	10	$1.23 \times 10^6 \pm 8.14$	$3.87 \times 10^4 \pm 13.01$	$4.97 \times 10^5 \pm 13.53$
14	10	$3.35 \times 10^8 \pm 45.94$	$2.17 \times 10^8 \pm 131.28$	$5.23 \times 10^6 \pm 74.13$
15	10	$4.53 \times 10^6 \pm 9.65$	$3.80 \times 10^5 \pm 3.96$	$2.70 \times 10^5 \pm 114.31$
16	10	$1.86 \times 10^7 \pm 28.02$	$1.10 \times 10^6 \pm 42.47$	$2.29 \times 10^6 \pm 8.96$
17	14	$2.07 \times 10^7 \pm 28.82$	$1.14 \times 10^6 \pm 201.98$	$7.09 \times 10^6 \pm 30.20$
18	10	$2.61 \times 10^5 \pm 17.72$	$7.06 \times 10^2 \pm 473.03$	$5.91 \times 10^4 \pm 7.09$
19	12	$7.07 \times 10^5 \pm 4.32$	$2.37 \times 10^4 \pm 41.57$	$3.39 \times 10^5 \pm 5.07$
20	3	$1.16 \times 10^6 \pm 6.07$	$4.55 \times 10^4 \pm 4.84$	$5.03 \times 10^5 \pm 3.37$

Allergens

Because a large percentage of dust mite and cockroach samples were below the limit of detection (LOD), we do not present the tables in the report. The cockroach allergen (Bla g2) had 76% of samples below the LOD. The GM of those above the LOD was 0.5 µg per square meter, with a geometric standard deviation (GSD) of 3.4. Two species of dust mites were measured, Der p 1 and Der f 1. Seventy-seven percent of the Der p1 species collected was below the LOD, and the Der f1 species had 80%. The GM and GSD of Der p1 and Der f 1 were 1.5 ± 3.6 and 3.7 ± 2.8 , respectively. Table 16 shows the levels of cat and dog allergens by floor. The highest levels of cat allergen were found on the 9th, 12th, and 14th floors. Research has found that levels ≥ 1 µg/g can exacerbate asthma symptoms and levels ≥ 8 µg/g can cause sensitization. Over half (52%) of all samples were above 1 µg/g, of which seven samples were above 8 µg/g. The floors that had the highest percentage of samples above 1 µg/g included the 9th, 12th, and 14th floors. For dog allergen, levels ≥ 2 µg/g may exacerbate asthma symptoms, whereas levels ≥ 10 µg/g are thought to cause sensitization. Dog allergen levels were highest on the 14th, 15th, and 19th floors, and about one-quarter of samples (27%) were above 2 µg/g, with 8 samples being above 10 µg/g. The floors with the highest percentage of samples above 2 µg/g were also the 14th, 15th, and 19th floors.

Table 16. The levels of allergens in dust (microgram per gram dust: µg/g) by floor (August 2007)

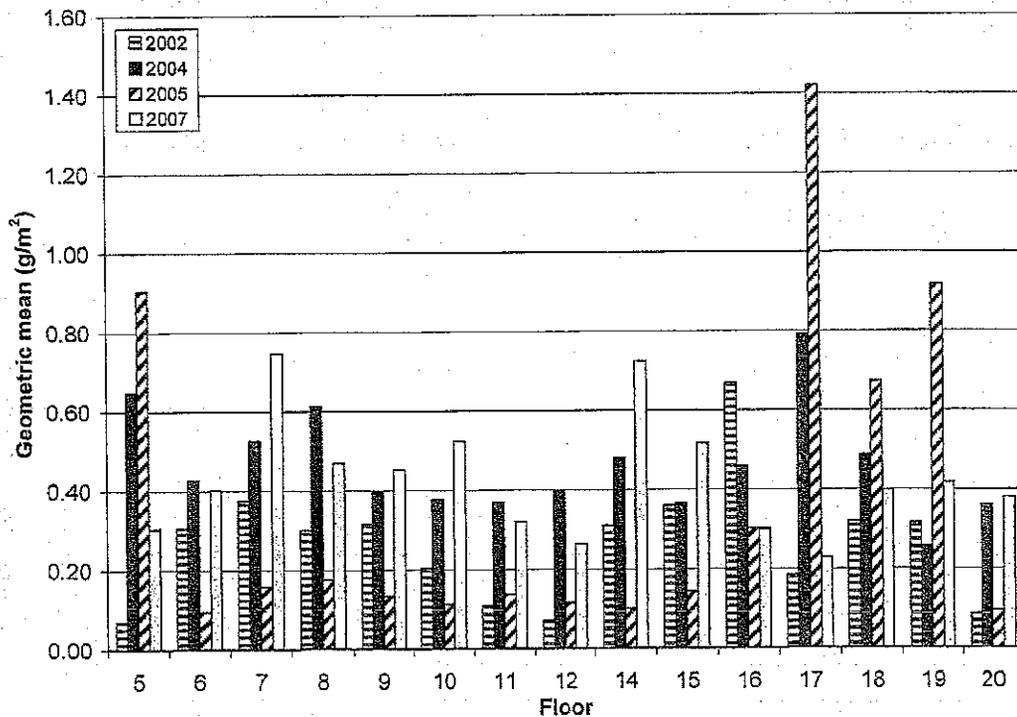
Floor	No. of Samples	Cat allergen GM \pm GSD	Cat allergen % above 1 µg/g (n)	Dog allergen GM \pm GSD	Dog allergen % above 2 µg/g (n)
All	148	0.57 \pm 6.67	52% (77)	0.79 \pm 3.99	27% (40)
5	4	0.49 \pm 4.25	50% (2)	0.56 \pm 2.07	0% (0)
6	10	0.27 \pm 7.82	30% (3)	0.82 \pm 6.06	30% (3)
7	11	0.31 \pm 6.71	45% (5)	0.73 \pm 3.56	27% (3)
8	11	0.56 \pm 6.57	45% (5)	0.93 \pm 5.83	36% (4)
9	12	1.88 \pm 6.38	75% (9)	0.73 \pm 4.09	25% (3)
10	10	0.69 \pm 8.86	60% (6)	0.61 \pm 4.61	20% (2)
11	11	1.52 \pm 3.99	64% (7)	0.50 \pm 2.76	9% (1)
12	10	2.65 \pm 2.15	90% (9)	0.81 \pm 3.75	30% (3)
14	10	1.81 \pm 4.01	80% (8)	1.34 \pm 5.03	50% (5)
15	10	0.59 \pm 4.98	60% (6)	1.19 \pm 5.10	40% (4)
16	10	0.25 \pm 6.43	40% (4)	0.60 \pm 2.88	20% (2)
17	14	0.23 \pm 5.24	21% (3)	0.53 \pm 3.59	14% (2)
18	10	0.18 \pm 5.67	30% (3)	0.53 \pm 2.69	10% (1)
19	12	0.30 \pm 8.24	42% (5)	2.09 \pm 3.79	50% (6)
20	3	0.96 \pm 11.39	67% (2)	0.92 \pm 3.60	33% (1)

Comparisons of environmental results over four surveys (2002, 2004, 2005, and 2007)

Dust

Dust loading (the amount of dust collected per square meter) may indicate general cleanliness of the building environment. In addition, dust accumulated on floor carpet can serve as a reservoir for microbial agents and support microbial growth with enough moisture. Accumulated dust can also be re-suspended into the air by occupants' or routine cleaning activities, which in turn results in inhalation exposure of the occupants to microbial agents in dust. Figure 9 shows the average (GM) amount of dust collected per square meter by floor of the building. Several floors (5th, 17th, 18th, and 19th floors) had exceptionally high amounts of dust per m² in the 2005 survey when compared with the other three surveys. Except for these floors and the 16th floor, the amount of dust collected in the 2007 survey was higher than that of the 2005 survey.

Figure 9. Average (GM) amount of floor dust collected (gram per square meter) by floor and year



Total culturable fungi

The overall building average (GM) of total culturable fungi in 2007 was about one order of magnitude higher than those in 2002, 2004, and 2005 (Figure 10). In addition, all 15 occupied floors of the building had elevated average (GM) levels of culturable fungi in 2007 when compared to 2002 (Figure 11). The most frequently found fungal genera with relatively high concentrations over all four surveys were *Alternaria*, *Aspergillus*, *Aureobasidium*, *Cladosporium*, *Epicoccum*, *Penicillium*, *Phoma*, *Pithomyces*, and yeasts (Figures 12 and 13). However, the elevated levels of total culturable fungi in 2007 resulted from an increased concentration of predominant hydrophilic fungi (Yeasts, *Phoma herbarum*, *Chaetomium globosum*, *Mucor plumbeus*, *Rhizopus stolonifer*, *Stachybotrys chartarum*: water-loving fungi requiring ≥ 0.9 water activity which is defined as the amount of free or available water in

substrates) and some of the mesophilic fungi (*Alternaria alternata*, *Aureobasidium pullulans*, *Cladosporium cladosporioides*: fungi requiring ≥ 0.8 and < 0.9 water activity) (Figures 14 and 15). When we categorized the floors into tertile exposure groups based on the rank order of the floor-specific averages of total culturable fungi as described in the Methods, higher floors (14th floor or higher) of the building were more likely to be categorized into high exposure group across the four surveys (Figure 16).

Figure 10. Average (GM) concentration of total culturable fungi per gram of carpet dust in building by year

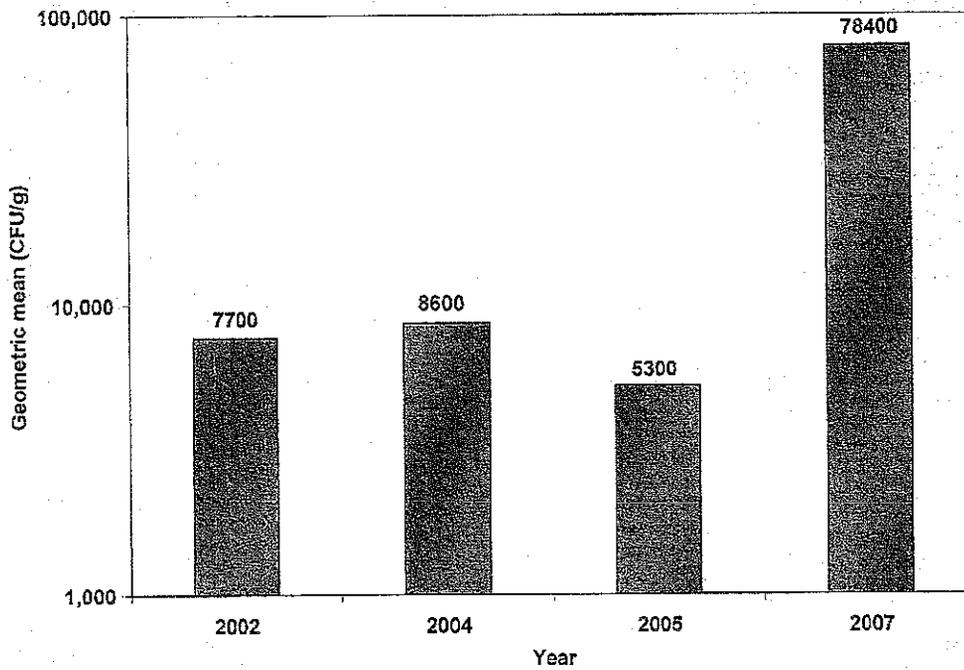


Figure 11. Average (GM) concentration of total culturable fungi (CFU/g) by floor and year

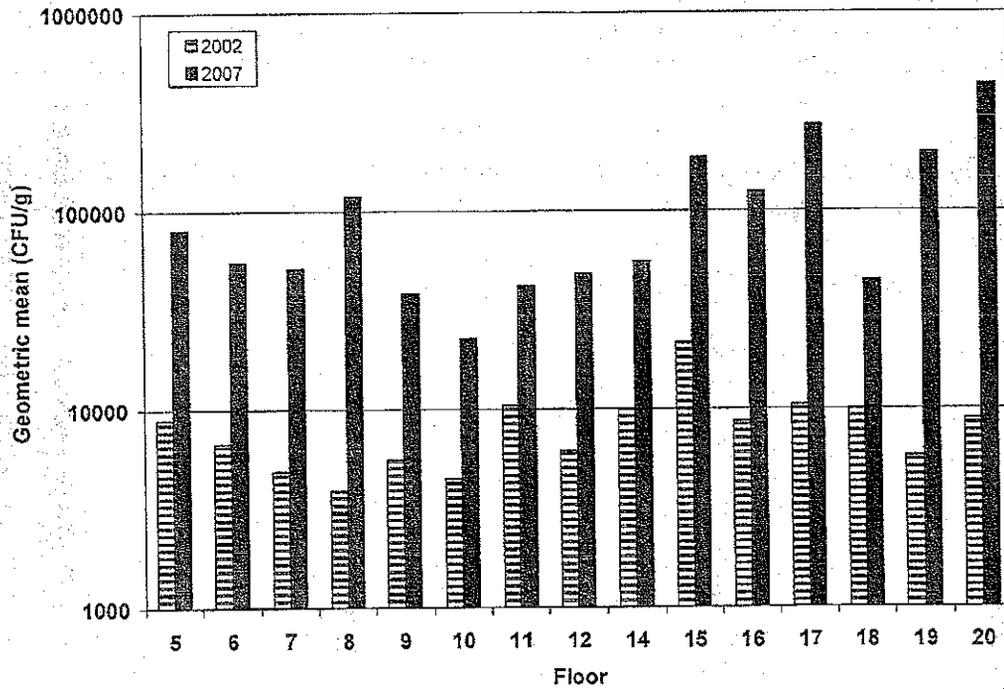


Figure 12. Percent of samples recovered with fungi (predominant fungal genera only) by year

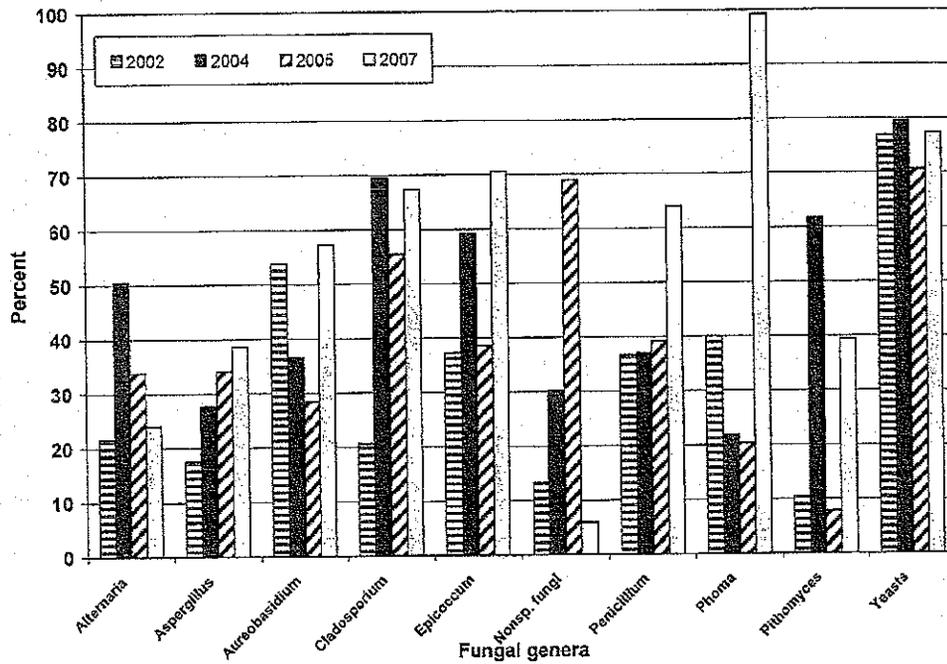


Figure 13. Average (GM) concentration of predominant fungal genera among detectable samples by year

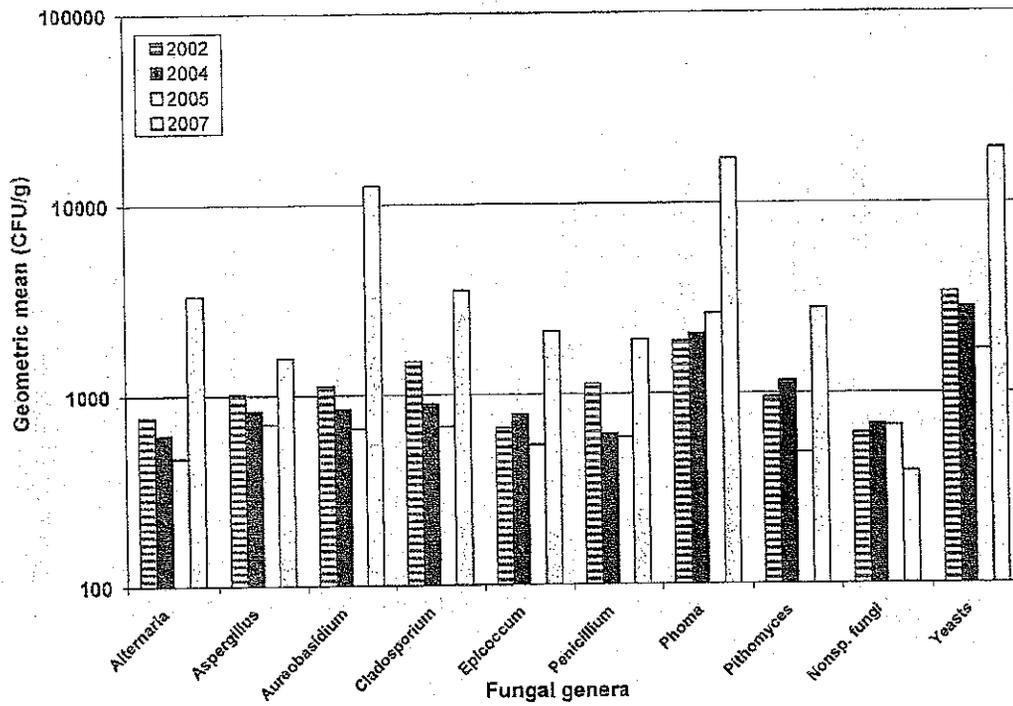


Figure 14. Overall building average (GM) concentration of hydrophilic fungi by year

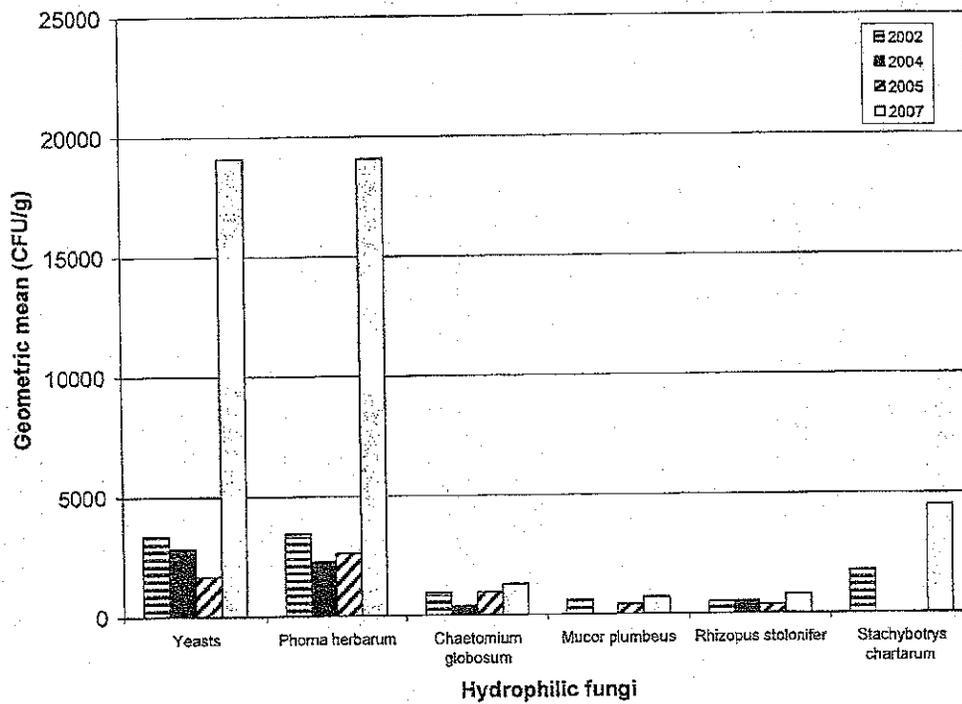


Figure 15. Overall building average (GM) concentration of mesophilic fungi by year

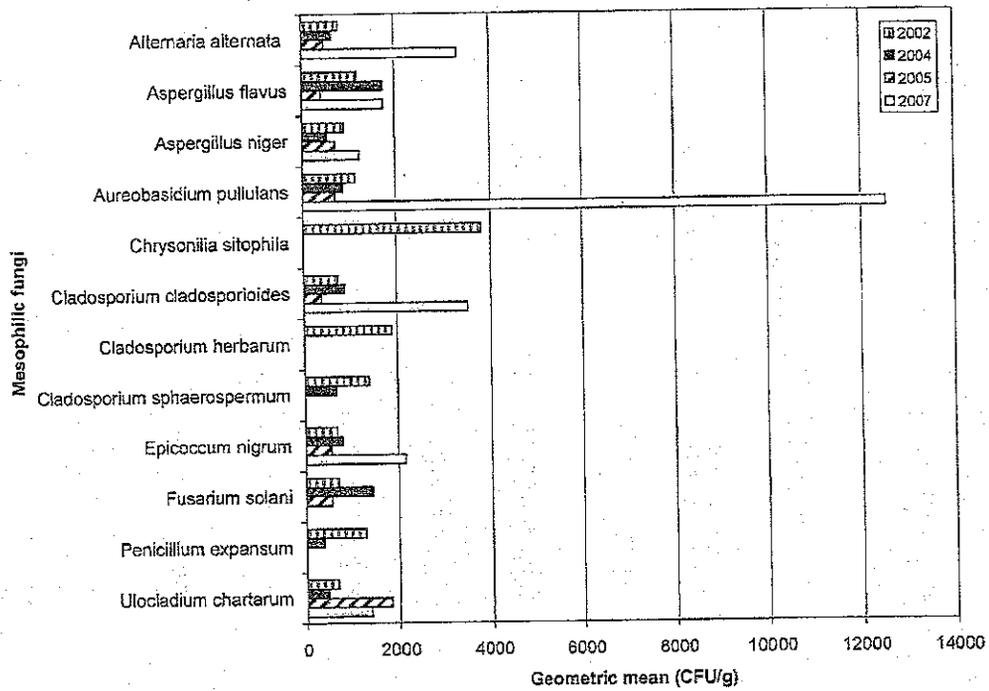
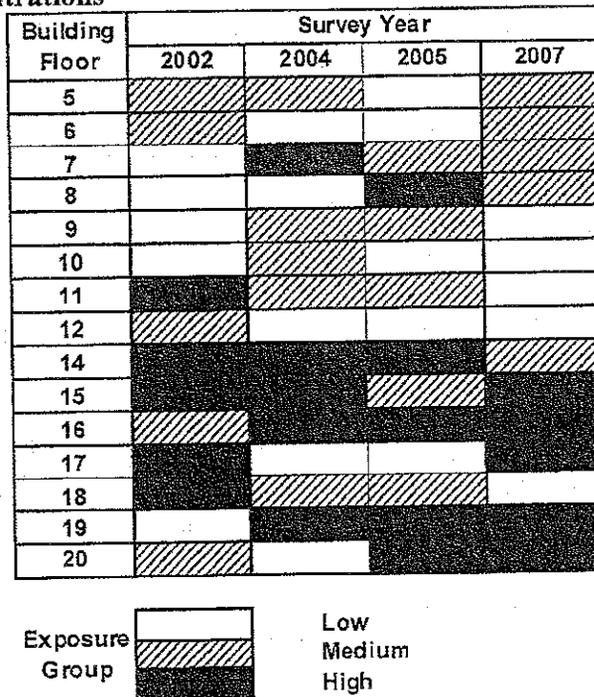


Figure 16. Changes in exposure group by floor over the four survey periods based on average fungal concentrations



Ergosterol Results

The overall building average (GM) of ergosterol in the 2007 survey was also higher than those in 2002 and 2004 (we did not measure ergosterol in the 2005 survey) as shown in Figure 17. Except for the 5th, 7th, 10th, 15th, and 18th floors, the floor-specific ergosterol levels for the rest of the floors of the building were higher in the 2007 survey than in the 2002 and 2004 surveys (Figure 18). Similarly, the upper floors of the building (14th or higher) were more likely to be categorized into the higher exposure group in tertile categorization across the four surveys (Figure 19).

Figure 17. Average (GM) concentration of ergosterol per gram of carpet dust in building by year

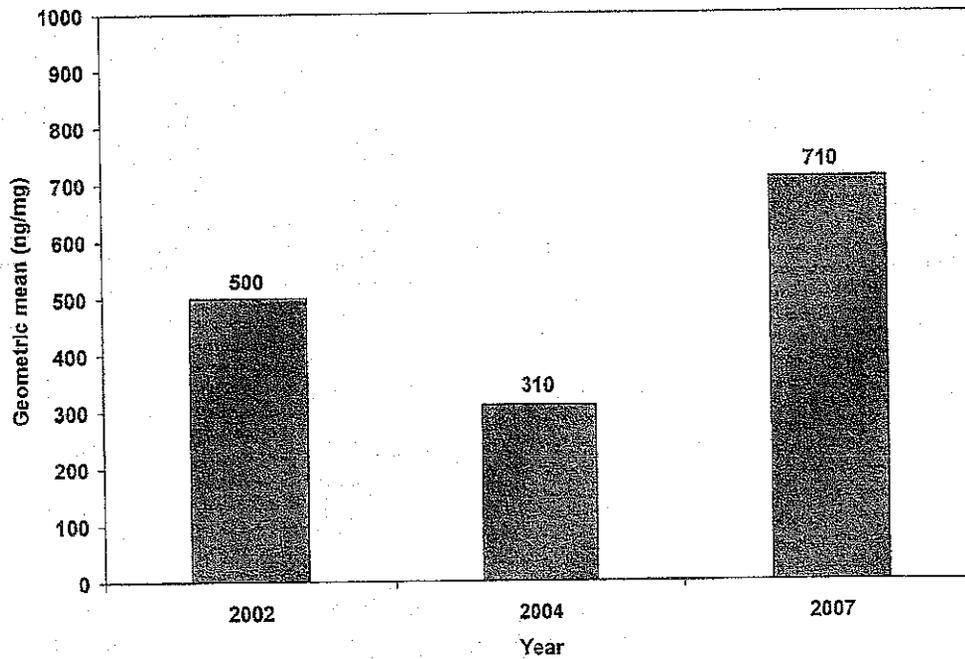


Figure 18. Average (GM) concentration of ergosterol by floor and year

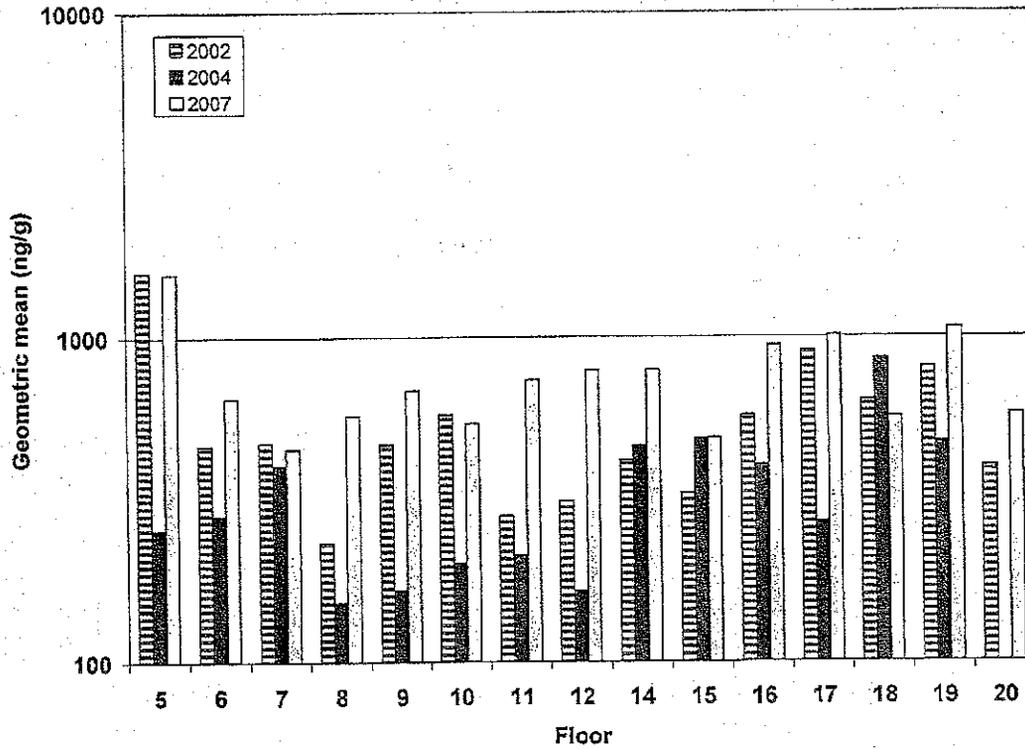


Figure 19. Changes in exposure group by floor over the four survey periods based on average (GM) ergosterol concentrations

Building Floor	Survey Year			
	2002	2004	2005	2007
5	High	Medium	Not Measured	High
6	Medium	Medium		Medium
7	Medium	High		Low
8	Low	Low		Low
9	Medium	Low		Medium
10	High	Low		Low
11	Low	Medium		Medium
12	Low	Low		Medium
14	Medium	High		High
15	Low	High		Low
16	Medium	Medium		High
17	High	Medium		High
18	High	High		Low
19	High	High	High	
20	Low	Low	Medium	



Endotoxin Results

The overall building average (GM) (27,000EU/g) of endotoxin in the 2007 survey was similar to that in the 2005 survey, but significantly more than two fold higher than in the 2002 and 2004 surveys (Figure 20). The levels of endotoxin for the 5th, 14th, 17th, 18th, 19th, and 20th floors were elevated in the 2007 survey compared to the 2005 survey, but in the lower floors of the building (6th, 7th, 8th, 9th, 10th, 11th, and 12th floors) endotoxin levels of the 2005 survey were substantially higher than those of the other surveys (Figure 21). In the 2005 survey, the lower floors of the building were more likely to be categorized into the higher exposure group in tertile categorization (Figure 22).

Figure 20. Average (GM) concentration of endotoxin per gram of carpet dust in building

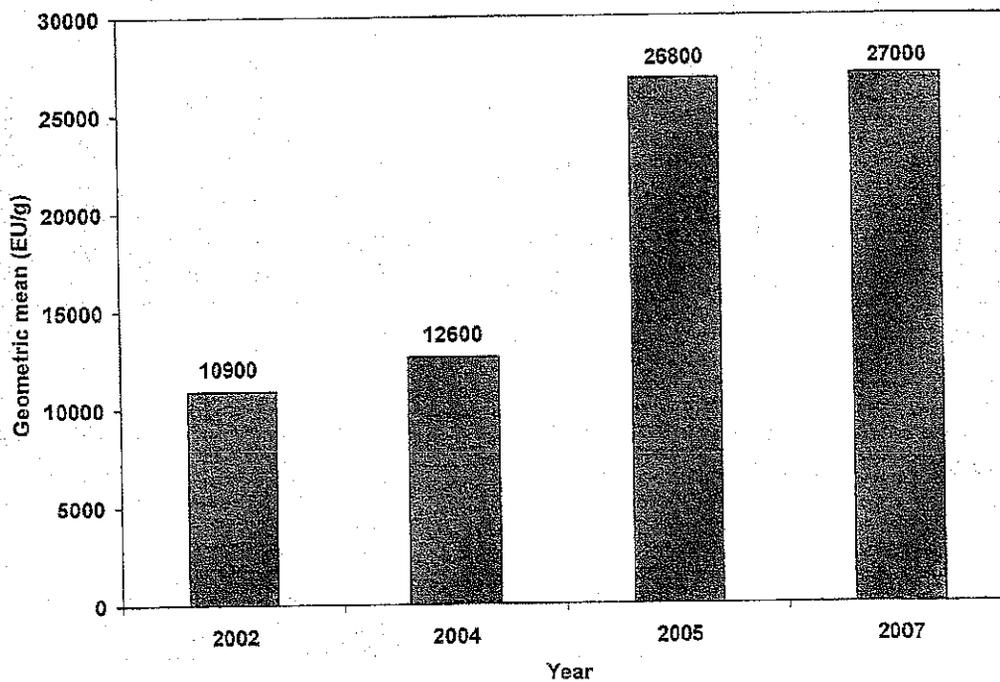


Figure 21. Average (GM) concentration of endotoxin by floor

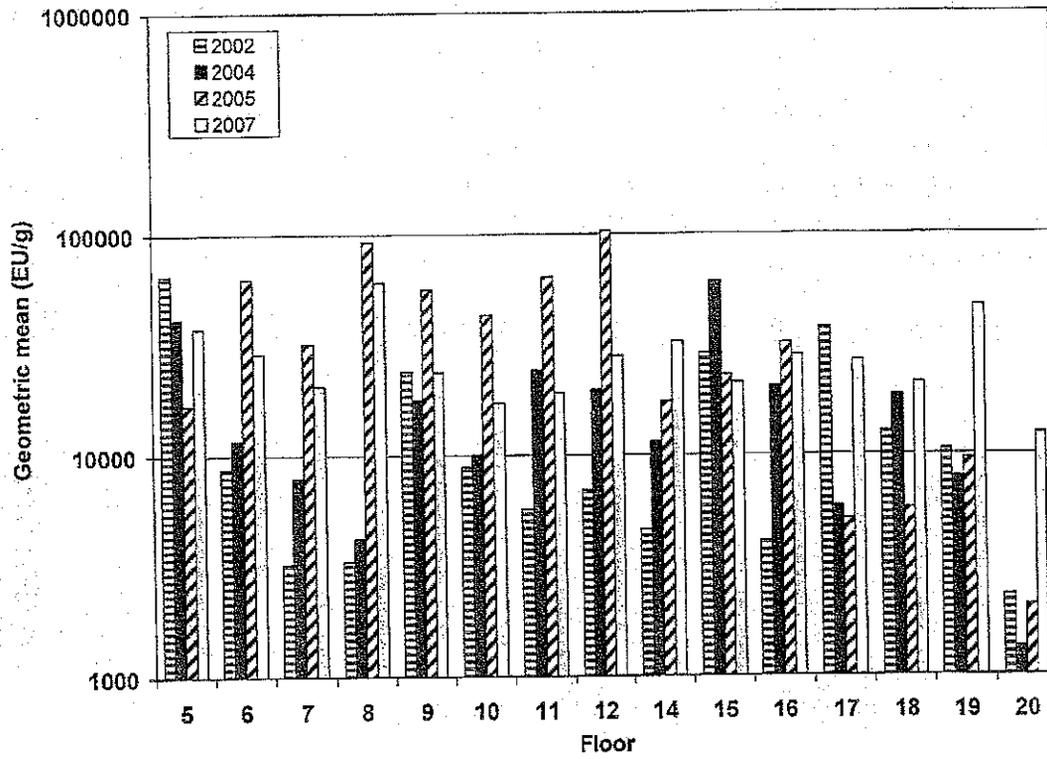


Figure 22. Changes in exposure group by floor over the four survey periods based on average (GM) endotoxin concentrations

Building Floor	Survey Year			
	2002	2004	2005	2007
5	High	High	Low	High
6	Medium	Medium	High	Low
7	Low	Low	Medium	Low
8	Low	Low	High	High
9	High	Medium	High	Medium
10	Medium	Medium	Medium	Low
11	Medium	High	High	Medium
12	Medium	High	Medium	High
14	Low	Medium	Medium	High
15	High	High	Medium	Medium
16	Low	High	Medium	Medium
17	High	Low	Low	Medium
18	High	Medium	Low	Low
19	Medium	Low	Low	High
20	Low	Low	Low	Low

Exposure Group

	Low
	Medium
	High

In summary, analysis of the 2007 dust samples showed:

1. Increased fungal levels in 2007 compared to previous surveys.
2. Higher fungal levels on upper floors (>14th floor) compared to lower floors.
3. The presence of fungi known to be associated with damp conditions.
4. Higher endotoxin levels in 2007 than 2002, but similar to 2005.

Associations of exposure to environmental microbial agents with respiratory illnesses in the 2007 survey

The logistic regression models used to examine associations of environmental exposure and illnesses included an individual respiratory symptom that improved when away from the building or a defined respiratory illness as a model health outcome, a categorical environmental variable of each microbial agent as an exposure of interest (tertile exposure variable as described in the Methods), and demographic factors (age, gender, smoking status, and building tenure) as covariates.

Table 17 shows that the occupants in the highest exposure groups (3rd tertile floors) for total fungi and hydrophilic fungi had an increased risk of work-related wheeze, shortness of breath, and coughing attacks (OR = 1.6 to 2.0; p-values < 0.05), compared to those in the lowest exposure group (1st tertile floors). Occupancy on floors with the highest levels of ergosterol also had an increased risk of work-related wheeze and chest tightness (OR: 2.1 and 1.8, respectively; p-values < 0.05). Both medium and high levels of endotoxin and glucan (2nd and 3rd tertiles) were associated with an increased risk of work-related wheeze, chest tightness, and shortness of breath (OR: 1.8-2.2; p-values < 0.05), and high levels of bacteria were associated with work-related wheeze and shortness of breath (OR: 1.7 and 1.8, respectively; p-values < 0.05). Exposure to increased levels of cat allergen and medium levels of ergosterol and bacteria had protective effects on work-related coughing attacks. When we included total fungi, ergosterol, and endotoxin in the model at the same time (multiple environmental variable model), the highest tertile for endotoxin had significant and stronger associations with work-related chest tightness and shortness of breath (OR: 2.5 and 2.6, respectively) than those in single environmental variable models, although the associations with work-related lower respiratory symptoms for total fungi and ergosterol were decreased (data not shown).

For upper respiratory symptoms, only the highest level of glucan was significantly associated with an increased risk of work-related nasal symptoms (OR: 1.6; p-value < 0.05) (Table 18). Dog and cat allergen were protective for work-related throat symptoms, and medium levels of ergosterol and bacteria also were protective for work-related nasal symptoms. In the multiple environmental variable models, total fungi showed protective effects for risk of nasal and sinus symptoms and ergosterol for throat symptoms (data not shown).

Table 19 shows that high levels of total or hydrophilic fungi and bacteria, as well as medium levels of endotoxin, significantly increased the risk of work-related flu-like achiness (OR=1.9-2.2; p-value < 0.05), and total fungi was also associated with work-related itchy skin (OR: 1.7; p-value < 0.05). Increased exposure to hydrophilic fungi and cat allergen decreased the risk of work-related itchy skin. For the multiple environmental variable models, the association of total fungi with flu-like achiness was decreased and insignificant when compared to that of the single environmental variable model (data not shown).

We defined respiratory cases, epidemiological asthma (epi-asthma), asthma-like symptoms, and post-occupancy physician-diagnosed asthma using questionnaire responses as described in the Methods. Table 20 indicates that occupants in the highest exposure group (3rd tertile) for total culturable fungi showed a significantly (p-values < 0.05) increased risk of having epi-asthma (OR=1.9) or asthma-like symptoms (OR=2.1), compared to those in the lowest exposure group. Occupants having the highest exposure to ergosterol also had a significantly (p-values < 0.05) increased risk of being a respiratory case (OR=1.8), having epi-asthma (OR=1.9), asthma-like symptoms (OR=1.9-2.0), or post-occupancy asthma (OR=3.6). A high exposure to endotoxin significantly (p-values < 0.05) increased the risk of being a respiratory case (OR=2.0), having epi-asthma (OR=2.5), asthma-like symptoms (ORs=1.8-2.2), or post-occupancy asthma (OR=4.2) and showed a stronger effect than either total culturable fungi or ergosterol. High exposure to endotoxin, bacteria, and ergosterol showed the strongest effect with physician-diagnosed post-occupancy asthma as opposed to other health outcomes. In general, we observed exposure-response relationships in the association of respiratory illnesses with exposures based on culturable fungi, ergosterol, and endotoxin measurements. Exposure to dog or cat allergens had a protective effect on being a respiratory or asthma case. The multiple environmental variable models reduced the strength of associations between total fungi, ergosterol, and endotoxin with these health outcomes and the associations were insignificant possibly due to lack of statistical power (data not shown).

Table 18. Associations of exposure to microbial agents (tertile exposure group) with work-related nasal and sinus symptoms and mucus membrane irritations occurring in the last 12 months (August 2007)

Environmental exposure parameter (Low/Medium/High based on floor tertile- Low: comparison group)	Nasal symptoms	Sinus symptoms	Eye symptoms	Throat symptoms
Total fungi Medium High	0.7 (0.5-1.1) 1.1 (0.8-1.6)	0.8 (0.5-1.3) 0.9 (0.6-1.5)	1.2 (0.8-1.8) 1.0 (0.7-1.5)	0.8 (0.4-1.3) 1.5 (1.0-2.4)
Hydrophilic fungi Medium High	0.9 (0.6-1.4) 1.2 (0.8-1.8)	0.8 (0.5-1.2) 0.9 (0.6-1.5)	0.9 (0.6-1.4) 0.9 (0.6-1.4)	0.7 (0.4-1.2) 1.5 (0.9-2.3)
Ergosterol Medium High	0.5 (0.4-0.8)* 1.0 (0.7-1.4)	0.8 (0.5-1.4) 0.9 (0.6-1.5)	0.7 (0.5-1.1) 0.8 (0.6-1.2)	0.6 (0.3-1.0) 1.4 (0.9-2.2)
Endotoxin Medium High	1.1 (0.7-1.6) 0.7 (0.4-1.1)	1.2 (0.7-1.8) 1.1 (0.7-1.9)	1.0 (0.7-1.5) 1.1 (0.7-1.8)	1.4 (0.8-2.2) 1.0 (0.6-1.7)
Total bacteria Medium High	0.6 (0.4-0.9)* 1.1 (0.8-1.7)	0.8 (0.5-1.3) 0.9 (0.6-1.5)	0.7 (0.4-1.0) 0.8 (0.5-1.2)	0.6 (0.4-1.1) 1.4 (0.9-2.3)
Glucan Medium High	1.2 (0.7-1.8) 1.6 (1.1-2.5)*	1.3 (0.7-2.1) 1.5 (0.9-2.4)	0.6 (0.4-1.0) 0.9 (0.6-1.4)	1.0 (0.5-1.6) 1.2 (0.7-2.0)
Dog (Can f 1) Medium High	1.1 (0.7-1.6) 1.0 (0.6-1.5)	1.4 (0.9-2.2) 1.5 (0.9-2.5)	1.4 (0.9-2.1) 1.3 (0.9-2.1)	0.6 (0.3-0.9)* 0.8 (0.5-1.3)
Cat (Fel d 1) Medium High	1.1 (0.7-1.6) 0.8 (0.5-1.2)	1.2 (0.8-1.9) 1.2 (0.7-1.9)	1.0 (0.7-1.5) 0.8 (0.5-1.2)	0.5 (0.3-0.8)* 0.5 (0.3-0.8)*

*Odds ratios are statistically significant at $\alpha=0.05$.

Table 19. Associations of exposure to microbial agents (tertile exposure group) with work-related systemic symptoms and skin irritations occurring in the last 12 months (August 2007)

Environmental exposure parameter (Low/Medium/High based on floor tertile- Low: comparison group)	Fever/chills	Flu-like achiness	Fatigue	Itchy skin
Total fungi Medium High	0.6 (0.3-1.3) 0.9 (0.5-1.7)	0.9 (0.5-1.6) 1.9 (1.2-3.3)*	1.0 (0.6-1.7) 1.5 (0.9-2.3)	0.5 (0.2-1.1) 1.7 (1.0-2.9)*
Hydrophilic fungi Medium High	0.9 (0.4-1.9) 1.0 (0.5-2.0)	0.8 (0.4-1.5) 1.9 (1.1-3.2)*	0.8 (0.5-1.3) 1.3 (0.9-2.0)	0.3 (0.2-0.8)* 1.6 (0.9-2.6)
Ergosterol Medium High	0.9 (0.4-1.9) 1.0 (0.5-2.1)	0.6 (0.4-1.2) 1.1 (0.7-1.9)	0.7 (0.4-1.2) 1.2 (0.7-1.8)	0.8 (0.4-1.5) 1.5 (0.9-2.7)
Endotoxin Medium High	1.2 (0.6-2.4) 1.1 (0.5-2.3)	1.9 (1.1-3.3)* 1.2 (0.6-2.3)	1.1 (0.7-1.6) 1.0 (0.6-1.6)	1.3 (0.7-2.3) 1.0 (0.5-2.0)
Total bacteria Medium High	1.2 (0.6-2.5) 0.9 (0.4-1.9)	1.2 (0.7-2.3) 2.2 (1.3-3.8)*	0.7 (0.5-1.2) 1.3 (0.8-2.0)	0.9 (0.5-1.7) 1.3 (0.7-2.3)
Glucan Medium High	1.1 (0.5-2.5) 1.3 (0.6-2.8)	1.8 (0.9-3.4) 1.6 (0.9-3.0)	1.4 (0.8-2.3) 1.1 (0.6-1.7)	1.2 (0.6-2.5) 1.7 (0.9-3.1)
Dog (Can f l) Medium High	0.9 (0.4-1.8) 1.2 (0.6-2.5)	0.6 (0.3-1.0) 1.3 (0.8-2.3)	0.8 (0.5-1.2) 1.0 (0.7-1.7)	0.6 (0.3-1.1) 0.9 (0.5-1.6)
Cat (Fel d 1) Medium High	0.8 (0.4-1.6) 1.0 (0.5-2.1)	1.0 (0.6-1.6) 0.8 (0.4-1.4)	0.9 (0.6-1.4) 0.7 (0.5-1.2)	0.5 (0.3-0.9)* 0.4 (0.2-0.8)*

*Odds ratios are statistically significant at $\alpha=0.05$.

Table 20. Associations of exposure to microbial agents (tertile exposure group) with respiratory cases, epidemiologic definition of asthma, asthma-like symptoms, and post-occupancy asthma (August 2007)

Environmental exposure parameter (Low/Medium/High based on floor tertile- Low: comparison group)	Case/Control	Epi asthma	Asthma-like symptoms 12 mo.	Asthma-like symptoms 4wk.	Post-occupancy asthma
Total fungi Medium High	1.4 (0.8-2.4)	1.8 (1.0-3.5)	1.2 (0.7-2.1)	1.7 (0.8-3.5)	1.8 (0.8-4.3)
	1.6 (0.9-2.6)	1.9 (1.0-3.4)*	1.5 (0.9-2.6)	2.1 (1.1-4.1)*	2.0 (0.9-4.4)
Hydrophilic fungi Medium High	1.0 (0.6-1.7)	1.0 (0.5-1.9)	1.1 (0.6-1.8)	1.0 (0.5-2.0)	1.1 (0.5-2.6)
	1.3 (0.8-2.3)	1.4 (0.8-2.6)	1.5 (0.9-2.4)	1.7 (0.9-3.2)	1.6 (0.7-3.5)
Ergosterol Medium High	1.1 (0.6-1.8)	1.0 (0.5-2.0)	1.2 (0.7-2.1)	0.9 (0.5-1.9)	1.3 (0.5-3.3)
	1.8 (1.0-3.1)*	1.9 (1.1-3.5)*	1.9 (1.1-3.3)*	2.0 (1.0-3.8)*	3.6 (1.6-8.3)*
Endotoxin Medium High	1.5 (0.9-2.5)	1.6 (0.8-2.9)	1.4 (0.9-2.4)	1.7 (0.9-3.4)	2.1 (0.9-5.0)
	2.0 (1.1-3.8)*	2.5 (1.3-5.0)*	1.8 (1.0-3.3)*	2.2 (1.1-4.7)*	4.2 (1.6-10.7)*
Total bacteria Medium High	1.0 (0.6-1.8)	1.0 (0.5-1.9)	1.3 (0.8-2.2)	0.9 (0.4-1.9)	1.1 (0.4-2.8)
	1.6 (1.0-2.8)	1.8 (1.0-3.2)	1.6 (0.9-2.7)	1.8 (0.9-3.5)	2.4 (1.1-5.2)*
Glucan Medium High	1.2 (0.6-2.1)	1.1 (0.6-2.1)	1.3 (0.7-2.3)	1.1 (0.5-2.2)	1.7 (0.7-4.2)
	0.9 (0.5-1.6)	0.7 (0.4-1.3)	1.1 (0.6-1.9)	0.9 (0.4-1.7)	1.1 (0.5-2.7)
Dog (Can f 1) Medium High	0.6 (0.3-1.0)*	0.5 (0.3-0.9)*	0.6 (0.4-1.1)	0.5 (0.3-1.1)	0.3 (0.1-0.8)*
	0.9 (0.5-1.6)	0.9 (0.5-1.7)	0.9 (0.5-1.6)	0.9 (0.5-1.9)	0.8 (0.3-1.8)
Cat (Fel d 1) Medium High	0.5 (0.3-0.9)*	0.5 (0.2-0.8)*	0.5 (0.3-0.9)*	0.4 (0.2-0.9)*	0.4 (0.2-0.8)*
	0.6 (0.3-1.0)	0.5 (0.2-0.9)*	0.7 (0.4-1.1)	0.4 (0.2-0.9)*	0.4 (0.2-1.1)

*Odds ratios are statistically significant at $\alpha=0.05$.

SUMMARY AND CONCLUSIONS

The NIOSH 2007 investigation and longitudinal analyses of all 4 surveys demonstrate that the new onset of diseases such as asthma, hypersensitivity pneumonitis, and sarcoidosis have been declining since 2000 or 2001, but that there is still an excess of respiratory illnesses (physician-diagnosed asthma, wheeze, shortness of breath, and upper respiratory symptoms) among building occupants when compared to national or CT state data. Even after we adjusted these prevalences for the entire building population using non-participant survey data, the prevalence ratios for asthma and wheeze still remained elevated and were statistically significant. One-third to one-half of symptomatic persons in the 2007 survey reported that their symptoms improved when away from the building. The various respiratory and non-respiratory symptoms related to the building environment were more prevalent in occupants who had worked at the building for longer time periods (before 2004), compared to the occupants with a shorter occupancy time (after 2004). Lower respiratory symptoms consistent with asthma and post-occupancy physician-diagnosed asthma were significantly associated with exposure to the highest tertile level of culturable fungi, ergosterol, and endotoxin within the building. These findings indicate that the remediation activities undertaken for the past several years before 2007 seemed to contribute to declining of incident illnesses among occupants of the building, but that the remediation did not resolve the health issues in the building.

Our environmental data analyses on changes in the levels of microbial agents over the four NIOSH surveys indicate that in 2004 and 2005, the levels of total culturable fungi and ergosterol in floor dust had been similar to or lower than the levels found in 2002. However, the levels in 2007 were higher than those found in 2002. The increase in fungi levels in 2007 consistently occurred across all 15 occupied floors and was mostly contributed by an increase in levels of hydrophilic fungi (water loving fungi such as *Phoma* and *yeasts*). The upper floors in the building (14th floor or higher), where historical water incursion mostly took place, were more likely to be categorized into the highest fungal exposure group in tertile categorization. In contrast, high levels of endotoxin did not show any distinct pattern, except for in 2005 when high exposure levels were clustered in the lower floors (12th floor or lower) of the building. The overall mean level of endotoxin was also highest in 2007 of all the NIOSH surveys, although the level in 2005 was close to that in 2007.

Measurement of culturable fungi or other microbial agents in floor dust for exposure assessment in the NIOSH studies has both strengths and limitations. Although it is not a direct measure of inhalation exposure, measurement of microbial agents in dust may be a good indicator for long-term exposure because airborne dust tends to accumulate in the floor over time and floor dust can serve as a reservoir for microbes. The NIOSH study findings also support the usefulness of surface dust sampling as an exposure assessment tool in epidemiologic studies. In these studies, we demonstrated that the measurements of microbial agents (total culturable fungi, hydrophilic fungi, ergosterol, and endotoxin) in floor dust were significant predictors of post-occupancy physician-diagnosed asthma, asthma-like symptoms, or various work-related upper and lower respiratory symptoms. In addition, utilization of surface dust sampling method has been supported by other public health organizations. The Institute of Medicine report *Damp Indoor Spaces and Health* (IOM 2004) stated that surface

dust sampling may be the method of choice for examining the association between fungal exposure and chronic health outcomes such as asthma. As noted by an American Industrial Hygiene Association (AIHA) publication on indoor mold published in 2008 (Presant B, Weekes DM, Miller JD. 2008. Recognition, Evaluation, and Control of Indoor Mold., Fairfax, VA, AIHA), "Settled dust is much less influenced by short-term fluctuations and has commonly been used as an exposure assessment tool for many substances indoors for 15 years." The book also stated, "The mass of fine dust per unit area combined with the activity in the building at the time of sampling has been used to estimate long-term patterns in potential inhalation exposures." Given that air sampling methods have significant limitations in use for exposure assessment (e.g. potential misclassification of occupants' exposure with limited number of short-term air samples), dust sampling methods are promising for large epidemiological studies.

With the information we have, we do not know if increased levels of culturable fungi in the floor dust in 2007, as compared to 2002 levels, are indicative of water-damaged areas or damp environments inside the building. According to the Department of Public Works (DPW) records reviewed by NIOSH, the first major construction activity related to water intrusion began in 2000. The repair of roof copings and brick caulking that was completed between March 2000 and November 2000 reportedly stopped 95% of the water intrusion associated with roof leaks. Remedial action completed in 2000 and 2001 was a mixture of cleaning, replacement of carpet and wallboard, upgrades to the air handling systems, and repairs to the building exterior. The carpet on each floor of the building was cleaned. In addition, interim repairs, including caulking, began around windows associated with leaks during a heavy rain event in March 2001. Water-stained carpet was replaced on the 17th, 18th, and 19th floors. Water-stained wallboard on the 5th, 17th, and 19th floors was replaced as well. Permanent repairs on the building exterior designed to prevent water incursion began in April 2002. However, although all of these remediations had been undertaken, there were still some indications that the building had current water incursions before the 2007 NIOSH survey. Occupants had reported intermittent window leaks in several locations on the 16th, 17th, 18th, and 19th floors since the 2002-2003 major remediation that included window repairs. In June and July 2007, DPW requested Silver Petrucelli & Associates, Inc. to conduct a water infiltration study. Through water flood testings on windows, Silver Petrucelli & Associates, Inc. identified failure of the flashing above the windows in those upper floors with reported leaks. In addition, a DPW response to an employee e-mail question dated August 26, 2008 indicated that there were still two areas with water leaks on the 18th floor. This information, along with no evidence of changes in cleaning practices and no changes in environmental sample analysis methods, indicate that increased fungal levels in 2007 floor dust might be a result of incomplete remediation or previously remediated areas that may have started to fail again.

RECOMMENDATIONS

Based on our four investigations and data analyses, we recommend the following:

1. Remediation of the building should be completed according to previous environmental consultants' recommendations such as found in the Turner Building Science Group report from 2005.
2. Initiate a routine maintenance program for evaluation of water damage in the building including regular observational assessment of water stain, mold growth, mold odor, and dampness, and systematic evaluation of window leaks, roof leaks, and functionality of exterior walls.
3. Continue to communicate with occupants regarding indoor environmental complaints (water damage, water stains, indoor air quality etc.) and health complaints.
4. Initiate a surveillance program to monitor occupants' symptoms and new onset of possible building-related illnesses.
5. Continue to practice daily or routine cleaning and housekeeping protocols, including HEPA vacuuming, to more efficiently remove potential microbial agents or other contaminants, and to minimize accumulation of dust in floor carpet.